Introduction to Environmental Geology

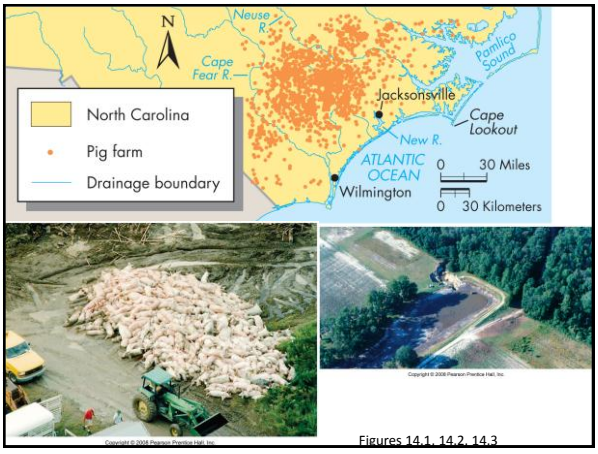
Jennifer Barson – Spokane Falls Community College

Chapter 13: Overview

- Define water pollution
- Discuss some of the common water pollutants
- Understand methods for groundwater pollution treatment
- Understand important processes related to wastewater treatment and management

Case History: NC Bay of Pigs

- Hurricane Floyd hit NC in September 1999
- Catastrophic water pollution as a result of the floodwater from Hurricane Floyd
- More than 38 pig waste lagoons washed out, 250 million gallons of pig wastes into creeks, rivers, and wetlands
- Approx. 250 pig operations flooded out
- Polluted water through schools, churches, homes, and businesses
- Estimated 30,000 hogs, 2 million chickens, and 735,000 turkeys died



Figures 14.1, 14.2, 14.3

Case History: NC Bay of Pigs

- In 1997, a state law was enacted that prohibited building new waste lagoons and sewage plants on floodplains
- In the spring of 1999, the governor proposed a 10-year plan that would phase out the state's 4,000 animal waste lagoons
- Hurricane Floyd occurred before these changes could be enacted
- In 2007, the state passed legislation to ban construction or expansion of new lagoons and spray fields
- On-site treatment facilities to replace swine lagoons

Water Pollution

- Degradation of water quality as measured by biological, chemical, or physical criteria
- Judged according to the intended use of the water
- A pollutant is a substance that, in excess, is known to be harmful to living organisms

Primary water pollution problem worldwide:

- Lack of clean drinking water free of disease-causing organisms or substances
- Particularly acute in developing world

Water Pollution

- Water pollution: Refers to degradation of water quality as measured by biological, chemical, or physical criteria
- Pollutants: Any substance that, in excess, is known to be harmful to desirable living organisms
- The greatest water pollution problem in the world today is lack of disease-free drinking water for about 20 percent of the world's population
- Waterborne diseases that kill about 2 million people a year, and most of the deaths are of children under the age of 5

Common Pollutants

Oxygen-demanding waste

- Pathogenic waste
- Nutrients
- Petroleum
- Toxic waste
- Sediment
- Thermal plumes


TABLE 14.1 Selected Chemicals That Agricultural, Industrial, and Municipal Processes Produce, Use, or Release to Impact Water Quality. Rates Are Millions (10^6) of Tons per Year

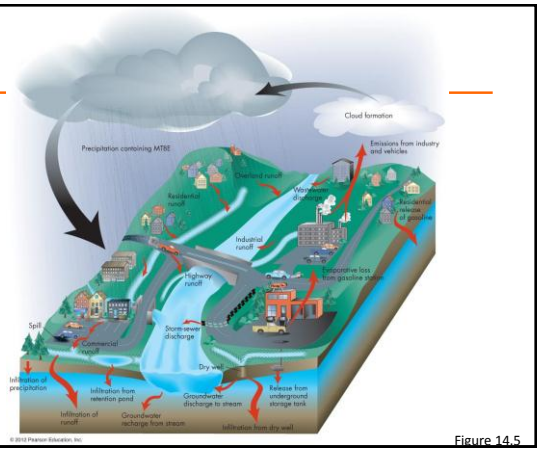


Figure 14.5

Common Pollutants

Oxygen-demanding waste:

- Dead organic matter decomposed by bacteria, an oxygen-demanding process
  - Biochemical Oxygen Demand (BOD): High BOD associated with high level of decaying organic matter in water, reducing DO (**dissolved O**) for other healthy organisms
  - Sources of oxygen-demanding waste: natural processes, agricultural applications (~33%), urban sewage, and runoff (storm events)

