CDM

Designing the Characterization of a Site with Chlorinated Solvents

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Presentation Outline

- Introduction
- Summary of basic concepts affecting characterization of chlorinated solvent sites
  - Physical properties
  - Fate and transport
- Major elements of chlorinated solvent contaminated site characterization
  - Hydrogeology
  - Contaminant distribution
  - Geochemical conditions
  - Microbiological
  - DNAPL source area architecture
- Summary

Introduction

- Chlorinated solvents are ubiquitous contaminants in soil and groundwater at sites throughout the US.
- For example, 8 of the top 20 contaminants detected at NPL sites are chlorinated solvents, including TCE (1st) and PCE (3rd).
- The U.S. Department of Defense (DoD) alone has approximately 3,000 sites contaminated with chlorinated solvents.

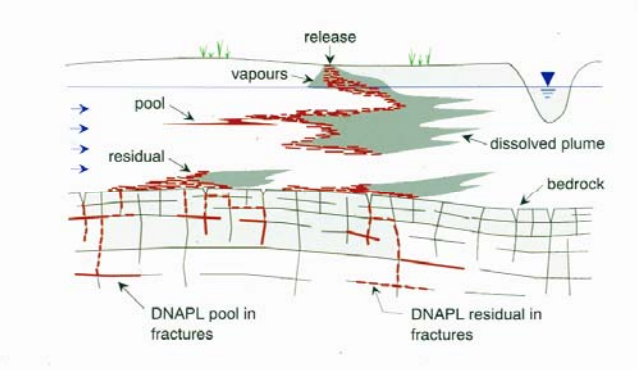
Introduction (cont.)

- Properties of chlorinated solvents present unique challenges for characterization and remediation.
- This presentation discusses how to design a characterization program for a chlorinated solvent site.
- For purposes of this talk, contaminants covered include chlorinated ethenes, ethanes, and methanes.
- Also, characterization is defined as the initial data collection performed prior to remediation implementation.

Major Concepts for DNAPL Fate and Transport

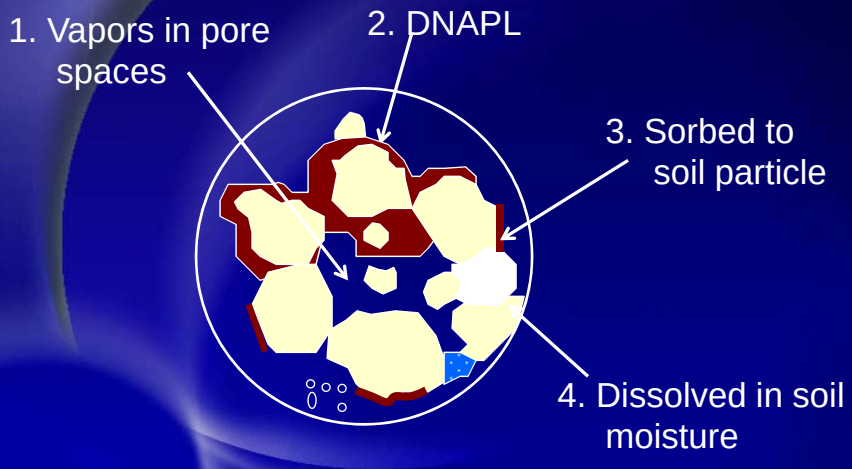
Several properties of chlorinated solvents impact design of a characterization program

- **Partitioning**
- **Saturation**
- **Retardation**
- **Rebound**



Source: ITRC, 2004

Partitioning of Contaminant



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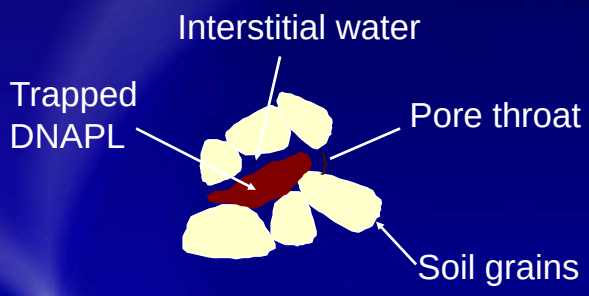
Saturation

