Phytoremediation: A General Overview

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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

Definition

- Phytoremediation is treatment of contaminated environmental sites by plants

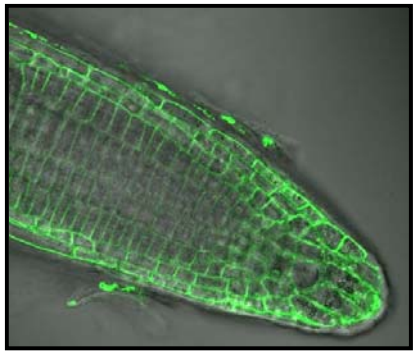


Degradation Technique

- 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 biodegredation by microorganisms along with sorption into soil and roots used by Sung.

$$\frac{\partial \theta_{rhw} C_{rhw}}{\partial t} = -\frac{\partial}{\partial z}\left(q_w C_{rhw} - D_{Hw} \frac{\partial \theta_{rhw} C_{rhw}}{\partial z} \right) - a_s p_b \left(k_1 C_{rhw} - C_{rhs} \right)$$

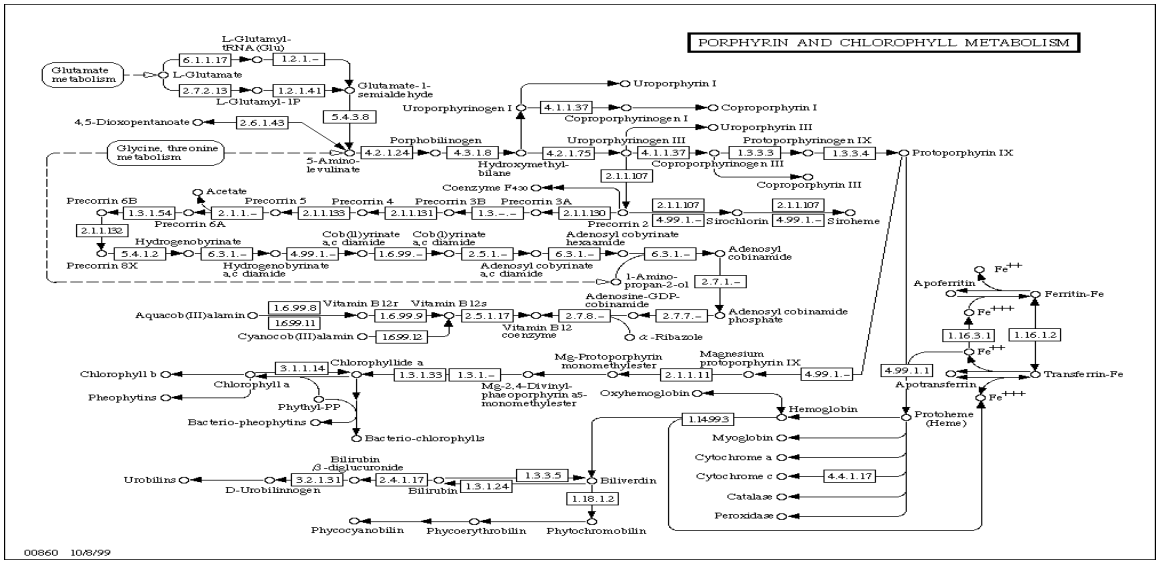
$$- k_m C_m \left(\frac{C_{rhw}}{K_{rhw} + C_{rhw} + K_i C_{rhw}^2} \right) \left(\frac{C_{rhp}}{K_{rhp} + C_{rhp}} \right) - \sigma_r K_{nrw} \left(K_{rw} C_{rhw} - C_r \right) - U_w T_{scf} C_{rhw}$$