Common Pollutants

Pathogenic Microbes:

- Fecal coliform bacteria
- Harmful risks from E. coli
- Billions exposed to waterborne diseases
  - Especially in poor, underdeveloped countries
  - Outbreaks in developed countries: GA water park '98, Walkerton public water supply in Ontario '00, CA spinach contamination '06
- Epidemic risks of waterborne disease during natural disasters (earthquake, tsunami, flood)

Common Pollutants

Nutrients:

- Two important nutrients: nitrogen (N) and phosphorus (P), in the form of phosphates, PO_4^{2-}
- Cultural eutrophication –
  - Algae bloom, triggering BOD problem
  - Reducing environment releases heavy metals
- Major sources of nutrients –
  - Fertilizers, feedlots, domestic use, discharge from wastewater treatment plants
- Areas of land use risk…agriculture and urban

Dead Zone - < 2mg/L DO

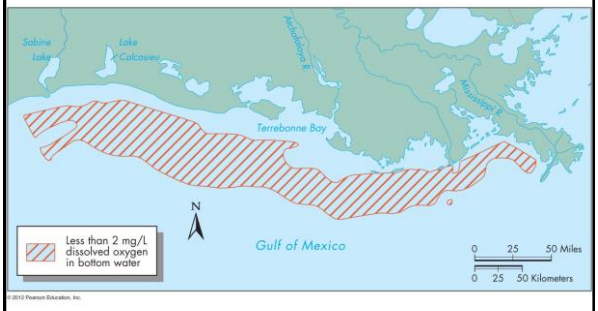


Figure 13.6

Common Pollutants

Oil (hydrocarbon):

- Major problems –
  - Water pollution
  - Ecosystem damage
  - Interrupted socioeconomic conditions in community
- Major sources –
  - Oil spills from tankers and pipelines
  - On- or offshore production plants
  - War (e.g., Gulf war, 2006 Lebanon)
  - Deepwater Horizon 2010 in Gulf of Mexico

Exxon Valdez, AK

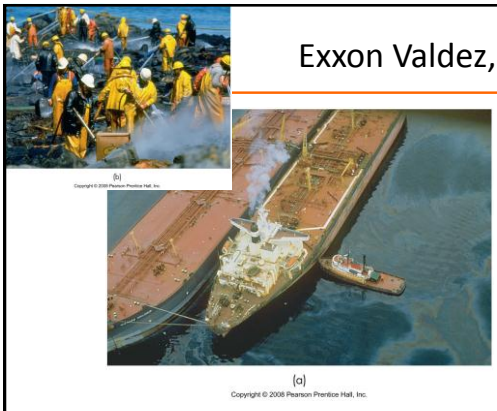
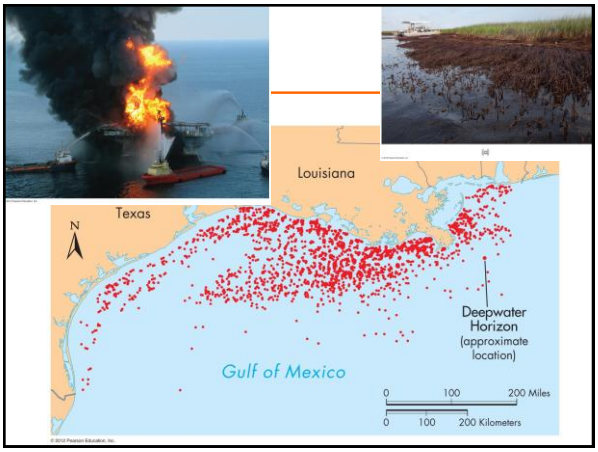


Figure 14.8



Common Pollutants

Toxic waste:

- Synthetic organic chemicals…up to 100,000 chemicals in use, especially POP's (persistent organic pollutants)
  - Carbon-based, often contains reactive chlorine
  - Synthetic, don't break down, accumulate in tissues
- Heavy metals: Pb, Hg, Zn, Cd
- Radioactive materials

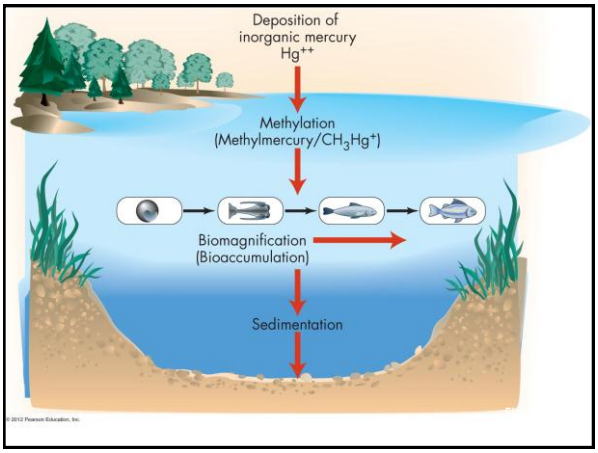


TABLE 14.2 Selected Persistent Organic Pollutants (POPs)

