Movement of light, heat, and chemicals in water

Diffusion in water

- How do abiotic materials move in water?
- Related to:
  - Concentration gradient
  - Temperature
  - Currents
  - Size of material
  - Sediments
  - Organisms

Fick's law

- Diffusion flux (J) = constant * ΔC / ΔX
  - C = concentration; X = distance
  - Constant = D = *diffusion coefficient*
- So…how do you enhance flux?

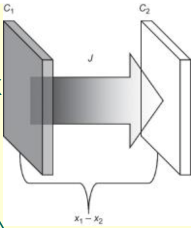


Fig. 3.2

Substance	Medium	Molecular weight	D ($cm^2 \cdot s^{-1}$)
Tobacco mosaic virus	Water	40,000,000	0.03×10^{-6}
Human serum albumin	Water	69,000	0.61×10^{-6}
Inulin	Water	5,500	1.5×10^{-6}
Sucrose	Water	342	5.2×10^{-6}
Glycine	Water	75	10.0×10^{-6}
Oxygen	Water	32	18.0×10^{-6}
Oxygen	Air	32	0.2

Vogel (1988)

Fast or slow?

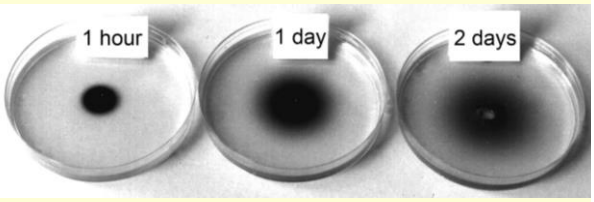
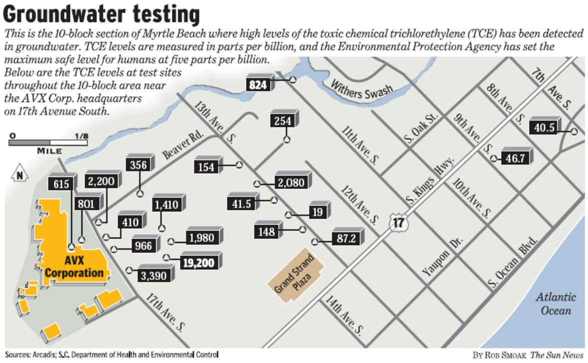


Fig. 3.1

Fick's law in action



Currents and diffusion

- Water currents = **transport diffusion**, **eddy diffusion**, or **advective transport**
- Compare with **molecular diffusion**
  - Transport diffusion is much faster (by at least 1000X)
  - At small spatial scales, molecular diffusion more important because turbulence is not present (Re?)

Diffusion boundary layer

- Similar to the flow boundary layer, but defined by the region where molecular diffusion dominates
- Biogeochemical constraint as well as a physiological constraint

Stream biofilm

Organisms and diffusion

- Size and shape of organisms influence rates of diffusion
- Are high or low surface area:volume ratios good for diffusion?
  - Recall Fick's Law
- How do large organisms deal with diffusion? Do small ones care?

Daphnia

Sturgeon

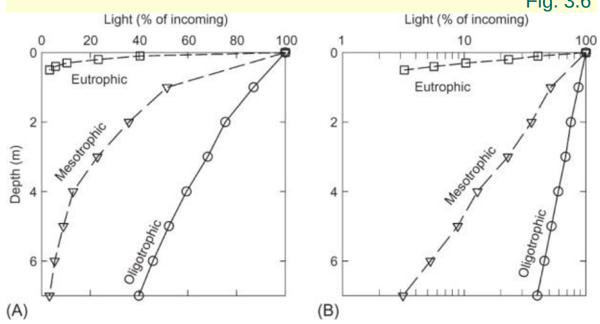
Light in water

- Why study light?
  - Photosynthesis
  - Sensory cue
  - UV increases
  - Heating, leading to …
- What happens to light when it strikes the surface of water?
  - Three possibilities

Light intensity and depth

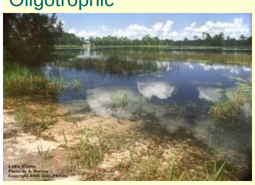
- Light intensity <u>decreases</u> logarithmically with depth = **attenuation**