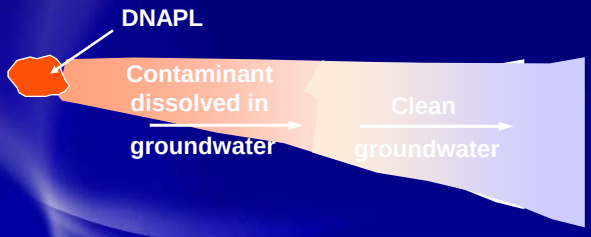
$$S_{NAPL} = V_{NAPL} / PV$$



Source: ITRC, 2004

Retardation

- A dissolved species has a slower velocity than ambient groundwater flow
  - Sorption onto soil surfaces
  - Sorption onto organic matter
  - Partitioning into a non-aqueous phase



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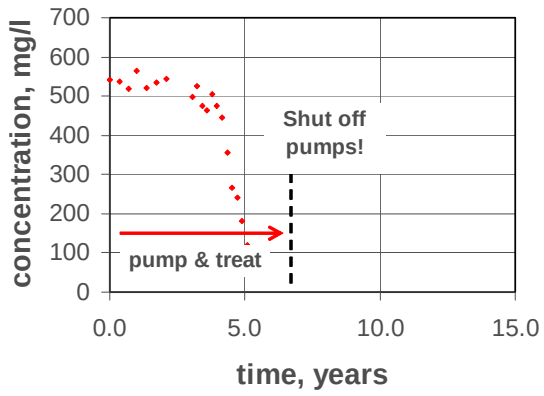
Rebound



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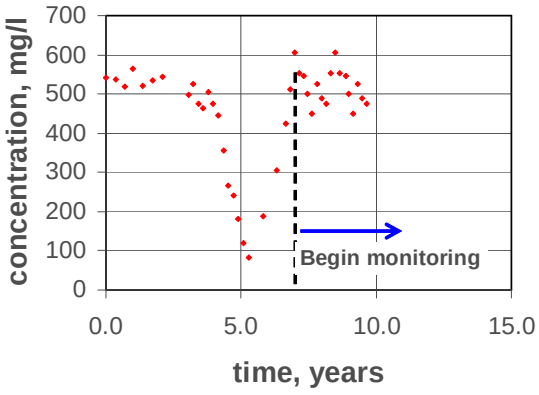
Rebound



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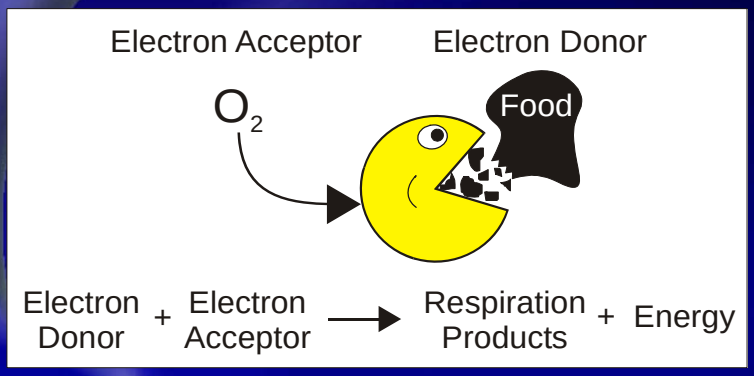
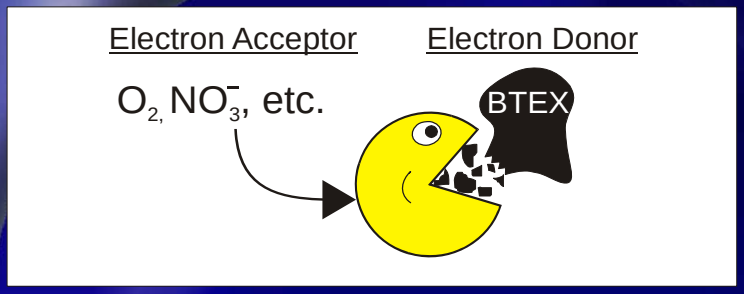
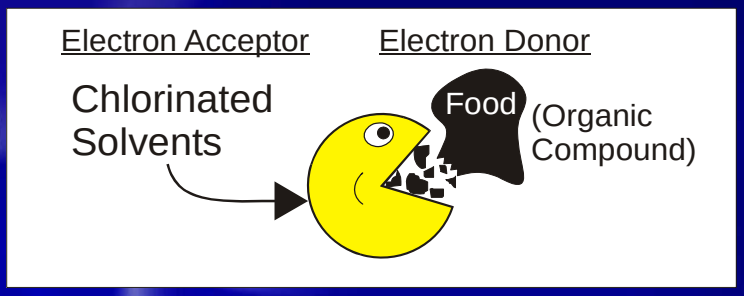
Microbial Metabolism

