Bioremediation of Contaminated Soils

An Evaluation of *In Situ* and *Ex Situ* Techniques

Ex Situ Remediation Techniques

- Thermal Techniques
- Physical/Chemical Techniques
- Bioremediation Techniques
  - Landfarming
  - Biopiling
  - Bioreactors

Thermal *Ex Situ* Remediation

- Best to remove: petroleum hydrocarbons (TPH), polycyclic aromatic hydrocarbons (PAH), benzene, toluene, ethylbenzene, xylenes (BTEX), phenolic compounds, cyanides, and chlorinated compounds like polychlorinated biphenyls (PCB), pentchlorphenol (PCP), chlorinated hydrocarbons, chlorinated pesticides, polychlorinated dibenzodioxins (PCDD), and polychlorinated dibenzofurans (PCDF).

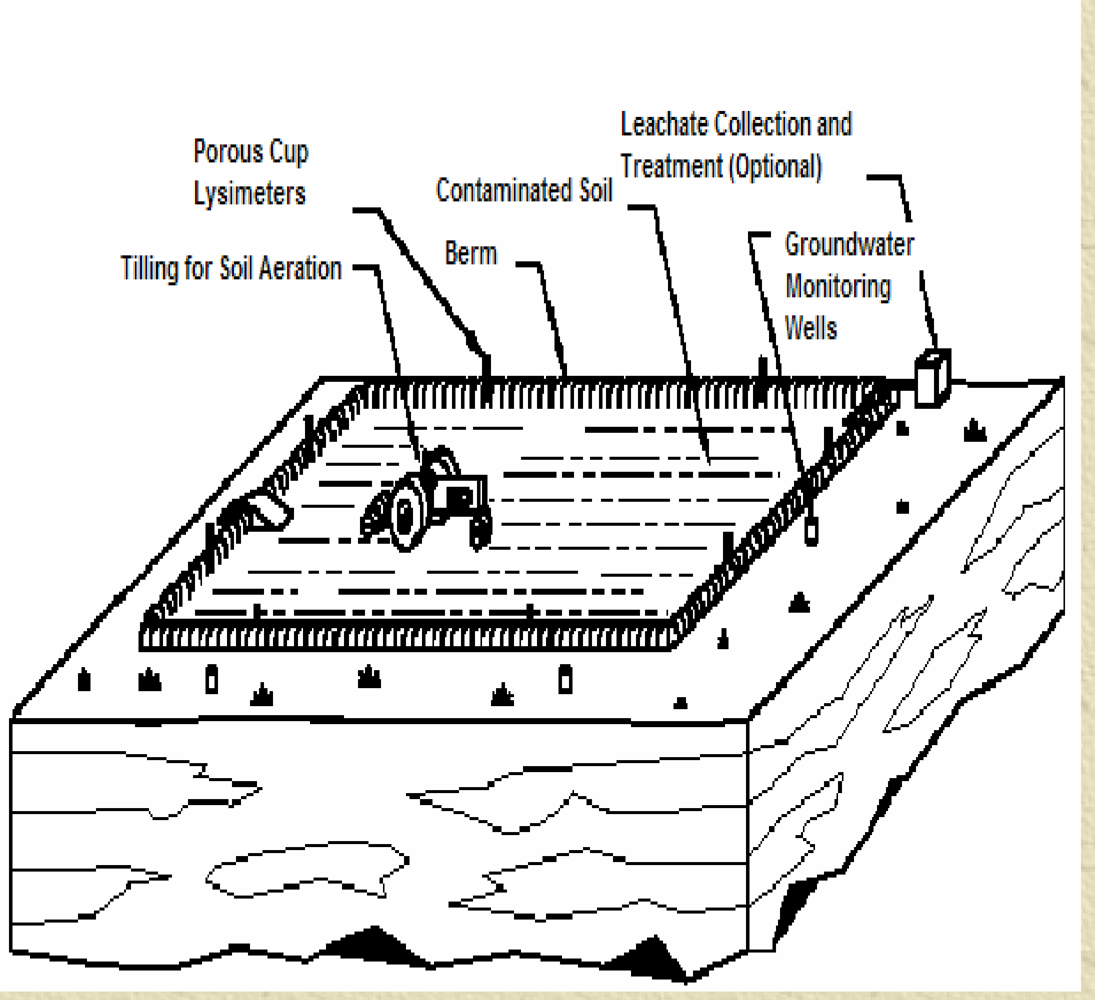
Physical/Chemical *Ex Situ* Remediation

- Wash water and vapors from this treatment must also be properly disposed of which adds to the costs.
- This method is most effective at removing BTEX, TPH, PAH, PCB, heavy metals, and dioxins.