Chemical	Example of Use
Aldrin[1]	Insecticide
Atrazine	Herbicide
DDT[1]	Insecticide
Dieldrin[1]	Insecticide
Endrin[2]	Insecticide
PCBs[1]	Liquid insulators in electric transformers
Dioxins	By-product of herbicide production

[1]Banned in the United States and many other countries.

[2]Restricted or banned in many countries.

Data in part from McGinn, Anne Platt, "Phasing Out Persistent Organic Pollutants," in Lester R. Brown, et al., *State of the World 2000* (New York: Norton, 2000).

Sediment Pollutants

Sediment pollution:

- Sand and smaller particles
- Polluted streams, lakes reservoirs, ocean
- Major sources –
  - Soil erosion, dust storms, floods, and mudflows
- Greatest water pollutant by volume
- May deposit undesirable materials on productive croplands

Common Pollutants

Thermal pollution:

- Temperature increases, less dissolved oxygen
- Adverse changes to the habitats of organisms
- Economic impacts
- Major sources –
  - Hot water discharge from industrial processes
  - Power plants (hydroelectric)
  - Abnormal ocean currents

Figure 14.14

SW 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 then provide on-site treatment and mitigation…prevention would be best

SW Pollution and Treatment

Nonpoint sources of pollution:

- Nonpoint sources are diffused, intermittent, and hard to specifically identify
- Causes of nonpoint pollution are often regional, cumulative, and compounded
- Influenced by land use, climate, hydrology, topography, and geology
- Common sources –
  - Urban runoff, agriculture, mining (acid drainage)

Kellogg, ID

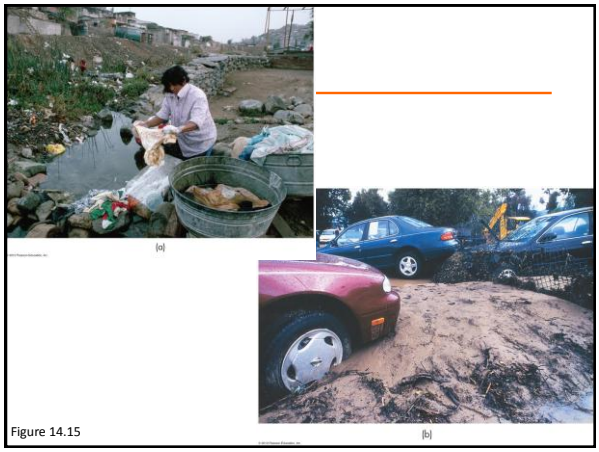


Figure 14.15

Acid Mine Drainage

- Acid mine drainage: refers to acidic water with elevated concentrations of dissolved metals that drains from coal or metal mines
- Acid mine drainage is water with a high concentration of sulfuric acid (H_2SO_4)
- Acid mine drainage is produced by complex geochemical and microbial reactions
- The acid water is extremely toxic to plants and animals in aquatic ecosystems
- The Tar Creek area in Oklahoma was at one time designated by the EPA as the nation's worst example of acid mine drainage

GW Pollution and Treatment

Why care about groundwater pollution?

- GW is the most abundant freshwater source
- ~50% of people in U.S. depend on GW for drinking water
- Effects of chronic exposure to low pollutant levels are not known
- United States Geological Survey in 1991 started program to assess water quality nationwide
- Triggers other environmental problems:
  - SW pollution, subsidence, saltwater intrusion, etc.