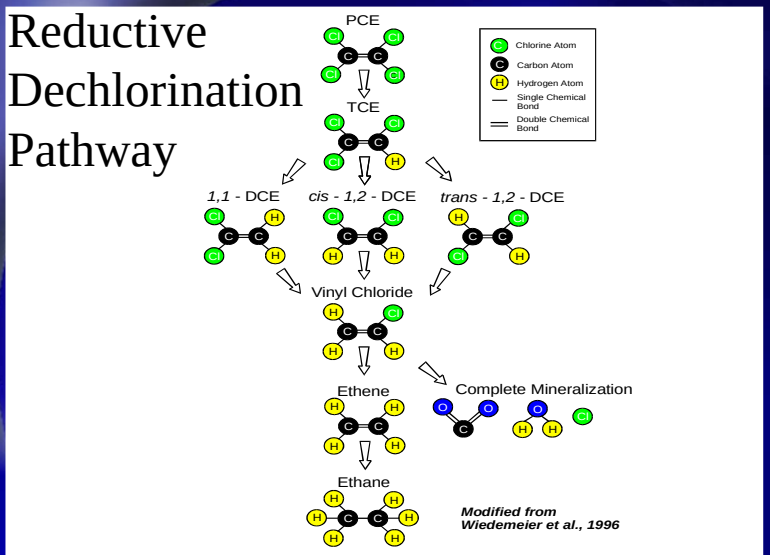


Bioremediation

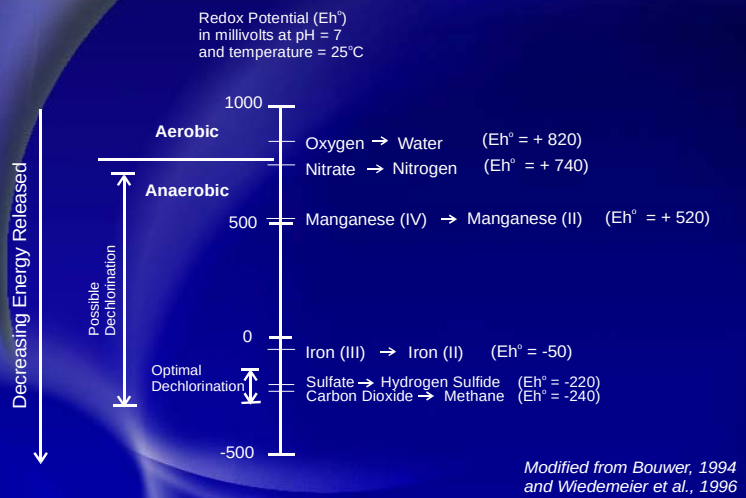


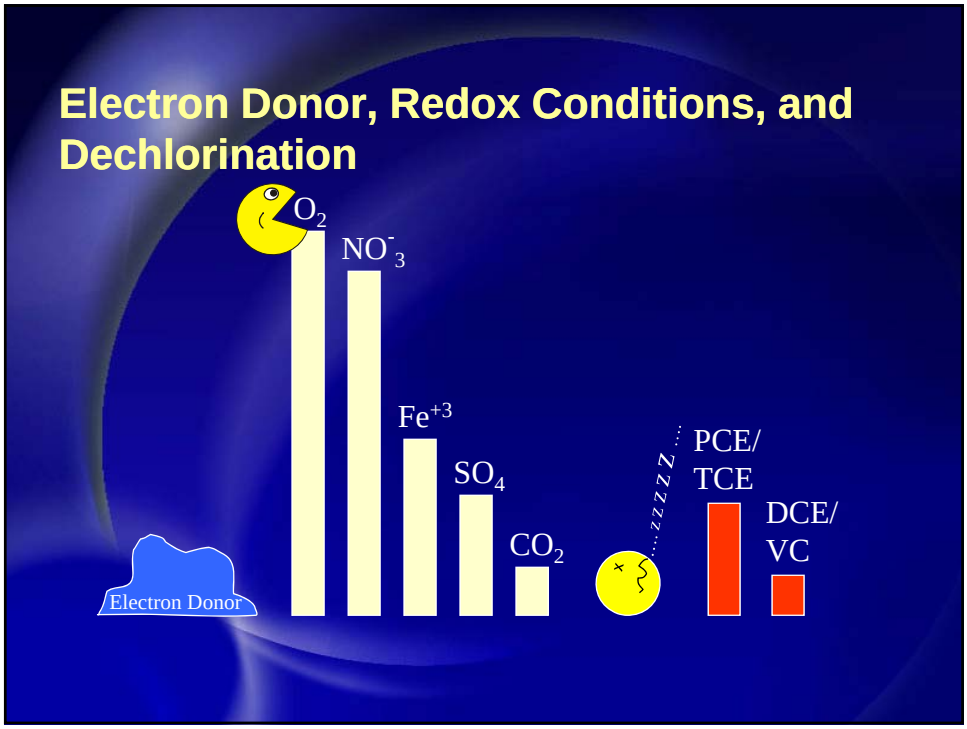


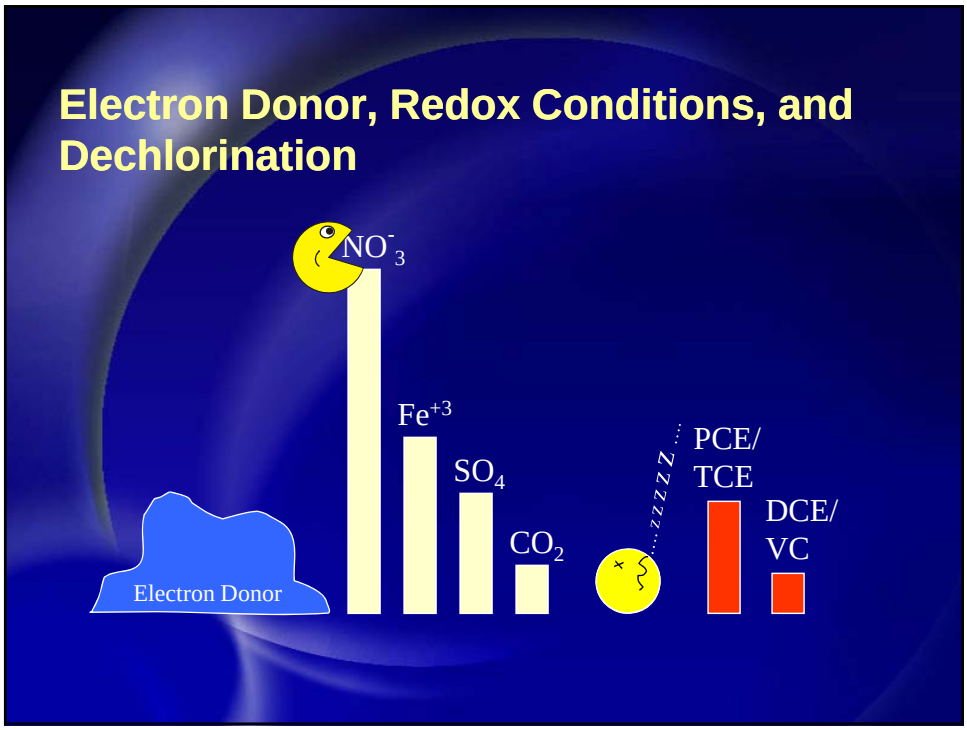
Reductive Dechlorination Pathway



Oxidation-Reduction Potential and Energy