Ex Situ Bioremediation

Landfarming

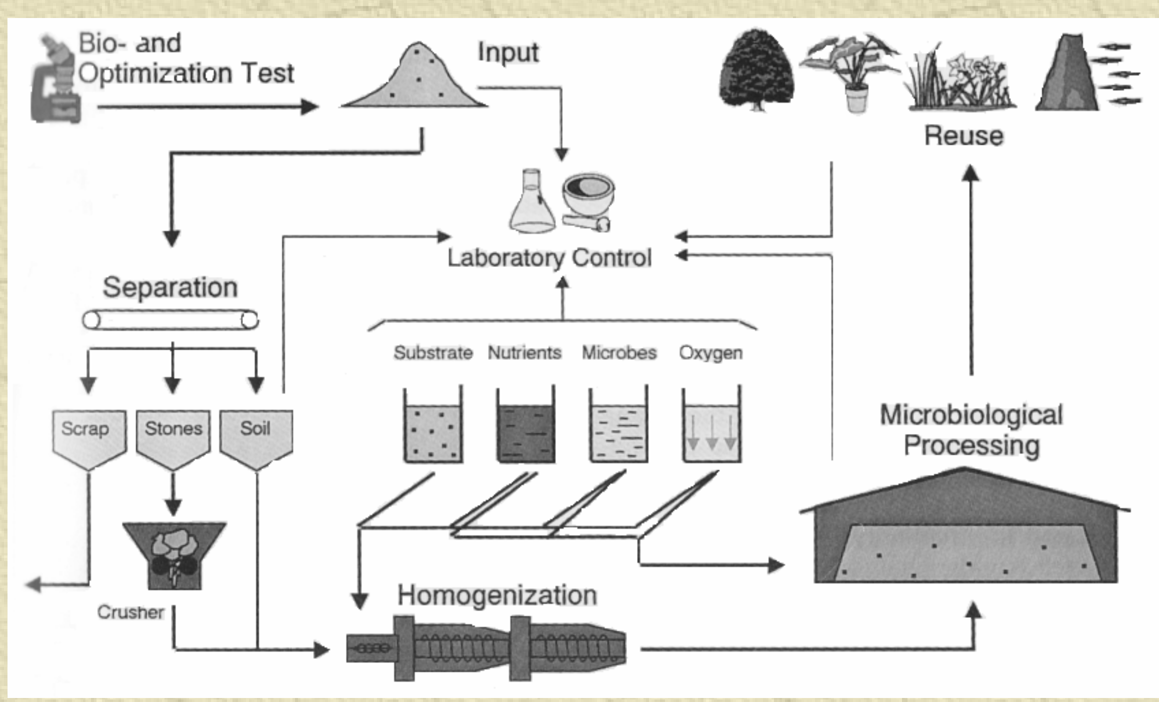
- Most effective at removing PAH and PCP



