

CVEN 4474/5474 Haz Waste Outline

- “Enhanced” Pump and Treat
 - Surfactants
 - Solubilizers
- Ex situ treatment options

“Enhanced” Pump and Treat

- Extraction efficiency for contaminants in pump and treat limited by high sorption to solids and/or slow dissolution rates from NAPLs
- GOAL: Increase aqueous solubility to increase “extraction” into the water phase
 - May also mobilize NAPLs by decreasing the interfacial tension

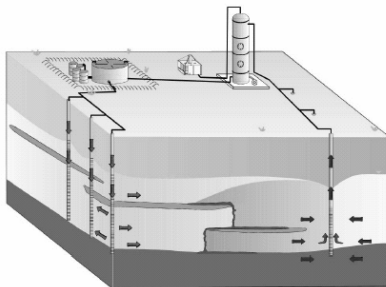
Remedies for Contamination at SF sites (1982-99)

- 16 sites (2%) with in situ soil flushing
- 6 sites with ex situ soil washing
- 4 sites with ex situ solvent extraction
- Ex-situ: dig out contaminated soil and “wash” in a batch reactor above ground
 - only for reasonably shallow contamination
 - excavation costs may be prohibitive

pre Dsn Characterization

- Aquifer characterization
 - partitioning of extracting agent to the solids and/or NAPLs
 - solids (colloid) mobilization and/or swelling the reduces aquifer permeability due to amendment
- Biocompatibility and toxicity
 - use environmentally compatible agents [avoid injecting one toxic compound to minimize another]

Generic “model” of enhanced pump and treat



Battelle and Duke, 2002

Surfactant Enhanced Aquifer Remediation (SEAR)

Surfactants typically injected at 0.1-7%

Anionic	Soaps (LAS) Sulfate Phosphates Sulfosuccinates	low sorption to soil more biotoxic higher concs needed
Nonionic	Ethoxylated alcohol	medium sorption to soil most biocompatible
Cationic	ammonium	high sorption to soil highly biotoxic NOT used

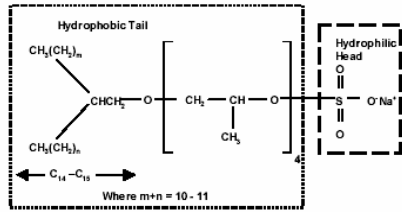


Figure 4-2. Molecular Structure of Aifoterra 145-4PO Sulfate™ Surfactant

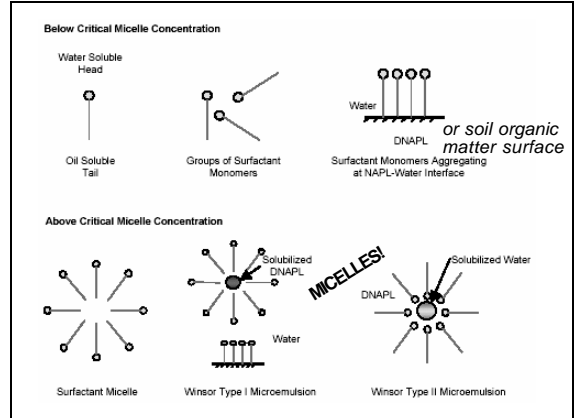


Table 1-2. SEAR Advantages and Limitations

Advantages	Limitations
1. Can address a wide variety of NAPL contaminants	1. Requires extensive source-zone characterization compared to dissolved-phase technologies
2. Overcome mass transfer limitations of dissolved-phase technologies such as P&T and in situ chemical oxidation by accomplishing: a) Orders of magnitude increase in contaminant solubility b) Low interfacial tensions to mobilize contaminant c) Efficient contacting of contaminated zones using forced hydraulic gradients via the use of a series of injection and extraction well pairs	2. Requires competent capillary barrier to avoid downward mobilization of contaminants
3. Rapid removal of NAPL accomplished in weeks and months rather than years	3. Higher liability associated with potential for unintended mobilization of DNAPL
4. Accomplishes higher DNAPL removal efficiencies and uses fewer chemicals than cosolvent flooding	4. High cost of waste treatment relative to a destructive technology such as in situ chemical oxidation
5. Safe to use near occupied buildings	5. Design and implementation requires personnel with considerable expertise
6. Can be implemented without aquifer dewatering	6. Performance may suffer in shallow, low permeability, and heterogeneous aquifers

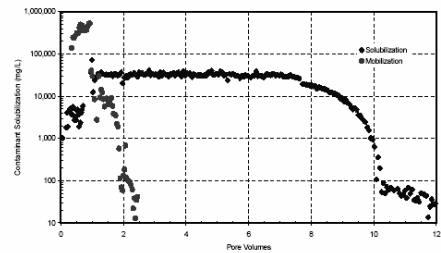
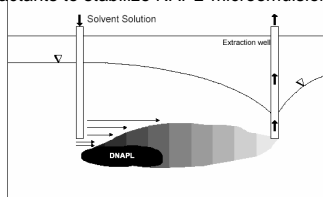


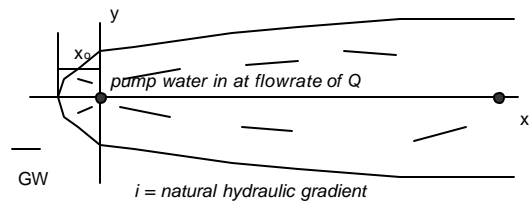
Figure 4-6. Soil Column Comparison of Solubilization and Mobilization Remediation Approaches

Solvent Flushing

- alcohols commonly used
 - >50%; ethanol, 2-propanol
- alcohols may also be bacteria substrate to enhance contaminant biodegradation
- use with surfactants to stabilize NAPL microemulsions



Design: Well Spacing



- use similar equations for "extraction" design
- "pair" injection and extraction wells

Treat Pumped GW Ex-Situ

likely contributes significantly to overall cost and complexity!

