Water: Resources and Pollution

Properties of Water

a. Water has a very unique chemical structure
- **i.** Two Hydrogen atoms bonded to one Oxygen
- **ii.** Because oxygen pulls so strongly on the hydrogen atoms, it causes the hydrogens to be slightly positive, while the oxygen becomes slightly negative
- **iii.** Water is therefore a **polar molecule**, meaning it has positive end and a negative end.
- **iv.** Because opposite charges attract, the negative ends of one molecule are attracted to the positive ends of another forming **hydrogen bonds**.
1. **Hydrogen bonds** are not true chemical bonds and they are not very strong but they are responsible for many of water's characteristics.

b. Water exists in three states, all of which occur naturally on the earth.
- **i.** Liquid: Most familiar
- **ii.** Gas: Water Vapor
- **iii.** Solid: Ice

c. The different states of water are a function of the amount of energy the molecules have.
- **i.** The more energy that water molecules have, the more they move.

1. The movement of molecules is registered as **heat**. The more the molecules move, the hotter the substance.
2. Heat is measured in terms of **temperature.**

✓ The greater the **temperature,** the more **heat,** the more the molecules move, the more space they occupy and therefore the greater the volume, while their mass remains the same.

✓ Because **Density = mass/volume,** an increase in volume with constant mass means a decrease in **density.**

- **i.** This is why hot air, or water, rises.

3. **Hydrogen bonds** tend to keep water molecules together and therefore require more energy in order to heat water.

✓ This is why water is such a good coolant.

- **ii.** If enough energy is added to water, the **hydrogen bonds** break and the water leaves the liquid state and becomes a gas.
- **iii.** If enough energy is taken from water, the **hydrogen bonds** get stronger and the water molecules form a crystal lattice.

1. Because of this crystal lattice, the space occupied by the water molecules (i.e. the volume) increases when water is solid, even though it has the same mass as when it was liquid.
2. Therefore, the density of the solid, ice, is less than the liquid, water.

✓ This is why ice floats.

3. Breaking those hydrogen bonds to change ice to liquid, takes a lot of energy.

- ✓ **The Latent Heat of Melting** is the amount of energy required to melt a substance.
  - **i.** Water has a higher latent heat of melting than any other commonly occurring substance
- ✓ **Heat capacity** is the hat that must be added to raise the temperature a substance by a given amount.
  - **i.** Water has a very high heat capacity
    - **1.** Most marine organisms do not experience extreme changes in temperature.
- ✓ **Latent heat of Evaporation** is the energy it takes to change water from a liquid to a gas.
  - **i.** Water has the highest **latent heat of evaporation** of any natural substance.
    1. This makes water very good for cooling organisms. Think sweat.

Importance of Water Resources

Water resources are important because of

- ✓ Essential for life
  - **1.** Dissolves nutrients and distributes them to cells
  - **2.** Regulates body temps
  - **3.** Supports structures
  - **4.** Removes waste
  - 5. About 60% of body is water

On an average an American family of four consumes >1000m^3 (264,000 gals)/ year

Where does water come from?

- ✓ Hydrologic cycle
  1. Major reservoir is the ocean (96.5% of total)
  2. The rest is fresh water
- ✓ 87% of fresh water is in ice and snow
  - Of the liquid fresh water, 95% is ground water.
- ✓ This means that we subsist on 0.1% of the planet's water.
- ✓ Lakes, rivers and streams only account for 3% of all liquid freshwater or about 0.015% of the total water on the planet
- ✓ Latitudinal gradients
  - Most precipitation is in the tropics
  - The least precipitation is around 30° N and 30°S, the desert belts
- ✓ Geographic factors
  - Mountains
- ✓ The windward sides get most of the rain
  - i. Ex: Mount Waialeale on the island of Kauai, Hawaii gets 460 in (12 m) of rain/year
- ✓ The leeward sides get the least rain
  - i. Iquique in the Chilean desert, has never recorded rain.

Groundwater Resources

- ✓ water found underground
  1. Largest compartment of liquid freshwater
  2. Plants get moisture from a relatively shallow layer of soil containing both air and water, the **zone of aeration.**
  3. **Zone of saturation** is where soil pores are filled with water, the source of water in most wells and the top of this zone is the **water table.**
  4. **Aquifers** are geologic layers that contain water
- ✓ May consist of porous layers of sand or gravel, or of cracked or porous rock
- ✓ Below an aquifer, a relatively impermeable layer of rock or clay keeps water from seeping out at the bottom.
- ✓ Areas where surface water filters into an aquifer are called **recharge zones**

i. Most aquifers recharge slowly and road and house construction or water use at the surface can further slow recharge rates.

- ✓ About 2 billion people (1/3 of world pop) depend on groundwater.

Water Availability and Use

Renewable water supplies are resources that are replenished regularly

1. Mainly surface water and shallow groundwater
2. Most plentiful in the tropics, where rainfall is heavy

Water rich and water poor countries

4. Water availability is measured in terms of renewable water per capita, so population and water availability are key.

- ✓ Desert countries 'mine' water, so it's not renewable on a human time scale.

Water Use

Water can be reused if not too badly contaminated

- ✓ **Withdrawal** is the total amount of water taken from a water body
- ✓ **Consumption** is loss due to evaporation, absorption or pollution

Rates of use

- ✓ Water use has increased about twice as fast as population growth

i. Water wars may be the major source of hostilities in the 21st century.

