

CVEN 4474/5474 Haz Waste Outline: Site Clean-up Methods

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

In Situ Bioremediation

- Use bioprocesses to degrade contaminants in soil and/or groundwater to clean-up sites
 - Used at Superfund sites for soil remediation (29 sites) & GW remediation (19 sites)
 - 2nd most used in situ soil remediation method at Superfund sites
 - Widely used at Underground Storage Tank (LUST) sites

Natural:

- In the environment, bioactivity occurs naturally
- Bacteria that can degrade toxic organics are widespread
- Rate of biodegradation limited by:
 - Electron acceptors -- Nutrients
 - Co-substrates -- Temperature
 - Moisture -- pH
 - Competition -- Toxicity

Engineer

- Create optimal conditions to increase biodegradation rates
 - Bioventing, air sparging = add oxygen
 - Groundwater remediation = add nutrients, electron acceptors, electron donors, etc.
 - Increase bioavailability by increasing desorption = increase temp; add surfactants
 - Add bacteria - usually doesn't work well in situ since non-native bacteria die in subsurface; ok for ex situ treatment

Natural Bioremediation

(natural attenuation; intrinsic bioremed)

When?

1. Contaminant is biodegraded by natural bacteria
2. Natural bacteria needed are present at the site
3. Show the bacteria are actively degrading the contaminants at the site NOW
4. The RATE of biodegradation is sufficient for protection of human health and the environment (RISK)

Prove the above points by lab data, field data, and modeling

Is natural bioremediation occurring?

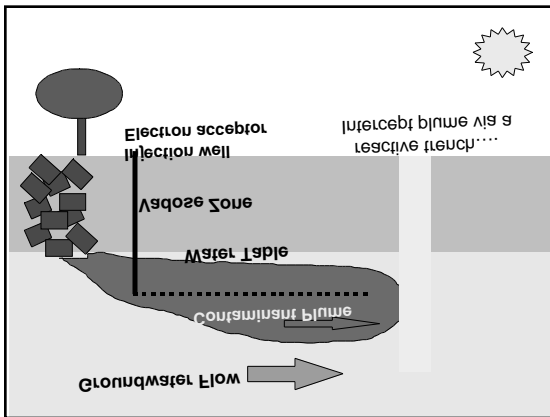
- At 217 sites in Texas with hydrocarbon (gasoline) contamination
 - For GW plumes of benzene >75% were stable or shrinking AND <250 ft long
- At 273 fuel sites in California
 - Slowly shrinking plume size or stable at <250 ft
- Other locations (widespread)
 - Some chlorinated solvent plumes (bigger but some are still stable and/or shrinking)

Natural Bioremediation is NOT a “do nothing” approach

- Time, sampling, and money are needed to prove natural attenuation provides acceptable risk levels
- Long-term monitoring of the groundwater plume, etc. are required
 - 20-50 yrs or more!

Engineer In Situ Bioremediation

- Add electron acceptors
 - Air (bioventing, air sparging), H_2O_2 , NO_3 ,...
- Add nutrients
 - Nitrogen (ammonia), phosphorus,
- Add co-substrates
 - Lactate, hydrogen, molasses (anaerobes) or methane, propane, etc. (aer. Comatabolism)
- Add via injection wells, interception trenches



Ex Situ Bioremediation

- Used at 42 Superfund sites (9% of all technol)
- Can use to treat (degrade) organic contaminants in air, water, and soil
- Ex situ designs can better control factors that affect biodegradation (temp, pH, N,...)
- A primary factor which distinguishes designs is whether the bacteria are stationary in the reactor or mobile in the liquid

Types of Ex Situ Bioreactors

	GAS	LIQUID	SOIL
bacteria suspended in water	bioscrubber suspended growth	completely mixed (CSTR)	bioslurry
		plug flow	
		sequencing batch reactor	
bacteria fixed or attached in reactor	biofilter	trickling filter	landfarming
	biotrickling filter	fluidized bed reactor	composting
		membrane reactor	(biopile) soil heaping

CSTR

- If ideally mixed, the concentration of substrate and biomass IN the reactor is the same as the concentrations LEAVING the reactor
- Advantages:
 - low concentrations of contaminants will not be toxic to bacteria due to dilution
 - uniform concentrations of electron acceptors and nutrients throughout
- Disadvantages: low concentrations of contaminants due to dilution will be biodegraded slower

Example: CSTR design (similar to municipal wastewater tmt)

- Design a reactor to treat 100 gpm B(a)P contaminated groundwater removed by pump&treat down to drinking water limits
- What volume of reactor is needed?