Electron Donor, Redox Conditions, and Dechlorination
O_2
NO^-_3
Fe^{+3}
SO_4
CO_2
PCE/ TCE
DCE/ VC
Electron Donor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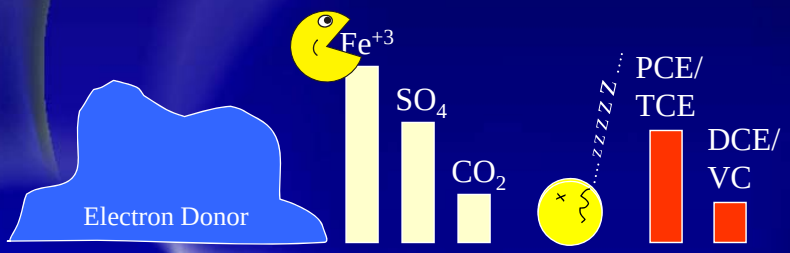
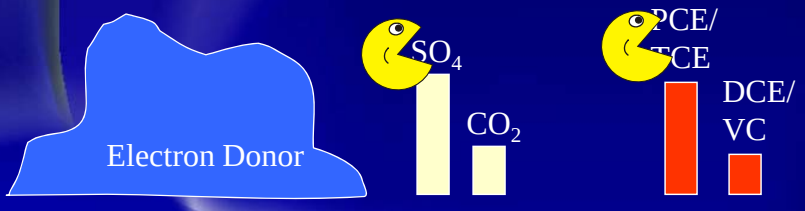