- Air stripping or steam stripping (organics)
- Carbon adsorption (organics)
- Ion exchange (metals, inorganics)
- Chemical oxidation (organics)
- Biological tmt (org; usu. in series w/ others)
- Membrane filtration (reverse osmosis)
- Fluids separation
 - Oil:water sep. for NAPLs
 - Liq/Liq extraction

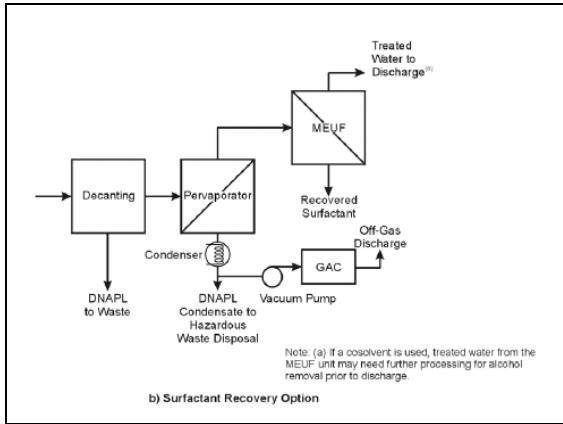
- Air stripping or steam stripping (organics)
 - strip volatile contaminants from the extracted liquid into air
 - steam stripping: heat to increase organic compound volatility (semi-volatiles)
 - must treat contaminated air
 - works poorly for low volatility compounds
 - surfactants decrease Henry's !
 - foaming of surfactants
 - low cost/higher cost

- Carbon adsorption (organics)
 - pass water through a bed of granular activated carbon
 - contaminants sorb out of the liquid onto the solid phase
 - sorption capacity is eventually exhausted and must regenerate or replace carbon
 - works well for hydrophobic compounds

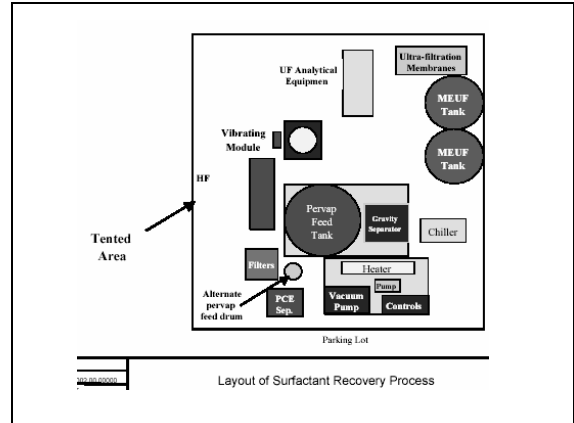
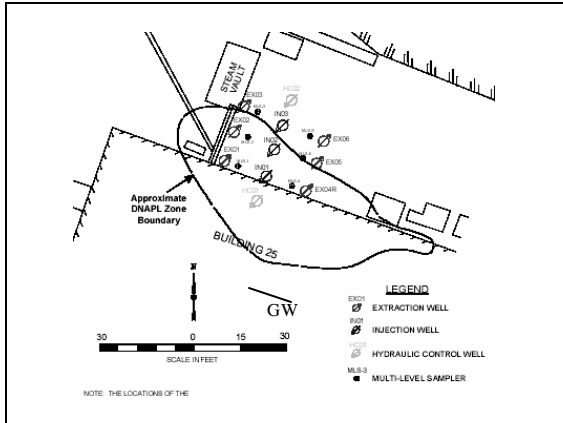
- Pervaporation
 - a membrane process in which a liquid is maintained at atmospheric pressure on the feed or upstream side of the membrane and where the permeate is removed as a vapour because of a low pressure existing on the permeate or downstream side (maintained by a vacuum)
 - Works for volatile compounds
 - no surfactant foaming problems
 - fouling resistant
 - more expensive than air stripping

- Liquid/Liquid Extraction
 - Works for volatile, semi-volatile, and non-volatile compounds
 - no foaming with surfactants
 - Interface stability of concern
 - emerging technology
 - more difficult regeneration

- Membrane filtration (reverse osmosis)
 - can select varying pore sizes to retain different elements
 - UF can retain surfactant micelles
 - NF or RO can separate organics and/or ions from the water
 - “retentate” or concentrate stream can be re-injected (surfactant) OR must be further treated
 - membrane fouling, expensive power requirements



- ### Example: Camp Lejeune NC
- PCE DNAPL
 - Anionic surfactant flooding on a pilot scale
 - 4% Alfonic & 16% isopropyl alcohol
 - 58 days, 29,700 gal injected (5 pore volumes)
 - removed 76 gal PCE (left ~29 gal in situ)
 - NAPL mobilization and enhanced solubilization
 - Ex situ pervaporation followed by UF micelle separation and re-injection



Projected full scale cost for 1 acre site

Pre-construction cost	\$2.0M
bench scale tests, preliminary field tests	
Construction cost	\$4.0 M
Wells, pumps, ex situ treatment/recovery	
O&M cost	\$6.4M
Chemicals, labor, analysis, power	
Performance assessment	\$0.3M
TOTAL COST	\$12.8M

note: saved \$0.2M by surfactant recovery