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Welcome to ITRC's Internet-based Training – *Surfactant/Cosolvent Flushing Of DNAPL Source Zones*

Thank you for joining us. Today's training focuses on the ITRC Technical and Regulatory Guidance Document entitled:

"Technical and Regulatory Guidance for Surfactant/Cosolvent Flushing Of DNAPL Source Zones"

The training is sponsored by: ITRC and EPA-TIO

Creating Tools & Strategies to Reduce Technical & Regulatory Barriers for the Deployment of Innovative Environmental Technologies

Surfactant/Cosolvent Flushing of DNAPL Source Zones

Surfactant/cosolvent flushing is a DNAPL removal technology involving the injection and subsequent extraction of chemicals to solubilize and/or mobilize DNAPLs. The chemicals are injected into a system of wells positioned to sweep the DNAPL source zone within the aquifer. The chemical flood and the solubilized or mobilized DNAPL is removed through extraction wells and the liquids are either disposed or treated onsite. The technology is a mature technology in the petroleum-engineering field of Enhanced Oil Recovery (EOR), supported by decades of research and field tests. Environmental applications constitute a new usage for the technology, and have become more common in recent years. The technology has been shown to be effective for several DNAPL types, including spent degreasing solvents (TCE and TCA), dry cleaning solvents (PCE), heavy fuel oils and coal tar/creosote. Laboratory work has also demonstrated applicability to PCB-containing mineral oils. The primary appeal of the technology is its potential to quickly remove a large fraction of the total DNAPL mass. Technical challenges include locating and delineating the DNAPL source zone, estimating the initial DNAPL mass and spatial distribution, characterizing the hydraulic properties of the aquifer, delivering and distributing the injected chemicals to the targeted zone, and designing the optimum chemical formulation for a given DNAPL composition and soil type. Typical concerns include the cost of disposal of the effluent, regulatory permitting for underground injection of tracers or flushing agents, the overall impact of unremoved DNAPL, and the expertise of the personnel involved in site remediation. The purpose of this training is to familiarize you with the recently released *ITRC Technical and Regulatory Guidance for Surfactant/Cosolvent Flushing of DNAPL Source Zones* (DNAPL-3). This document provides technical and regulatory information to help you understand, evaluate and make informed decisions regarding potential surfactant/cosolvent flushing projects. Included is a description of the technology, system operation, performance assessment, regulatory considerations, stakeholder concerns, case studies, and technical references.

ITRC – Interstate Technology and Regulatory Cooperation (www.itrcweb.org)

EPA-TIO – Environmental Protection Agency – Technology Innovation Office (www.clu-in.org)

ITRC Course Moderator: Mary Yelken (myelken@earthlink.net)

ITRC – Shaping the Future of Regulatory Acceptance

- **Natural Attenuation of Chlorinated Solvents in Groundwater: Principles & Practices**
- **Advanced Techniques for Installation of Permeable Reactive Barriers**
- **Diffusion Samplers**
- **Phytotechnologies**
- **ISCO (In Situ Chemical Oxidation)**
- **Systematic Approach to In Situ Bioremediation (Nitrates, Carbon Tetrachloride, Perchlorate)**
- **Characterization & Remediation of Soils at Closed Small Arms Firing Range**
- **Constructed Treatment Wetlands**
- **Surfactant/Cosolvent Flushing of DNAPL Source Zones**
- **Munitions Response Historical Record Review (MRHRR) Radiation Risk**
- **Radiation Risk Assessment: Updates & Tools**

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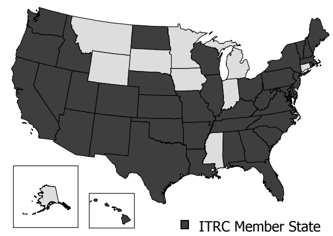

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The bulleted items are a list of ITRC Internet Training topics – go to www.itrcweb.org and click on "internet training" for details.

The **Interstate Technology and Regulatory Council (ITRC)** is a state-led coalition of regulators, industry experts, citizen stakeholders, academia, and federal partners that work to achieve regulatory acceptance of environmental technologies. ITRC consists of 40 states (and the District of Columbia) that work to break down barriers and reduce compliance costs, making it easier to use new technologies and helping states maximize resources. ITRC brings together a diverse mix of environmental experts and stakeholders from both the public and private sectors to broaden and deepen technical knowledge and streamline the regulation of environmental technologies. Together, we're building the environmental community's ability to expedite quality decision-making while protecting human health and the environment. With our network approaching 6,000 people from all aspects of the environmental community, ITRC is a unique catalyst for dialogue between regulators and the regulated community.

ITRC originated in 1995 from a previous initiative by the Western Governors' Association (WGA). In January 1999, it affiliated with the Environmental Research Institute of the States, ERIS is a 501(c)3 nonprofit educational subsidiary of the Environmental Council of States (ECOS). ITRC receives regional support from WGA and the Southern States Energy Board (SSEB) and financial support from the U.S. Department of Energy, the U.S. Department of Defense, and the U.S. Environmental Protection Agency.

To access a list of ITRC State Point of Contacts (POCs) and general ITRC information go to www.itrcweb.org.

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Surfactant/Cosolvent Flushing Of DNAPL Source Zones

Presentation Overview
- Introduction
- Description and Overview
- Geological & Chemical Issues
- Questions and answers
- Process Design & Implementation
- Regulatory, Health & Safety, Stakeholder
- Questions and answers
- Links to additional resources
- Your feedback

Logistical Reminders
- Phone Audience
  - Keep phone on mute
  - * 6 to mute your phone and again to un-mute
  - Do NOT put call on hold
- Simulcast Audience
  - Use ? at top of each slide to submit questions
- Course Time = 2.25 hours
- 2 Question & Answer Periods
- Links to Additional Resources
- Your Feedback

No associated notes.

Meet the ITRC Instructors

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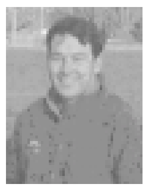

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Ana Vargas has been working for the Arizona Department of Environmental Quality (ADEQ) Superfund Programs Section for the last 15 years. She is responsible for the management of five State Superfund sites in the Phoenix area dealing with chlorinated solvents. Ana is the Interstate Technology Regulatory Council (ITRC) team leader for the Surfactant/Cosolvent team. Ana received her B.S in Chemical Engineering from the University of Puerto Rico in 1985. Prior to working for ADEQ, Ana was responsible for the development of qualification standards and related training material for senior Naval reactor plant operators in the U.S. Navy Nuclear Propulsion Program. Ana is fluent in both English and Spanish and has also served as a translator between ADEQ and Phoenix Hispanic communities in environmental issues, when needed.

Hans W. Meinardus is a senior hydrogeologist with INTERA, Inc. in Austin, Texas. He has a BS and an MS in Geology from Texas A&M University, with a specialization in Hydrogeology under Dr. Pat Domenico. He has worked with INTERA (formerly Duke Engineering and Services from 1997-2001) since graduation in 1991. For the past eight years he has specialized in NAPL source zone characterization, remediation, and remediation performance assessment, and has been involved in the development and deployment of innovative NAPL characterization and remediation technologies. Mr. Meinardus has been the INTERA project manager at Hill Air Force Base in Utah since 1995 where he was responsible for conducting Partitioning Interwell Tracer Tests (PITTs) (including the first full-scale implementation in 1998-99), three successful surfactant-flood remediation demonstrations (1996-7), and three full-scale surfactant floods (1999-2002). Mr. Meinardus was responsible for quantitatively delineating the volume and extent of the DNAPL source at Hill AFB's Operable Unit 2, and also assisted in the design and implementation of a cometabolic bioventing demonstration. He is currently involved in a post-surfactant flood bioremediation study at OU2, and is managing several other efforts to characterize contaminated sites, assess remedial options using numerical simulation studies, and to remediate NAPL source zones. His numerical ground-water flow and transport modeling experience includes developing, using, and managing three-dimensional single-phase and multi-phase numerical models for use in site investigation and in the design and evaluation of remedies at various facilities contaminated with NAPLs, lead, and arsenic. He has been an instructor for numerous DNAPL site characterization and remediation short courses, including ESTCP workshops. In addition, he has co-authored several peer-reviewed papers and presented on various NAPL topics at numerous conferences. Mr. Meinardus currently serves on the DNAPL team of the Interstate Technology Regulatory Council (ITRC).

