Phytotechnology: Current Trends and Prospects

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Office of Solid Waste and Emergency Response
U.S. Environmental Protection Agency
Technology Innovation Office

Clients for Information on Technology Innovations

Technology Vendor

Responsible Party/Owner Operator

Federal/State Project Manager

Consulting Engineer

International Markets

Investor Community

Technology Vendors
Technology Innovation Thrusts

• Advocate “smarter” technologies for the characterization and cleanup of contaminated sites

• Work with clients to identify and understand better, faster, and cheaper options

• Seek to identify and reduce barriers to the use of innovative technologies
Outline

• Future Remediation Market
• Phytoremediation at Superfund Sites
• Remediation Technology Development Forum
• Conclusions
• Technology Innovation Program Information Sources
## Estimated Number of Sites and Remediation Cost 2004-2033

<table>
<thead>
<tr>
<th>Program</th>
<th>Sites</th>
<th>Cleanup Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPL</td>
<td>686 – 946</td>
<td>$24 – 50 B</td>
</tr>
<tr>
<td>RCRA, CA</td>
<td>3,800</td>
<td>$31 – 58 B</td>
</tr>
<tr>
<td>RCRA, UST</td>
<td>95,000 – 155,000</td>
<td>$12 – 19 B</td>
</tr>
<tr>
<td>DOD</td>
<td>6,400</td>
<td>$33 B</td>
</tr>
<tr>
<td>DOE</td>
<td>5,000</td>
<td>$35 B</td>
</tr>
<tr>
<td>Civilian Agencies</td>
<td>3,000</td>
<td>$15 – 22 B</td>
</tr>
<tr>
<td>States &amp; Private</td>
<td>150,000</td>
<td>$30 B</td>
</tr>
<tr>
<td>Total Range</td>
<td>235,000 – 355,000</td>
<td>$174 – 253 B</td>
</tr>
<tr>
<td>Middle Value</td>
<td>294,000</td>
<td>$209 B</td>
</tr>
</tbody>
</table>
Estimated Number of Sites and Cleanup Cost 2004-2033

Total = $209 Billion

- NPL $32B
- RCRA-CA $45B
- DOE $35B
- States & Private $30B
- Civilian Agencies $19B
- UST $16B
- DOD $33B

Total Sites = 294,000

- NPL 736
- RCRA-CA 3,800
- States & Private 150,000
- Civilian Agencies 3,000
- DOE 5,000
- DOD 6,400
- UST 125,000

Total = $209 Billion
Superfund Source Control Treatment Projects (FY 82-02)

Ex situ 499 (58%)

In situ 364 (42%)

- Incineration (on-site) (43) 5%
- Bioremediation (54) 6%
- Thermal Desorption (69) 8%
- Chemical Treatment (10) 1%
- Incineration (off-site) (104) 12%
- Soil Vapor Extraction (213) 25%
- Solidification/Stabilization (157) 18%
- Other (ex situ) (42) 5%
- Other (in situ) (27) 3%
- Flushing (16) 2%
- Chemical Treatment (12) 1%
- Other (ex situ) (42) 5%
Superfund: Trends in Percentage of Groundwater RODs Selecting In Situ Treatment (FY 1986 - 2002)*

* Includes information from an estimated 70% of FY 2002 RODs.
Phytoremediation at Superfund Sites

- Selected 18 times
- 17 different states
- Applications
  - 5 projects for soil only
  - 6 projects for groundwater only
  - 6 projects for both soil and groundwater
- Projects address chlorinated VOCs, metals, pesticides, and hydrocarbons
- Many use trees
Phytotechnologies at Superfund Sites (Cont’d)

- 2 Pre-design
- 4 Design
- 9 Ongoing
- 3 Completed

- Represent small portion of Superfund soil and groundwater remedies
## Superfund Remedial Actions (FY 1982 – FY 2002*)

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Contaminants</th>
<th>Media</th>
<th>Vegetation</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aberdeen Pesticide Dumps (OU5)</td>
<td>Pesticides</td>
<td>Groundwater</td>
<td>Hybrid Poplar</td>
<td>Operational</td>
</tr>
<tr>
<td>Aberdeen Proving Grounds (Edgewood Area, J-Field Soil OU)</td>
<td>PCA, PCE</td>
<td>Soil &amp; Groundwater</td>
<td>Hybrid Poplar, Magnolia, &amp; Silver Maple</td>
<td>Operational</td>
</tr>
<tr>
<td>Argonne National Lab. West 1</td>
<td>Cesium-137, Silver, Mercury, Chromium</td>
<td>Soil &amp; Groundwater</td>
<td>Hybrid poplar, willow, gamagrass</td>
<td>Completed (99-02)</td>
</tr>
<tr>
<td>AT&amp;SF Albuquerque Superfund Site</td>
<td>PAHs, Zn</td>
<td>Soil</td>
<td>NR</td>
<td>Pre-design</td>
</tr>
<tr>
<td>Atlas Tack Corp. (OU1)</td>
<td>Benzene, Cr, Cu, Cyanide, Hg, Ni, Zn</td>
<td>Groundwater</td>
<td>NR</td>
<td>Design</td>
</tr>
<tr>
<td>Boarhead Farm</td>
<td>Benzene, Cd, Ni, TCE</td>
<td>Soil &amp; Groundwater</td>
<td>NR</td>
<td>Designed/ Not Installed</td>
</tr>
</tbody>
</table>

