In Situ Treatment of Groundwater Contaminated with NAPL: Fundamentals and Case Studies

Conference Background and Opening Remarks
December 10, 2002
Chicago, IL

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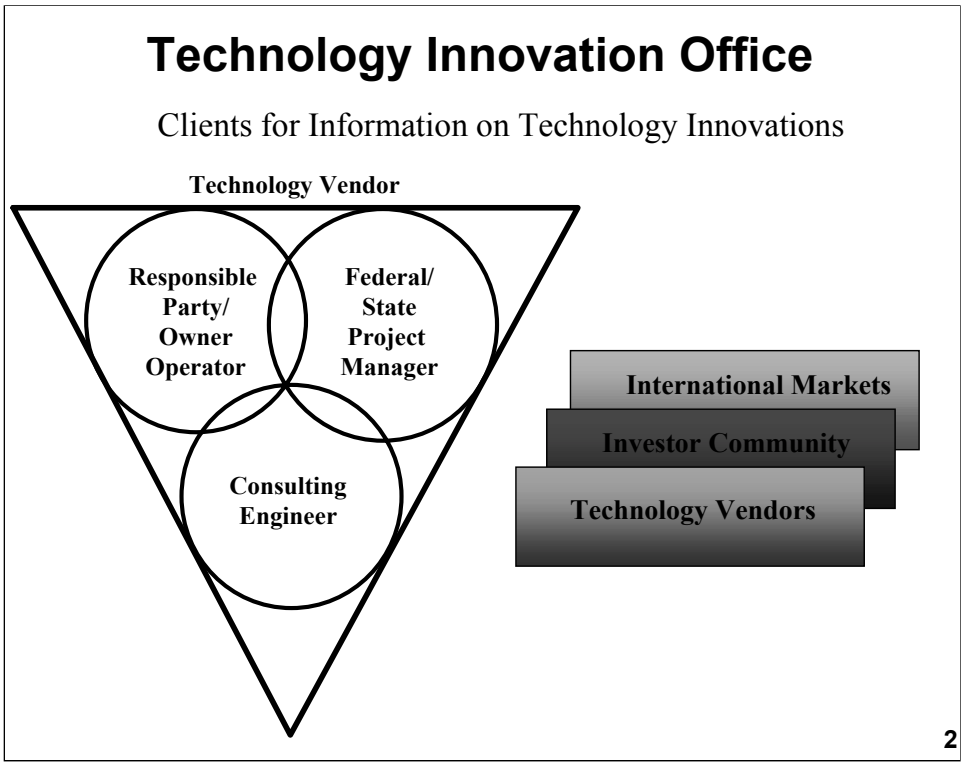

International markets are of growing importance to our office, and EST officers are a vital link to foreign companies charged by their goverments to remediate haradous waste sites.

TIO's Mission

- Advocates "smarter" technologies for the characterization and cleanup of contaminated sites
- Works with clients to identify and understand better, faster, and cheaper options
- Seeks to identify and reduce barriers to the use of innovative technologies

Ranking Criteria for Difficulty in Remediating Ground Water

TIO Update to NRC Table, October 2002

Hydrogeology	Mobile Dissolved (Degrades/ Volatilizes)	Mobile Dissolved	Strongly Sorbed, Dissolved	Strongly Sorbed, Dissolved (Degrades/ Volatilizes)	Separate Phase LNAPL	Separate Phase DNAPL
Homogeneous, Single Layer	1	1-2	2	2-3	2-3	1-2
Homogeneous, Multiple Layers	1	1-2	2	2-3	2-3	2 ?
Heterogenous, Single Layer	2	2	3	3	3	3 ?
Heterogenous, Multiple Layers	2	2	3	3	3	4
Fractured Bedrock	3	3	3	3	4	4