Mark A. Hasegawa is an Associate with Hasegawa Engineering Ltd. in Lethbridge, Alberta. He has a BS in Civil Engineering from Brigham Young University and a MS in Environmental Engineering from the University of Oklahoma, with a specialization in Process Design and Surfactant Chemistry under Dr. David Sabatini. While at the University of Oklahoma, Mark was selected to teach two courses: the introduction to water chemistry and computer assisted engineering analysis. Mark has worked in the environmental remediation field for 10 years and has specialized in NAPL/DNAPL remediation, and process design, and has been involved in the development and deployment Surfactant Enhanced Subsurface Remediation. Mr. Hasegawa has supervised over 10 surfactant enhanced NAPL remediation projects including several DNAPL sites which include: McClellan AFB, Alameda Naval Air Station, a Chemical Plant in Michigan, Dover AFB, and Tinker AFB. Mark was project manager for the aforementioned project and supervised process design for each project. He has extensive experience in performing risk analysis at sites and has supervised the completion of numerous site specific risk assessments. He was also one of three approved trainers utilized by the state of Oklahoma to train consultants on the implementation of Risk Based Corrective Action in the state. Mark is also a registered professional Engineer in several states and provinces. In addition, he has co-authored several peer-reviewed papers and presented on various DNAPL and risk assessment topics at numerous conferences. Mr. Hasegawa currently serves on the DNAPL team of the Interstate Technology Regulatory Council (ITRC).

Technology Description and Overview

Ana Vargas

Ana Vargas has been working for the Arizona Department of Environmental Quality (ADEQ) Superfund Programs Section for the last 15 years. She is responsible for the management of five State Superfund sites in the Phoenix area dealing with chlorinated solvents. Ana is the Interstate Technology Regulatory Council (ITRC) team leader for the Surfactant/Cosolvent team. Ana received her B.S in Chemical Engineering from the University of Puerto Rico in 1985. Prior to working for ADEQ, Ana was responsible for the development of qualification standards and related training material for senior Naval reactor plant operators in the U.S. Navy Nuclear Propulsion Program. Ana is fluent in both English and Spanish and has also served as a translator between ADEQ and Phoenix Hispanic communities in environmental issues, when needed.

The DNAPL Problem

- Cleaning up contaminated sites with dense-non aqueous-phase liquids (DNAPLs) present one of the biggest challenges in the environmental remediation field.
- There's a presumption, in some situations, that aquifer restoration is not feasible when DNAPLs are present.
- The issue of feasibility and arguments for and against remediating DNAPL source areas are the focus of a recent document entitled *DNAPL Source Reduction: Facing the Challenge* (ITRC, 2002).

Surfactant/Cosolvent Flushing is one of the technologies that treats DNAPL source zones.

No Associated Notes

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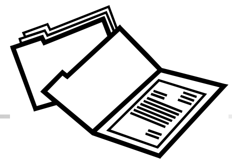
What will you learn from this course?

- Basics of surfactant/cosolvent flushing technology
- Applications and limitations of the technology
- Steps that must be taken to delineate DNAPL source zone characterization prior to design, installation, and operation
- Design and operational issues
- Regulatory requirements, health and safety issues, stakeholder issues

No associated notes

Course Content



- Technology Description and Overview
- Geological Design Considerations and Issues
  - Geosystem Model
  - DNAPL Source Zone Delineation and Characterization
  - Aquifer Properties Characterization
  - Laboratory Studies/Chemical Selection
- Process Design and Implementation
  - Mixing/Injection Issues
  - Extraction System Issues
  - Monitoring and Sampling
- Regulatory Requirements, Health and Safety Issues, Stakeholder Issues

No associated notes

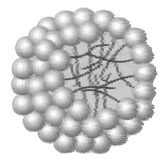
Key Concepts/Definitions

- DNAPL - dense, non-aqueous phase liquid; DNAPL entry location is where the liquid entered the subsurface
- DNAPL zone - is the volume of pore space in the subsurface contaminated with DNAPL (also called "source" or "source zone")
- saturation - fraction of the soil pore volume that is filled with DNAPL
- capillary barrier - geologic unit that impedes migration of DNAPLs due to the small size of its pore spaces; it should be of substantial thickness and $k=<10^{-6}$ cm/sec

No associated notes

Key Concepts/Definitions (Cont'd)

- mobility control – the ability to direct fluid flow into less permeable/accessible zones in the subsurface via the use of water-soluble polymers, gels or surfactant-based foams
- wettability - affinity of one immiscible fluid for a solid surface in the presence of a second or third immiscible fluid
- micelle - aggregations of surfactant monomers



- microemulsion - thermodynamically stable swollen micellar solution, i.e., contaminant and water molecules partitioned into the center of a micelle.
- SEAR – surfactant-enhanced aquifer remediation.

No associated notes

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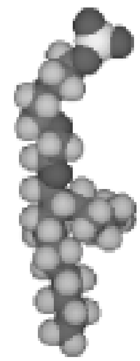
What are Surfactants?

- The term "surfactant" is a short way of saying surface active agents.
- A surfactant is a molecule composed of a hydrophilic (water loving) **head with a salt complex** and a hydrophobic (water fearing) **tail with a hydrocarbon chain**.
- Surfactants are compounds that alter the properties of organic-water interfaces.
- Surfactants solubilize and/or mobilize zones containing DNAPL.

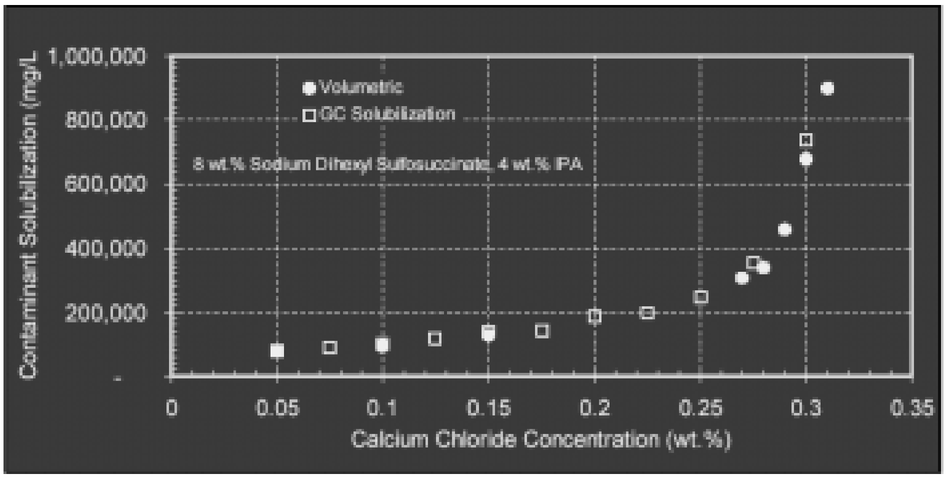


Soap is a common example of a surfactant

Like soaps, surfactants used to mobilize DNAPLs can cause foaming when exposed to surface air

How Surfactants Work: Solubilization

- Surfactants can enhance contaminant solubilization



No associated notes

What are Cosolvents?

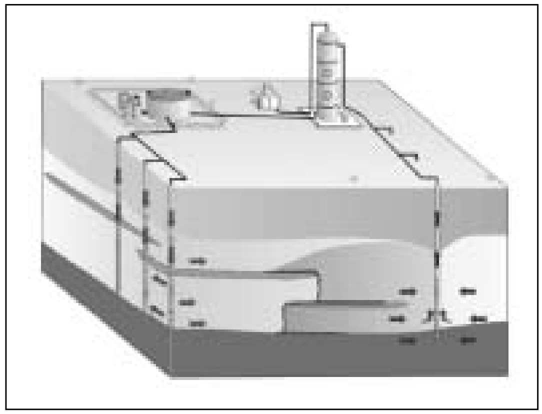
- Cosolvents are similar to surfactants in that they also alter the properties of solution interfaces.
- Cosolvents are commonly alcohols such as ethanol, methanol, and isopropanol.
- Cosolvents are often combined with surfactants to improve flood performance.

No associated notes

What is Surfactant/Cosolvent Flushing?

- It is a DNAPL-removal technology that involves the injection and subsequent extraction of chemicals to solubilize and/or mobilize DNAPLs.

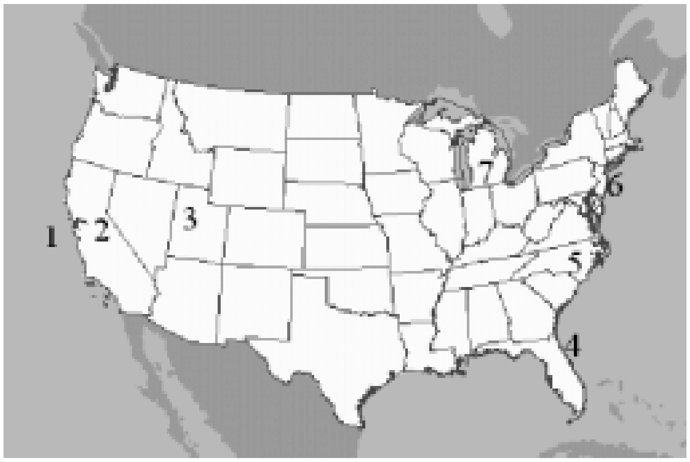
- The produced liquids are then either disposed off-site for treatment, or treated on site to remove contaminants and then reinjected to remove additional mass.



