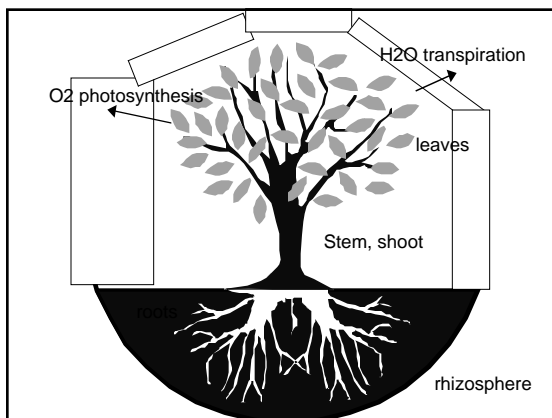


## Haz Waste: Site Clean-up Methods

- 1. In-Situ Vadose Zone Soil
  - Soil Vapor Extraction
  - Bioventing
  - Phytoremediation
- 2. In-situ groundwater/aquifer tmt
  - Bioremediation, Phytoremediation
- 3. Ex-Situ contaminated gas treatment (incin, carbon ads, bio)
- 4. Ex-situ groundwater/soil tmt
  - Bioremediation, phytoremediation

## Phytoremediation

- The use of macroscopic plants to aid in cleaning up contamination from soils and water (groundwater and surface water)
- A “conventional” example: constructed wetlands for municipal wastewater treatment
- *over 40 U.S. firms and 25 foreign companies using or developing phytoremediation*



## Phytoremediation: General Effects

- Can control groundwater migration
  - Uptake GW changing gradients
- Roots can serve as adsorption sites
  - Soil total “foc” (inc. root matter) increased
- Surface vegetation can minimize off-site migration of surface dust
- Changes in vegetation can be used to help locate contaminated areas
  - Contamination is toxic to some plants, so changes vegetation patterns
  - Aerial photography

## Phytoremediation: Organics

- Plants can help bacteria in the soil
  - Excrete organics that serve as co-substrates or inhibit non-toxics-degrading bacteria
  - Organics from the plants can change the redox state (usually making it more anaerobic)
  - Roots can provide more oxygen into the soil
  - Usually 10 - 100x bacteria in rhizosphere soil
- Plants can uptake organics and degrade them using enzymes in the plants
- Plants can uptake organics and respire them into the air (phytovolatilization)
  - TCE, BTEX, chlorinated benzenes w/ trees

## Phytoremediation: Inorganics

- Phytovolatilization (selenium)
- Plants can uptake metals and transform
  - Change redox state
  - Ex: Cr+6 to Cr+3 in water hyacinth
- Plants can accumulate metals in the roots and “shoots” (above-ground) portions of the plants
  - Hyperaccumulate (100-1000x std plants)
  - Some toxicity threshold (mg metal/kg plant) eventually reached

## Applications of Phytoremed

- In Situ clean-up
  - Plant selected species at the site
    - Due to toxicity may use seed or mature plants
  - Uptake contaminants from the soil and/or groundwater into the plant
    - Important different between root and shoot accum.
    - “Translocation” describes movement from root to shoots
  - If metals, must harvest plant to “remove” metals from the site
- Ex situ clean-up
  - Hydroponics most common where plants grown in contaminated water (no soil)

## Design Issues Relevant to Phyto.

- Growth conditions suitable to climate
- Root depth
- Root concentration factor
- Excreted compounds
- Mean daily uptake rate of water
- Concentration movement into plant shoots
- Enzymes produced by the plant
- Resistance to toxicity

## Design Issues (cont.)

- Select plant
- Where to locate plants
  - Areally over contaminated area
  - “Barrier” along a boundary
- Maintenance to keep plants viable
  - Water, fertilize, pest species
- Maintenance related to toxics
  - Collect leaves and dead plant material
  - Harvest and replanting cycles (if needed)

## Terms

- Accumulation Coefficient (AC) =  
 $\text{mg toxic/kg plant mass} / \text{mg toxic/kg soil}$   
or  $\text{mg toxic/kg plant} / \text{mg toxic/L water}$
- Phytotoxicity threshold = mg toxic/kg plant
- Accumulation threshold = max mg toxic/kg plant
  - Examples: 25% tree sap Ni, 3% dry mass Zn and 1% dry mass lead

## Plants and Examples

- Poplar trees
  - TCE and 1122TeCA transpired by trees (volatilized out of tree as parent compd)
  - TCE degraded to trichloroacetic acid (TCAA), DCAA, trichloroethanol
  - Use dealkylating and hydrolyzing enzymes to degrade atrazine (pesticide)
  - Uptake and degrade TNT in hydroponics

## More plants and examples

- Alfalfa plants sped biodegradation of a PCB congener by 2 bacterial species in lab studies
- Alfalfa plants sped microbial biodegradation of MTBE in soil and had some uptake of MTBE
- Alfalfa plants sorbed gold, copper, lead, Cr<sup>3</sup>, Ni<sup>2</sup>, Cd<sup>2</sup>, Zn<sup>2</sup> (pH dependent)

### More Plants and Examples

- Sunflowers
  - Bioaccumulate radiation from ponds near Chernobyl (hydroponics)
- Indian mustard
  - Uptake Pb, Cr, Cd, Ni, Zn, Cs137, St90
- Tamarsk – tolerates high arsenic
- Eucalyptus – tolerate high arsenic

### More plants and examples

- Wetland plants contain nitroreductase enzymes which degrade explosives (TNT)

### Risk concerns

- Bioconcentrated metals in plant shoots can be eaten by animals....
- Metals accumulated in leaves may migrate off-site when they drop
- Root sorbed compounds can be released back into the soil when plant dies
- Phytovolatilization can increase risk of inhalation of toxics (BTEX, TCE)