Electron Donor, Redox Conditions, and Dechlorination



Electron Donor, Redox Conditions, and Dechlorination

Elements of Chlorinated Solvent Site Characterization: Hydrogeology

- As with any other contaminant, an in depth understanding of site hydrogeology is key.
- Key parameters
  - Depth to water and total depth of contamination
  - Hydraulic conductivity
  - Hydraulic gradient
  - Effective porosity
  - Aquifer matrix

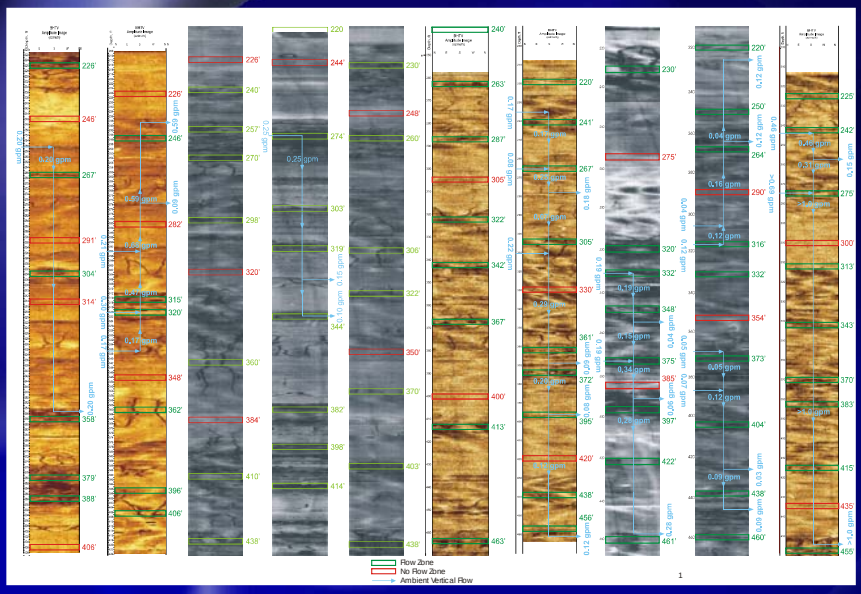
Elements of Chlorinated Solvent Site Characterization: Hydrogeology

- Characterization activities
  - Water level measurements
  - Slug/pump tests
  - Tracer tests
  - Soil sampling (for physical properties)

Elements of Chlorinated Solvent Site Characterization: Hydrogeology

- Fractured rock sites present special challenges.
- It is important to understand the extent to which fractures control flow.
- Several techniques are available to assess fractured rock sites
  - Geophysical logging techniques
  - Televiewers
  - Heat pulse and electromagnetic flowmeters
  - Downhole video cameras
- These will be discussed in detail in a later session.

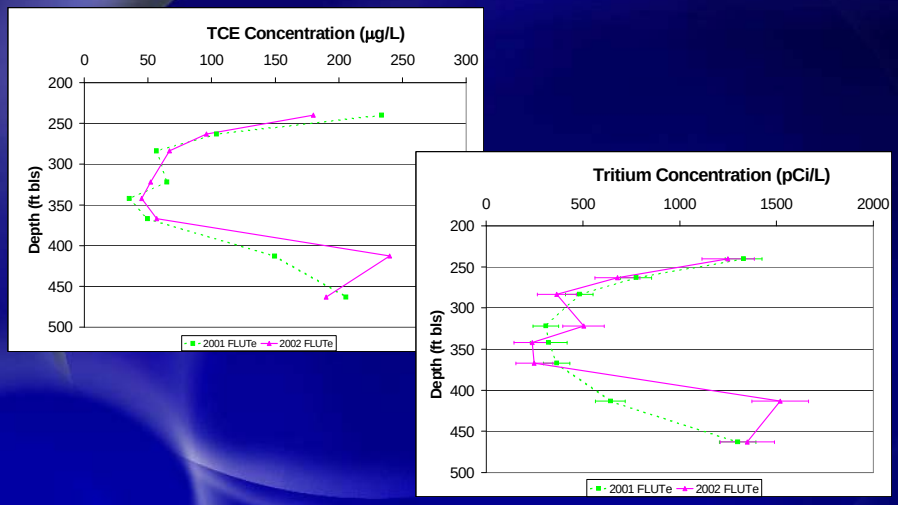
Example of fractured rock characterization



Elements of Chlorinated Solvent Site Characterization: Contaminant Distribution

- Key parameters:
  - Contaminant extent (i.e. leading edge of the plume)
  - Variation with depth (3-D distribution)
  - Presence of daughter products
- Characterization activities
  - Standard groundwater sampling
  - Temporary groundwater sampling using direct push technology
  - Multi-level sampling

Elements of Chlorinated Solvent Site Characterization: Contaminant Distribution



Elements of Chlorinated Solvent Site Characterization: Contaminant Distribution

- The concentrations of reductive daughter products needs to be assessed.
- In some cases these products are more mobile and more toxic than the parent contaminants.
- High concentrations of daughter products may indicate suitability of bioremediation or MNA as a remedy.