The appeal of surfactant/ cosolvent flushing is its potential to quickly remove a large fraction of the total DNAPL mass.

No associated notes

Where Has This Technology Been Implemented?



1. **Alameda Naval Air Station (NAS)***
2. **McClellan Air Force Base (AFB)**
3. **Hill AFB***
4. **Sages Dry Cleaners***
5. **Marine Corp Base Camp Lejeune***
6. **Dover AFB**
7. **Spartan Chemical Co.***

*Case summaries are provided in the ITRC Surfactant/Cosolvent Technical Guidance Document

No associated notes

Applicability

Relative Applicability as it Relates to Different Geologic Environments

Less Heterogeneous	
High Permeability (sand and gravel, >10^{-3} cm/sec)	1
Moderate Permeability (silts, silty sands and clayey sands, 10^{-3} to 10^{-4} cm/sec)	2
Low Permeability (silty clays and clay, <10^{-5} cm/sec)	4
Heterogeneous	
Moderate Contrasts	1
Large Contrasts	3
Fractured Rock	4

Shown to be effective for several DNAPL types, including spent degreasing solvents (TCE and TCA), dry cleaning solvents (PCE), heavy fuel oils and coal tar/creosote.

Surfactant/cosolvent flushing is primarily used to target the removal of DNAPLs and is not well suited for the remediation of dissolved, sorbed, or volatilized plumes.

Note: 1 is the most favorable

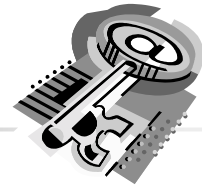
No associated notes

Limitations

- It is a complex technology
- It is limited by aquifer heterogeneities (not yet been proven to be effective in clays or fractured rock)
- A considerable amount of laboratory and modeling work is required prior to implementation
- There is a risk that DNAPL could be mobilized and not recovered with the extraction system
- Uncontrolled mobilization can result in migration of contaminants into previously uncontaminated aquifer regions
- Extracted groundwater with surfactant/cosolvent and DNAPL requires a significant degree of handling

No associated notes

Key Issues and Concerns



- Determining extent of DNAPL zone
- Estimating the initial volume of DNAPL mass
- Properly characterizing hydraulic properties of aquifer
- Finding optimum chemical formulation for a given DNAPL composition and soil type
- Successfully delivering and distributing injected chemicals to targeted zone
- Making sure that uncontrolled vertical and horizontal migration is avoided
- Proper handling and treatment of fluids recovered and wastes generated

No associated notes

Setting Goals for DNAPL Source Remediation

- DNAPL sites pose special cleanup challenges. Due to their complex nature, a phased approach to characterization is important.
- Remedial goals should be different for DNAPL zone compared to dissolved plume (plume containment and/or aquifer restoration vs. mass reduction to an established level)
- Removing DNAPL mass while managing dissolved-phase plume downgradient of source can significantly shorten the duration of cleanup

No associated notes

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Visual Breakthrough Curve

5 6 7 8 9 10 11 12 1 2 3 4 5 6

pm am

Before SEAR 900 mg/L

After 8 mg/L SEAR

"SEAR" is an acronym for "Surfactant Enhanced Aquifer Remediation"

Note that the recovery wells are recovering only clear water prior to introduction of the surfactant, and then begin to recover the mobilized DNAPL.

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Designing a Chemical Flood

Hans Meinardus

Hans W. Meinardus is a senior hydrogeologist with INTERA, Inc. in Austin, Texas. He has a BS and an MS in Geology from Texas A&M University, with a specialization in Hydrogeology under Dr. Pat Domenico. He has worked with INTERA (formerly Duke Engineering and Services from 1997-2001) since graduation in 1991. For the past eight years he has specialized in NAPL source zone characterization, remediation, and remediation performance assessment, and has been involved in the development and deployment of innovative NAPL characterization and remediation technologies. Mr. Meinardus has been the INTERA project manager at Hill Air Force Base in Utah since 1995 where he was responsible for conducting Partitioning Interwell Tracer Tests (PITTs) (including the first full-scale implementation in 1998-99), three successful surfactant-flood remediation demonstrations (1996-7), and three full-scale surfactant floods (1999-2002). Mr. Meinardus was responsible for quantitatively delineating the volume and extent of the DNAPL source at Hill AFB's Operable Unit 2, and also assisted in the design and implementation of a cometabolic bioventing demonstration. He is currently involved in a post-surfactant flood bioremediation study at OU2, and is managing several other efforts to characterize contaminated sites, assess remedial options using numerical simulation studies, and to remediate NAPL source zones. His numerical ground-water flow and transport modeling experience includes developing, using, and managing three-dimensional single-phase and multi-phase numerical models for use in site investigation and in the design and evaluation of remedies at various facilities contaminated with NAPLs, lead, and arsenic. He has been an instructor for numerous DNAPL site characterization and remediation short courses, including ESTCP workshops. In addition, he has co-authored several peer-reviewed papers and presented on various NAPL topics at numerous conferences. Mr. Meinardus currently serves on the DNAPL team of the Interstate Technology Regulatory Council (ITRC).

Design Components

- Surface Facilities and Pipeline Completions
- Waste Treatment and Recycling
- Subsurface Design
  - Well Array configuration, locations, screened intervals
  - Chemical ingredients and amounts
  - Flow Rates and Concentrations (influent and effluent)
  - Durations
  - Monitoring locations/frequencies
- Systematic Treatment Concept (integration with other remedial processes)

Discussion of advective processes

Subsurface Remediation Design Basis

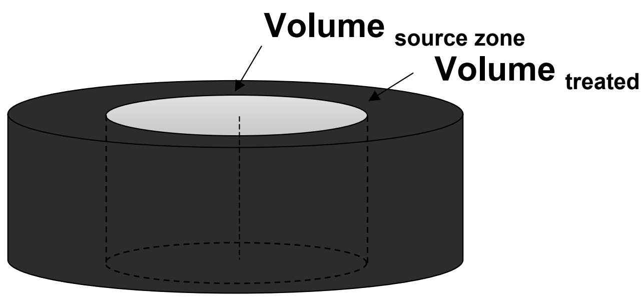
- Source Zone (Geosystem) Characterization
  - Design Basis
  - Baseline for Performance Assessment
- Laboratory Studies
  - surfactant selection
  - phase behavior
  - bench-scale testing
- Numerical design modeling
- These tasks have to be integrated with the process design

No associated notes

The Importance of Accurate Source Data

Cost

- If $\text{Volume}_{\text{source zone}} = \text{Volume}_{\text{treated}}$, treatment costs will be minimized.

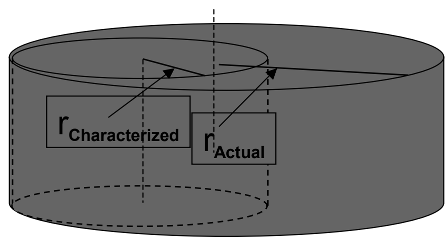


No associated notes

The Importance of Accurate Source Data

Performance

- If NAPL volume is missed, then plume concentrations will rebound.



No associated notes

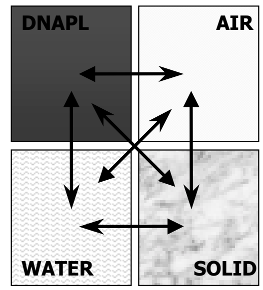
What is a "Geosystem Model"?