Ex Situ Bioremediation

Biopiling

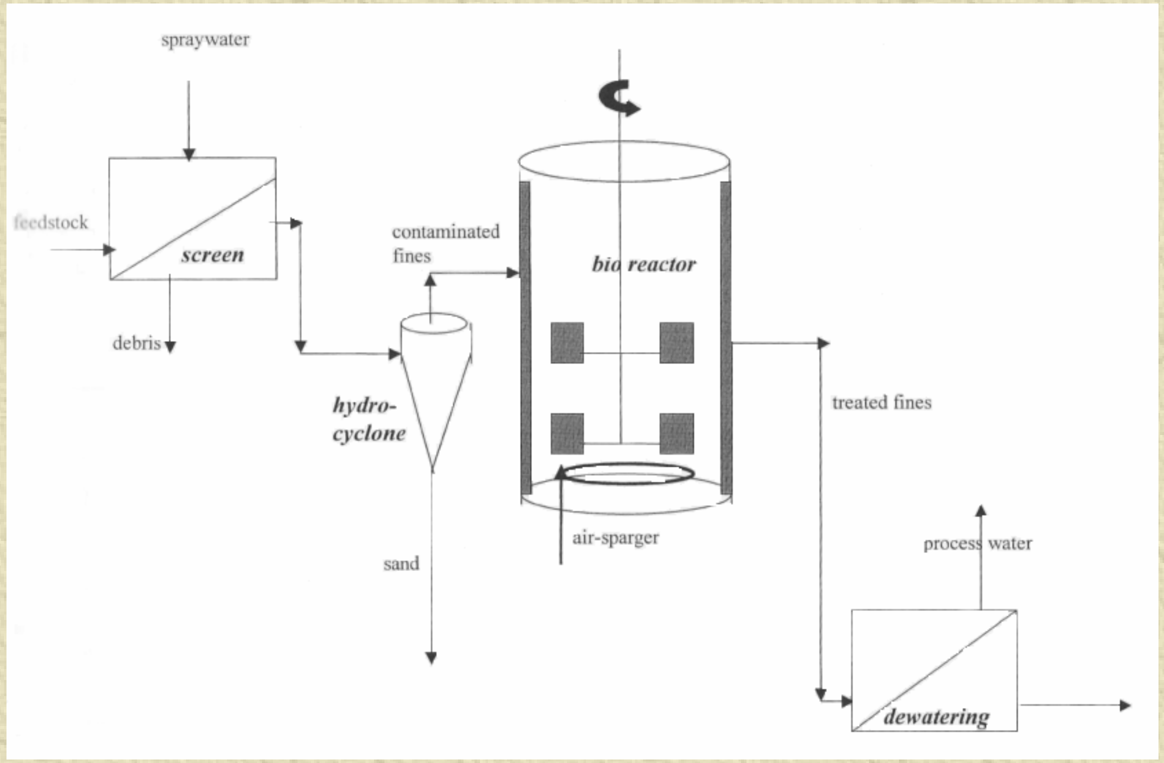
- Biopiling is most effective in treating pollutants such as BTEX, phenols, PAHs with up to 4 aromatic rings, and explosives such as TNT and RDX.



Ex Situ Bioremediation

Bioreactors

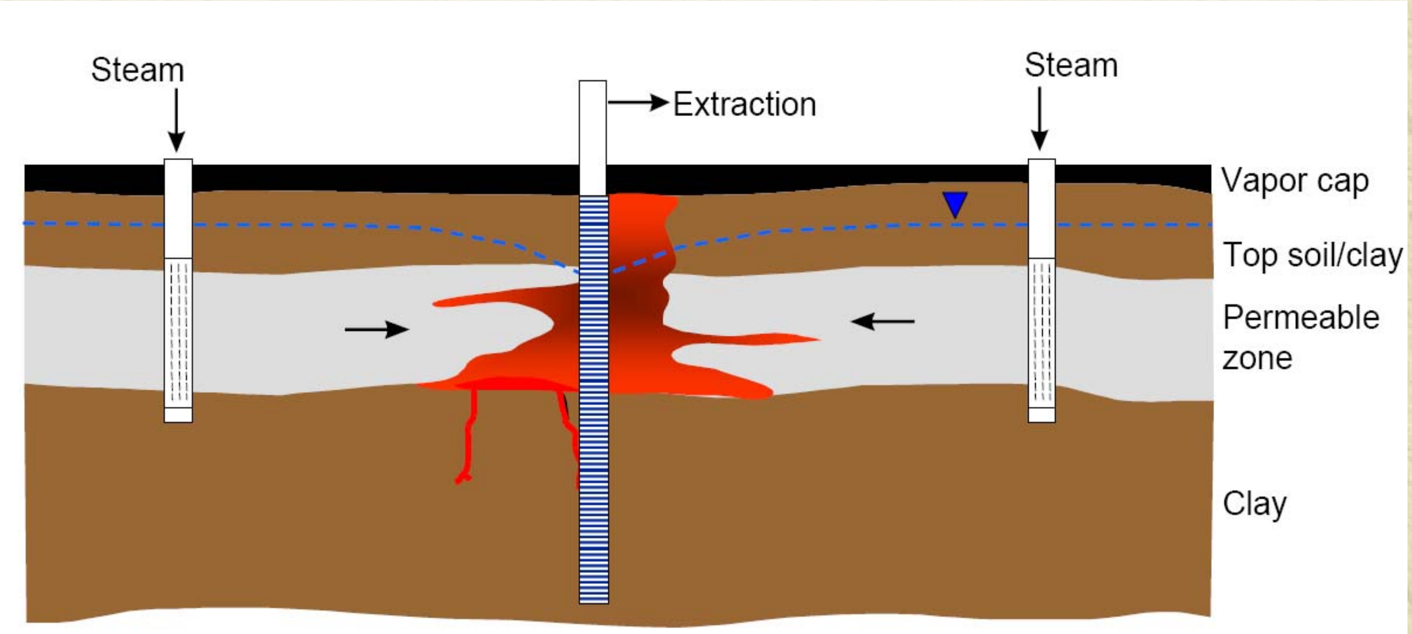
- Bioreactors are most successful at removing PAHs and PCBs.