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

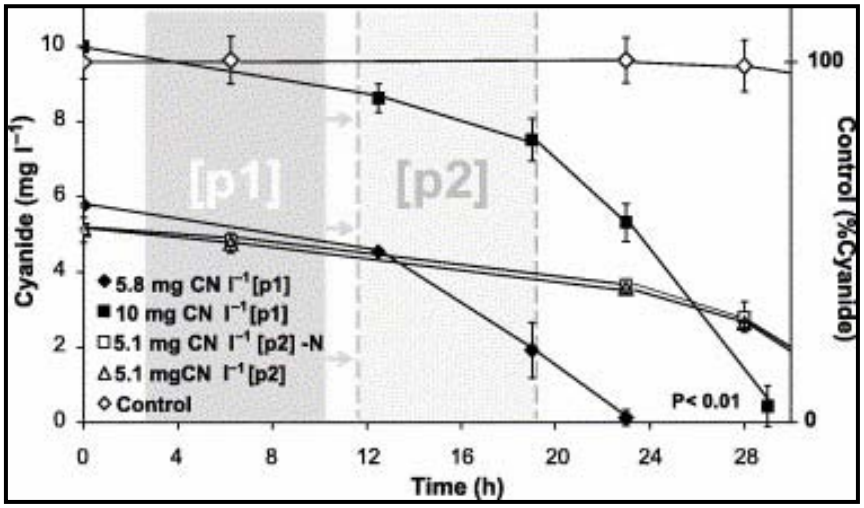
- January 2000: Romania
  - Gold mine dam burst, leaching 100,000kg of cyanide into local watershed
- 1991 leaching incident: Summitville, CO
  - Worst Cyanide leach in U.S history
  - Killed all aquatic life in 17 miles (27 km) of the Alamosa River
  - 160 million U.S. gallons needed treatment

Water Hyacinth

- 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

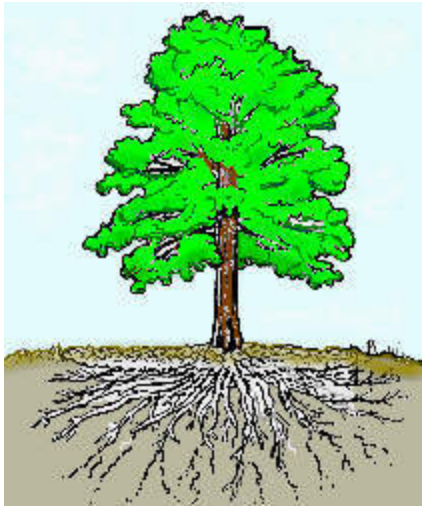
Plant	Chelate added	W/O Chelate	After Addition	Total Pb	Reference
Pea	2g HEDTA	90	10600	2450	Huang et al., 1997a
Cabbage	0.9g EDTA	125	5010	10600	Shen et al., 2002
Cabbage	2.9g EDTA	3	90	1100	Grcman et al., 2001
Sunflower	5.8g CDTA	67	5200	4000	Cooper et al., 1999
Indian Mustard	2.9g EDTA	313	5000	600	Baylock et al., 1997
Redtop	5.8g EDTA	25	3000	4000	Cooper et al., 1999
Corn	2g HEDTA	60	10200	2450	Huang et al., 1997a
Corn	5.8g CDTA	36	2600	4000	Cooper et al., 1999
Corn	0.44g EDTA kg^-1	90	500	2500	Wu et al., 1999
Ryegrass	4g EDTA kg^-1	96	24000	6750	Deram et al., 2000
Ryegrass	1g EDTA kg^-1	330	330	110	Albasel and Cottenie, 1985

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

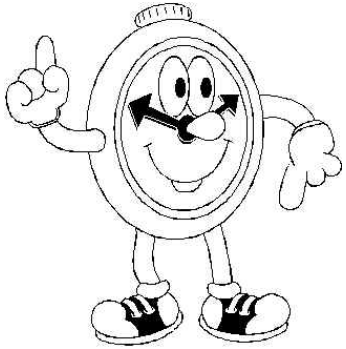
Containment Technique

- 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 phytostabalization
- Not typically used



Application Considerations

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



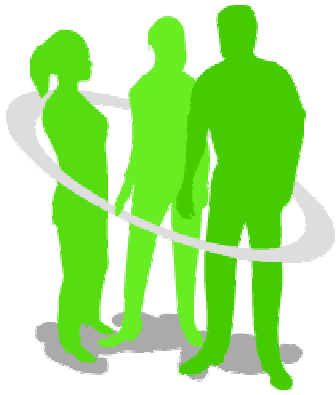
Application Considerations

- Economical
  - Cost

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

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?