Transport and Fate of Toxics in the Environment

Practice Problems No. 1

1. A farm is 1000 hA in area and receives 1,100 mm/yr of rainfall. Of that annual rainfall 50% percolates into the groundwater under the farm and the rest runs off into nearby streams that drain off the property. The farmer supplements rain in the dry season with irrigation water from a well that draw groundwater from beneath his land. (Assume the groundwater is recharged only by the rainfall that percolates under the farm boundaries; no inflow from more distant groundwater). Of the irrigation/well water used, 80% is lost to evapotranspiration and the rest percolates back into the groundwater below the farm. If the farmer is sustainable in his water use and does not want to deplete his groundwater supply, what is the maximum volume of water can he draw from the well per year? (I.e, the rate that maintains a steady state reserve of water in the groundwater.)

2. A river has a flow of 10 m3/s and an average cross-sectional area of 15 m2. A small factory discharges chrome plating wastes at a flow rate of 20 L/s with a total concentration of toxic hexavalent chromium (Cr(VI)) of 200 mg/L. Assume no chemical reactions in this problem.

    A. When the Cr(VI) has fully mixed with the river downstream, what is the steady state concentration of Cr(VI)?
    B. How does this compare to a drinking water standard for Cr(VI) of 50 ppb?

3. In the river system in prior problem, new research suggests that the toxic Cr(VI) is chemically reduced to the relatively harmless trivalent chromium, Cr(III). The reaction is first order with a measured decay coefficient of 0.14 h-1. What is the Cr(VI) concentration at a point 12 km downstream from the discharge?

4. Asmall shallow lake has a surface area of 100 hA and an average depth of 6 m. Two streams enter the lake with flows:
    Q1 = 1.2 m3/s
    Q2 = 2.0 m3/s
    A single outlet stream has a flow of Q3 = 3.0 m3/s. The effects of groundwater flows are unknown. In the summer during which you study the lake the rainfall is negligible and summer evaporation is estimated to be 2 mm/d.

    A. What is the contribution of groundwater (either input or output) for this lake? Provide a quantitative answer.
    B. What is the average "face velocity" of groundwater flow as it enters or leaves the sediment of the lake? (I.e., the "groundwater" water velocity at a point just inside the lake from the sediment, not in the sediment itself.)
    C. What is the hydraulic residence time of the lake?

5. One of the streams (Stream 1) feeding the lake above receives a steady flow of atrazine herbicide from a nearby fruit orchard. The concentration of atrazine in Stream 1 is measured at 100 ug/L (ppb). In this system there is no apparent degradation of atrazine and it is not volatile.
    A. What is the mass flow (in mg/d) of atrazine out of the orchard?
    B. What is the steady state concentration of atrazine in the lake?