In Situ Remediation Techniques

- Thermal Techniques
- Chemical/Physical Techniques
  - Pump and Treat
  - Soil Vapor Extraction
- Bioremediation Techniques
  - Bioventing
  - Biosparging
  - Bioslurping
  - Phytoremediation
  - Passive Treatments

Thermal *In Situ* Remediation

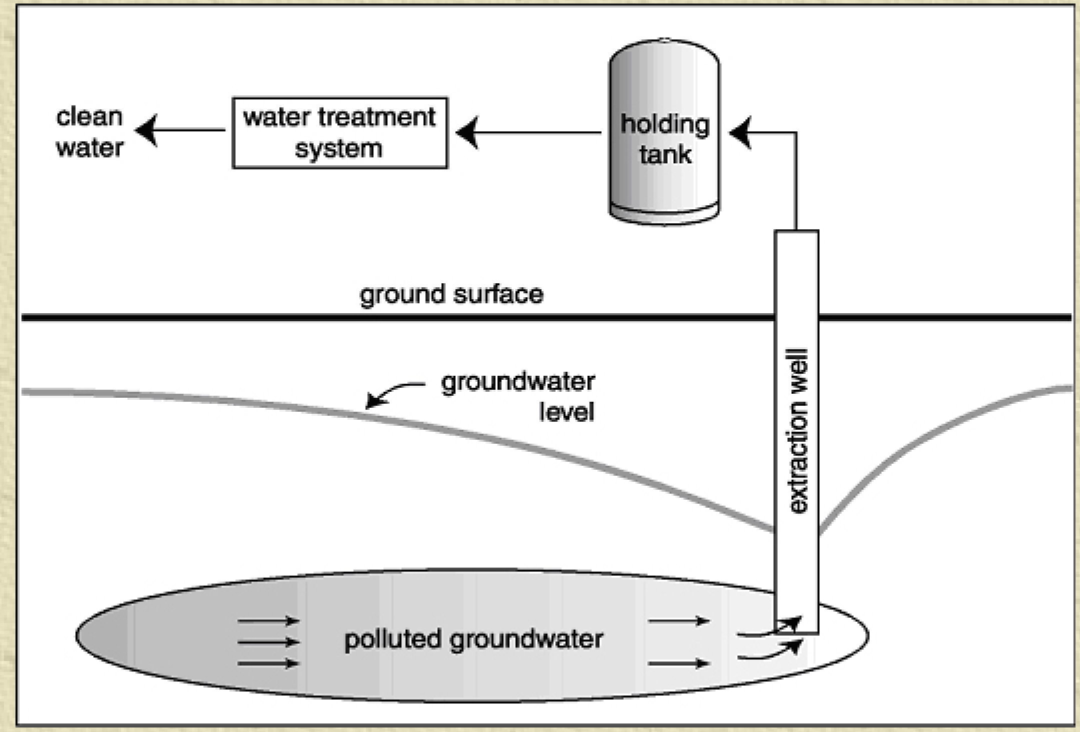


- Only effective at removing pollutants that can be removed at low temperatures such as BTEX
- Soil must be homogenous, permeable, and have a low organic content