- Comprehensive description of the source zone:
  - Hydrostratigraphy
  - Hydrogeology
  - Geochemistry
  - Physical properties of the DNAPL
  - Multi-phase fluid flow parameters
- Progresses from conceptual to quantitative
- Guides characterization and becomes the remediation design basis

No associated notes

Using a Geosystem Approach

- Dynamic
- Iterative
- Focused (Data Quality Objectives)
- Funnel
  - rapid screening methods
  - DNAPL specific delineation
  - Becomes design basis

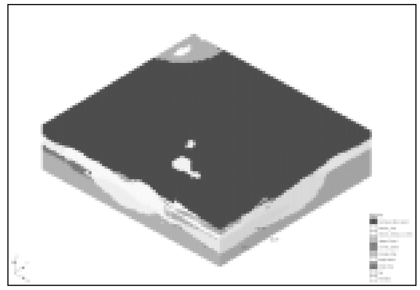


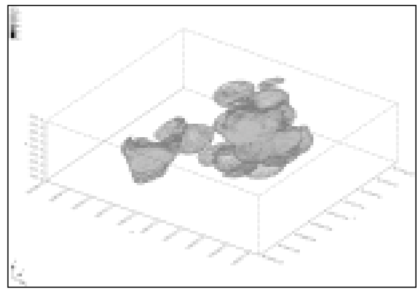
Partitioning Theory

No associated notes

Source Zone Characterization: Task List

- Define hydrostratigraphy
- Map capillary barriers
- Determine hydrogeologic parameters
- Update geosystem model
- Estimate DNAPL distribution, volume, and extent





Discussion of depositional environment and other factors that influence the DNAPL locations

Data Types needed for Chemical Flushing

- DNAPL physical properties
- Detailed hydrostratigraphy
  - grain-size distributions
  - capillary barrier properties and structure
  - FOC (fraction organic content)
- Hydraulic testing
  - permeabilities
  - heterogeneity
- S_n - DNAPL saturation distribution and extent

FOC = Fraction Organic Content

Characterize the DNAPL

- DNAPL-Water Interfacial Tension
- DNAPL-Flushing Agent Interfacial Tension
- Viscosity
- Density
- Wettability of the DNAPL-Aquifer System (Amott and USBM tests)

No associated notes

Source-Focused Desk Top Review

- Look for:
  - release point
  - release history and volume (ha!)
  - NAPL properties
  - hydrostratigraphy (where is the NAPL going?)
  - plume attributes
- Assimilate data into Geosystem (scoping calculations)
- Identify data gaps and evaluate data needs
- Plan objectives for investigation

No associated notes

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Conventional Characterization Tools

- Groundwater samples
- Remote sensing (geology/hydrogeology)
  - EM surveys
  - seismic/ground-penetrating radar (GPR)
  - borehole geophysics
- Soil gas surveys (vadose zone)
- Soil Samples (geology/hydrogeology)
  - DPT
  - Drilling

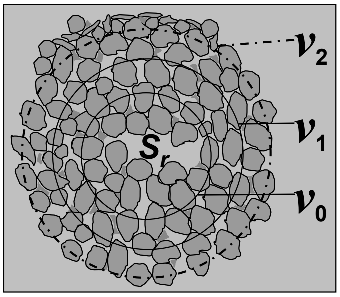
"DPT" refers to "Direct Push Technologies"

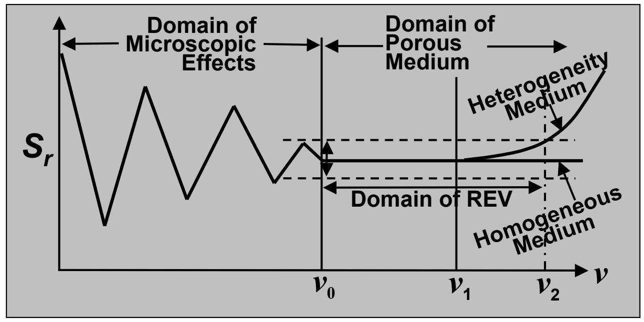
Conventional Characterization Tools (cont.)

- Water sampling
  - solubility limitations
  - the use and abuse of the 1% rule
  - degradation products
  - possible NAPL recovery for analysis
- Using a drill rig

No associated notes

Representative Elementary Volume (REV)





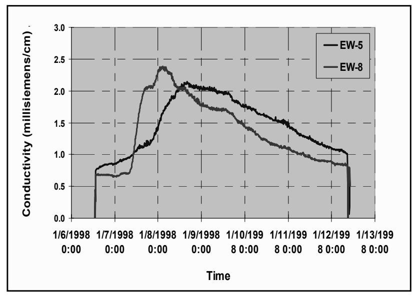
- **Est. range of REV for NAPL in soil** **= 10-10^4 cm^3 = 0.0003 to 0.3 ft^3**
- **Volume of typical soil sample** **= 30-10^2 cm^3 = 0.001 to 0.01 ft3**

Conclusion: In order to characterize a DNAPL source zone adequately, you need LARGE NUMBERS of good soil samples!

A key concept of the EPA TRIAD approach is that you must obtain "Decision-Quality Data." For a DNAPL source zone, this can mean that a lot of samples may be required to allow you to make the proper remedial design decisions.

Hydrogeologic Properties

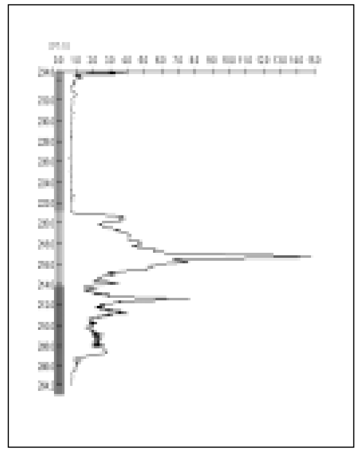
- Grain Size Distributions
- Aquiclude Properties (porosimetry, geochemistry)
- Pumping/Slug Tests
- Conservative Interwell Tracer Tests (CITTs)
  - Extraction and Injection wells
  - Hydraulic Conductivity
  - Dispersivity
  - Transport Properties
  - Swept Pore Volume



No associated notes

DNAPL Characterization Tools

- Ribbon NAPL Sampler (FLUTe™)
- SUDAN IV Dye
- Radon Flux
- CPT-based NAPL tools
  - permeable membrane (MIP)
  - HydroSparge
  - fluorescence
  - discrete water samplers
  - other sensors (Raman, GeoVis, etc)



CPT/LIF

CPT = cone penetrometer LIF = laser induced flourescence

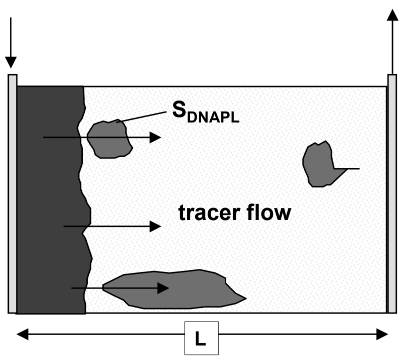
CPT is applicable only in environments that allow for the operation of push tools. Gravels, cobbles, caliche, and rock are examples of geologic environments that are not favorable to CPT.

Partitioning Interwell Tracer Tests (PITTs)

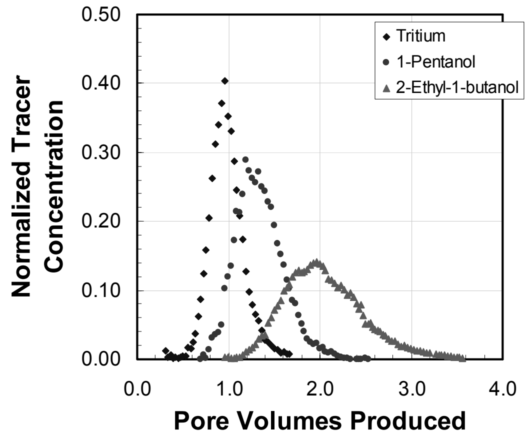
- Developed for NAPL site characterization by DE&S and Dr. Gary Pope at UT Austin
- Adopted by EPA & the USAF for technology performance assessment at Hill, AFB, Utah
- Over 40 conducted since 1994
- U.S. Patent No. 5,905,036

No associated notes

Partitioning Tracer Test with DNAPL



$$R_f = \frac{\bar{t}_p}{\bar{t}_n} = 1 + \frac{K S_N}{1 - S_N}$$

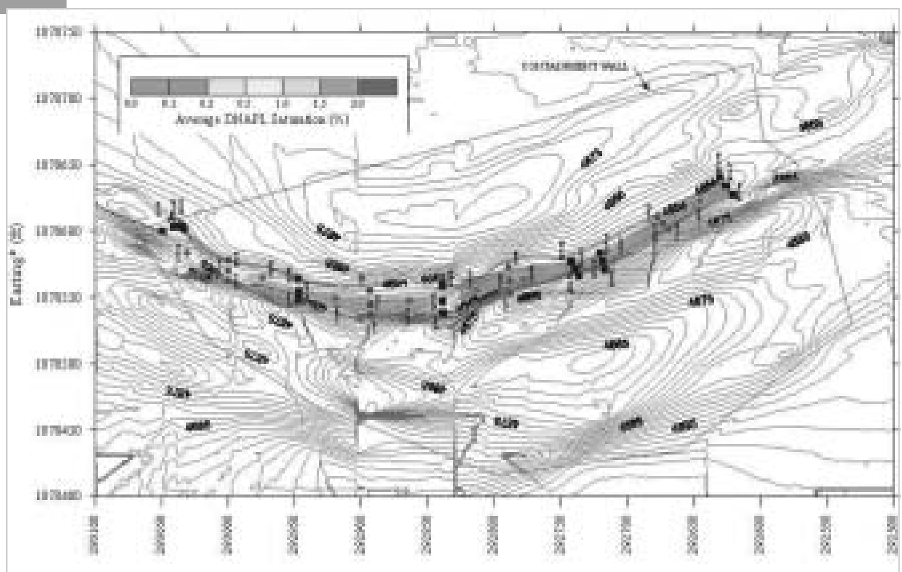


Saturation = 8.1%

Notes;