Elements of Chlorinated Solvent Site Characterization: Geochemistry

- Key parameters
  - Redox sensitive parameters – dissolved oxygen, nitrate, ferrous iron, sulfate, methane, ORP
  - Biological activity parameters – pH, alkalinity, total organic carbon/chemical oxygen demand
  - Water quality parameters – TDS, temperature, specific conductance, metals
- Data collection
  - Standard groundwater sampling techniques

Elements of Chlorinated Solvent Site Characterization: Geochemistry

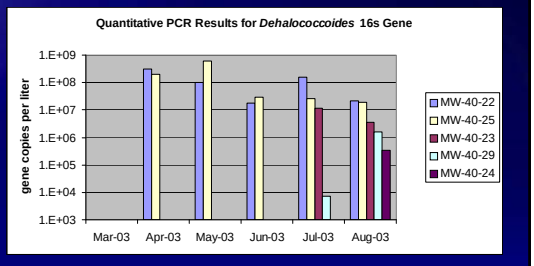
- Redox conditions are invaluable for determining active processes in the subsurface.
- If processes are known to be active, remedies can be designed to enhance them.
- Limiting factors can be identified
  - Low/high pH
  - Limited buffering capacity
  - High TDS or metals

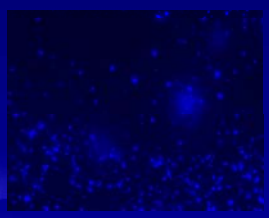
Elements of Chlorinated Solvent Site Characterization: Microbiology

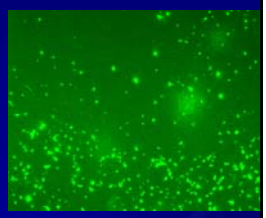
- Key parameters
  - Heterotrophic plate counts
  - DNA data for key dechlorinating microbes
  - Microbial community profiling
  - RNA/metabolic activity
  - Enzyme activity
- Data collection
  - Standard groundwater sampling/filtering techniques with specialized analytical techniques

Elements of Chlorinated Solvent Site Characterization: Microbiology

- Analytical techniques
  - Quantitative polymerase chain reaction (qPCR)
  - T-RFLP community profiling
  - Clone libraries/DNA sequencing
  - FISH
  - Enzyme probe analysis







Elements of Chlorinated Solvent Site Characterization: DNAPL Architecture

- The characterization of DNAPL source areas is the most challenging aspect of chlorinated solvent sites.
- Since the source area "feeds" the plume, it must be understood in order to restore groundwater.
- DNAPL is not found at many sites; its presence is inferred from other data.
- Key parameters
  - Presence/absence of DNAPL
  - DNAPL saturation – mobile or residual source area
  - Mixture of contaminants

Elements of Chlorinated Solvent Site Characterization: DNAPL Architecture

- Data Collection
  - Standard groundwater sampling
  - Soil sampling in both vadose zone and saturated zone
  - Colorimetric methods (e.g. FLUTe Ribbon NAPL sampler)
  - Geophysical techniques
  - Partitioning interwell tracer tests
- Several techniques will be discussed in other sessions.

Executing the Characterization Program

- Data collection guidance should be followed
  - Data quality objectives process
  - Triad approach
- Several elements of the characterization program can be collected as a one time measurement
  - Hydraulic testing
  - "background" aquifer conditions (organic carbon, pH, buffering capacity

Executing the Characterization Program

- Other parameters are more useful if more than one round of data are collected
  - Plume extent
  - Contaminants and daughter products
  - Redox conditions
  - Microbial community
- A mix of field and laboratory methods can be used
  - Field methods provide near real-time data; more data points collected for same price

Summary

- Characterization of chlorinated solvent sites involves elements similar to other contaminations.
- DNAPL assessment and microbiological characterization are somewhat unique to chlorinated solvent sites.
- Currently available methods can be used to guide data collection