least difficult = 1 / most difficult = 4

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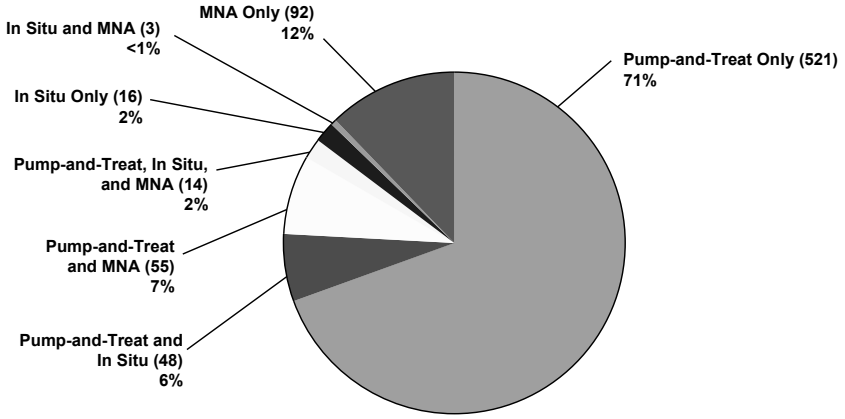
1) Fractured rock the most difficult
2) Need to share experiences of practitioners
3) Need to develop an R&D strategy linked to the needs of the practitioner
4) Define the "State of Practice" for the International conference.

Types of Sites Likely to Have Significant NAPL

- Chlorinated Solvents - TCE most common contaminant at NPL sites
- Wood Treaters - > 80 sites on NPL
- Former Manufactured Gas Plants (MGP) - Estimated 3,500-35,000 sites
- Petroleum Refineries - Large quantities of LNAPL
- Dry Cleaners - Very prevalent class for state cleanup programs

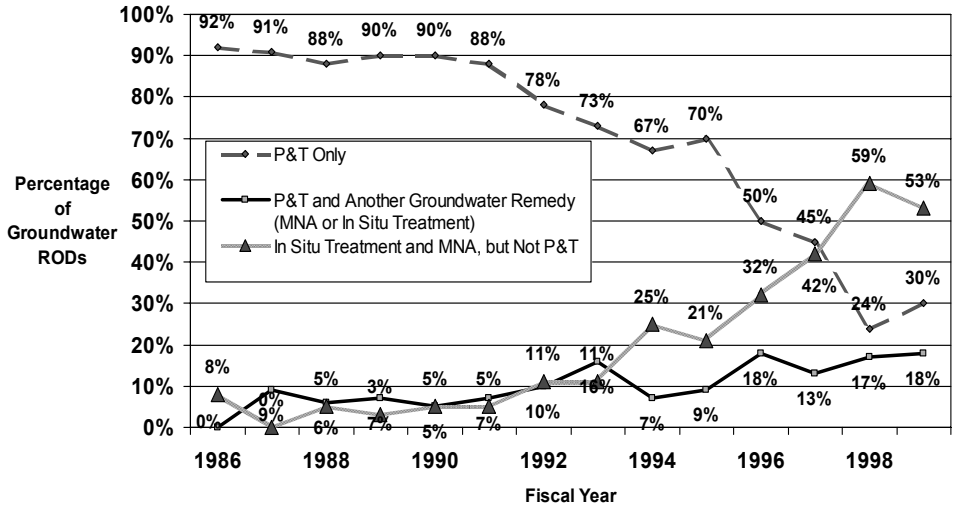
Superfund Remedial Actions:
Groundwater Remedies (FY 1982 - FY 1999)

Total Sites With Pump-and-Treat, Monitored Natural Attenuation (MNA) and In Situ Groundwater Treatment Remedies = 749



Source: *Treatment Technologies for Site Cleanup: Annual Status Report (Tenth Edition)*, U.S. EPA, EPA 542-R-01-004, February 2001