This test was performed at Hill AFB near Salt Lake City, Utah

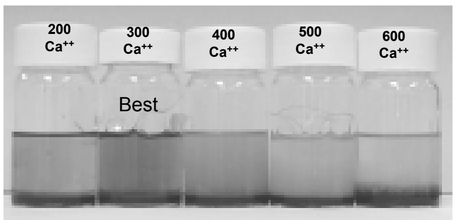
Remedial Design Basis



A paleochannel at Hill AFB forms a hydrogeologic trap for DNAPL

Laboratory Studies

Phase Behavior



Before **After**

Column Tests

No associated notes

Surfactant Selection

- Compatibility with site soil and NAPL, may require tailoring NAPL-specific surfactants
  - incompatibility can cause pore plugging
- High NAPL solubilization, IFT reduction
- Biodegradability
- Above-Ground Treatability
- Commercial availability & economics

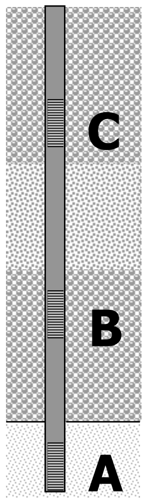
No associated notes

Mobility Control

- Goal - improve sweep efficiency
  - mitigate the effect of heterogeneity
  - reduce surfactant mass needed
- Two Types
  - polymer - injectate viscosity
  - foam - gas phase viscosity and mobility
- Pressure Pulsing

Mobility control concepts were developed in the petroleum industry

Surfactant/Foam Process



Soap is the most common example of a surfactant. When exposed to air, surfactants may foam as does soap.

The foam in units B & C causes the fluid flow to be re-directed to the less permeable zone Unit A.

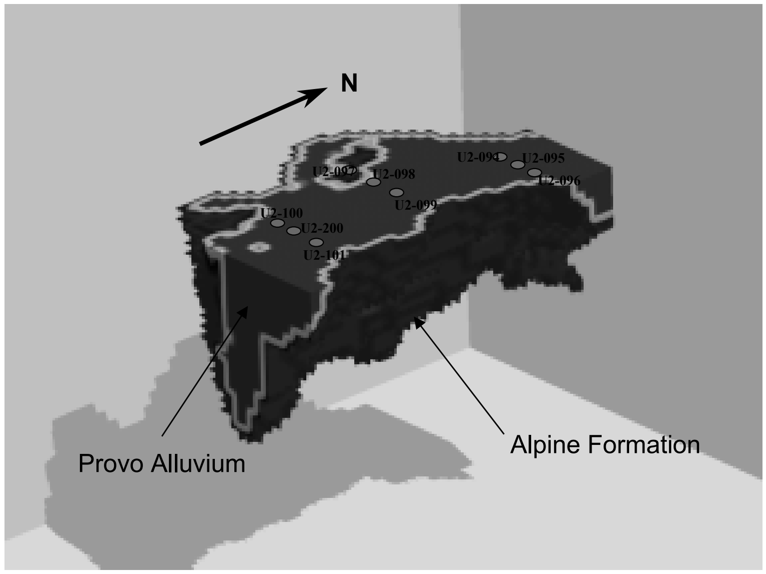
Numerical Design Modeling

UTCHEM

- Chemical flood simulator from the University of Texas
- Multi-phase, multi-dimensional chemical compositional simulator
- Biodegradation, vadose zone capability
- U.S. EPA (1999) approved numerical simulator

No associated notes

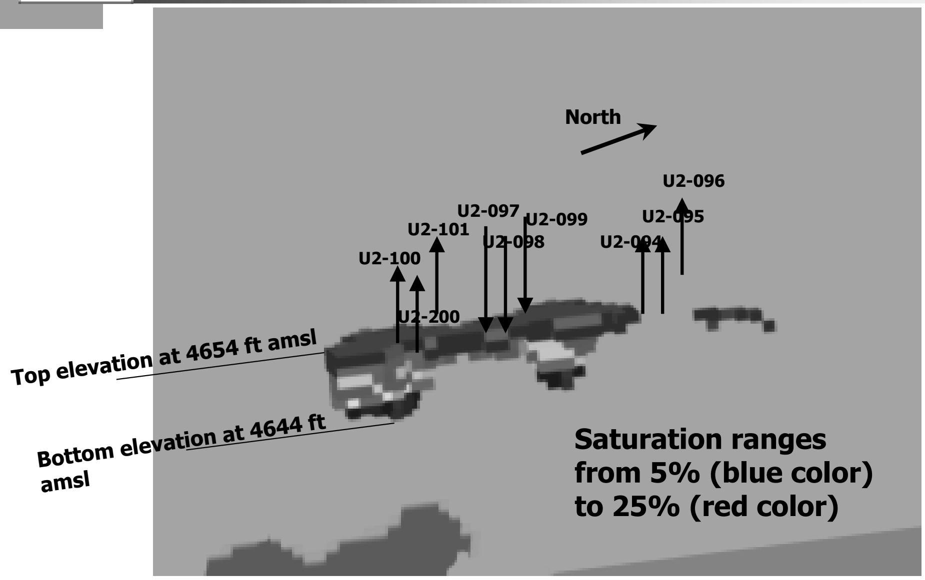
Calibrated UTCHEM Design Model



Contaminated Aquifer Permeability Structure

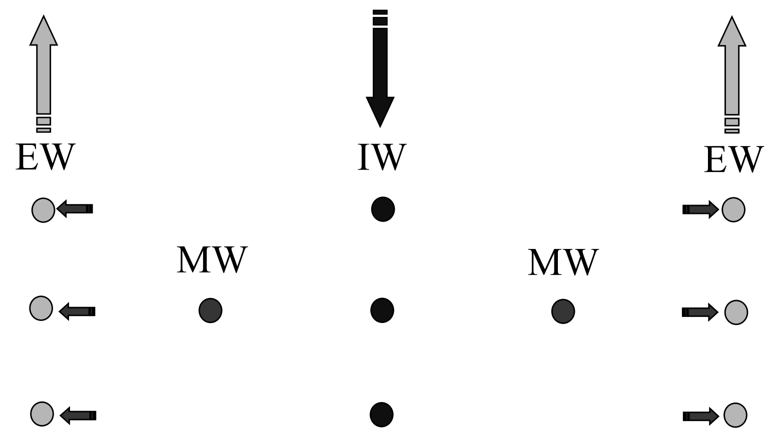
Computer model used to optimize the surfactant flood design

Pre-SEAR DNAPL Saturations



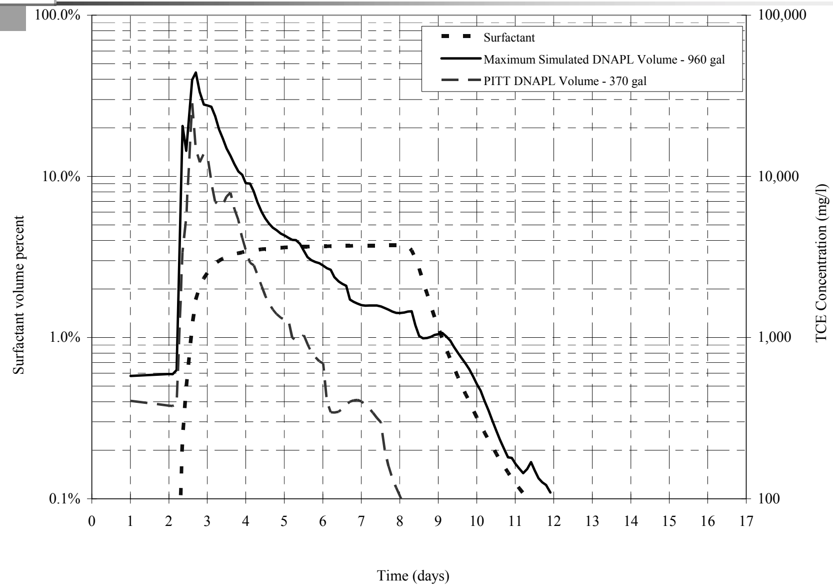
No associated notes

Divergent Line Drive



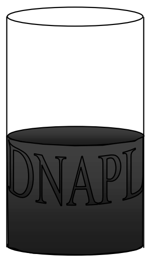
IW = Injection Well, and EW = Extraction Well

