Environmental Geology
Chapter 14 WATER POLLUTION

- **Water Pollution** is degradation of water quality as measured by biological, chemical, or physical criteria ..... Based on:
  - Intended use
  - Departure from chemical or physical norm
  - Public health/ecological impacts

- **Pollutants** are any substances that, in excess, are known to be harmful to living organisms.

- **Common Pollutants**
  - Oxygen-demanding waste (common organic waste)
  - Pathogenic waste (pathogenic microbes)
  - Nutrients
  - Petroleum (oil)
  - Toxic waste (chemicals, heavy metals, radioactive waste)
  - Sediment
  - Thermal plumes

- **Oxygen-demanding waste**
  - Dead organic matter decomposed by bacteria, which needs Oxygen
  - BOD: High BOD associated with a high level of decaying organic matter in water, reducing O for other healthy organisms
  - Sources of oxygen-demanding waste: Natural processes, agricultural applications, urban sewage, and runoff

- **Pathogenic microbes**
  - Fecal coliform bacteria
  - Harmful risks (diseases and death) of *E. coli*
  - Billions exposed to waterborne diseases, especially in poor countries
  - Outbreaks do occur in developed countries, e.g., 400,000 cases in WI, 1993
  - Epidemic risks of waterborne diseases during natural disasters

- **Common harmful microorganisms:** *E. coli, Giardia & Cryptosporidium*

- **North Carolina “Hog-saster” caused by pathogenic microbes-fecal coliform bacteria**
  - Massive number of hog farms in coastal N.C.
  - Minimally regulated waste disposal practices
    - Unlined waste ponds widespread
  - Area is low, flat, coastal floodplain
  - Hog farm sizes in North Carolina grew by 500% during the early and mid-1990s
– Expansion largely due to lax regulations on location and waste disposal practices
– Many facilities located themselves in flood-prone areas along the NC coastal plain
– Subject to periodic heavy rains from nor’easters and hurricanes
– Hurricane Floyd dropped up to 20 inches of rain on the area in 1999
– Many waste ponds were overtopped and/or breached, leading to MASSIVE surface water contamination with hog waste
– Many people and animals adversely affected
– Hurricane Floyd destroyed many of these farms and spilled 1 million tons of hog waste products into rivers and other bodies of water throughout the area
– Ecological disaster occurred, killing fish, plants and becoming a hazardous nuisance to human residents throughout the area as well
– Similar, though smaller scale, incidents related to release of hog waste have killed fish in streams in MO and IA

• Nutrients
  – Two important nutrients: N, P
  – Major problems: Cultural eutrophication—algae bloom, triggering BOD problem - Too much oxygen demanding waste can lead to increases in algae and a lowering of oxygen content in the water “Dead Zones” can be created. For example: There is a Dead Zone at depth in bottom water – Gulf of Mexico-near shore, and on the Island of Maui there are algal buildup problems due to excess nutrients from wastewater and agricultural runoff.
  – Major sources for nutrients: Fertilizer, feedlots, and discharge from wastewater treatment plants
    • Eutrophication (overabundance/”bloom” in algae, etc.) Red tides/rivers “turn to blood”

• Oil
  – Major problems: Polluted water, ecosystem damage, interrupted socioeconomic conditions of a community
  – Major sources: Oil spills from tankers and pipelines, on- or offshore oil production, war (e.g., Gulf War)

• Toxic waste
  ➢ Hazardous chemicals, e.g., Love Canal, MTBE, TCE, Benzene, Dioxin, etc.
  ➢ Heavy Metals: Pb, Hg, Zn, Cd
  ➢ Biomagnification of methyl mercury in aquatic organisms ((e.g. fish) – Predator fish accumulate more from consuming other fish (to a dangerous level))
- Radioactive materials

- **Sediment pollution - a resource “out of place”**
  - Sand and smaller particles
  - Polluted streams, lakes, reservoirs, even ocean water
  - Major sources: Soil erosion, dust storms, floods, and mudflows
  - Greatest pollutant by volume

- **Thermal pollution**
  - Temp increases, less dissolved oxygen
  - Adverse changes to the habitats of organisms
  - Economic impacts
  - Major sources: Hot-water discharge from industrial operations, power plants, “abnormal” ocean currents

- **Surface Water Pollution and Treatment**
  - Point sources of pollution
    - Point sources are discrete, confined, and more readily identifiable
    - Common sources: Landfills, discharge from wastewater treatment plants, discharge from industries, power plants, storm water runoff, etc.
    - Identify sources, on-site treatment and mitigation, prevention
  - Non-point sources of pollution
    - Non-point sources are diffused, intermittent, and hard to specifically identify
    - Causes of non-point pollutions often regional, cumulative and compound
    - Examples:
      - Run-off from streets and fields
      - Acid mine/tailings drainage
        - Sulfide minerals produce sulfuric acid in presence of oxygenated surface waters and microbes
        - pH’s of <1 can be achieved!
    - Multiple factors: Land-use, climatic, hydrologic, topographic, geologic
    - Pollution reduction needs comprehensive and regional studies

- **Success Stories – Cuyahoga River, Ohio**
  - River burned in 1969!
  - Since has been largely remediated and turned into several protected scenic, recreational, and heritage sites

- **Success Stories – Chesapeake Bay, MD & VA**
  - High mercury levels in fish and shellfish caused bans on fishing
– Nitrates and phosphates in effluent entering bay
– Filtering oyster populations have been devastated (1% of historically enormous populations – filtered entire bay in 3-4 days!)
– From 1966-1975 Kepone insecticide (used for ant/roach traps) was released into James River (banned in 1975)
– Declining Kepone Levels since it was banned

• **Groundwater Pollution and Treatment**

  • **Why care about ground water pollution?**
    – Most abundant freshwater source
    – Growing dependency on GW
    – ~ 50% of people in U.S. depend on GW for drinking water
    – Triggers other environmental problems, subsidence, saltwater intrusion, etc.

