Phytoremediation

Outline

- What is phytoremediation
- Types and examples
- Other removal methods
- Pros
- Cons

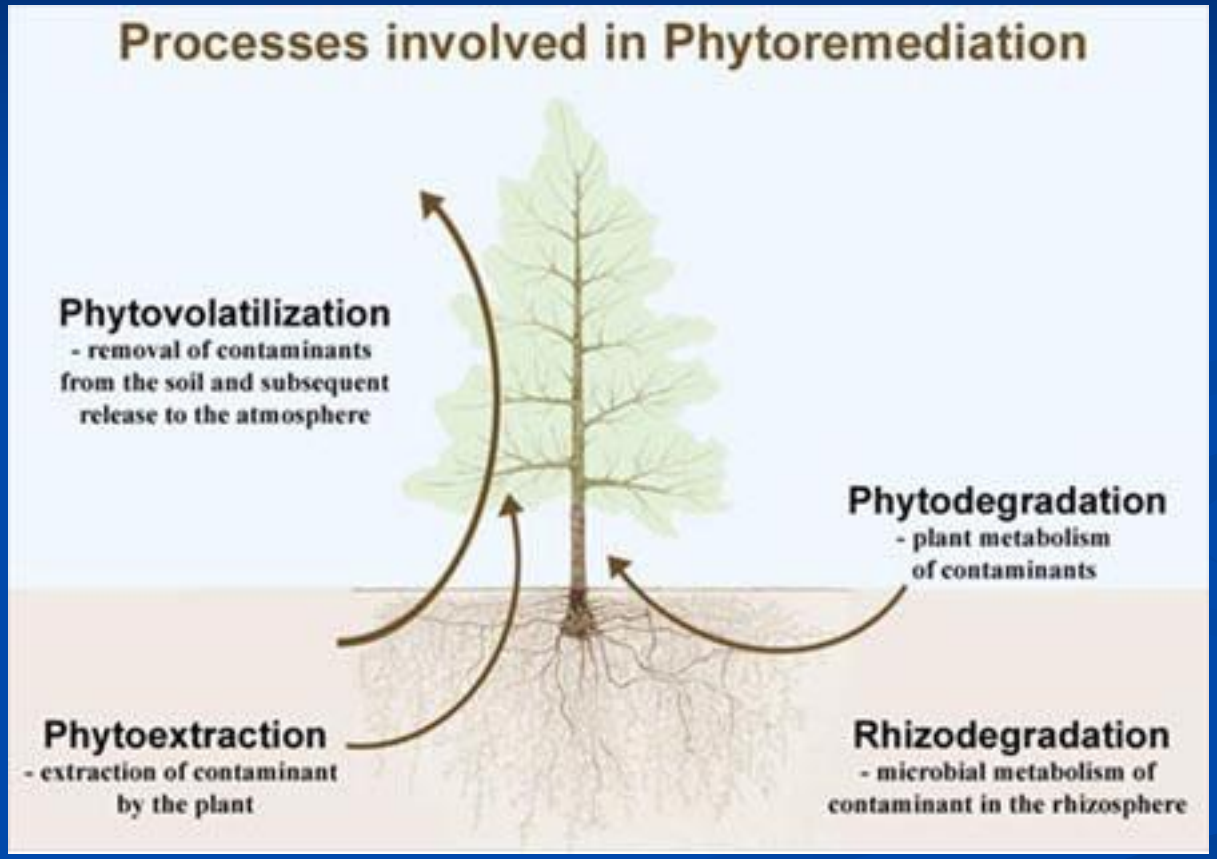
What is phytoremediation?

- Using living plants for contaminant removal, degradation, or containment
- Clean up soil and or groundwater
- Can remove organics, metals, leftover pesticides, explosives, radioactive waste
- Used independently or with other cleanup methods to reduce costs

Types

- Phytoextraction
  - Uptake by plants and accumulation in leaves or stem
- Phytodegradation
  - Plants metabolize contaminants
- Rhizodegradation
  - Plants promote microbial activity that breaks down contaminants
- Phytovolatilization
  - Uptake and transpiration

Overview


Processes involved in Phytoremediation
Phytovolatilization
- removal of contaminants from the soil and subsequent release to the atmosphere
Phytodegradation
- plant metabolism of contaminants
Phytoextraction
- extraction of contaminant by the plant
Rhizodegradation
- microbial metabolism of contaminant in the rhizosphere

Mechanisms

Mechanism	Process Goal	Media	Typical Contaminants	Plant Types
Phytostabilization	Containment	Soils, sediments, sludges	As, Cd, Cr, Cu, Pb, Zn	Herbaceous species, grasses, trees, wetland species
Rhizodegradation	Remediation by destruction	Soils, sediments, sludges, groundwater	Organic compounds (TPH, PAHs, BTEX, pesticides, chlorinated solvents, PCBs)	Herbaceous species, grasses, trees, wetland species
Phytoaccumulation	Remediation by extraction and capture	Soils, sediments, sludges	Metals: Ag, Au, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Zn; Radionuclides: ^{90}Sr, ^{137}Cs, ^{239}Pu, $^{234, 238}U$	Herbaceous species, grasses, trees, wetland species
Phytodegradation	Remediation by destruction	Soils, sediments, sludges, groundwater, surface water	Organics compounds, chlorinated solvents, phenols, pesticides, munitions	Algae, herbaceous species, trees, wetland species
Phytovolatilization	Remediation by extraction from media and release to air	Soils, sediments, sludges, groundwater	Chlorinated solvents, MTBE, some inorganics (Se, Hg, and As)	Herbaceous species, trees, wetland species
Evapotranspiration	Containment and erosion control	Groundwater, surface water, stormwater	Water soluble organics and inorganics	Herbaceous species, grasses, trees, wetland species

http://www.itrcweb.org/PHYTO2.pdf

Phytoextraction

- Metal hyperaccumulators - Alpine pennycress
  - Concentrate zinc, cadmium, nickel in stems and leaves
  - Takes in 30,000ppm zinc and 1,500ppm cadmium as opposed to 100ppm and 1ppm, respectively
  - 30 times as much as usually poisons other plants
  - Harvested and burned, ashes sold as high-grade zinc ore
  - Also research in adding citrate to soil to make uranium more soluble for 100 times higher uptake