Selection of P&T for Superfund Remedial Actions 1986 - 1999



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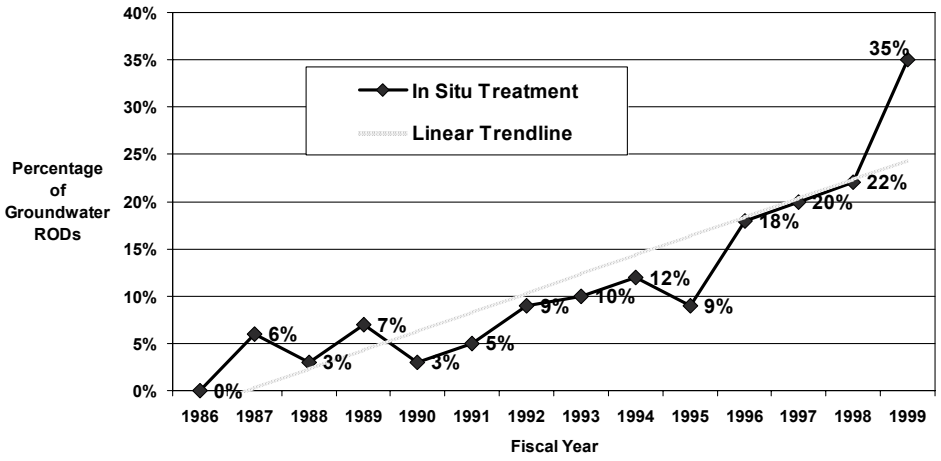
Percentage of Groundwater RODs includes groundwater P&T, in situ treatment, and MNA remedies. Groundwater containment and groundwater other remedies are not included.

In Situ Groundwater Treatment for Superfund Remedial Actions 1986 - 1999



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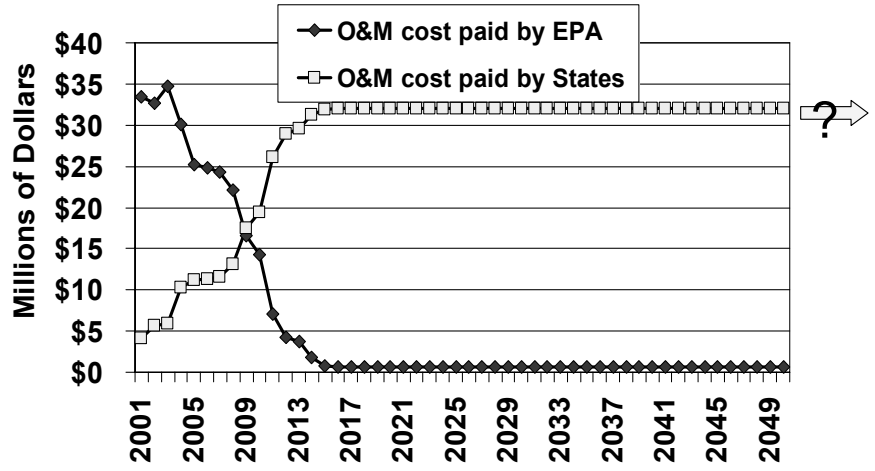
In Situ Treatment includes RODs selecting in situ groundwater treatment alone and those selecting in situ groundwater treatment with any other remedy.

Estimated Annual Costs Incurred for O&M at Fund-lead P&T Systems



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Trend lines reflect 78 of the 88 Fund-lead P&T systems. We do not have sufficient information (I.e., O&F and/or transition dates) for the 10 remaining systems.

Assumptions:

1) during LTRA EPA pays for 90% of the O&M costs while the State pays for the remaining 10%

2) after LTRA EPA pays for 0% of the O&M costs and the State pays for 100%.

3) Annual O&M costs remain constant throughout operation of site

4) No costs associated with aquifer monitoring upon system shutdown

5) Sites are not turned over to PRPs

6) Costs are not discounted.

7) Estimates of remedy completion and transition to States are accurate

Of the total of 88 Fund-lead P&T sites, 35 (or 40%) reported that NAPL is present or suspected at the site in a survey.

Of the 20 sites evaluated by the RSE team, 17 (or 85%) sites had NAPL present or suspected (only 12 had reported the presence of NAPL in the survey). In opinion or RSE team, the majority of sites with NAPL had not sufficiently recognized presence of NAPL in designing P&T system and setting site goals.

Superfund Pump and Treat Optimization Initiative

- 2-yr nationwide study to evaluate/optimize 20 Fund-lead P&T systems
- Cost reductions identified at 17 of 20 sites
  - Total potential cost savings exceeds $5M/yr
  - Over 30 yrs this could save EPA and States $150M
- Improvements in remedy protectiveness identified at 17 of 20 sites
  - Lack of sufficient evaluation of capture zones highest priority

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RSE process is an independent expert review of operating pump and treat systems. RSE team consists of 2-4 senior engineers and geologists working with site personnel (contractors, RPM) to evaluate all aspects of the operating system. RSEs typically cost $25K and were performed by EPA contractor and US Army Corps of Engineers. RSE evaluations look for opportunities to reduce operating and lifecycle costs (e.g., eliminate or replace redundant or unnecessary equipment, reduce operator labor) and improve remedy protectiveness (is remedy achieving its subsurface goals – contain plume and/or meet regulatory concentration in groundwater).

