

ES 106 Water Cycle, Groundwater, Pollution

- I. Water cycle
  - A. 22% of precipitation falls on land
  - B. 77% of water stored on land is ice
  - C. 14% of fresh water stored on land is groundwater
- II. Groundwater
  - A. drinking water source for ½ of US
  - B. Enters by infiltration
    - 1. soil moisture
    - 2. drains to groundwater
      - a. zone of saturation—pores filled
      - b. zone of aeration—pores contain water and air
      - c. water table—surface of zone of saturation
  - C. storage
    - 1. contained in aquifer
      - a. porous and permeable
      - b. water moves slowly
    - 2. aquitard is impermeable
  - D. movement
    - 1. slowly through small openings—water has high surface tension
    - 2. hydraulic pressure forces water toward lower pressure
    - 3. gravity draws it downward—sometimes overpowered by hydraulic pressure/hydraulic head
- III. springs
  - A. water table intersects surface
    - 1. aquitard conducts to surface
    - 2. hydraulic head pushes upward
  - B. hot springs
    - 1. heated by cooling igneous rock or geothermal gradient
    - 2. geyser special type of hot spring
      - a. hydraulic pressure of overlying water suppresses boiling
      - b. overcome with addition of heat over time
      - c. as water rises, further reduction in pressure allows more boiling
- IV. Wells
  - A. Draw water from aquifer
  - B. Zone of saturation may be depressed due to withdrawal
    - 1. drawdown of water table
      - a. cone of depression
      - b. may refill seasonally with recharge
      - c. may be permanent if aquifer compresses
  - C. artesian flow
    - 1. hydraulic pressure is above water table
      - a. flowing artesian—above well head
      - b. non-flowing artesian—rises upon intersection of water table

## V. Groundwater concerns

### A. Withdrawal exceeds recharge in many areas

1. 'mining' a non-renewable resource
2. water tables in some areas drop 1 meter per year
3. may not ever recharge, if aquifer has compressed
  - a. overlying land packs grains after water leaves void space
  - b. land subsidence several meters in some areas

### B. Contamination

1. organic leachate
    - a. sources
      - 1) septic tanks
      - 2) farm wastes
      - 3) sewage system failure
    - b. removal
      - 1) natural filtering by sand and gravel
      - 2) oxidation by chemicals and assimilation by organisms
      - 3) if aquifer has proper characteristics: mostly optimal porosity
  2. other pollution sources: road salt, fertilizer, pesticide, leaking underground tanks/pipelines, landfills, impoundment ponds
    - a. Denver: pesticide production
    - b. Minneapolis: wood preservatives
    - c. Potato production: aldecarb antifungal compound
  3. Nitrates: from fertilizer—blue baby syndrome: impaired hemoglobin
  4. VOC: solvents spilled, discarded, buried storage leaking—persistent
- ### C. Cleanup of groundwater costly, difficult, mixed rate of effectiveness

## VI. Drinking water

### A. standards Established by EPA

1. milligrams per liter is parts per million
2. parts per billion is milligrams per 1000 liters
3. dilution is a poor solution to pollution

### B. Purifying Drinking water

1. remove dirt and bacteria
  - a. add slaked lime, aluminum sulfate to coagulate
  - b. allow to settle, filter through sand and gravel
2. improve taste by aeration, also removes volatile impurities
3. disinfect
  - a. Cl<sub>2</sub> gas—residual effect after leaving treatment
  - b. O<sub>3</sub> or UV light—kills bacteria and viruses, no residual effect

### C. Other domestic water sources

1. desalination of brackish water feasible on large scale
  - a. distillation
    - 1) vaporize with fuel or sun
    - 2) condense to collect water
    - 3) cost, space
  - b. reverse osmosis fresh water passes semipermeable membrane
    - 1) freshens salt water until osmotic pressure is built
    - 2) apply pressure to salty side forces fresh water out of salty

## VII. Sewage treatment methods

- A. primary treatment: settling ponds removes solids
- B. secondary treatment: aerobic bacteria metabolize organic matter
  - 1. sand and gravel filter bed
  - 2. aeration encourages aerobic bacteria activity
- C. advanced treatment: filtration
  - 1. activated carbon/charcoal: removes solvents, pesticides, metals
  - 2. reverse osmosis: removes most impurities
- D. disinfect is last step
  - 1. chlorine kills bacteria, not viruses, has residual effect
  - 2. ozone, UV kills both, no residual effect

## VIII. Geologic work of groundwater

- A. Dissolves rock: limestone more common than salt, gypsum
- B. Caverns
  - 1. groundwater dissolved limestone along cracks, bedding planes
  - 2. calcium ions, bicarbonate ions, carbonate ions flushed away
  - 3. depositional features in caverns from these ions re-precipitating
    - a. dripstone features
      - 1) stalactites—on ceiling
      - 2) stalagmites—on ground
      - 3) columns—joined stalactites and stalagmites
      - 4) soda straws, angel wings, cave pearls
    - b. formation due to loss of dissolved CO<sub>2</sub> changing pH of water
- C. Karst terrain: usually limestone land area with solution collapse of underground openings, can be on salts also
  - 1. sinkholes—collapsed caverns
    - a. Florida, Kentucky, Indiana, New Mexico
    - b. Gradual dissolution, sudden collapse
    - c. Enhanced by removal of groundwater
      - 1) Exploitation for municipal/industrial/agricultural purposes
      - 2) Mitigation of swampland for development
  - 2. typical features of karst terrain
    - a. sinkholes
    - b. disappearing streams, lack of through-flowing streams
    - c. steep-sided solution valleys
    - d. haystack buttes: common in southeastern Asia