Sources of Withdrawal

ii. Worldwide agriculture claims about 70% of water withdrawal

iii. Industry withdraws about 25% of water world wide, mostly for the cooling of power plants.

iv. Domestic accounts for about 6%

Shortages

- ✓ Clean drinking water and basic sanitation are necessary to prevent disease

i. U.N. estimates at least 1.1 billion people lack access to adequate drinking water and 2.4 billion don't have adequate sanitation.

ii. By 2025, about 2/3 or world's population will live in water-stressed countries.

- ✓ Access to clean water

i. In Ethiopia, 94% of population lacks access to clean water
ii. 2/3 of world's households have to fetch water from outside.
iii. In Peru, boiling water to prevent cholera uses up to 1/3 of a poor family's income just securing and purifying water.

✓ Depleting Water Resources

i. In U.S. groundwater is being withdrawn from aquifers faster than natural recharge can replace it.
   1. Excessive pumping
      a. Dries up wells, causing people to abandon towns
      b. Aquifers will collapse, San Joaquin Valley has sunk >10m in 50 yrs
      c. Leads to salt intrusion in coastal areas.

Can we increase water supplies?

✓ No, not on the large scale
✓ Increase access on the local scale

i. Dams
   1. Divert water and create hydroelectric power.

Water Pollution

Sources of Pollution

1. **Point sources** discharge pollutants from specific locations, such as drain pipes, ditches or sewer outfalls

✓ Factories, mines, power plants

2. **Nonpoint sources** are scattered or diffuse, having no specific location where they discharge into a particular body of water.

✓ Very hard to monitor and regulate
✓ Lawns, gold courses, construction sites, streets, parking lots
✓ **Atmospheric deposition** is nonpoint source pollution carried by air currents

Biological Pollution

5. **Infectious Agents-** pathogens

✓ Typhoid, choler, amoebic dysentery, enteritis, polio, hepatitis
✓ Malaria, yellow fever and filariasis are transmitted by insects with aquatic larvae
✓ 25 million deaths/year are from water-related diseases

i. Mostly comes from untreated human waste, or animal wastes
ii. Not a big problem in developed world
iii. 80% of all diseases in undeveloped countries can be attributed to waterborne pathogens

Eutrophication: Having waters rich in nutrients that promote a proliferation of plant life, especially algae,

✓ Eutrophication leads to oxygen depletion

i. Sewage increases nutrient levels in the ocean causing large algae blooms
ii. After the bloom dies, microbes decompose the algae using up all the oxygen in the water

✓ Without oxygen, other organisms, such as fish, die

Measuring Water Quality

- ✓ Can be difficult to find specific pathogens
- ✓ Use **coliform bacteria**, those that lie in intestines, as a proxy.
  - **i.** If there's coliform bacteria, it indicates waste is in the water.
- ✓ **Dissolved oxygen** is also used as a proxy
  - **i.** Oxygen >6ppm will support game fish and other desirable life forms.
  - **ii.** Oxygen <2ppm only supports worms, bacteria, fungi and other detritus feeders and decomposers
  - **iii.** Water gets oxygen by being aerated from turbulence and mixing
    1. Flowing water can recover quickly from depletion
  - **iv.** Adding organic materials like sewage can stimulate oxygen consumption
    1. **Biological Oxygen Demand (BOD)**, the amount of oxygen consumed by aquatic microorganisms

Types of Water Pollution

- ✓ **Groundwater Pollution**
  - **i.** EPA estimates every day 4.5 trillion liters of contaminated water seep into the ground in the U.S. from septic tanks, cesspools, agriculture, etc.
  - **ii.** Greatest is from agriculture
    1. Pesticides commonly contaminate aquifers
  - **iii.** Every year 1.5 million Americans get sick from infections from fecal contamination
- ✓ **Ocean Pollution**
  - **i.** It all ends up in the ocean
    1. 6 million metric tons of plastic garbage are tossed into the ocean every year.
    2. 3-6 million metric tons of oil are discharged into the ocean every year, most is not from big oil spills, but from cleaning tanks and bilges and coastal discharge.

Pollution Control

Easiest way to deal with it is to not produce it.

- ✓ Taking lead out of gasoline has reduced lead contamination
- ✓ Banning DDT and PCB's has helped reduce contamination.
- ✓ Agriculture

  Soil conservation maintains soil fertility and protects water quality
- ✓ Preserving wetlands helps them act as natural processing facilities for removing sediment and contaminants.

Sewage Treatment

- ✓ Natural processes
  - **i.** Where populations are low, natural processes can eliminate wastes quickly
- ✓ Municipal Sewage Treatment

i. In the past 100 years, sanitary engineers have developed effective municipal wastewater treatment systems.

1. **Primary treatment** separates large solids from the waste stream Settling tanks allow grit and some dissolved organic solids to fall out as sludge.
   a. Water drained from the top of the settling tanks has up to 75% of the organic matter
2. **Secondary treatment** uses aerobic bacteria to break down dissolved organic compounds
   a. Effluent from the secondary treatment is treated with chlorine, UV light or ozone
3. **Tertiary treatment** removes dissolved metals and nutrients.