We also expect that PRPs are performing reviews similar to RSEs although their review may be more focused on cost reduction rather than improving remedy protectiveness. US AF, Army and Navy are actively pursuing similar optimization efforts.

Results…..

Although a significant amount of savings in annual O&M were identified, we also identified problems with remedy protectiveness.

The most common problem associated with remedy protectiveness was the lack of sufficient evaluation of capture zones. We are not adequately evaluating whether the systems are achieving capture and other goals (e.g. cleanup to MCLs) set forth in the ROD. This was found at 17 out of 20 site. Regions have indicated this problem extends to sites other than Fund-lead P&T. (e.g. RCRA and Superfund site with PRPs).

Key Message from Reviews

GROUNDWATER REMEDIATION SYSTEMS REQUIRE ACTIVE MANAGEMENT

- Revisit system objectives
- Evaluate subsurface performance
- Evaluate above ground performance
- Evaluate potential cost reductions
- Develop exit strategy
- Evaluate contract efficiency

Rethinking Source Term vs. Plume Management

- Potential source term control solutions
  - Steam/Heat
  - Chemical oxidation
  - Surfactant-cosolvent flushing
- Outstanding issues
  - Science
  - Policy
  - Other (Economic – Public and Private sector)

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ESTCP Demonstration and Comparison of Transport Optimization Techniques for Pump and Treat Systems

Three DOD pump and treat sites will be included in the study. Three different mathematical approaches to optimizing the pump and treat systems will be used and compared at each site. Umatilla Army Depot has been selected as the first site. The two additional sites will be selected by the end of May but are anticipated to be Tooele Army Depot and George Air Force Base or Shaw Air Force Base.

Optimization analyses have begun on Umatilla Army Depot and will conclude in July 2001. Optimization of the remaining two sites will begin in June 2001(site 2) and August 2001(site 3). Results for all three sites are anticipated by December 2001.

The final report for this project will include the results of the three optimization analyses for each pump and treat site (in a case study format). A comparison of the different approaches will also be included in the final report. The final report is anticipated in April 2002. An addendum to the final report will be prepared to summarize the implementation and field validation of optimization modeling. The addendum is anticipated in September 2002.

Further Resources re: Optimization

- Elements for Effective Management of Operating Pump and Treat Systems (final October 2002)
- Best Practices for Evaluating Ground Water Capture Zones (draft December 2002)
- Inventory of Optimization Approaches for Remediation Systems (USACE draft June 2002)
- Special topic area for the Federal Remediation Technologies Roundtable web site -- (http://www.frtr.gov/optimization)

All documents to be available at www.cluin.org

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Elements of effective management of operating pump and treat systems is the 18 page joint OERR/TIO document that discusses the following:

1. Setting system goals and exit strategies
2. Evaluating performance and effectiveness of the system
3. Evaluating cost effectiveness
4. Contracting considerations
5. Optimization and continuous improvements