  • **GW pollution hazard impact is related to the:**
    – Amount of contaminant discharged
    – Chemical concentration or toxicity
    – Degree and duration of exposure of people or other organisms to the pollution

• **GW Pollution Comes from a variety of sources:**

  **TABLE 12.1 Common Sources of Groundwater Pollution and Contamination**

<table>
<thead>
<tr>
<th>Source</th>
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<tbody>
<tr>
<td>Leaks from storage tanks and pipes</td>
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<tr>
<td>Leaks from waste-disposal sites such as landfills</td>
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<tr>
<td>Seepage from septic systems and cesspools</td>
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<tr>
<td>Accidental spills and seepage (train or truck accidents, for example)</td>
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<tr>
<td>Seepage from agricultural activities such as feedlots</td>
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<td>Intrusion of saltwater into coastal aquifers</td>
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<td>Leaching and seepage from mine spoil piles and tailings</td>
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<td>Seepage from spray irrigation</td>
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<tr>
<td>Improper operation of injection wells</td>
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<tr>
<td>Seepage of acid water from mines</td>
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<tr>
<td>Seepage of irrigation return flow</td>
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<tr>
<td>Infiltration of urban, industrial, and agricultural runoff</td>
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• **Groundwater Protection Program in Arizona**
  • Must use engineered controls or treatment to ensure that groundwater will not be contaminated
• Example: Liners for ponds and landfills to prevent seepage of contaminants down to groundwater
• 1986 – First State groundwater protection ACT
• Why?- Arizona relies heavily on GW resources

• **GW pollution vs. surface water pollution**
  - Residence time difference - GW is replenished more slowly – as water slowly seeps down to the water table
  - Environmental conditions: Inflow, flow rate, Dissolved oxygen, sunlight
  - Harder to track pollution sources
  - More difficult and expensive to clean up
  - May pose long-term risks
  - Takes longer to “get polluted” and longer to clean up than surface waters

• **Groundwater Pollution and Treatment**
  • Saltwater intrusion
    - More than half of the world’s population lives in or near the coastal zones
    - GW pollution from saltwater intrusion is not a local isolated problem
    - Causes major water supply problems in NY, FL, CA
    - Case History: Long Island
  • Saltwater intrusion mechanism
    - Water table is inclined oceanward
    - Wedge of saltwater is inclined landward
    - Overpumping of GW
    - Severe drawdown of GW causes saltwater ascension
      - Salt water is more dense than fresh water and is located below the fresh water. Pumping draws in saltwater from below as the salt water wedge migrates landward.

• **Groundwater Treatment**
  • Pretreatment studies
    - Identify contaminants and their characteristics of transport behavior
    - Identify the characteristics of aquifer geology (factors controlling GW flow—physical dimensions, structure)
    - Determine the hydrologic characteristics of polluted aquifer(s)—flow direction, flow rates, discharge and recharge conditions
    - Select possible treatment strategies and methods

How contaminants behave when they percolate down to groundwater
• Groundwater Pollution & Pumping - contaminants percolate downward and dissolve in groundwater. Some contaminants may not be dissolved—they either float on top of the water table, or sink.
• Petroleum contamination (oil and gas) – (e.g. from Underground & Above Ground Storage Tanks – These chemicals are lighter (less dense) than water (floaters)-orange

• Solvents – are chemicals that are typically heavier (denser) than water (sinkers)

• Groundwater Pollution – Contaminant “Plumes” - Contaminants dissolved in groundwater move as a “plume” downgradient”.

• Groundwater Pollution & Pumping – With Addition of High Volume Pumping Well & Drawdown – Pollutants can be drawn into wells that were not previously contaminated as a result of pumping

• Treatment Methods
  • Extraction Wells (pump and treat)
  • Bioremediation (e.g. bacteria-microbes used to “eat” organic contaminants
  • Vapor Extraction (pumping air out of soil and burning off toxic vapors)
  • Permeable Treatment Beds (to intercept plume of contaminants and treat GW)
  • Air sparging (pumping air through GW to vaporize contaminants for removal by vapor extraction)
  • Treatment Methods – Groundwater & Vadose Zone

• Water Quality Standards
  • MCLs—Maximum Contaminant Levels
  • Permissible limits for 83 contaminants
  • MCLGs—Maximum Contaminant Level Goals
  • The maximum level at which no adverse health effects from a lifelong exposure
  • SMCLs—Suggested Maximum Contaminant Levels Nonenforceable limits for contaminants that affects aesthetic qualities in drinking water

• Waste Water Treatment
  • Law: Used/waste water must be treated
  • Break the potential vicious cycle of waste water entering the general water cycle
  • Tier treatment and reuse system
    ➢ Septic system—rural residential areas
    ➢ Water treatment plant for towns and cities
    ➢ Innovative ways for recycling and reclaiming waste water