Lecture 23: Groundwater Contamination

Key Questions
1. What are some examples of point sources of groundwater contamination?
2. What are some examples of non-point sources of groundwater contamination?
3. Why is nitrate the most common groundwater pollutant?
4. Why is the Abbotsford-Sumas aquifer susceptible to nitrate contamination?
5. What are some examples of a LNAPL?
6. What are some examples of a DNAPL?
Sources of Groundwater Contamination
Examples of Point Sources

- On-site septic systems
- Leaky tanks or pipelines containing hydrocarbons
- Leaks or spills at manufacturing facilities
- Municipal landfills
- Livestock wastes (manure lagoons)
- Leaky sewer lines
- Spills related to highway or railway accidents

Examples of Non-point Sources

- Fertilizers on agricultural land
- Pesticides on agricultural land and forests
- Contaminants in rain, snow, and atmospheric fallout

Agricultural Pollutants

- Pesticides (organic chemical)
- Herbicides (organic chemical)
- Fertilizers
Nitrate is the most common world-wide groundwater pollutant
Nitrogen fertilizers are major sources of nitrate

Nitrogen inorganic commercial and organic manure fertilizers are added to the soil to supplement nutrients for crops.
Liquid manure spreading in Whatcom County
Excess nitrogen in the soil is converted to nitrate by the help of bacteria.
Non-Point Nitrate Contamination

Nitrate derived from fertilized fields is called a “non-point” source contaminant because it covers large surface areas on the aquifer.
Nitrate Leaching

Rainfall (or irrigation water) percolating into the soil transports nitrate in the soil to the surface of the aquifer (water table).
Nitrate is transported through an aquifer by groundwater.
Why is nitrate in drinking water a problem?

Nitrate can affect red blood cells and reduce their ability to carry oxygen to the body. In most adults and children these affected blood cells rapidly return back to normal.

However the blood cells of infants can take much longer to return to normal. As a result, infants who are given water with high levels of nitrate (or foods made with nitrate contaminated water) may develop a serious health condition due to the lack of oxygen. This condition is called methemoglobinemia or “blue baby syndrome.”

The above information was extracted from a State of Washington Department of Health Fact Sheet (DOH PUB. # 331-214).
http://www.doh.wa.gov/ehp/dw/Publications/nitrate_english_spanish.htm
How is nitrate in drinking water regulated?

• The U.S. EPA has established a Maximum Contaminant Level (MCL) of 10 milligrams per liter (mg/L) for nitrate.

• Public water systems are required to sample for nitrate on a regular basis.

• There is no required sampling of private individual wells.

The above information was extracted from a State of Washington Department of Health Fact Sheet (DOH PUB. # 331-214).
http://www.doh.wa.gov/ehp/dw/Publications/nitrate_english_spanish.htm
Groundwater is vulnerable to nitrate contamination where there is a combination of:

- Rainfall (or irrigation)
- Agricultural land use
- Permeable soils
- Shallow water table
Nitrate Vulnerability Map

The red areas on this map indicate regions that are highly susceptible to groundwater nitrate contamination.
Vulnerability map. Probability (in percent) of detecting nitrate at concentrations of 3 milligrams per liter or greater in wells that are 50 feet deep in the Puget Sound Basin.
The lowlands over the aquifer are agriculturally productive.

Whatcom County’s Raspberry Industry is #1 in the Nation.
Whatcom County’s Dairy Industry is #2 in the State (~60,000 cows)
Southern British Columbia is dominated by poultry industries and raspberry and...
Groundwater flows south from BC into Whatcom County
Elevated nitrate concentrations in the aquifer are due to agricultural practices on both sides of the border.

The concentrations can exceed the US-EPA maximum contaminant level (MCL) of 10 mg-N/L.

Well water with nitrate greater than 10 mg-N/L is not safe to drink.
Nutrient management in Whatcom County is difficult to assess because of nitrate transport from BC.
International Mitigation Strategy

In 1992 the Abbotsford-Sumas International Task Force was formed to coordinate groundwater protection efforts in the aquifer.

Members represent government agencies, tribes, cities and counties on both side of the border. Their goals are to

- Collect and Coordination Scientific Data
- Manage Activities Threatening the Aquifer
- Assist with Legislation and Policy Advice
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.
Leaking underground gasoline tanks are a common source of LNAPL contamination.
Gasoline will slowly dissolve into the groundwater and create a plume that will flow with the groundwater.
One cup of gasoline will make a volume of water equivalent to an Olympic-size swimming undrinkable!

Olympic swimming pool is 660,000 gallons
Organic Solvents, are different that 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
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
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**

Figure 1. Locations of six study basins on Whidbey and Camano Islands, Island County, Washington.
Superfund sites in Washington State
Hanford Site
Reverse Wells
Also known as injection wells, reverse wells served as disposal areas for liquid contaminants by pumping them directly back into the soil.

Pits, Trenches & Landfills
Solid and liquid wastes in barrels were buried in pits, trenches, or unlined landfills. As the containers break down contaminants enter the soil.

Underground Storage Tanks
There are 177 tanks at Hanford storing more than 53 million gallons of high and low-level waste. Sixty-seven single-shell tanks are known or suspected to have leaked. It is estimated that past releases have amounted to about 1 million gallons.

Crib, Ponds, Trenches & French Drains
Cooling and waste water was directed to storage cribs, ponds, trenches, or French drains (perforated pipes allowed liquid to release into rock-lined soil-covered trenches).

Plant Waste Discharge
Some facilities at Hanford disposed of waste directly to the soil outside the 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
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 m³ 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).