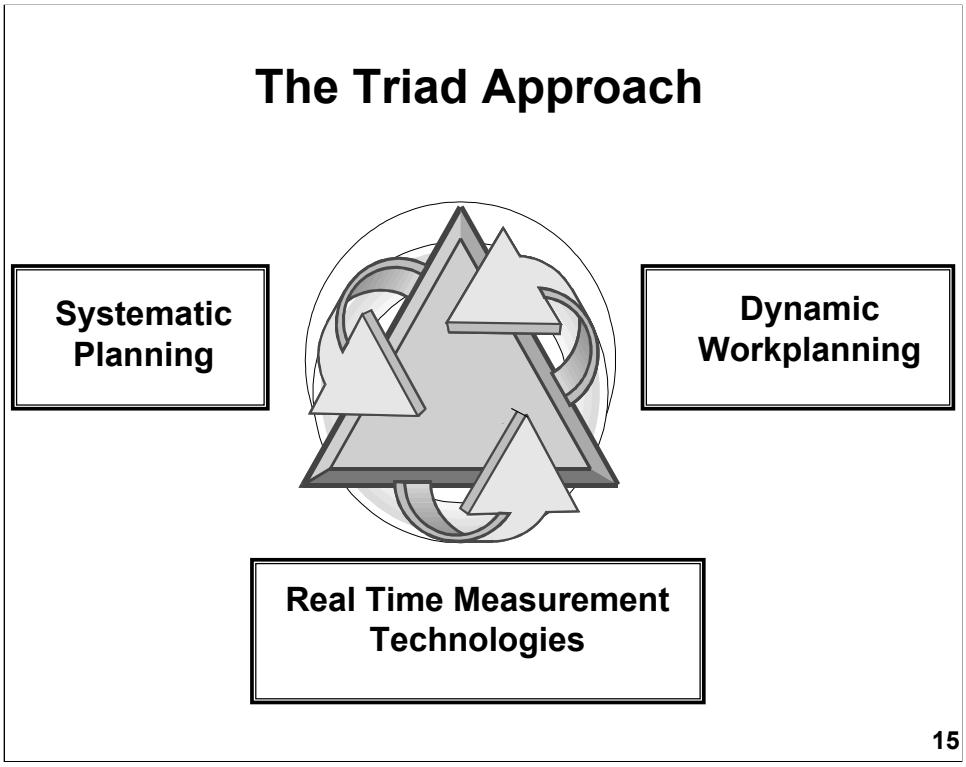
We discuss minimum data that needs to be collected from and operating P&T system and how that data should be analyzed to evaluate system performance. We also discuss common areas for cost reduction and how improved contracting options can reduce long-term costs.

Evaluating capture is not straight forward. Often times sites do not have enough ground water monitoring wells to accurately determine if hydraulic capture is achieved. For this reason other lines of evidence such as contaminant concentrations, analytical models, and flow and transport models are used to help in the evaluation.

The USACE prepared a draft document that provides and inventory of different optimization approaches such as system reviews (RSEs, RPO), hydraulic and transport optimization, and monitoring optimization. Expect a draft soon, but no date given by USACE and OERR

NAPL Site Characterization

- Essential component of the remedial package
- Currently tool-limited for more complex scenarios
  - Large facilities/chlorinated solvents/heavier PAHs
- Subject of future technical information transfer efforts
- EPA/Army COE/DOE--Argonne actively investing in the rollout of the “Triad” approach to site monitoring



Systematic Planning

Site and decision-specific issues; charts best course to reach project goals

Dynamic Work Plans

Field based decision making allows for a seamless flow of site activities = fewer mobilizations

Guides data collection to support CSM

On-site Analysis Definitions of terms used during the course

Benefits of the planning process

Major planning steps

Applications of field-based sampling and analytical technologies

Documentation of accelerated approaches

Support Implementation of dynamic work plans

Technology/Methods/QC are based on data use and on-site decision making in mind

Characteristics of the "Triad"

- Fully maximizing capabilities of **field analytical instruments** and rapid sampling tools
- **Systematic planning**
  - Meeting site or project-specific goals vs. prescriptive methods "checklists"
  - Relying on thorough advance planning/up-front understanding of the site
  - Global view of project, ultimate goals
- **Dynamic** or adaptive decision making
- Bringing together the right **team**
- Changing **perception**
  - Requirements for accurate, protective, and defensible decisions
  - Time, money, and quality

DNAPL *Investigation* Technologies: Current Resources

- Field Analytic Technology Encyclopedia (FATE) (http://fate.clu-in.org)
- Technology Overview: DNAPLs – Review of Emerging Characterization and Remediation Technologies, June 00 (http://www.itrcweb.org)
- Innovations in Site Characterization: Geophysical Investigation at Hazardous Waste Sites, Aug 00 (http://clu-in.org/techpubs.htm)

DNAPL *Investigation* Resources (cont.)

- Technologies for DNAPL Investigation (~100 pp), July 02, TIO report (http://clu-in.org/techpubs.htm)
- Strategies for Characterizing DNAPL Contamination, Fall 02, ITRC report (http://www.itrcweb.org)

DNAPL *Treatment* Technologies: Current Resources

- Technology Evaluation Report: Technologies for Dense Nonaqueous Phase Liquid Source Zone Remediation – Dec 98
  (http://www.gwrtac.org)

- Technology Status Review: In Situ Oxidation – Nov 99
  (http://www.estcp.org/documents)
- Guidance for In Situ Oxidation at Contaminated Sites:Technology Overview with a Focus on Permanganate Systems, Siegrist et al, DOE Jan 2000

DNAPL *Treatment* Resources (cont.)

