Survey Objectives

- To gain knowledge on phytoremediation as a method for treating contaminated sites
- Provide insight into the main techniques
  - Degradation
  - Extraction
  - Containment
- Tools drawn upon for application consideration
Phytoremediation is treatment of contaminated environmental sites by plants.
Degradation Technique

- Process by which a chemical compound is broken down into defined products
- Two methods
  - Root zone degradation (Rhizofiltration)
  - Metabolism within the plant (potential volatilization)
Method 1: Rhizofiltration

- Chelating agents (for metals) or enzymes mobilize contaminants before uptake
  - Often microbe assisted
- Limited knowledge
- Tested in two ways
  - Soil Metabolism studies
  - Isolation and culturing of microbe species
Experiment on Soil Metabolism

- Sung’s Experiment
  Used Johnsongrass to evaluate dynamic root model for treating the liquid phase contaminants TNT and chrysene.
A Display of Complexity

- Model equation including biodegradation by microorganisms along with sorption into soil and roots used by Sung.

\[
\frac{\partial \theta_{\text{rhw}} C_{\text{rhw}}}{\partial t} = - \frac{\partial}{\partial z} \left( q_w C_{\text{rhw}} - D_{\text{Hw}} \frac{\partial \theta_{\text{rhw}} C_{\text{rhw}}}{\partial z} \right) - a_s p_b \left( k_1 C_{\text{rhw}} - C_{\text{rhs}} \right) \\
- k_m C_m \left( \frac{C_{\text{rhw}}}{K_{\text{rhw}} + C_{\text{rhw}} + K_i C_{\text{rhw}}^2} \right) \left( \frac{C_{\text{rhp}}}{K_{\text{rhp}} + C_{\text{rhp}}} \right) - \sigma_r K_{\text{nrw}} \left( K_{\text{rw}} C_{\text{rhw}} - C_r \right) - U_w T_{\text{scf}} C_{\text{rhw}}
\]
Issues With Method 1

- Rely on models generated from recent knowledge
- There is limited understanding of plant-microbe relationships
- Biochemical pathways in plants are complex
Method 2: Metabolism Within Plants

- Contaminant taken into plant and then broken down by metabolic processes within the plant producing less-toxic products
Experiment by Morikawa and Erkin

- Cleaning the air by use of genetically modified Arabidopsis plants
- Remediate nitrogen dioxide
- Other compounds:
  - PAHs (Polynuclear Aromatic Hydrocarbons)
  - TPHs (Total Petroleum Hydrocarbons)
  - PCBs (Polynuclear Aromatic Hydrocarbons)
Issues With Method 2

- Process of chemical substitution to take care of contaminants (bioavailability)
- Volatilization of toxic compounds
- Limited understanding of biochemistry
Extraction Technique

- Using a plant to accumulate contaminants for ‘harvest’ and proper disposal
- Typically applied to heavy metal, radionuclides contaminated sites
- Either occurs naturally or assisted by chemical agents
Cyanide Removal by Extraction

- One teaspoon of 2% solution can kill a person.
- µg/L range kills aquatic life
- mg/L range kills animals
- Over 200,000,000 pounds of cyanide is used in U.S. mining each year
Gold/Silver Mining
Cyanide Disasters

- **January 2000: Romania**
  - Gold mine dam burst, leaching 100,000kg of cyanide into local watershed

- **1991 leaching incident: Summitville, CO**
  - Worst Cyanide leach in U.S history
  - Killed all aquatic life in 17 miles (27 km) of the Alamosa River
  - 160 million U.S. gallons needed treatment
Water Hyacinth

- Low maintenance
- Quickly spreads
- Significant root mass

Drawbacks
- Climaticly limited to tropical regions
- Multiplication issue (potential to be invasive)
Experiment by Mathias Ebel

- Simulating mining tailing ponds
- Results showed high tolerance for HCN and a feasibility for use in extraction
Using Soil Additives

- E. Lombi and EDTA treatment of maze
  - Monitored uptake of Cd and Zn
  - Increased solubility but little effect on uptake
- Schmidt’s Experiments
  - Showed an increase in uptake associated with additives
<table>
<thead>
<tr>
<th>Plant</th>
<th>Chelate added</th>
<th>W/O Chelate</th>
<th>After Addition</th>
<th>Total Pb</th>
<th>Reference</th>
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<tr>
<td>Pea</td>
<td>2g HEDTA</td>
<td>90</td>
<td>10600</td>
<td>2450</td>
<td>Huang et al., 1997a</td>
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<td>5010</td>
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<td>Shen et al., 2002</td>
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<td>67</td>
<td>5200</td>
<td>4000</td>
<td>Cooper et al., 1999</td>
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<td>Baylock et al., 1997</td>
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<td>Deram et al., 2000</td>
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<td>330</td>
<td>330</td>
<td>110</td>
<td>Albasel and Cottenie, 1985</td>
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Beneficial Reclamation

- Selenium and G.S Bañuelos’ study
  - USDA recommends 200µg Se be taken daily
  - Plants grazed upon that can uptake Se used
    - Grazing animals would eat the plants, then be slaughtered for selenium enriched meat
    - Provides a commercial application and reduces disposal costs
Containment Technique

- Long-lived plant (i.e. a tree) will be used to accumulate contaminants around the roots, binding them to a specific area
  - Prevents leaching and dispersal
  - Does not actually remediate
- Another name is phytostabilization
- Not typically used
Application Considerations

- Technical
  - Plant capability
  - Protectiveness
  - Time span
  - Backup Plan
Application Considerations

- Economical
  - Cost

<table>
<thead>
<tr>
<th>Problem</th>
<th>Remediation Type</th>
<th>Cost (in Thousands)</th>
<th>Conventional Choice</th>
<th>Cost (in Thousands)</th>
<th>Projected Savings</th>
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<tbody>
<tr>
<td>Lead in soil 1 acre</td>
<td>Extraction, harvest disposal</td>
<td>$150-250</td>
<td>Excavate and landfill</td>
<td>$500</td>
<td>50-65%</td>
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<tr>
<td>Solvents in Groundwater</td>
<td>Degradation and hydraulic control</td>
<td>$200 to install plus some maintenance</td>
<td>Pump and Treat</td>
<td>$700 annual running cost</td>
<td>50% cost savings by 3rd year</td>
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<td>2.5 acres</td>
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<tr>
<td>TPH in soil 1 acre</td>
<td>In situ degradation</td>
<td>$50-100</td>
<td>Excavate and landfill incinerate</td>
<td>$500</td>
<td>80%</td>
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Application Considerations

- Social
  - Potential to do harm
  - Uncertainty in data
  - Genetic engineering
  - Foreign plant species
  - Sites need long term monitoring and funding
Limiting Factors

- Root Contact
- Root Depth
- Growth Rate
- Contaminant Concentration
- Plant Uptake Ability

- Climate/Soil
  - pH
  - Temperature
  - Soil type
  - Moisture content
QUESTIONS?