Mechanism

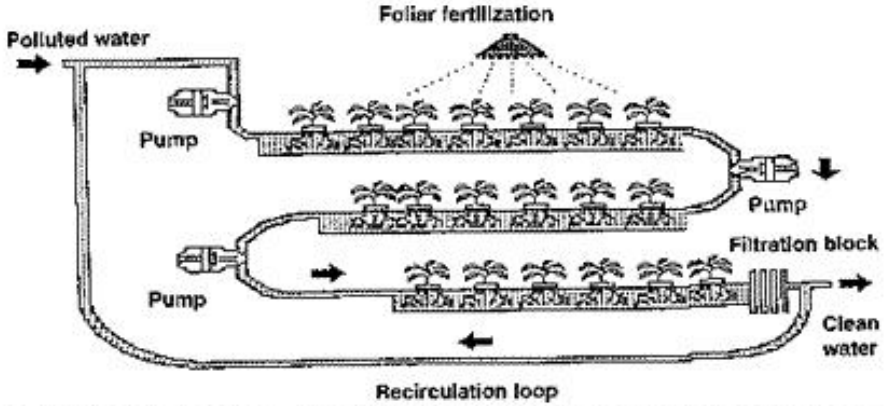


Figure 2. Flow-through rhizofiltration system. The system contains 8-12 week-old sunflower plants with roots immersed in flowing contaminated water.

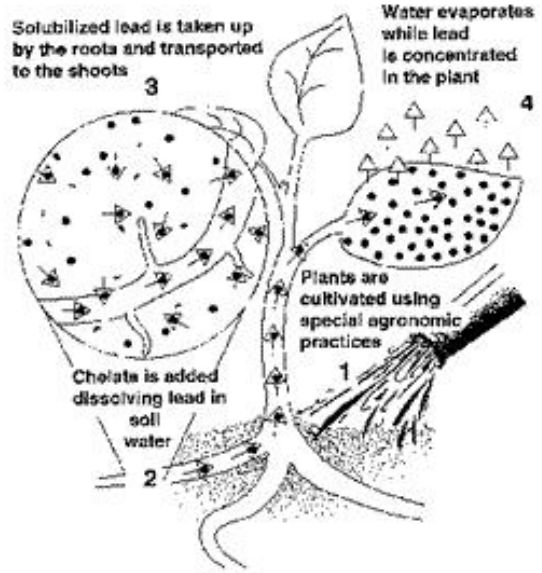


Figure 1. Phytoextraction of lead from soils

Phyto/Rhizodegradation

- Poplar trees
  - Can uptake and metabolize atrazine (toxic herbicide) in soil
  - Also stimulates microbes in soil to further degrade contaminants
  - Enzyme nitroreductase can break down TNT
  - Saplings bring levels below detectable limits within a few weeks

Phytovolitalization

- Indian mustard
  - Take up selenium from the soil, contaminant around oil wells, power plants, and mining operations
  - Convert to dimethyl selenide and release to atmosphere
  - Less desirable process because atmospheric effects generally unknown

Continuing research

- MTBE – poplar and eucalyptus saplings
- Perchlorate – willows and cedars
- Arsenic – ferns
- Depleted uranium – tumbleweeds
- DDT – pumpkins

Other methods of removal

- Removal and landfilling of contaminated soil
- Incineration of contaminants
- Surfactants used to wash contaminants out of soil
- Ion exchange, reverse osmosis, other methods in contaminated groundwater

Pros of Phytoremediation

- Reduction in landfill volume
  - 30 tons of ash vs. 5,000 tons soil for 2.5 acre site, 18in deep
- Low maintenance
- Positive public opinion
- Cost benefits

Cost benefits

Table C-2 Cost Advantage of Phytoextraction for Metals (Schnoor, 1998)

Type of Treatment	Cost/m^3 ($)	Time Required (months)	Additional factors/expense	Safety Issues
Fixation	90-200	6-9	Transport/excavation Long-term monitoring	Leaching
Landfilling	100-400	6-9	Long-term monitoring	Leaching
Soil extraction, leaching	250-500	8-12	5,000 m^3 minimum Chemical recycle	Residue disposal
Phytoextraction	15-40	18-60	Time/land commitment	Residue disposal

Table C-3 Cost Advantage of Phytoremediation (Enhanced Rhizosphere Bioremediation) of Soils Using Fine-Rooted Grasses Compared to Other Techniques (Schnoor, 1998)

Type of Treatment	Range of Costs $/Ton
Phytoremediation	$10–35
In-situ Bioremediation	$50–150
Soil Venting	$20–220
Indirect Thermal	$120–300
Soil Washing	$80–200
Solidification/Stabilization	$240–340
Solvent Extraction	$360–440
Incineration	$200–1,500

Cons

- Much slower to implement, seasonal process
- Not as effective with very high concentrations
- Limited by root depth
- Toxicity of biodegradation products not always known
- Possibility of contaminants entering food chain

Chemicals free pools …