- In Situ Thermal Treatment Site Profiles – 67 projects
  (http://clu-in.org/products/thermal)
- In Situ Chemical Oxidation-- 200+ projects
  (http://clu-in.org/products/chemox)
- In Situ Surfactant/Cosolvent Flushing-- 46 projects (7 full-scale)
  Data Base under development
- In Situ Thermal Treatment Design Guide –
  Joint USACE/EPA effort – In preparation

Remediation Technologies Development Forum: NAPL Clean Up Alliance

- Mission: Develop technically practicable, cost-effective solutions to remediation of large sites contaminated with petroleum hydrocarbons (e.g., oil refineries)
- Formed in 2001; co-chaired by EPA Region 8 and Chevron/Texaco
- 15 members participate on the "core team" and many more "associate" members

http://www.rtdf.org/public/napl

RTDF-NAPL Alliance
Current Projects

- Evaluation of innovative technologies for LNAPL removal - 2 Region 8 sites (Texaco and Conoco)
- LNAPL decision-making framework document
  - Guide for characterization and remediation at large-scale LNAPL sites (draft 3/03)
- LNAPL Technical Training (anticipated 2003)
  - Characterization, mobility, and removal
- Pursuing additional state and EPA members
  - Recent discussions with ASTSWMO and TNRCC

Conoco is a warm water flood project that is nearly complete. Innovative characterization methods were employed to help

Determine locations of mobile and soluble LNAPL. Warm water flood was targeted at the mobile/soluble areas.

Texaco hasn't selected a technology yet – they are currently in the technology screening and characterization process.

State Coalition for Remediation of Dry Cleaners (SCRD)

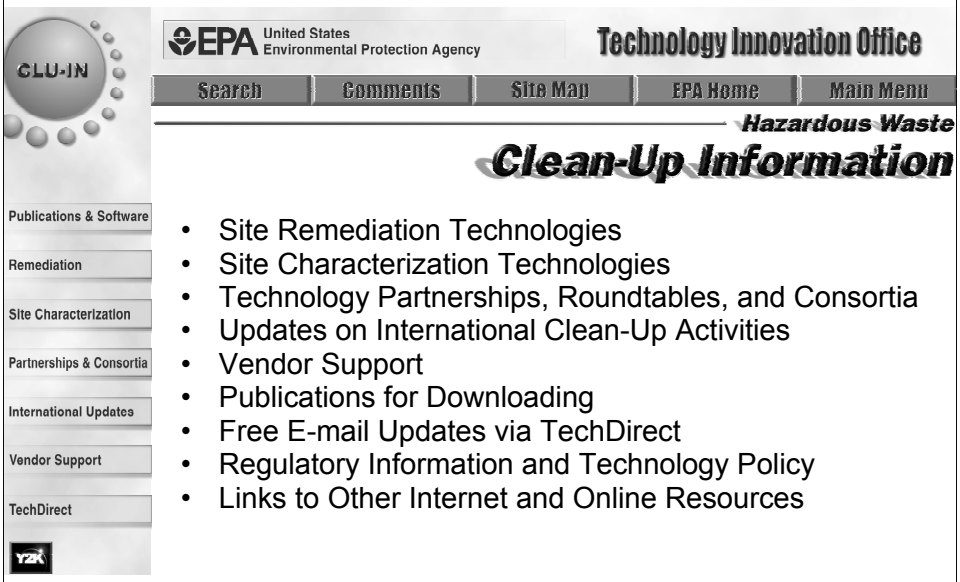
- Public-public partnership formed by TIO with 11 states having legislation; formed in 1998
- Mission: Share information on technical solutions and other issues re: PCE in soils and ground water from leaks, spills and drainfields
- States that are drafting legislation also attend (GA, LA, NM)
- Driving force in many states is deed transfers

SCRD- Resources (cont.)