TABLE 14.3 Common Sources of Groundwater Pollution and Contamination

Leaks from storage tanks and pipes
Leaks from waste-disposal sites such as landfills
Seepage from septic systems and cesspools
Accidental spills and seepage (e.g., train or truck accidents)
Seepage from agricultural activities such as feedlots
Intrusion of saltwater into coastal aquifers
Leaching and seepage from mine spoil piles and tailings
Seepage from spray irrigation
Improper operation of injection wells
Seepage of acid water from mines
Seepage of irrigation return flow
Infiltration of urban, industrial, and agricultural runoff

Table 14.3

Groundwater Pollution

- It is estimated that 75 percent of the 175,000 known waste-disposal sites in the country may be producing plumes, or bodies of contaminated groundwater
- Groundwater pollution hazard impact depends on
  - Amount of contaminant discharged
  - Chemical concentration or toxicity
  - Degree and duration of exposure of people or other organisms to the pollution

GW Pollution and Treatment

GW pollution hazard impact:

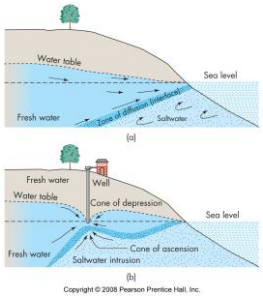
- Amount of contaminant discharged
- Chemical concentration and toxicity
- Degree and duration of exposure of people or other organisms to the pollution
- Rate of movement and direction of pollution plume

GW 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 treatment strategies and methods

GW Pollution and Treatment



Saltwater intrusion

- Results from over-pumping of GW in coastal areas
- Caused problems in New York, Florida, California, and others
- Cone of depression forms in freshwater, a cone of ascension develops in adjacent saltwater

Figure 14.19

GW vs. SW Pollution and Treatment

GW pollution versus SW pollution:

- Residence time difference
- Environmental conditions – inflow, flow rate, dissolved oxygen, sunlight, temperature
- Difficult to track pollution sources and expensive to clean up
- Can pose long-term risks to entire environment

TABLE 14.4 Methods of Treating Groundwater and Vadose-Zone Water

Extraction Wells	Vapor Extraction	Bioremediation	Permeable Treatment Bed
Pumping out contaminated water and treatment by filtration, oxidation, air stripping (volatilization of contaminant in an air column), or biological processes	Use of vapor-extraction well and then treatment	Injection of nutrients and oxygen to encourage growth of organisms that degrade the contaminant in the groundwater	Use of contact treatment as contaminated water plume moves through a treatment bed in the path of groundwater movement; neutralization of the contaminant by chemical, physical, or biological processes

National Water-Quality Assessment Program

- In the past 25 years, great improvements in manufacturing, processing, and wastewater-treatment facilities
- The program integrates both surface-water and groundwater systems that monitor and study aquatic ecosystems
- The goals of the program are to:
  - Carefully describe current water-quality conditions for many of the freshwater streams and aquifers in the United States
  - Monitor and describe water-quality changes over time
  - Increase understanding concerning the human and natural factors that affect the nation's water quality

Water Quality Standards

- Health effects of chronic exposure to very low levels of chemical contaminants is unknown
- Safe Drinking Water Act of 1974
  - Expanded in 1986 to include 83 contaminants
- EPA has set standards for many contaminants
  - Only coliform bacteria and nitrate are thought to pose *immediate* health hazard
- National Primary Drinking Water Standards (Table 14.5)

Water Quality Standards

- MCLs – maximum contaminant levels
- Permissible for 83 contaminants
- MCLGs – maximum contaminant level goals
  - The maximum level at which no adverse health effects from a lifelong exposure
- SMCLs – no enforceable limits for contaminants that affect aesthetic qualities in drinking water

TABLE 14.5 National Drinking Water Standards: Some Examples

Contaminant	Maximum Contaminant Level (mg/L)	Comments/Problems
Inorganics		
Arsenic	0.05	Highly toxic
Cadmium	0.01	Kidney
Lead	0.015[1]	Highly toxic
Mercury	0.002	Kidney, nervous system
Selenium	0.01	Nervous system
Asbestos	7 MFL[2]	Causes benign tumors
Fluoride	4	Leads to skeletal damage
Organic chemicals		
Pesticides		
Endrin	0.0002	Nervous system, kidney
Lindane	0.004	Nervous system, kidney, liver
Methoxychlor	0.1	Nervous system, kidney, liver
Herbicides		
2,4D	0.07	Liver, kidney, nervous system
Silvex	0.05	Nervous system, liver, kidney
Volatile organic chemicals		
Benzene	0.005	Cancer
Carbon tetrachloride	0.005	Possible cancer
Trichloroethylene	0.005	Probable cancer
Vinyl chloride	0.002	Cancer risk
Microbiological organisms		
Fecal coliform bacteria	1 cell/100 mL	Indicator—disease-causing organisms

[1]The action level for lead related to treatment of water to reduce lead to the safe level. There is no maximum contaminant level for lead.
[2]MFL = million fibers per liter with fiber length > 10 micrometers.
U.S. Environmental Protection Agency.

