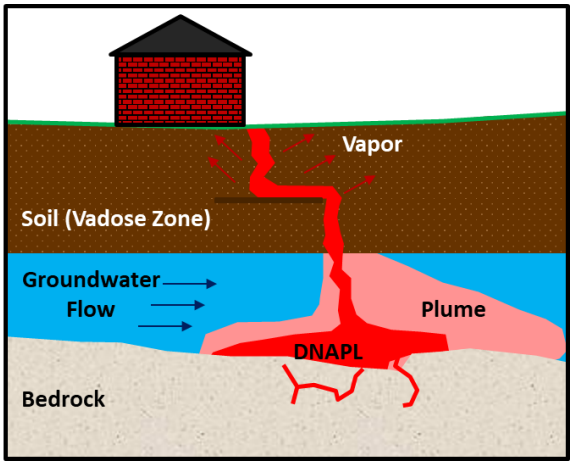
Cleanup of Chlorinated Solvent Sites

What are chlorinated solvents and why are they so hard to clean up?

Chlorinated solvents are industrial chemicals that are harmful to human health. Two of the most problematic chlorinated solvents are the chemicals trichloroethylene ("TCE") and tetrachloroethylene ("PCE"). These chemicals have a number of uses, including as a degreasing agent (TCE) and dry-cleaning fluid (PCE). Like most chlorinated solvents, TCE and PCE are liquids that are denser (heavier) than water; if discharged or spilled into the environment, they will sink through the ground until they reach an impenetrable layer (such as clay or bedrock). Pools or "fingers" of these chemicals below the ground surface are referred to as Dense Non-Aqueous Phase Liquids or "DNAPL" (pronounced *de-napple*).



Though DNAPL does not usually move far, it can slowly dissolve in groundwater (like table salt dissolves in a glass of water), and that contaminated groundwater (a "plume") can move thousands of feet. It can also evaporate into pockets of air within the soil, and potentially enter buildings through underground pathways. To stop this *source* of groundwater and air contamination, the DNAPL pools and fingers must be located and treated—two things that are very difficult to do.

How do you clean up sites where TCE and/or PCE DNAPL are present?

In most cases it's not practicable (or even possible) to dig up DNAPL, which can be present deep below the ground surface. Rather, various technologies are used to try to pump or vacuum them from the subsurface. Other approaches do not involve removing them from the ground, but rather destroying or detoxifying them in place ("*in-situ*"). Examples include:

- **Chemical Destruction**: Chemicals are injected into wells located near areas of known or suspected DNAPL, which react with and destroy the DNAPL. These chemicals are usually "oxidants," and the process is known as "*In-situ* Chemical Oxidation," or "ISCO." There are several possible oxidants to chose from; the biggest challenge is making sure the oxidants injected into the ground make their way to where the DNAPL is located. Other chemicals, called "reductants" can be used in the same manner.
- **Soil Vapor Extraction**: Volatile DNAPL (like PCE and TCE) in soil above the water table can be removed by applying a vacuum and extracting the vapors liberated by the DNAPL.
- **Thermal Treatment**: Heat is applied to the ground to boil the groundwater and vaporize the DNAPL, which is then captured by Soil Vapor Extraction.
- **Enhanced biodegradation**: Chlorinated solvents naturally "biodegrade," or transform into less harmful compounds, in the environment. Enhanced biodegradation involves injection of nutrients and sometimes microbial cultures to increase the rate of degradation.
- **Monitored Natural Attenuation**: This technique does not effectively remove or destroy DNAPL but may be a good option to treat the groundwater plume that emanated from the DNAPL. It relies on biodegradation and other naturally-occurring processes.

Remediation of Chlorinated Solvent Sites

What are some of the benefits and limitations of the available remedial technologies?

Technology	Benefits	Limitations
Chemical Destruction	▪ Adaptable for a wide range of contaminants, concentrations, and site conditions ▪ Treats DNAPL/source areas and groundwater plumes	▪ Delivery of chemical additives can be difficult (geology-dependent) ▪ Some risk associated with chemical handling ▪ Multiple applications often needed
Enhanced Biodegradation	▪ No reactive chemicals; reduces risks associated with handling and associated with discharge to surface waters ▪ Effective for a range of chlorinated solvents	▪ Less aggressive than other options (most effective at low to moderate concentrations) ▪ Can “stall” at intermediate compounds ▪ Delivery of additives can be difficult (geology-dependent)
Soil Vapor Extraction	▪ Effective in dry soils (above the water table) ▪ May mitigate vapor intrusion	▪ Does not address DNAPL or other contaminants below the water table ▪ Extended operations may be needed
Thermal Treatment	▪ Shortest timeline (months) ▪ Effective at a range of concentrations and in difficult geological environments	▪ Does not directly treat groundwater plume outside source area(s) ▪ Some risk of exposure for adjacent properties during operational period
Monitored Natural Attenuation	▪ Least expensive ▪ Lowest risk associated with implementation	▪ Not an active remedy ▪ Does not address DNAPL/source material

Can technologies be combined or staggered?

Yes. It is common to select different technologies for different areas of a site or use them at different times in the same area of a site. For example, chemical destruction or thermal treatment may be used in a DNAPL, and enhanced biodegradation used to treat the groundwater plume (or as a “polishing” step after the bulk of the contaminant mass is removed from the source area).