that the site have a continuous confining clay layer beneath the contamination. Costs are related to aquifer permeability, concentration and type of contaminant and the availability of existing treatment facilities. Effective source zone remediation, by any technology, requires comprehensive site characterization to obtain remedial design data.

Surfactant studies need to be conducted on a site-specific basis for a given NAPL composition. A well-designed surfactant test to accomplish high NAPL mass removal requires a carefully-chosen surfactant and a comprehensively characterized site.

Advantages

- NAPL removal is rapid and efficient.
- Multicomponent NAPL, i.e. NAPL mixtures, can be treated.
- Can avoid long-term liability associated with a persistent contamination source.
- Provides a cost-effective alternative to pump and treat systems for source area remediation.

Limitations

- High level of expertise required in design and implementation.
- Waste treatment may require specially constructed facilities.
- Not an economical approach for NAPL confined exclusively to low permeability sediments ($K < 10^{-4}$ cm/sec).

SEAR wellfield at MCB Camp Lejune, NC

DNAPL Technology Application Team

The DNAPL Technology Application Team (TAT) can provide assistance with source area site characterization, with the implementation of SEAR, as well as the application of other source removal technologies. Documentation is being developed to assist Navy and Marine Corps users in selecting the most cost-effective and timely solutions for their (D)NAPL sites.

For more information on SEAR, contact:

(805) 982-1660, DSN: 551-1660
or
(805) 982-4991, DSN: 551-4991

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NAVFAC

Surfactant Enhanced Aquifer Remediation

Surfactant Enhanced Aquifer Remediation tank farm

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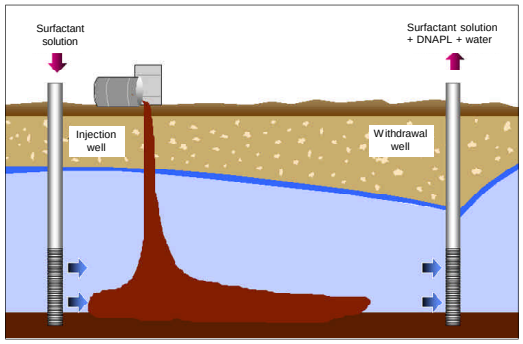
What is Surfactant-Enhanced Aquifer Remediation (SEAR)?

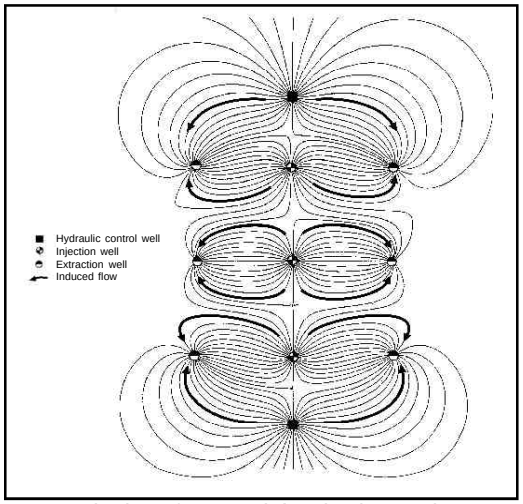
SEAR is a cleanup technique effectively removs high concentrations of undissolved liquid phase organic contaminants from the subsurface. SEAR flushes the contaminated soil with a surfactant solution that contains ingredients that are common in household cleaners and detergents. The surfactant formulation typically includes an alcohol co-solvent and an electrolyte. SEAR techniques have been used by the oil industry to enhance oil recovery since the 1960s.

Surfactants have the ability to reduce the interfacial tension between the organic and aqueous phase contaminants and greatly increase the solubility of the contaminants. This allows the solubilized and/or mobilized contaminants to be removed by the surfactant flood. The injected solution and dissolved contaminants are then removed from the ground by extraction wells.

Following a surfactant flood, water is injected into the contaminated zone to remove any residual surfactant solution and associated contaminants. The movement of the injected chemicals in the subsurface is controlled through careful monitoring and adjustment of injection



Schematic of Surfactant Enhanced Aquifer Remediation



Typical surfactant injection/extration well field showing hydraulic capture

and extraction rates and the use of hydraulic control wells as needed.

The extracted liquid is sent through a gravity separator and then processed through an air or steam stripper to remove the contaminant prior to discharge to a local publicly owned treatment works (POTW). Alternatively, surfactant and/or co-solvent may be recovered from the contaminant-stripped stream and reused in the flushing process.

NAPL Contaminants

Contaminants residing in the subsurface in an undissolved state are often referred to as "non-aqueous phase liquids (NAPLs)." Residual NAPL is very difficult to remove as capillary forces often hold the NAPL in place. SEAR is well suited for the removal of residual NAPL, although it can also be used to accelerate the movement of larger quantities of free-phase NAPL from low permeability media.

While most SEAR projects conducted to date have addressed chlorinated hydrocarbons, SEAR can be used for almost any NAPL due to the wide variety of commercially available biodegradable surfactants. By heating the surfactant, high viscosity liquids can also be removed.

Dense non-aqueous phase liquids (DNAPLs) such as the chlorinated hydrocarbons are the most difficult to cleanup since they are heavier than water and will sink deeper into the aquifer when mobilized. The use of SEAR for DNAPL removal requires carefully controlled conditions to avoid spreading the contaminants.

Technology status

Over fifteen pilot-scale SEAR demonstrations have been conducted to date. Recent technology advances permit higher contaminant removal efficiencies with fewer pore volumes of flushing solution. For example, in a 1996 study conducted at Hill AFB, near Salt Lake City, Utah, 98% contaminant removal efficiency was accomplished using less than three pore volumes of surfactant solution.

During 1999, the Navy completed SEAR demonstrations at Marine Corps Base Camp Lejeune, North Carolina; Naval Base Pearl Harbor, Hawaii; and at Naval Air Station Alameda, California. Altogether, these studies removed tetrachloroethylene, 1,1,1-trichloroethane, 1,1,-dichloroethane, 1,1,-dichloroethylene, and high viscosity Navy fuel oil from the subsurface.

Larger-scale SEAR demonstrations are currently planned at Hill AFB, Utah and at an EPA Superfund site in New Hampshire.

Will SEAR work at my site?

SEAR may be applied at any site with sufficient permeability ($K \leq 10^{-4}$ cm/sec) and where the hydraulic control of fluids in the contaminated aquifer may be maintained. Regulators may prefer