Chemical/Physical *In Situ* Remediation

Pump and Treat Technique

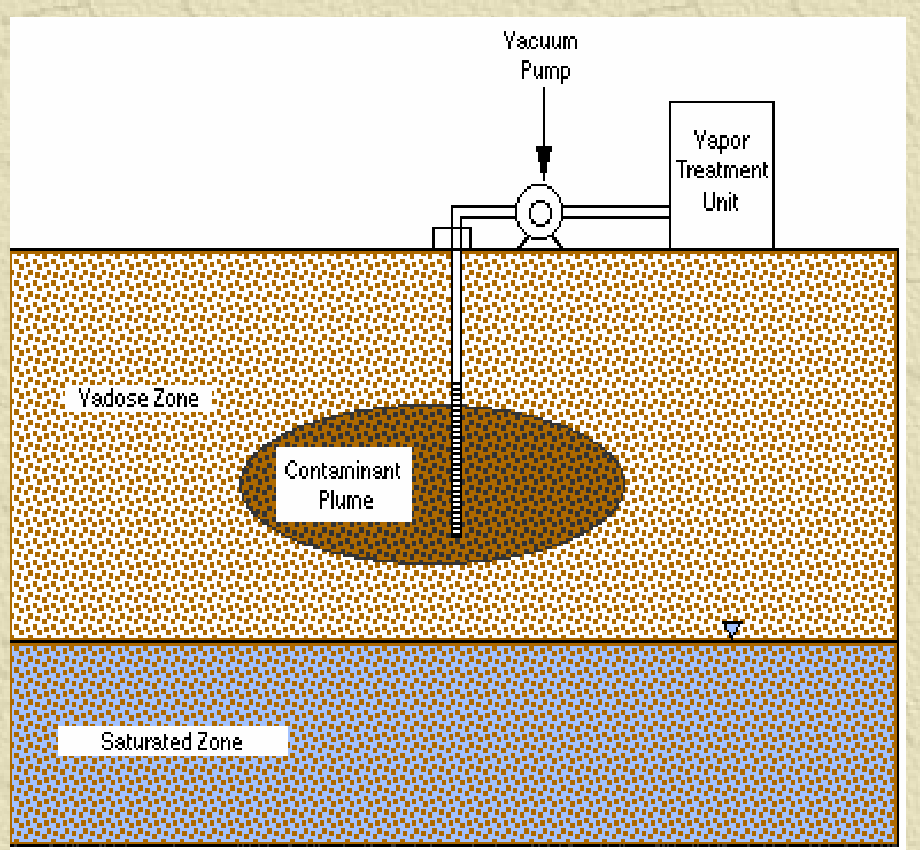
- Most effective at removing PAHs and TCEs
- Limited by soil permeability



Chemical/Physical *In Situ* Remediation

Soil Vapor Extraction

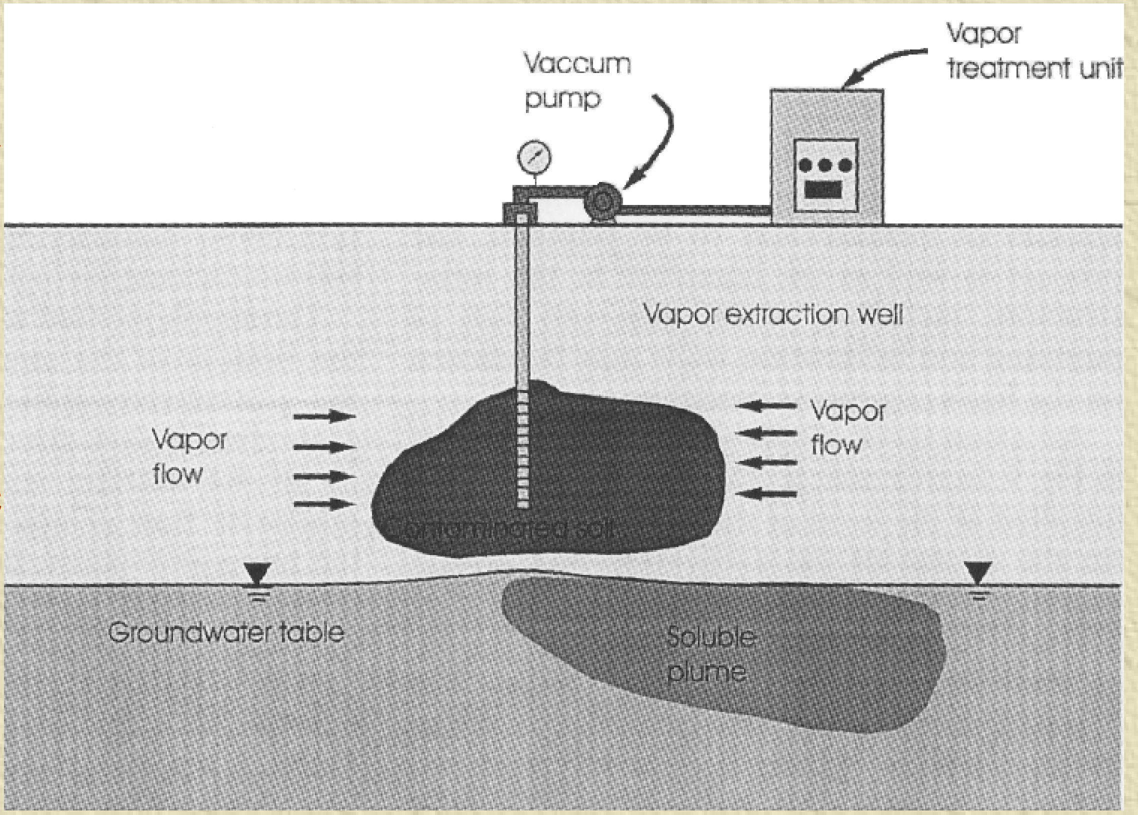
- A high percentage of fine soil or a high degree of saturation can also hinder the effectiveness of soil vapor extraction.
- This technique rarely achieves complete contaminant removal, but is very useful when combined with other techniques.