Fig. 3.6



Lake trophic state interlude

Oligotrophic



Eutrophic

Three lakes in Florida

Mesotrophic

Attenuation coefficient

- η, describes how rapidly light is attenuated
  - AKA extinction coefficient
- $\eta = (\ln I_1 - \ln I_2)/(z_2 - z_1)$
  - I = light intensity at a certain depth
  - Z = depth

Attenuation and Secchi depth (1)

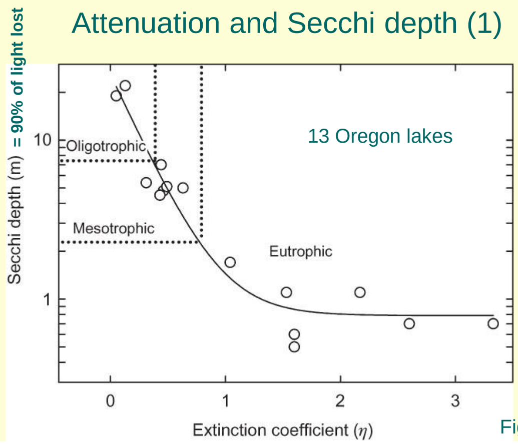
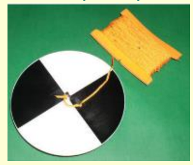


Fig. 3.7

Attenuation and the Secchi disk (2)

- Father Pietro Angelo Secchi (1865)

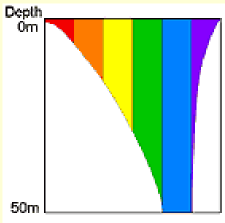


2 inches

6 inches

Light quality and depth

- Specific wavelengths of light can be attenuated selectively
  - Pure water transmits ___ light most efficiently
  - Chlorophyll absorbs red and blue light most efficiently
  - Cyanobacteria have pigments that can use green light



Oscillatoria, a cyanobacterium

Light quality and eutrophication

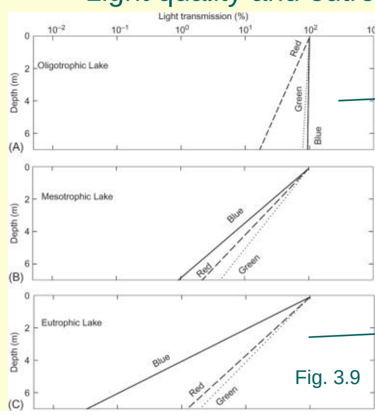
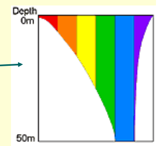


Fig. 3.9



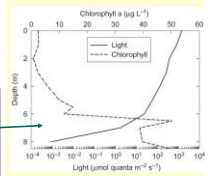
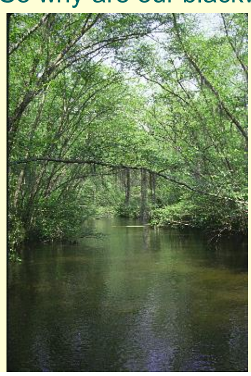


Fig. 3.10

Water color (1)

Water color (2)

- So why are our blackwater rivers 'black'?



What about UV?

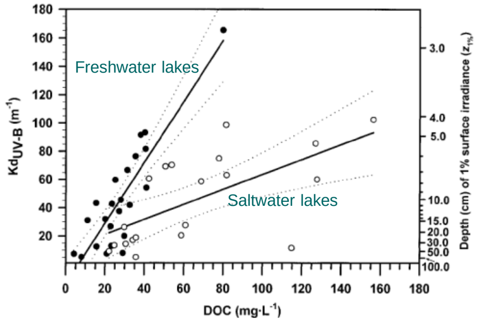


Fig. 1. Vertical attenuation coefficients (K_d, in m^{-1}) and depths ($z_{1\%}$, in cm) at which 1% of the surface irradiance remained as a function of DOC concentration for UV-B radiation (280–320 nm). Filled circles = freshwater lakes; open circles = saline lakes. Dotted lines are the 95% confidence intervals about each regression. Regression statistics are provided in Table 2.

Arts et al. (2000)