Predicted Performance



Predicted effluent characteristics during the flood

Questions and Answers



No associated notes

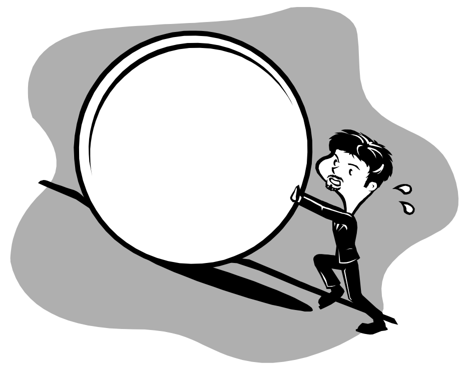
Process Design and Implementation

Mark Hasegawa

Mark A. Hasegawa is an Associate with Hasegawa Engineering Ltd. in Lethbridge, Alberta. He has a BS in Civil Engineering from Brigham Young University and a MS in Environmental Engineering from the University of Oklahoma, with a specialization in Process Design and Surfactant Chemistry under Dr. David Sabatini. While at the University of Oklahoma, Mark was selected to teach two courses: the introduction to water chemistry and computer assisted engineering analysis. Mark has worked in the environmental remediation field for 10 years and has specialized in NAPL/DNAPL remediation, and process design, and has been involved in the development and deployment Surfactant Enhanced Subsurface Remediation. Mr. Hasegawa has supervised over 10 surfactant enhanced NAPL remediation projects including several DNAPL sites which include: McClellan AFB, Alameda Naval Air Station, a Chemical Plant in Michigan, Dover AFB, and Tinker AFB. Mark was project manager for the aforementioned project and supervised process design for each project. He has extensive experience in performing risk analysis at sites and has supervised the completion of numerous site specific risk assessments. He was also one of three approved trainers utilized by the state of Oklahoma to train consultants on the implementation of Risk Based Corrective Action in the state. Mark is also a registered professional Engineer in several states and provinces. In addition, he has co-authored several peer-reviewed papers and presented on various DNAPL and risk assessment topics at numerous conferences. Mr. Hasegawa currently serves on the DNAPL team of the Interstate Technology Regulatory Council (ITRC).

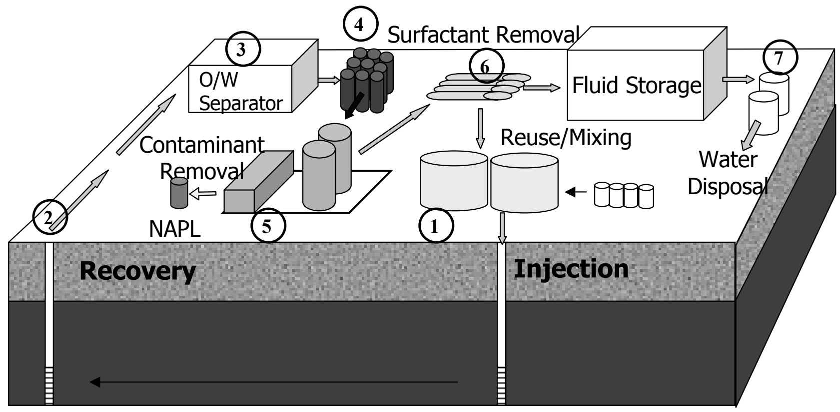
Integrated Design Process

- When additives are used to increase the solubility or mobility of containments in the groundwater there is a profound effect on subsequent treatment of produced fluids.
- These issues must be considered



Processes that help remove the contaminants in the subsurface make it harder to treat the effluent

Generic SEAR Process Diagram



"SEAR" is "Surfactant Enhanced Aquifer Remediation"

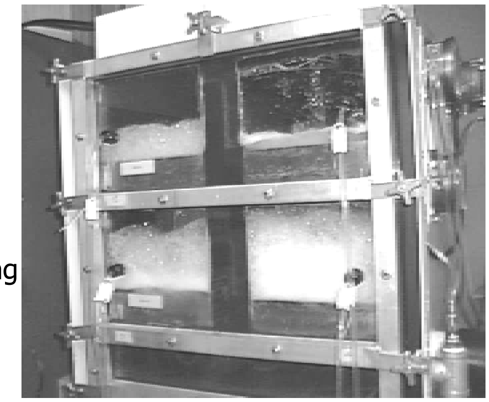
Key Issues to Consider

- Cost
- Waste disposal and criteria for contaminants and potential additives
  - This can affect chemical formulation
- Chemical recycling and re-injection
- Fluid composition, pressure and flow quantity
- Infrastructure
  - Water, electric, gas, phone
- Footprint
- Temperature
- Process sensitivity and reliability
- Unit processes strengths and weaknesses
- Most of these processes have been used in other industries

Cost is the primary issue that influences the treatment design

Design Process

- Determine design criteria
  - Influent concentrations
  - Effluent criteria
  - Flow
  - Viscosity
  - Cost limitations
  - Other interferences
- Prepare preliminary process diagram
- Conduct bench/ pilot scale testing if necessary
- Identify limitations in design
- Finalize design



Surfactants can be very sensitive to hard water

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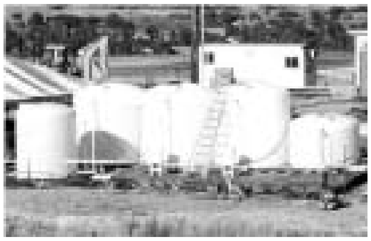
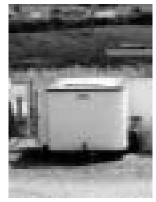
Mixing/Injection System Issues





20,000 gal Mixing Tanks → **Control Trailer** → **In-Line Mixer <u>Inside</u> Trailer**

- Reagent transportation
- Reagent receiving and storage
- Make-up water supply
- Staging and mixing process
  - Inline vs. batch
  - Sensitivity of solution

- Injection rate, pressure, and concentration control
- Logging injection parameters
- Sampling for QA/QC and process control
- Contingency planning and spill control
- Logistics (unloading)

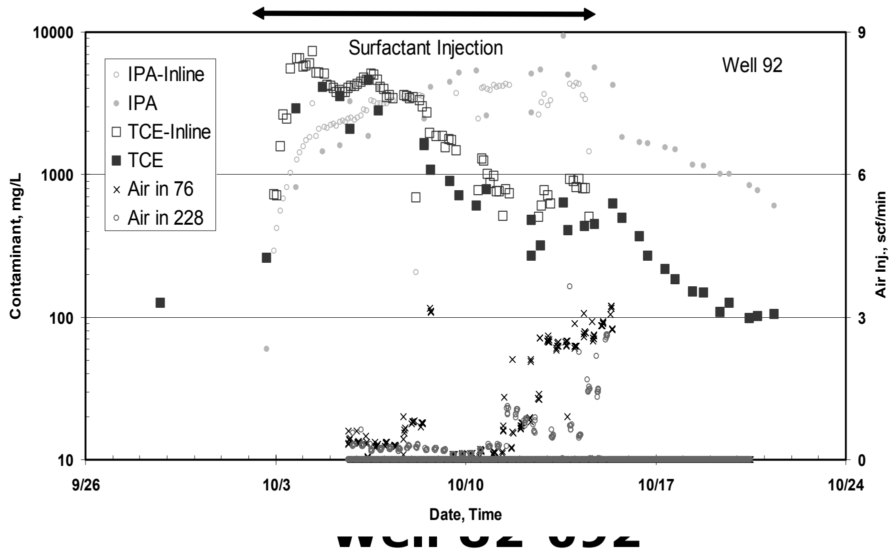
The physical process systems have improved markedly since the technology was first used

Extraction System Issues

- Pump types (shear) and plumbing
- Water-level monitoring (hydraulic control)
- Rate control and volume logging
- Sampling for Performance Assessment and process control
- Effluent treatment operations
- Contingency planning and spill control

No associated notes

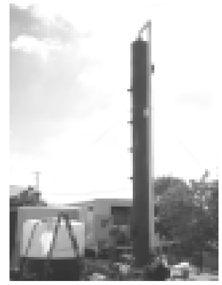
Breakthrough Curve
IPA – Isopropyl Alcohol



Actual curve from a flushing project. The process equipment must be designed to handle the variations in the extracted fluids.