Water Quality and Stream Ecosystems in the United States

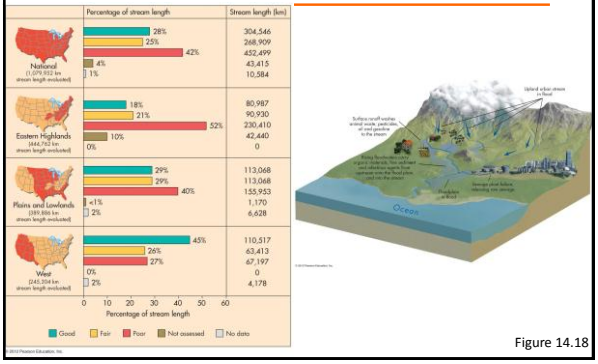
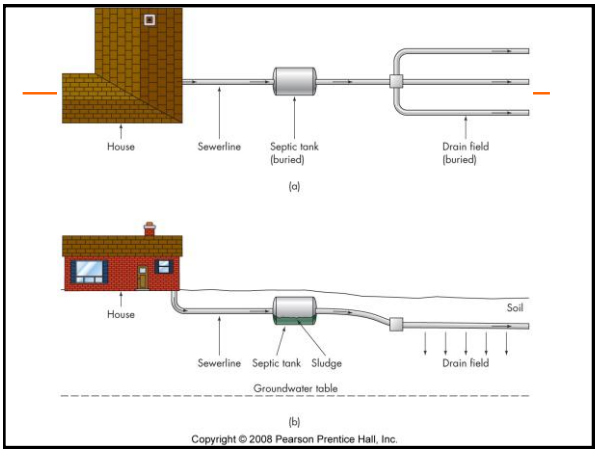


Figure 14.18

Wastewater Treatment

- Used wastewater must be treated…it's the law
- Break the potential cycle of wastewater 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 wastewater (golf courses, agriculture)
  - New technologies for innovative wastewater treatment



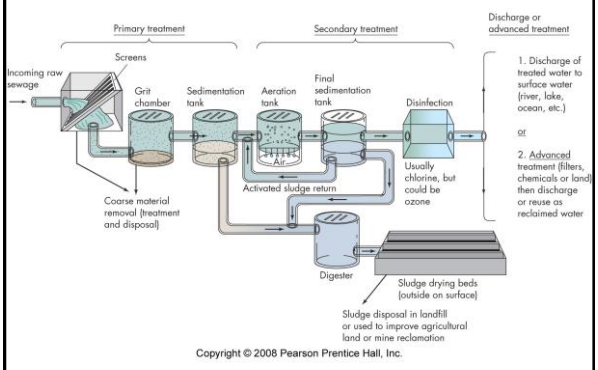
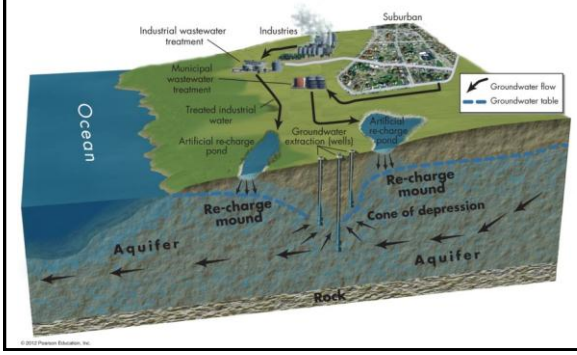


Figure 14.21

Wetlands as Treatment Sites

- Both natural and human-constructed wetlands: good places to treat or partially treat wastewater (WW)
- For communities with difficulty purchasing expensive WW treatment plants or desire a good alternative
- Warm-humid and hot-dry climates had successful experiences

Wastewater Renovation and Conservation Cycle



Federal Legislation

Rewriting of major environmental laws

- 1990s: debate and controversy regarding water pollution
- Purpose of amendments was to provide greater flexibility to industry
- Strong public support for clean air and water caused backlash

Imposition of new rules

- Clinton imposed new pollution controls in 2000
  - Focused on non-point source pollution
  - Will take at least 15 years to implement fully

Reduce Effects of Water Pollution

- Develop and refine better ways to evaluate water pollution problems and their impact on aquatic life and the health of people
- Implement new and innovative, cost-effective water treatment technologies
- Develop products and processes that minimize production of water pollutants and their release into the environment

Critical Thinking Topics

- What can individual citizens do to reduce groundwater pollutants?
- Does surface water contamination automatically trigger groundwater pollution at a given location?
- What are the major point and nonpoint sources of water pollution in your community?
- What current water laws and legislation are you familiar with? Are there any problems with them?