CE/ESR 479/579 Fate and Transport of Toxics in the Environment

Problem Set 7 (2016)

1. Before beginning this problem, review the background material entitled **Speciation of Metals in Sediments: Sulfide Precipitation and Adsorption** posted on the course Website for Week 7.

   In this problem set we will consider the behavior of the contaminants of concern in the sediments of Whitaker Slough, a portion of the Columbia Slough system in North and NE Portland. We will use actual field data from the Slough, and we will take into account both AVS and adsorption.

   On the attached sheet (end of this document) you'll find chemical and physical data for Whitaker Slough. Note that the Slough has been divided up into five reaches. The first reach begins at the downstream end of Whitaker Slough where it joins the main stem of the Columbia Slough. Subsequent segments are one mile in length, each moving upstream. The last reach is approximately 1.5 miles long and represents the upper most reach of Whitaker Slough. The chemical data for sediments include the total organic carbon (TOC) on a percent basis. AVS and metal concentrations are given in *milli*mole/kg as indicated. Also included are data (in units of micrograms/kg) for a common form of polychlorinated biphenyls (PCB), a commercial mixture called Arochlor 1254. PCBs are known cancer-causing agents and are the main risk to human health, via consumption of fish, in the Slough. Whitaker Slough receives a considerable input of groundwater. During the summer months, the groundwater is typically the only significant source of water flowing through the slough. Data is given for the groundwater flows in each segment.

   a. Calculate the amount of each metal that is *not* bound to AVS in the sediment for each segment of Whitaker Slough. Then calculate the interstitial water concentration of each metal for each segment, taking into account *adsorption* onto the sediment. For each metal use the relationships described in the online document entitled Speciation of Metals in Sediments. Work up these calculations in a spreadsheet and present your results in tabular form using a spreadsheet. Make sure all rows and columns are clearly labeled. [2 pts]

   b. For Arochlor 1254, Schwarzenbach et al. report the best correlation for K_{oc} is

   $$\log K_{oc} = 0.88 \log K_{ow} - 0.27$$

   Use this to determine the aqueous concentration of Arochlor 1254 in the interstitial water for each reach. [1 pt]

   c. Assume that metals and Arochlor 1254 enter Whitaker Slough *only* by advective transport (via groundwater influx; data given in table.). Using the concentrations of metals in the interstitial water, calculate the **advective flux** of each metal in each segment due to groundwater flow **in units of [mg m^{-2} d^{-1}]**. Use the area of each segment to also calculate the mass flow of each metal into each segment **in units of g d^{-1}.** Once again, perform these calculations in your spreadsheet and present your data in spreadsheet format. [2 pt]

d. Note that uppermost reach receives only (sediment-contaminated) groundwater input, so the steady state pollutant concentrations in the water column is trivial to compute once you have the data from Part (a). But the next reach (3-4) receives both groundwater AND surface input from reach 4-5.5. Set up a simple mass balance model and calculate the predicted concentration of each pollutant in Reach 3-4. [1 pt]

2. A drunken fracas between two fishermen in a small boat has resulted in a ten-gallon can of gasoline being dumped into a mountain lake (it got ugly). Although the surface slick (LNAPL) has completely evaporated, some gasoline is now dissolved in the lake water. The lake is stratified, and the fully mixed epilimnion is 3.2 m thick (Hint: the depth is relevant). Consider the fate of two specific compounds in the fuel: *n*-pentane and cyclohexane, both initially present at concentrations of 50% of saturation (solubility). From a prior study at this lake the piston velocity for propane is known to be 3.4 cm/hr. For this calculation, neglect removal mechanisms other than volatilization. Choose an appropriate thin-film model and explain your choice. [4 pts total, 1 pt each part]

    a. Plot the expected concentration of *n*-pentane versus time over a period of 2 weeks.

    b. On the same axis, plot the concentration of cyclohexane over 2 weeks.

    c. How does the composition of the dissolved gasoline qualitatively change over time? I.e., do the relative proportions of component remain steady as volatilization occurs?

    d. In reality, what other processes do you think may remove gasoline from the lake in addition to volatilization?

(cont'd, next page)

Whitaker Slough, Portland, OR

Chemical Data

River Mile	TOC	AVS	Hg	Cu	Pb	Cd	Zn	Ni	PCB Arochlor 1254
Whitaker	%	mmol/kg	mmol/kg	mmol/kg	mmol/kg	mmol/kg	mmol/kg	mmol/kg	µg/kg
0-1	3.80%	0.384	4.60E-04	0.568	1.47	0.0078	2.64	0.315	26
1-2	2.93%	0.355	5.40E-04	0.595	0.51	0.012	3.04	0.336	37
2-3	3.59%	3.47	3.90E-04	0.635	0.47	0.013	3.82	0.385	82
3-4	4.75%	15.8	5.10E-04	0.614	0.54	0.0091	3.52	0.341	51
4-5.5	3.75%	1.29	4.70E-04	0.54	0.41	0.0072	3.01	0.383	58

Physical Data

River Mile	Width	Length	G/W Flux
Whitaker	m	m	L/m2/s
0-1	26	1609	0.0046
1-2	28	1609	0.0051
2-3	30	1609	0.0044
3-4	29	1609	0.0041
4-5.5	27	2719	0.0046

Assume total input of water in the summer
is only the groundwater input.