In Situ Bioremediation

Bioventing

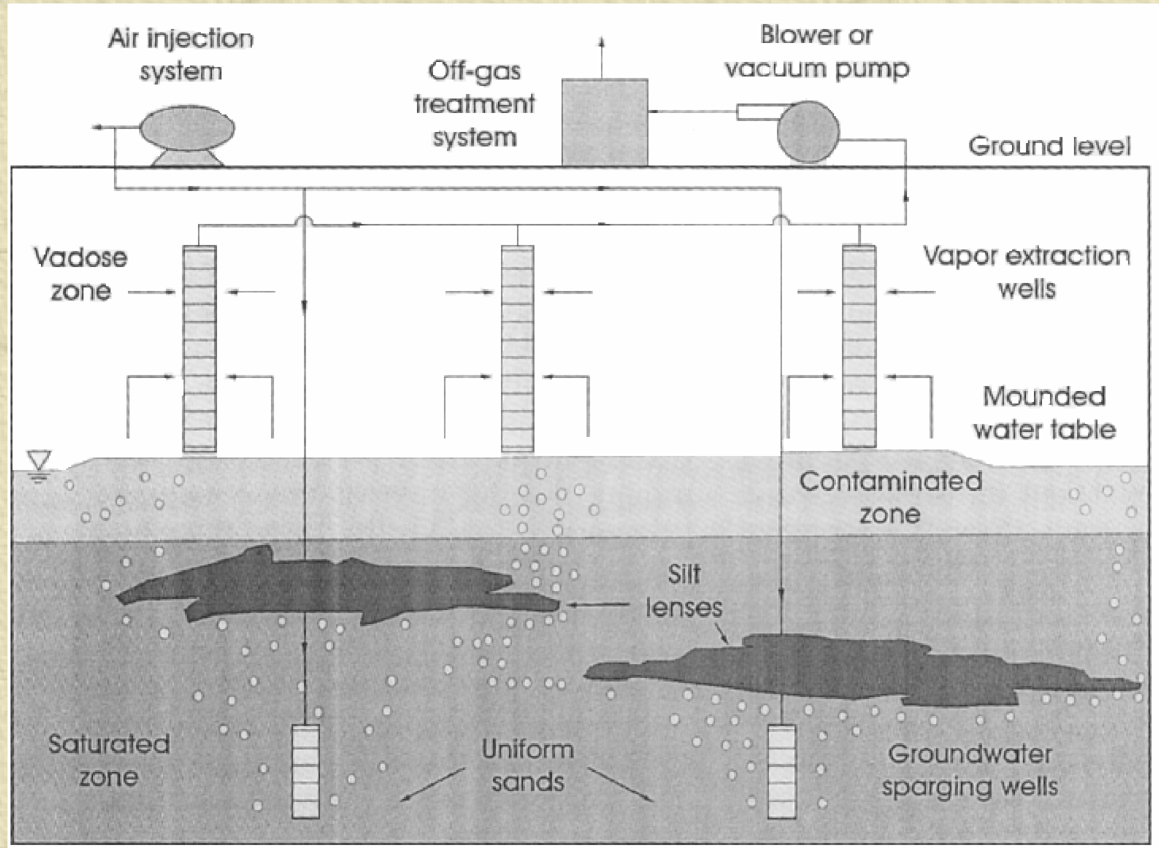
- The only technique that works in unsaturated soils
- Effective in removing petroleum hydrocarbons, aromatic hydrocarbons, and non-volatile hydraulic oils.



