HW3

Matthew Ross

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Setup

In this assignment you will be reviewing the major ideas we have covered in class so far including: watershed hydrology, history of water quality change, pollutant flux versus concentration, nutrient cycling, redox chemistry, gibbs free energy yield, algae blooms, weathering, and water treatment approaches.

This assignment counts for double compared to all the other assignments and should be an excellent way for you to prepare for the mid-term.

Question 1)

A wetland was constructed to remove nitrogen from a small municipality that couldn't afford to install a traditional wastewater treatment plant. However, the bedrock surrounding the community is rich in Gypsum ($CaSO_4$) which enriches the water in sulfate (SO_4^{2-}). A retired biogeochemist in the community pointed out that all this excess sulfate could make denitrification less likely. She's too old to really want to work out the math, so she has asked you: **Will denitrification likely occur in these wetlands?**

Setup

We'll start with where hw3 ended and Gibbs free energy. This time instead of estimating Gibbs free energy at standard state, we will calculate energy yield based on real-world concentrations using the equation for a generic reaction

$aA + bB = cC + dD$

$\Delta G = \Delta G^o + RTln\left(\frac{([C]^c * [D]^d)}{([A]^a * [B]^b)}\right)$

Where ΔG^o is the standard free energy yield of a reaction (calculated in hw3), R is the universal gas constant $R = 0.008314\frac{kJ}{molK}$ and K is temperature in Kelvin $K = Temp^oC + 273.15$

Evaluation

We will be using a slightly simplified equation for calculating denitrification vs sulfate reduction energy potential.

$4NO_3^- + 5CH_2O + 4H^+ -> 5CO_2 + 2N_2 + 7H_2O$ ΔG^o = -113 kJ

$SO_4^{2-} + 2CH_2O + 2H^+ -> 2CO_2 + H_2S + 2H_2O$ ΔG^o = -25kJ

To see if denitrification will likely occur in this wetland we need to know the concentrations of all the constituents and compute the actual gibbs free energy of sulfate reduction versus the gibbs free energy of denitrification. If one is more efficient than the other then those microbes will be more active.

compound	concentration_molar
no3	0.0004
ch2o	0.1600
h+	0.0001
co2	0.1000
n2	0.0010

compound	concentration_molar
h2o	0.1000
so4	0.3000
h2s	0.0002

Based on your analysis is denitrification likely to be the dominant redox pathway in this environment? Please show gibbs free energy calculations for both.

Question set 2 (watersheds)

1) What is a watershed?
2) What is a hydrograph?
3) The presenter at this conference talked about dilution, chemostasis, and enrichment. Could you draw these three ideas on a graph? What does each process tell us about how water pollution changes with flooding?
4) Can you name some elements that enrich, dilute, or are chemostatic with large changes in discharge?

Question set 3 (watershed ecosystem)

1) What is the watershed ecosystem concept?
2) What decade was this idea implemented?
3) What is one major result from the Hubbard Brook watershed experiments?

Question set 4 (nutrients)

1) What is Liebig's law of the minimum?
2) What is the Haber-Bosch process?
3) What is the Redfield ratio? What does it tell us about nutrient cycling?
4) How is phosphorus supplied to agricultural systems?

Question set 5 (concentration vs flux and algae)

1) A river has relatively high mean nitrate concentrations downstream of an ag field but the units are in molar and the river watch group usually reports concentrations in mg/L. What is the concentration of NO_3^- in mg/L of a 0.0004 molar (moles/liter) average NO_3^- concentration river?
2) A shrimp farming group that lives on the same river, just downstream is worried not about the concentration of NO_3^- but about the flux. What is the average daily flux of NO_3^- from the river if the average flow is 10 cubic feet per second. Flux should be reported in kg/day.
3) What is the annual flux?
4) Why might the farmers be concerned about flux more than concentration?
5) What are the consequences of excess nutrients in lakes or the ocean?
6) How does eutrophication happen?
7) What are two differences between algae and cyanobacteria?

Question set 6 (weathering and mining)

1) What is chemical weathering?
2) What conditions lead to high rates of chemical weathering?
3) How does the carbon cycle interact with weathering?
4) What is a "buffered" system?
5) How does mining alter weathering (give at least 2 examples)

Question set 7 (water treatment)

1) What is coagulation?
2) What is sorption?
3) What is floculation?
4) How does a water treatment plant use these processes to improve water quality (either drinking or wastewater treatment).
5) Name two other ways we can treat water to improve it's quality (remove nutrients, get rid of disease, etc. . .)

Question set 8 (general)

1) What is point-source pollution?
2) What is non-point source pollution?
3) Which is easier to control? Why?
4) How does the Clean Air Act impact modern day water quality? (That's not a typo, if you've come to class we talk a lot about how the Clean Air Act has modern day impacts on water quality.)