Talk Outline

- The challenge of remediation
- What are PRBs and what do they have to offer?
- A couple of case histories
- Lessons learned for environmental investigation and remediation
Groundwater Remediation 101

• **TO BE EFFECTIVE, YOU MUST KNOW:**

  • Where the *source* of the plume impacts are coming from.

  • Where the *dissolved chemical impacts* have gone, and how they are distributed.

  • How *significant* are the impacts.

• **IF THESE REMAIN UNKNOWN, IT IS HIGHLY LIKELY THAT YOU WILL FAIL** TO BE ABLE TO SUCCESSFULLY CLEANUP A CONTAMINANT PLUME!
Geologic Complexity

• Can cause plume movement in directions not expected by subsurface conditions only described by a classic ‘widely-spaced’ soil boring and monitoring well based subsurface exploration program.

• Subsurface data density limits the development of an accurate *Conceptual Site Model* that can adequately describe groundwater movement and plume progression, especially for large impacted chlorinated plume areas (say, greater than 1000 ft in length or greater than 10’s of acres in size).
PRBs

Basic Principles

- Design dependent on thorough site characterization.
- Collection of hydrogeologic, geochemical, microbial and geotechnical data.
- Full vertical and horizontal delineation of source area and limits of impacted groundwater.
DISTRIBUTION OF PCE CONCENTRATIONS IN GROUNDWATER

Urban Environment

Groundwater Flow

- 5 - 10 ppb PCE
- 10 - 50 ppb PCE
- 50 - 100 ppb PCE
- 100 - 300 ppb PCE
- 300 - 1,000 ppb PCE
- >1,000 ppb PCE
DISTRIBUTION OF PCE CONCENTRATIONS IN GROUNDWATER

SITE 1

SITE 2

SITE 3

SITE 4

Groundwater Flow

Legend:
- 5 - 10 ppb PCE
- 10 - 50 ppb PCE
- 50 - 100 ppb PCE
- 100 - 300 ppb PCE
- 300 - 1,000 ppb PCE
- >1,000 ppb PCE
Depth Below Top of Aquifer: 0 to 10 ft
Total Saturated Aquifer 50 ft
Depth Below Top of Aquifer: 10 to 20 ft

Total Saturated Aquifer 50 ft
Depth Below Top of Aquifer: 20 to 30 ft

Total Saturated Aquifer 50 ft
Permeable Reactive Barrier

*Definition*

- An in-situ permeable treatment zone designed to intercept and remediate a contaminant plume.
Groundwater Remediation Approaches

- Chemical source area
- Groundwater plume
- Monitored natural attenuation
- Extraction well
- Permeable reactive barrier (PRB) wall
- Remediated plume
- Reactive treatment 'gate'
- Remediated plume
- Impermeable funnel wall
PRB Materials

• Treatment by physical, chemical or biological processes.

• Designed as a ‘chemical reaction vessel’ to treat contaminants, but allows groundwater to pass through.
Design Parameters:
- Size: Length, Width (thickness), Depth
- Treatment Material Type, Mass, Concentration
- Aquifer/Wall Hydraulic Conductivity, Groundwater Velocity
- Parameters: Contact Residence Time, Chemical Reaction Rate
Remediation Challenges:
- **Constructability:** Injection pressures, material distribution
- **Aquifer inhomogeneity and anisotropy**
- **Aquifer geochemical variability**
Chlorinated Solvent Plumes

- Parent material products:
  - Perchloroethylene (PCE)
  - Trichloroethylene (TCE)
  - 1,1,1-Trichloroethane (1,1,1-TCA)

- Breakdown products include cis-1,2-Dichloroethylene (cis-1,2-DCE) and Vinyl chloride (VC).
Typical PRB Materials

- Granular iron (zero-valent iron (ZVI))
- Bio-barrier systems (lactate, molasses, vegetable/soybean oils)
Chlorinated Solvents

- Treatment via anaerobic bioremediation.
Groundwater Remediation 101

• MOST PLUME REMEDIATION EFFORTS ARE BASED ON A LACK OF DATA AND SUBSURFACE KNOWLEDGE TO BE EFFECTIVE!

  • The remediation takes too long or is never achieved.
  • The remediation costs too much.
  • The plume’s risk to human health and the environment is never able to be controlled.
Case History No. 1

- Multiple sources
- Small plumes
- Complicated geology
CASE HISTORY NO. 1

INDUSTRIAL SITE 2

COMMERCIAL SITE 1

RESIDENTIAL AREA

CEMETERY
Multiple Source Areas
Multiple Source Areas
Figure 13 - Typical Cross-Section CAP18™ Injection
Chemical Source Area A
August 2007

In-Situ Bioremediation with Soybean Oil
Multiple Source Areas
Case History No. 2

- Long plume
- Complicated geology
- How to clean it up?
Midwestern Geologic Complexity
Plume Search Area – Based on Hydrogeology
Interpreted Top of the Till from the Resistivity Data
Resistivity Slice Maps
Chlorinated Plume Delineation
Remediation of Chlorinated Plume

LEGEND

- **MW-32**: Mundell Monitoring Well Location
- **RP-8-M**: Mundell Remediation Progress Monitoring Piezometer Location
- **MW-18**: Astbury Monitoring Well Location

- Yellow: Approximate plume delineation of 50 ug/L of total chlorinated VOCs
- Magenta: Approximate plume delineation of 500 ug/L of total chlorinated VOCs
- Purple: Approximate plume delineation of 5,000 ug/L of total chlorinated VOCs

**Permeable Reactive Barriers**

**Source Removal and Treatment**
Remediation of Chlorinated Plume

Philosophy:
- Source Treatment with Multiple PRBs
- Spacing at year travel time intervals
- Pilot test – for design
- Monitor – Observational approach
Pilot Study – EHC PRB

Philosophy:
- Injection radius of influence
- Multi-row for contact time
- Geochemical monitoring
- Pilot test – for design
- Predict speed of remediation
Lessons Learned

- Most PRB failures are from a lack of subsurface data collection prior to final design.
- Wrong location, thickness and depth of PRB.
- PRB material under-designed for chemical concentrations.
THANKS!