In Situ Bioremediation

Biosparging

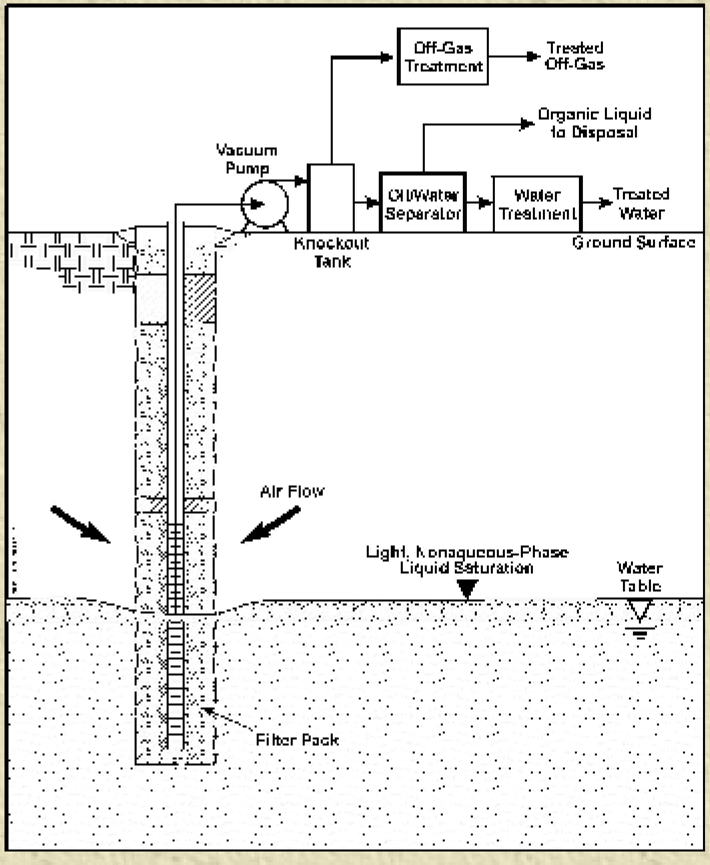
- Sparge points must be installed below the contaminated zone.
- The contaminated layer must be homogenous.
- Pilot studies must be completed to determine optimum pH, moisture content, temperature, nutrient content, and carbon sources.



In Situ Bioremediation

Bioslurping

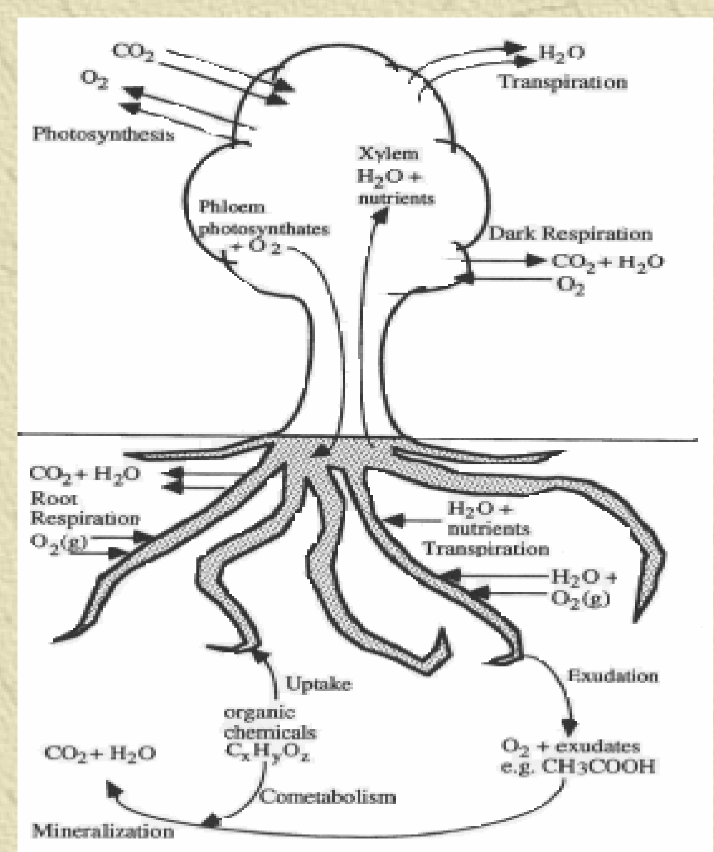
- Bioslurping is a unique *in situ* treatment technique in that it also treats free product phases floating on top of the groundwater. This technique applies a vacuum to extract soil vapor, water, and free product from the subsurface. Each of those substances is then separated and properly disposed of.