NR = Not Reported

* - Includes remedies from 40% of expected FY 2002 RODs.
# Superfund Remedial Actions (FY 1982 – FY 2002*)

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</thead>
<tbody>
<tr>
<td>Bofors Nobel (OU1)</td>
<td>As, BTEX, Pesticides, Zn</td>
<td>Soil, Sludge, &amp; Groundwater</td>
<td>NR</td>
<td>Design</td>
</tr>
<tr>
<td>Carswell Naval Air Station</td>
<td>TCE, DCE</td>
<td>Soil &amp; Groundwater</td>
<td>Eastern cottonwood</td>
<td>Operational</td>
</tr>
<tr>
<td>Combustion, Inc</td>
<td>DCA, PCB, Benzene, Toluene, Lead, Mercury, Nickel, Silver</td>
<td>Groundwater</td>
<td>Eucalyptus, poplar, native willow</td>
<td>Operational</td>
</tr>
<tr>
<td>Del Monte Corp.</td>
<td>PAHs, Zn</td>
<td>NR</td>
<td>NR</td>
<td>Operational</td>
</tr>
<tr>
<td>East Palo Alto</td>
<td>Benzene, Cd, Ni, TCE</td>
<td>soil</td>
<td>Eucalyptus, Tamarisk</td>
<td>Operational</td>
</tr>
<tr>
<td>Fort Dix</td>
<td>Lead</td>
<td>Soil</td>
<td>Indian mustard, sunflower, grasses</td>
<td>Completed (field demo)</td>
</tr>
</tbody>
</table>

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4/12/05
## Superfund Remedial Actions (Cont’d)

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<tr>
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<th>Vegetation</th>
<th>Status</th>
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<tbody>
<tr>
<td>Fort Wainwright</td>
<td>Pesticides, Petroleum Hydrocarbons</td>
<td>Soil</td>
<td>NR</td>
<td>Completed (97-01)</td>
</tr>
<tr>
<td>Idaho National Engineering Laboratory (USDOE, OU 21)</td>
<td>Ag, Cr, Cs-137, Hg, Se, Zn</td>
<td>Soil</td>
<td>Prairie Cascade, Willows, Kochia Scoparia</td>
<td>Operational</td>
</tr>
<tr>
<td>Naval Surface Warfare Center, Dahlgren, Site 17</td>
<td>Hg</td>
<td>Soil &amp; Groundwater</td>
<td>Hybrid Poplar &amp; Evergreen</td>
<td>Pre-design</td>
</tr>
<tr>
<td>Naval Undersea Warfare Station (4 Areas, OU1)</td>
<td>1,1,1-TCA</td>
<td>Groundwater</td>
<td>Poplar</td>
<td>Operational</td>
</tr>
<tr>
<td>Sangamo Electric Dump/Crab Orchard National Wildlife Refuge (PCB Areas OU)</td>
<td>DCE, PCE, Vinyl Chloride</td>
<td>Groundwater</td>
<td>Hybrid Poplar</td>
<td>Design/Planned 2006</td>
</tr>
<tr>
<td>Tibbetts Road</td>
<td>TCE</td>
<td>Groundwater</td>
<td>Poplar</td>
<td>Operational</td>
</tr>
</tbody>
</table>

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* - Includes remedies from 40% of expected FY 2002 RODs.
Other Applications of Phytotechnologies

- Ecological Restoration
- Land Revitalization

http://www.epa.gov/oswer/landrevitalization
Ecological Restoration

Bunker Hill Mining and Metallurgical Complex
Land Revitalization

That was then....

Landfill

Fly Ash Disposal Field
Land Revitalization

This is now!

Wetlands

Soccer Field
The purpose of the RTDF is to identify what government and industry can do together to develop and improve the environmental technologies needed to address their mutual cleanup problems in the safest, most cost-effective manner. The RTDF fosters public and private sector partnerships to undertake the research, development, demonstration, and evaluation efforts needed to achieve common cleanup goals.
Remediation Technologies Development Forum

• Partnerships between private industry, universities, and government (EPA, DOE, DOD) — each party provides resources and expertise
• Mutual priorities/user needs are identified
• Action Teams formed to further technology development
• Phytoremediation of Organics Action Team (1997)
  – TPH in Soil
  – Alternative Cover Assessment Program (ACAP)
  – Chlorinated Solvents

http://www.rtddf.org
RTDF TPH Project

- Goal to assess efficacy of vegetation to enhance degradation of aged petroleum hydrocarbons in soil
- Uses standardized protocol
- Plants include grasses, legumes, and trees
- 13 sites evaluated under different climatic conditions for 3 growing seasons
- Lessons Learned:
  - HC losses were subtle and difficult to measure
  - Plants grew well
  - Best results for “younger” sites
  - Plant roots facilitated deeper degradation

