Lecture 23: Groundwater Contamination II

Key Questions

1. What is a NAPL?
2. What are some examples of a LNAPL?
3. What are some examples of a DNAPL?
4. What groundwater contaminants are polluting Area 6 at the NAS site?
5. What is a Superfund Site?
6. Where are the Superfund Sites in Whatcom County?
Organic Liquids are another common source of groundwater contamination
LNAPL = Light Non-Aqueous Phase Liquid

LNAPLS are lighter than water so they float
Fuels are LNAPLs
Examples of LNAPLs include:

- Gasoline
- Kerosine
- Fuel oil
- Jet fuel
- Diesel fuel

Fuels are chemically processed and contain many different types of organic chemicals
BTEX compounds will slowly dissolve out of the gasoline into the groundwater and create a plume that will flow with the groundwater.
BTEX Compounds

Benzene  
Ethylbenzene  
Toluene  
Xylene

Benzene Ring  
\[ \text{C}_6\text{H}_6 \]
One cup of gasoline will make a volume of water equivalent to an Olympic-size swimming undrinkable!
Organic Solvents, are different than fuels
DNAPL = Dense Non-Aqueous Phase Liquid

DNAPLS are heavier than water so they sink
Solvents are DNAPLs
Organic solvents are examples of DNAPLs

- Trichloroethylene (TCE) or dry-cleaning fluid
- Trichloroethane (TCA) e.g., parts cleaner, degreaser
- Carbon tetrachloroide (CTET) is a reagent
- Toluene – paint thinner
- Turpentine – paint thinner
Whidbey Island Naval Air Station (NAS)

Figure 1. Locations of six study basins on Whidbey and Camano Islands, Island County, Washington.
Figure 1. Location of the Whidbey Island Naval Air Station and Area 6 landfill study area, Island County, Washington
(From URS Consultants, 1993a.)
Landfill with fuel products and organic solvents
Area 6 Landfill

fSouls and solvents

Ground water flow

Plume

Water table

Bedrock
Figure 2. Generalized hydrogeologic section showing stratigraphic units at Area 6.
(From URS Consultants, 1993a.)
Figure 2. Location of Area 6 landfill and surrounding features, including selected wells, hazardous waste storage area, and contaminant plumes.
The NAS site is a **Superfund Site**

Superfund is the federal government's program to clean up the nation's uncontrolled hazardous waste sites.
Superfund sites. Red equals current; green equals cleaned up; yellow indicates proposed site. As of November 29, 2010, there are currently 1,280 sites listed on the National Priority List, an additional 347 have been de-listed, and 62 new sites have been proposed.
Superfund sites in Washington State

Another source is [EPA’s Washington State List](https://projects.publicintegrity.org/Superfund/ViewDetails.aspx?st=WA)
Hanford Site
Generalized cutaway (cross-section) view of the layered sediments under the Hanford Site. The water table is shown by a dashed line and separates the saturated aquifer below from the vadose zone above.
Stratigraphic units underlying the Hanford Site.
Hanford Site

Missoula Flood Deposits
(Hanford Formation)
Figure C-4. Gravel-Dominated Sediments of the Hanford formation Exposed in Pit #30.

Figure C-5. Sand-Dominated Sediments of the Hanford formation Exposed at the Integrated Disposal Facility.
Hanford Site Groundwater Overview

Current Extent of Groundwater Contamination

- Approximately 80 square miles of groundwater contaminated above drinking water standards
Chemical Contaminants

- Nitrate
- Carbon tetrachloride
- Trichloroethene
- Hexavalent chromium
Water table and inferred flow directions
100 Area (Reactors)
100-K Area
Chromium Plume Distribution

100-K Pump & Treat Operations

Operated Since 1997
∼265 Kg Removed
Observed elevated Chromium in Aquifer Tubes Near The KW Reactor Area in 2004
200 Areas

Figure ES-1. This plan focuses on the remediation of the deep vadose zone in the Central Plateau of the Hanford Site (shown above in October 2007; photo is looking east).
As a result of past practices, up to 580 m$^3$ carbon tetrachloride (CT) was discharged to waste sites at the 200 West Area of the USDOE's Hanford Site near Richland, WA.
Figure C-8. Schematic of Transport Mechanisms and Distributions of Carbon Tetrachloride Phases (Rohay 1999).

- Unsealed Well Casing
- Wastewater Disposal Crib
- Carbon Tetrachloride Disposal Site
- Carbon Tetrachloride Vapor
- Moisture & Immiscible Carbon Tetrachloride
- Dissolved Carbon Tetrachloride from Soil Vapor
- Dissolved Carbon Tetrachloride from Immiscible Liquid Source
- Silt and Sand
- Sandy Gravel
- Calcite Layer
- Calcareous Sand and Silt
- Sand and Silt
- Sandy Gravel
- Basalt
- Sandy Gravel
- Silt and Clay
- Depth Below Land Surface (meters)

- Water table
- Lateral and vertical transport of carbon tetrachloride in the vapor phase by diffusion and atmospheric pumping
- Migration of hypothetical liquid phase of carbon tetrachloride along calcite layer and down well casing
- Perched water/vapor phase carbon tetrachloride interaction and downward migration between well casing and unsealed borehole wall

Groundwater Flow