- 1998 SCRD state survey of cleanup technologies
  - **61% natural attenuation**
  - **60% oxidation**
  - **57% air sparging**
  - **20% bioremediation**
- Database of drycleaner site profiles
  - **61 profiles**
  - **Source removal technologies**
  - **Small sites are a microcosms – technology application is quicker and more precise**

http://drycleancoalition.org

CLU-IN World Wide Web Site
http://clu-in.org



- Site Remediation Technologies
- Site Characterization Technologies
- Technology Partnerships, Roundtables, and Consortia
- Updates on International Clean-Up Activities
- Vendor Support
- Publications for Downloading
- Free E-mail Updates via TechDirect
- Regulatory Information and Technology Policy
- Links to Other Internet and Online Resources

TechDirect

Highlights

- Broadcasts periodic e-mail messages to list of over 14,500 subscribers
- Highlights events of interest to site remediation and site assessment professionals
- Describes new products and provides instructions on how to obtain them

Top 10 Websites For Hazardous Waste Management

1. **http://clu-in.org (or http://www.epa.gov/tio)**
2. **http://www.epareachit.org**
3. **http://www.frtr.gov**
4. **http://www.gwrtac.org**
5. **http://www.rtdf.org**
6. **http://www.epa.gov/ord/SITE**
7. **http://em-50.em.doe.gov**
8. **http://www.itrcweb.org/**
9. **http://www.serdp.org/research/research.html**
10. **http://www.epa.gov/etv/**

Walt, the only site you may not be familiar with is #10. This is the company that produces RIMS (the private sector Reachit). Their site has been expanded to include other features such as cost estimating, insurance products etc. A good example of for-profit information providers on the internet (paid for by advertisers).


Federal
Remediation
Technologies
Roundtable
NASA

FRTR
Remediation Case Studies

- Document cost/performance of clean-up technologies
- Includes full-scale cleanup and large-scale demonstrations
- 274 EPA, DoD, DoE cases
- Searchable by technology, contaminant, media (www.frtr.gov)
- Superfund, RCRA, State sites

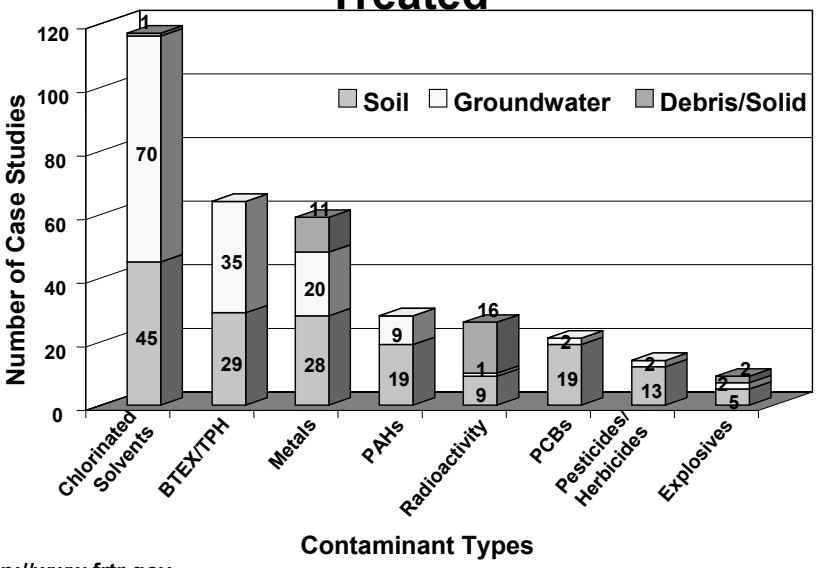
http://www.frtr.gov

FRTR Cost and Performance Guide

In Situ Groundwater Remediation Technologies with Recommended Reporting Elements

- Air Sparging
- Bioremediation
- Bioslurping
- Circulating wells (UVB)
- Cosolvents/surfactants
- Dual-phase extraction
- Dynamic underground stripping
- In situ oxidation (Fenton's Reagent)
- Natural attenuation of nonchlorinated compounds
- Natural attenuation of nonchlorinated hydrocarbons
- Permeable Reactive Barriers
- Pump and Treat
- Phytoremediation
- Steam flushing
- Vertical barrier walls

FRTR Case Studies: Summary of Contaminants and Media Treated *



http://www.frtr.gov

* Some case studies address more than one type of media/contaminant