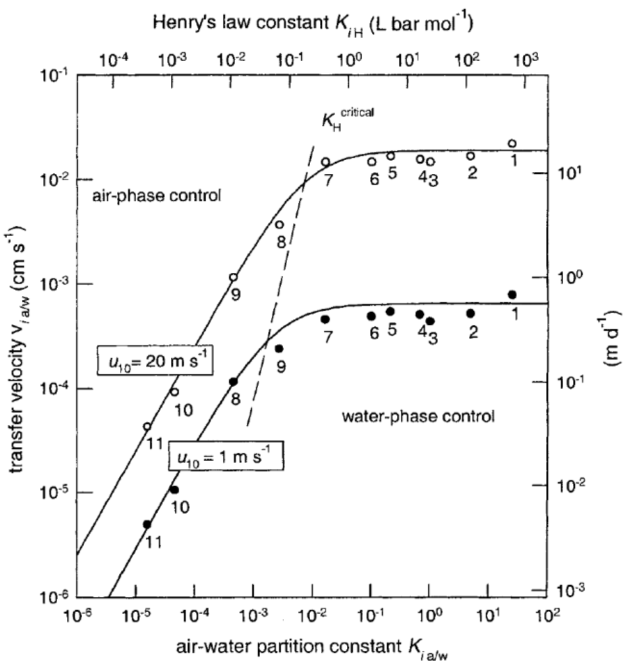
Carnegie Mellon University
Department of Civil and Environmental Engineering

12-725: Fate, Transport, and Physico-chemical Processes of Organic Compounds in Aquatic Systems

Problem Set #8 Spring 2020
Due 4/3/20

1. P19.7 in EOC

2. The following chart shows the water-side transfer velocity (v_w) vs. $K_{ia/w}$. Explain the trends observed in the graph.



3. A company using large quantities of trichloroethene (TCE) as a reagent resides on the Ohio River. An accidental release results in a slug of TCE in the river. After mixing, the average TCE concentration in the river is 6 mg/L. The summer flow rate in the Ohio is approximately 56 m^3/s, which corresponds to an average velocity of 0.27 m/s, and is 2 m deep. Assume that large eddies dominate, and that the wind speed is low enough (u_{10}=3 m/s) such that bubble enhancement is negligible.

   (a) Estimate the overall mass transfer coefficient, $v_{i,a/w}$, and the mass transfer rate constant, k_v, for TCE in the river. State any assumptions that you make.

   (b) Verify that liquid phase resistance controls the mass transfer of TCE from the river into the atmosphere. What fraction of the overall mass transfer resistance is attributed to the gas phase resistance? Calculate a revised estimate for the overall mass transfer coefficient, $v_{i,a/w}$, this time accounting for the gas phase resistance. Can the gas-phase resistance safely be ignored in this case?

(c) Assume that chlorophenol was released instead of TCE. Calculate $v_{i,w}$, $v_{i,a}$, $v_{i,a/w}$, and k_v for chlorophenol in the same river. Is the assumption that liquid-phase resistance controls the mass transfer of ethanol from the river to the atmosphere valid?

(d) Repeat part (a) but assume that the river bottom is fine-grained sand, and that large eddies do not dominate mass transfer from air to water.

4. Sediment caps comprised of granular material such as clean sand are sometimes used to isolate contaminated sediments from the overlying water column. The cap provides an additional length (L) the contaminants must diffuse through before they enter the water column. Consider a 30-cm sediment cap of quartz sand placed over a PAH contaminated sediment. The cap porosity is measured at 37% and the tortuosity is determined to be 1.4. The sand bulk density is measured at 1.52 g/cm^3.

(a) Estimate the effective diffusivity of fluorene (a model PAH) in the sand sediment cap assuming there is no sorption to the cap material.
(b) Assuming that the PAH concentration in the sediment remains constant, determine the time required for the fluorene concentration at x=10cm in the cap to reach 10% of the concentration in the sediment.
(c) Repeat this calculation, but assume that the fluorene concentration in the sediment is depleting. How different are your estimates for the time required to reach 10% of C_o at x=10cm in the cap?
(d) Determine the time required for the fluorene concentration at x=10cm in the sediment cap to reach 10% of the concentration in sediment for a sediment cap containing 0.3% organic carbon. You can assume that the concentration in the sediment remains constant.
(e) Repeat this calculation, but now incorporate 5% activated carbon on the sand cap. Does this improve the performance of the cap? By how much?
(e) Do you think capping with organic rich sands or with activated carbon can be an effective sediment remediation strategy? What are the potential problems with this approach?