Contaminant Removal From Extracted Groundwater

- Fines removal
  - Filters
  - Sedimentation
- Free Product separation
  - Oil water separation
  - Chemical assisted
- Dissolved chemical removal (up to 40,000 ppm)
  - Stripping technology (Liquid-Liquid, steam, air)
  - Sorption technologies
  - Solubility / volatility
  - Chemical effects (foaming, etc)



Once the contaminated water has been extracted from the ground, the contaminants must be removed prior to re-injection

Chemical Removal / Recycling

- Highly variable
- Function of cost and treatment objectiv
- Stripping technology
  - Steam
  - Air
- Physical Filtration
  - Micellar Enhanced Ultrafiltration (MEUF)
  - Ligand Enhanced Ultrafiltration (LEUF)
- Chemical removal/precipitation
  - Unique to chemical
  - Some surfactants pH and temperature sensitive

MEUF is an acronym for “Micellar-Enhanced UltraFiltration”

LEUF is an acronym for “L -Enhanced UltraFiltration”

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Monitoring and Sampling Issues

- Performance monitoring (Is the process working?")
- Data Objectives
- Sampling/Monitoring Parameters
- Data Quality Objectives
- Sampling/Monitoring Locations
- Purge/Waste Water Handling and Treatment
- Sampling/Monitoring Schedule
- Sample Logging, Control, and Handling
- Sample Analyses

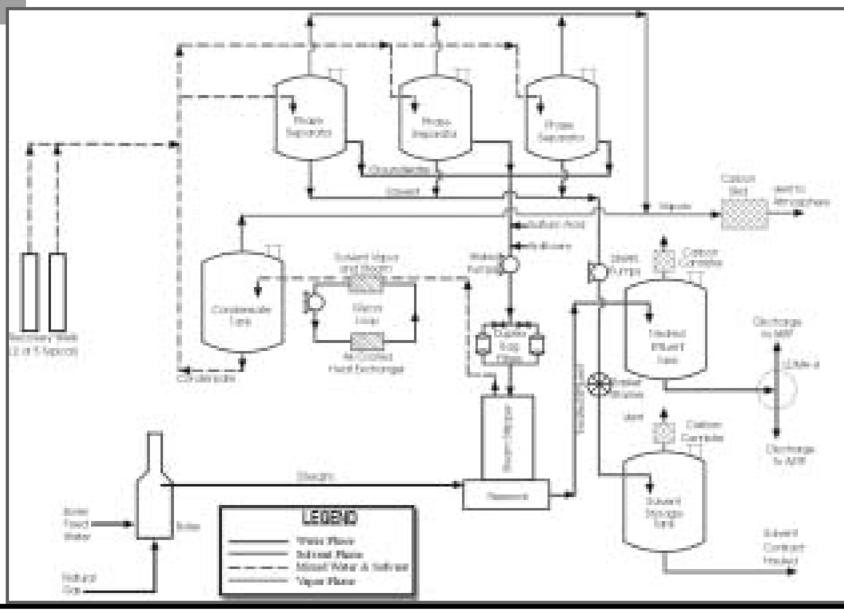
An onsite lab is very beneficial

Process Control Issues

- Control Parameters and Specifications
- Ranges and Tolerances
- Alarms and Alerts
- Trending and Logging/Reporting Needs
- System Reliability
- System Flexibility

No associated notes

Simplified Process Diagram for the SRS



SRS is "Surfactant Removal System"

Printing this slide may help you read the details

Design Example

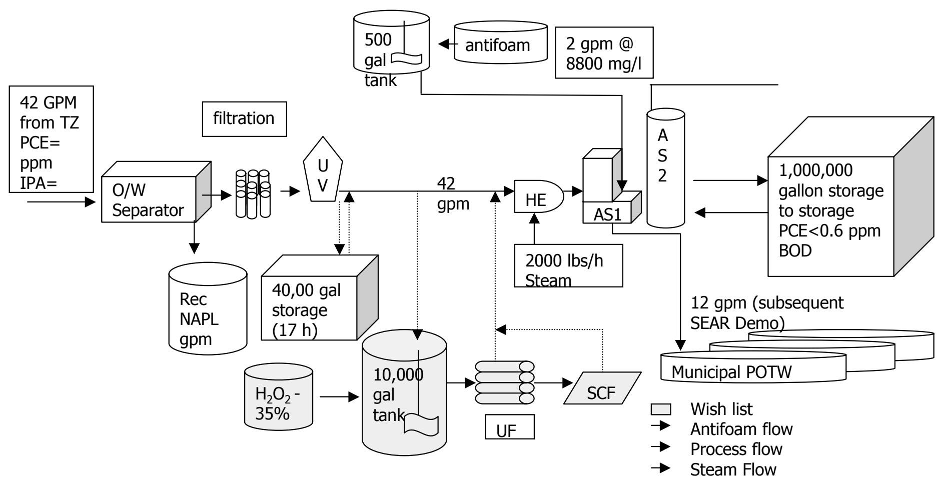
- Surfactant flood which included 8 % IPA
- Influent characteristics
  - PCE concentration from 0 – 6000 ppm
  - IPA 40,000 PPM
  - Flow rate = 50 gpm
- Treatment requirements
  - Discharge to POTW (publicly owned treatment works)
  - 2500 lb/d BOD (biological oxygen demand) limit
  - 5 ppb restriction on PCE
- Other considerations
  - Air emission restrictions for PCE, IPA
  - Ample storage onsite including 700,000 gallon tank
  - Onsite boilers
  - Maximum cost of $400,000

This data is from an actual surfactant flood project

POTW is an acronym for "Privately Owned treatment Works"

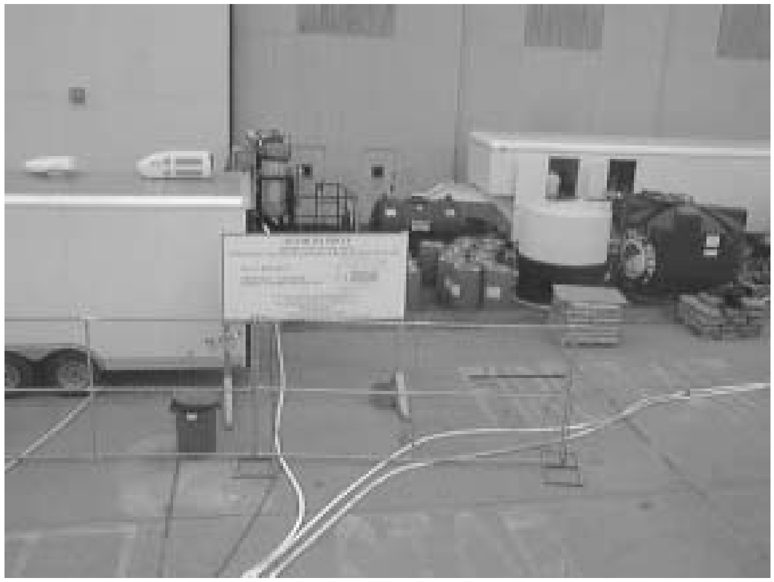
BOD is an acronym for "Biological Oxygen Demand"

Design Solution



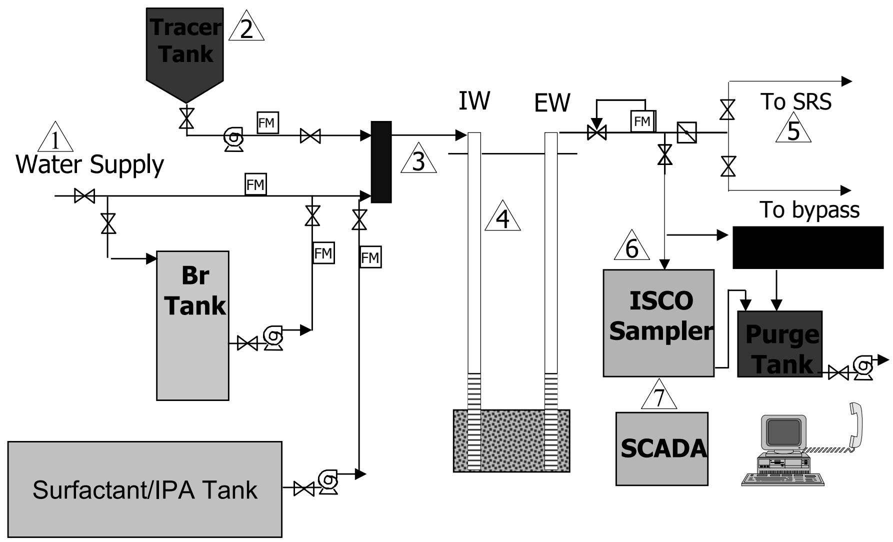
No associated notes

MPP L-L extraction and MEUF (Alameda)