Example CSTR dsn

- BaP in groundwater due to dissolution from a coal tar NAPL, mole fraction BaP is 10%
 - BaP sol from liq = 49.2 µg/L (1.5 µg/L solid)
 - Raoult's Law: $C_w @ \text{equil} = 0.1 \cdot 49.2 = 4.9 \text{ µg/L}$
 - Groundwater 1-10% equilibrium = 0.49 - 0.05 µg/L
- Drinking water limit = 0.2 µg/L

CSTR dsn cont.

- Biokinetics for BaP? (aerobic)
 - $Y = 0.2 \text{ mg bio/mg BaP}$, $k = 0.5 \text{ g/g-d}$, $K_s = 0.01 \text{ mg/L}$, $b = 0.001 \text{ d}^{-1}$
- Dsn Eqns based on mass balance on substrate degradation (BaP conc) and biomass growth (X)
 - CSTR with or without recycle?
 - Due to low yield, low population of X in the inlet water should recycle

CSTR Dsn cont.

- Concern about washing out bacterial population. Solve for minimum SRT:
 - $1/\text{SRT}_{\text{min}} = [YkS/(K_s+S)] - b$
 - ERROR** in text (S not S_0 ...bact. "see" S)
 - $1/\text{SRT}_{\text{min}} = [(0.2 \cdot 0.5 \cdot 0.0002)/(0.0102)] - 0.001$
 - $\text{SRT}_{\text{min}} = 1041 \text{ days}$ (LONG!)
- Assume use a membrane to achieve the long SRT needed, ~1100 days

CSTR Dsn cont.

- Solve for effluent conc from reactor
 - $S = K_s(1+b\text{SRT})/[\text{SRT}(Yk-b)-1]$
 - $S = 0.01(1+(0.001 \cdot 1100))/[1100(0.2(0.5)-0.001)-1]$
 - $S = 0.021/107.9 = 0.00019 \text{ mg/L} < 0.0002 \text{ ok}$

CSTR Dsn cont.

- Without recycle, $\text{SRT} = \text{HRT}$; with recycle $\text{SRT} > \text{HRT}$...given Q, the volume of reactor based on HRT ($\text{HRT} = V/Q$)
- Solve for biomass conc in reactor
 - $X = Y(S_0 - S) \text{SRT} / [(1+b\text{SRT}) \text{HRT}]$
 - HRT is a variable... a reasonable X ~50 mg/L?
 - $50 = 0.2(0.00049 - 0.0002)(1100)/[1 + 0.001(1100) \text{HRT}]$; then $\text{HRT} = 0.00061 \text{ days} = 0.87 \text{ min!}$
 - Since not much substrate, very low biomass concs... 5 mg/L X gives $0.00608 \text{ d} = 8.75 \text{ min}$

CSTR dsn cont.

- 8.75 min HRT, and 100 gpm flow
- Vol reactor = 875 gal
- Enough oxygen for bacteria?
 - Need: $C_{20}H_{12} + 23 O_2 \rightarrow 20 CO_2 + 6 H_2O$
 - 0.29 $\mu\text{g/L}$ BaP degraded * 1 $\mu\text{mol}/252.2 \mu\text{g}$
* 23 $\mu\text{mol}/1 \mu\text{mol}$ * 32 $\mu\text{g}/\mu\text{mol}$ = 0.85 $\mu\text{g/L}$
O₂ required
 - For aerobic conditions, O₂ this low will slow
biokinetics...mix and open to atmosphere
since BaP has low volatility

CSTR cont.

- Other contaminants present??
- Due to very low yield and long SRT, an
attached growth system is probably
better...
- Due to LOW BaP concentrations
needed in effluent, plug flow, batch
reactor, or trickling filter may be
better....
- If low yield on contaminant but need
dilution, FBR might be best