Solute Transport Assessed Exercise

The Ogata-Banks solution to the advection-dispersion equation is a valuable tool for quickly and efficiently estimating solute travel distances and times in groundwater. It is often used as a range-finding method to bound the spatial and temporal extents of solute transport problems.

Scenario:

Your organization has received a report concerning a site with a holding pond that has been contaminated with trichloroethene (TCE), a compound with an aqueous solubility of 1100 mg/L, following a pipe rupture. The holding pond was constructed without a geoliner, and dissolved-phase TCE has infiltrated the water table. The TCE concentration in the pond has been measured at full solubility.

The site is characterized by loamy, organic soil with a dry bulk density of 1.37 g/cm³, which is assumed to be homogeneous and isotropic in its hydraulic properties. Additional site data provided includes:

- **Hydraulic conductivity**: 2.43×10^{-5} m/s
- **Effective porosity**: 0.43
- **Hydrodynamic dispersion coefficient**: 9.10×10^{-8} m²/day
- **Hydraulic gradient**: -0.037

Sorption data for TCE is also provided in a spreadsheet to calculate the retardation factor (R) for the contaminant in the soil.

As the newly appointed contaminant hydrogeologist on the team, your task is to conduct an initial range-finding analysis for the travel time of groundwater impacts from the contaminated pond. Your supervisor has requested a concise, one-page memo that estimates the time required for TCE to reach a monitoring well located 80 meters downgradient at the property boundary. This information will be used to plan a response to the spill.

A batch equilibrium test has been conducted, though not yet validated. Your supervisor has asked that you perform both a one-dimensional conservative solute transport analysis (without sorption) and a second analysis incorporating sorption kinetics. Both results should be reported to provide a range of possible solutions.

Using the Ogata & Banks (1961) solution, create a memo that clearly and professionally communicates the answer the following questions:

1. *What is the estimated retardation factor (R) for TCE in the soil at the site?*
2. *How long will it take for TCE to be first detected in the monitoring well, and when will the maximum concentration be reached, considering sorption?*
3. *How long will it take for TCE to be first detected in the monitoring well, and when will the maximum concentration be reached, assuming no sorption (R=1)?*
4. *Explain the effect of varying the dispersion coefficient (higher and lower values) on your predictions.*

Include, as an appendix, a calculation spreadsheet, authored by you and clearly notated as supporting evidence for your engineering advice.

Your written memo should be no longer than one page (single-spaced). Introduce the problem, describe the scenario, and present the relevant data. Address points 1 through 4, ensuring that all necessary information is provided for your employer. You may include plots as additional pages and upload your spreadsheet if desired, as this will demonstrate your procedure and may help identify any calculation errors.

DUE DATE: NOVEMBER 15, 2024, 14:00

Tips:

- ***Pay attention to units!***
- ***Plotting the solution as a fraction (C/C_o) simplifies the spreadsheet.***
- ***When sorption is not considered, R=1.***
- ***Plotting a breakthrough curve at the monitoring well location will help determine transport times.***
- ***Breaking the Ogata-Banks solution into terms can minimize calculation errors in the spreadsheet.***

Batch Equilibrium Test Results

$C_{solution}$ mg/L	C* ug/g
60	19.76
60	18.81
60	17.65
40	13.55
40	12.45
25	10.3
25	8.8
25	8.3
15	6.76
15	5.94
15	5.64
8	4.35
8	3.94
8	3.45
5	3.12
5	3.04
3	3.13
3	2.51
3	2.45
1	1.94

Ogata-Banks (1961)

$$C = \frac{C_o}{2}\left[erfc\left(\frac{x - \left(\frac{v}{R}\right)t}{2\sqrt{\frac{Dt}{R}}} \right) + \exp\left(\frac{vx}{D}\right) erfc\left(\frac{x + \left(\frac{v}{R}\right)t}{2\sqrt{\frac{Dt}{R}}} \right) \right]$$