No associated notes

PITT/SEAR Process System



ISCO = in-situ chemical oxidation

Performance Assessment

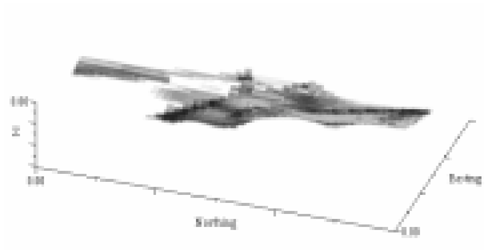
- Key Aspect of any Remediation Technology
- Easy to say, hard to do
- Performance criteria needs to be defined prior to starting the project

Methods Include;

- Soil Sampling – before and after
- Mass recovery
- Groundwater Concentrations – before and after
- Mass Flux in Groundwater - before and after
- Partitioning Tracer Tests
- Other Non-intrusive Methods

No associated notes

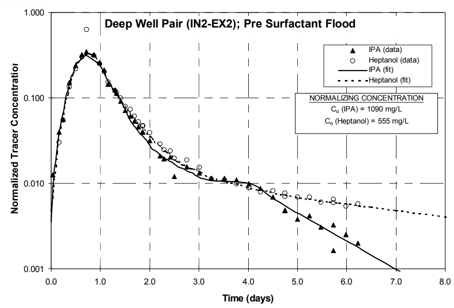
Remedial Performance Assessment: Pre-Remediation Baseline



Soil samples:
20 ± 13 gal DNAPL

227 soil samples

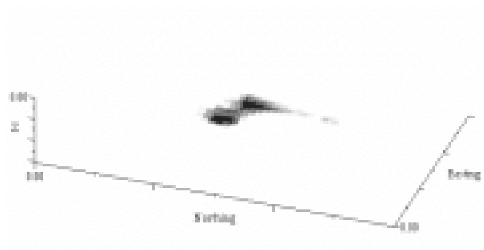
PITT:
21 ± 7 gal DNAPL



1997 AATDF Surfactant/Foam Flood

Meinardus, H.W., V. Dwarakanath, J. Ewing, G.J. Hirasaki, R.E. Jackson, M. Jin, J.S. Ginn, J.T. Londergan, C.A. Miller, and G.A. Pope. 2002. Performance Assessment of NAPL Remediation in Heterogeneous Alluvium. *Journal of Contaminant Hydrology*, 54(3–4): 173–193.

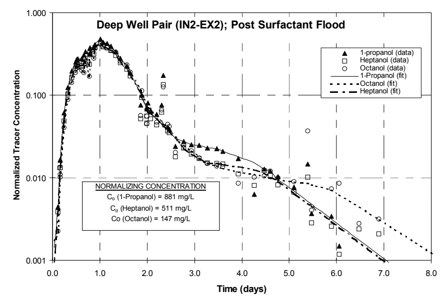
Remedial Performance Assessment: Post-Remediation Mass Remaining



Soil samples:
1.4 ± 0.9 gallons DNAPL

115 soil samples

PITT:
2.6 ± 2.0 gal DNAPL



1997 AATDF Surfactant/Foam Flood

No associated notes

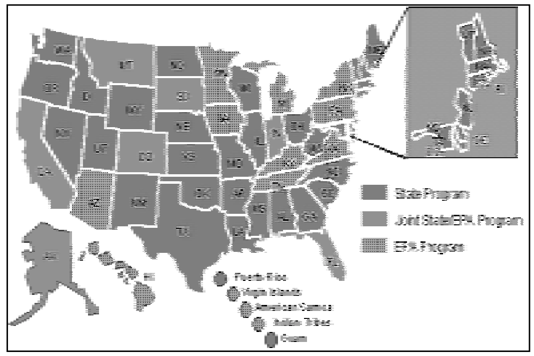
Regulatory Requirements, Health and Safety Issues, Stakeholder Issues

Ana Vargas

Ana Vargas has been working for the Arizona Department of Environmental Quality (ADEQ) Superfund Programs Section for the last 15 years. She is responsible for the management of five State Superfund sites in the Phoenix area dealing with chlorinated solvents. Ana is the Interstate Technology Regulatory Council (ITRC) team leader for the Surfactant/Cosolvent team. Ana received her B.S in Chemical Engineering from the University of Puerto Rico in 1985. Prior to working for ADEQ, Ana was responsible for the development of qualification standards and related training material for senior Naval reactor plant operators in the U.S. Navy Nuclear Propulsion Program. Ana is fluent in both English and Spanish and has also served as a translator between ADEQ and Phoenix Hispanic communities in environmental issues, when needed.

Regulatory Requirements

- Underground Injection Control (UIC) Program
- POTW permit for discharge to municipal sewer
- National Pollutant Discharge Elimination System (NPDES) for discharge to surface water
- RCRA LDRs (solid wastes generated during treatment)
- RCRA 3020 (b)
- Air quality permit



Breakdown of Responsibility for the UIC Program in the United States (June 2001)

Flushing technologies involve the introduction of chemicals into the ground. An NPDES or POTW permit may be required, depending on the method of discharge. An air quality permit may be required depending on the amount discharged to the air.

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Health and Safety Issues

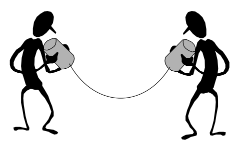
- High concentrations of alcohol can be flammable and explosive.
- Concentrated chemicals should be handled with care to avoid personal injury and damage to the environment during transportation, handling, and injection.
- Drums of flammable liquids and associated equipment should be properly grounded to avoid electrical hazards.
- Secondary containment of chemical storage tanks is necessary.
- A Site Safety Plan prepared in accordance with OSHA 29 CFR 1910.120

Surfactant flushing requires that workers handle chemicals that may be flammable or explosive. Secondary containment of chemicals must be considered.

Involving Stakeholders

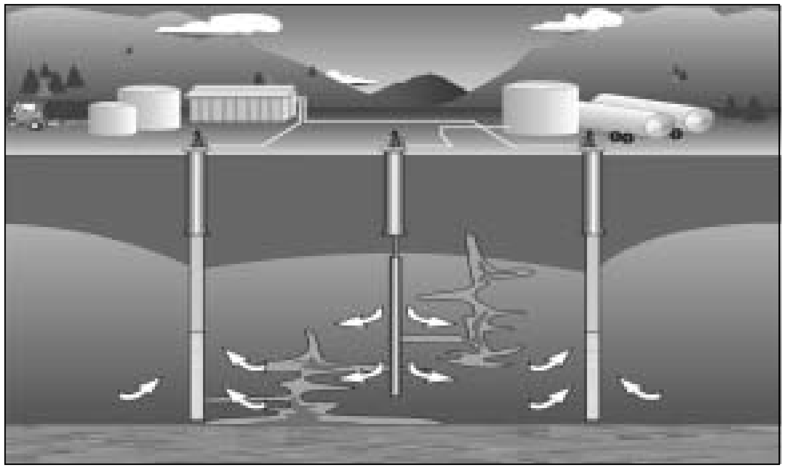
- Stakeholders should be involved at every stage of the evaluation, selection, and permitting (if necessary) of any treatment system
- Since surfactant/cosolvent flushing involves introduction of chemicals into environment, there's the obvious question "Will it do any harm?" This question must be answered carefully and honestly
- Explain the reasons why technology is likely to work and possible failure scenarios

COMMUNICATE, COMMUNICATE, COMMUNICATE!



Stakeholders should be involved in the process at an early stage, and must be educated so that they understand the technology.

Questions and Answers



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ITRC – Go to www.itrcweb.org

No associated notes

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Thank you for your participation

Links
To
Resources

Links to additional resources: http://www.clu-in.org/conf/itrc/flushing/resource.cfm

Your feedback is important – please fill out the form at: at http://www.clu-in.org/conf/itrc/flushing/feedback.cfm

The benefits that ITRC offers to state regulators and technology developers, vendors, and consultants include:

•helping regulators build their knowledge base and raise their confidence about new environmental technologies

•helping regulators save time and money when evaluating environmental technologies

•guiding technology developers in the collection of performance data to satisfy the requirements of multiple states

•helping technology vendors avoid the time and expense of conducting duplicative and costly demonstrations

•providing a reliable network among members of the environmental community to focus on innovative environmental technologies

•**How you can get involved in ITRC:**

•Join a team – with just 10% of your time you can have a positive impact on the regulatory process

•Sponsor ITRC's technical teams and other activities

•Be an official state member by appointing a POC (Point of Contact) to the State Engagement Team

•Use our products and attend our training courses

•Submit proposals for new technical teams and projects

•Be part of our annual conference where you can learn the most up-to-date information about regulatory issues surrounding innovative technologies