Problem set #1 Fall 2014

**GEOL1370: Environmental Geochemistry**

**Global water and energy cycles (Due Tuesday, 9/16)**

1. A nearly rectangular-shaped lake is 5 kilometers long, 2 kilometers wide, and 100 meters deep and contains 0.001 mg/L of dissolved mercury. A river discharges 2x1012 L/yr of water with a concentration of mercury of 0.0005 mg/L into the lake.

a) What is the water volume in the lake?  
b) What is the total mass of mercury in the lake?  
c) What is the residence time of mercury in the lake?  
d) Environmental scientists often need to estimate how long it takes for a system to return to its natural state after a perturbation (e.g., a sudden discharge of mercury into the lake). If we assume that the only way to remove mercury from the lake is through its outflow (i.e., the only way to clean out the mercury is by pushing out the contaminated water with natural clean water), then it takes **3 residence times of clean water** (not the mercury) to remove 95% of the contamination. In this particular example how long will it take for most (95%) of the mercury contamination of the lake to disappear?

e) Redo all the calculations in questions a, b and c for a lake with a volume ten times larger, but with the same mercury concentrations in lake and inflow stream water and the same river discharge rate. How long will it take for most (95%) of the mercury in the lake to be removed? Comment on how residence time of an environmental pollutant can affect the cleanup efforts.

1. a) Sensible heat flux and latent heat flux represent key ways for heat to transfer from the Earth’s surface to the atmosphere. Define sensible heat flux and latent heat flux. Based on Fig. 1.4 of the Berner and Berner text book, which flux is greater on the global basis? and by how many times?

b) Liquid water has the highest “latent heat of vaporization” (L) among all common liquids because of the strong hydrogen bonding between water molecules. This property makes water the ideal substance for transporting heat (through latent heat flux) from low latitude to high latitude regions on Earth. The heat of water vaporization varies with temperature:

L (cal g-1) = 596 cal g-1 – [(0.56 cal g-1 °C-1) × T (°C)]

Calculate the amount of heat that is released when 10 tons of rain is formed at 5°C from water vapor. (10 tons of water is enough to rain 0.2 cm on an area the size of a football field.)

c) Burning 1 barrel of oil on average yields 1.42 × 109 cal of energy. Calculate the amount of oil needed to produce the same amount of energy as forming 10 tons of rain at 5oC.

d) The state of Rhode Island (3140 km2) received an average of 5 cm of rain during Hurricane Irene. How many barrels of oil are needed to produce the same amount of energy as released during the formation of this amount of rain?

1. One way to study climate change for the past few hundred thousand years is by examining the airborne dust preserved in sediments at the bottom of oceans or lakes. Scientists analyze the rate of dust deposition and reconstruct the past climate based on the assumption that airborne dust is more abundant during dry periods and less so during wet periods.
2. Based on what we learned in class about atmospheric circulation patterns, where would you drill (in what ocean basin) in order to find such dust deposition that originated from the Sahara Desert?
3. Where would you drill in order to find such dust that originated from the Gobi Desert (China)?

c) Typically these particles are deposited on the ocean surface and settle out at a rate of 500 cm/year. How long would it take such particles to reach the bottom of the ocean at 4 km depth?

1. a) Why are there a net deficit of radiation at high latitudes and a new surplus of radiation at low latitudes? Explain ways that heat is transported from low latitude to high latitude regions on the earth surface, in order to balance out the unequal radiation energy.
2. How do the Gulf Stream and North Atlantic Deep Water (NADW) formation affect climate in Europe and Eastern North America? Assuming there is no atmospheric heat transport, how would climate change in these regions if NADW formation were to shut down? (In fact, turning on and off NADW formation has been suggested as one of the mechanisms for climatic change in the past).