In Situ Bioremediation

Phytoremediation

- Successfully removes TPH, BTEX, PAH, 2,4,6-trinitrotoluene (TNT), and hexahyro-1,3,5-trinitro-1,3,5 triazine (RDX).
- Limited by the depth the plants roots can reach.



In Situ Bioremediation

Passive Techniques:

- Activated Zones
- Bioscreens
- Reactive Walls
- Reactive Trenches
  - These techniques can be used when removing contaminants from non-homogenous soils.
  - These techniques are attractive because they have high longevity, no significant maintenance, and no nutrient replenishment.

Summary of Removable Compounds and Soil Constraints

Remediation Technique	Effectively Removed Compounds	Soil Constraints
Ex Situ Techniques		
Thermal Remediation	TPH, PAH, BTEX, PCB, PCP, PCDD, PCDF	No specific constraints
Soil Scrubbing	TPH, BTEX, PAH, PCB, heavy metals, dioxins	Must be made homogeneous to treat
Landfarming	PAH, PCP	No specific constraints
Biopiling	BTEX, PAH, TNT, RDX	Must be made homogeneous to treat
Bioreactors	PAH, PCB	Must be separated by particle size in order to treat
In Situ Techniques		
Thermal Remediation	BTEX	Must be homogeneous, have high permeability and low organic content
Chemical Oxidation	PAH, TCE	Must be permeable
Soil Vapor Extraction	BTEX	Must have low percent fines and correct moisture content
Bioventing	PAH, nonchlorinated solvents	Must be homogenous, may be unsaturated
Biosparging	PAH, nonchlorinated solvents	Must be homogenous and saturated
Bioslurping	Free Product (Petroleum)	Must be homogenous and saturated
Phytoremediation	TPH, BTEX, PAH, TNT, RDX	Must have contamination in shallow soil

Summary of Remediation Costs

Remediation Technique	Cost Range, \$/yd^3	Influencing Factors
Ex Situ Techniques		*Excavation and Transportation costs not included
Thermal Remediation	40 -1171	The use of incineration or desorption, fuel cost and quantity of soil treated in each batch
Soil Scrubbing	53-142	The quantity of soil treated in each batch and the pollutants being removed
Landfarming	75	Does not include cost of pilot study or lab tests which are substantial
Biopiling	30-60	The contaminant being treated, the need for pre and post treatment, and the possible need for emission control
Bioreactors	100-160	The use of a slurry or solid reactor; does not include infrastructure costs
In Situ Techniques		
Thermal Remediation	25-100	The specific method of thermal remediation used
Chemical Oxidation	No Data Found	No Data Found
Soil Vapor Extraction	300-1100	The contaminant being treated, the amount of time available to perform treatment, the number of wells needed for treatment
Bioventing	60-742	The contaminant concentration, the number of vent wells needed, the soil conditions
Biosparging	60-742	The contaminant concentration, the number of sparge points needed, the soil conditions
Bioslurping	No Data Found	No Data Found
Phytoremediation	112-1775	The number of trees planted in a specific area and the amount of contaminant present

Conclusions

- Must determine what is more important, costs or cleanup efficiency.
- Each site is different. Pilot studies and/or lab studies must be done for each one.
- More research is need in the area bioremediation, but funding is a major setback.

Questions?