Session 5B, Thursday 2:30pm
http://www.rtdf.org
RTDF Chlorinated Solvents

• Evaluation of Phytoremediation for Management of Chlorinated Solvents in Soil and Groundwater EPA 542-R-05-001
  – Brief introduction
  – Assess applicability
  – Design and placement
  – Monitoring and sampling
  – Reporting cost and performance
  – Answers to many frequently asked questions

http://www.rtdf.org
RTDF ACAP

- RTDF demonstrating effectiveness of 21 cover designs
- Nationwide side-by-side field demonstration of alternative covers for landfills and other waste sites
  - 11 sites in 7 states
  - Large (10 X 20 m) drainage lysimeters
- Focus on evapotranspiration (ET) type covers
  - Monolithic
  - Capillary barrier
- Conventional covers also being evaluated
  - Composite
  - Soil barrier
- Collect five years of data (2005 last year of data collection)

Session 6B, Friday 8:30am
http://www.acap.dri.edu
Inventory of Phytoremediation Field Studies

- Summer 2004 snapshot of projects in the field
- Chlorinated solvents, pesticides, explosives, and metals
- Full and pilot scale field projects
- U.S. and Canada
- No constructed wetlands or alternative landfill covers
- Info collected by two EPA grantees
Phytoremediation Field Studies

• Types of information collected:
  – Site name and location
  – Site characteristics
  – Planting date and description
  – Media treated
  – Vegetation types
  – Contaminants treated
  – Phytomechanism used
  – Project size, scale, and status
  – Operation and maintenance
  – Technology cost and performance
  – Lessons learned
  – Point of contact

http://www.cluin.org/studentpapers
Phytoremediation Field Studies
Fact Sheet

• Use of Field-Scale Phytotechnology for Chlorinated Solvents, Metals, Explosives and propellants, and Pesticides (EPA 542-R-05-002)
• 79 projects performed in 31 states
• Chlorinated solvents treated most frequently
• Most common mechanisms tried were phytoextraction and hydraulic control
• Peak in projects from 1996 to 2001
• Ranged in size from <0.5 acre to 1000 acres
• Found lack of published information on cost, performance and lessons learned
• If you have sites to add, see poster

http://www.cluin.org/
Locations of Phytotechnology Projects in the United States
Conclusions

• Many more answers to practitioner’s frequently asked questions (RTDF document)
• Phytotechnology has many potential roles in site cleanup:
  – Hydraulic plume control
  – Ecological restoration
  – Land revitalization
  – Niche applications
    • Arsenic
    • Core sampling for plume delineation
  – Alternative covers
• Need more cost and performance data
Technology Information Service

Highlights

- Broadcasts periodic e-mail messages to the list of 16,000 subscribers in 60 countries.
- Highlights events of interest to site remediation and site assessment professionals.
- Describes new products and provides instructions on how to obtain them.
EPA REACH IT System

• Free information service, searchable on-line
• Information on 310 treatment and 168 characterization technology vendors
• Site information on 1,811 EPA Superfund remediation projects
• Flexible search options include by technology, contaminant, media, and sites
• 30 new technologies added in 2004
• Easier-to-use website made available October 2004
• Phytotechnology: 10 Vendors, 22 Vendor Source Sites, 11 EPA Source Sites

www.epareachit.org
Phytotechnology Resources

**www.itrcweb.org**
- Phytoremediation Decision Tree, Dec 99, ITRC
- Phytotechnology Technical and Regulatory Guidance Document, Apr 01, ITRC
- Technology Overview Using Case Studies of Alternative Landfill Technologies and Associated Regulatory Topics (March 2003)
- Characterization, Design, Construction, and Monitoring of Mitigation Wetlands (February 2005)

**www.rtddf.org**
- Phytoremediation of Organics Action Team Information
- Evaluation of Phytoremediation for Management of Chlorinated Solvents in Soil and Groundwater
- RTDF Phytoremediation Bibliography (~1,400 citations)

**www.gwrtac.org**
- Technology Evaluation Report: Phytoremediation of Soil and Ground Water, Mar 02, GWRTAC
Phytotechnology Resources (Cont’d)

www.cluin.org

- Introduction to Phytoremediation, Feb 00, EPA
- Phytoremediation of Contaminated Soil and Groundwater at Hazardous Waste Sites, Feb 01, EPA
- Citizen’s Guide to Phytoremediation, April 01, EPA
- Phytoremediation Resource Guide, Jun 99, EPA
- Phytotechnologies Internet Seminar, May 01, ITRC
- Phytoremediation of VOCs in Groundwater, Feb 03
- Radionuclide Biological Remediation Resource Guide, Aug. 04
- Brownfields Technology Primer: Selecting and Using Phytoremediation for Site Cleanups, July 01
- D-Area Drip Irrigation-Phytoremediation Project: SRTC Final Report, Jan. 03
Top 10 Websites For Hazardous Waste Management

1. http://cluin.org (or http://www.epa.gov/tio)