Problem 6-6

For each of the solute breakthrough curves given below, describe what processes are likely causing the specific shape and location of the curves. Assume results are for laboratory columns and give brief, concise descriptions. The calculation were performed using STANMOD (Simunek et al., 1999), this code may be downloaded free of charge at http://www.pc-progress.com/en/Default.aspx?stanmod

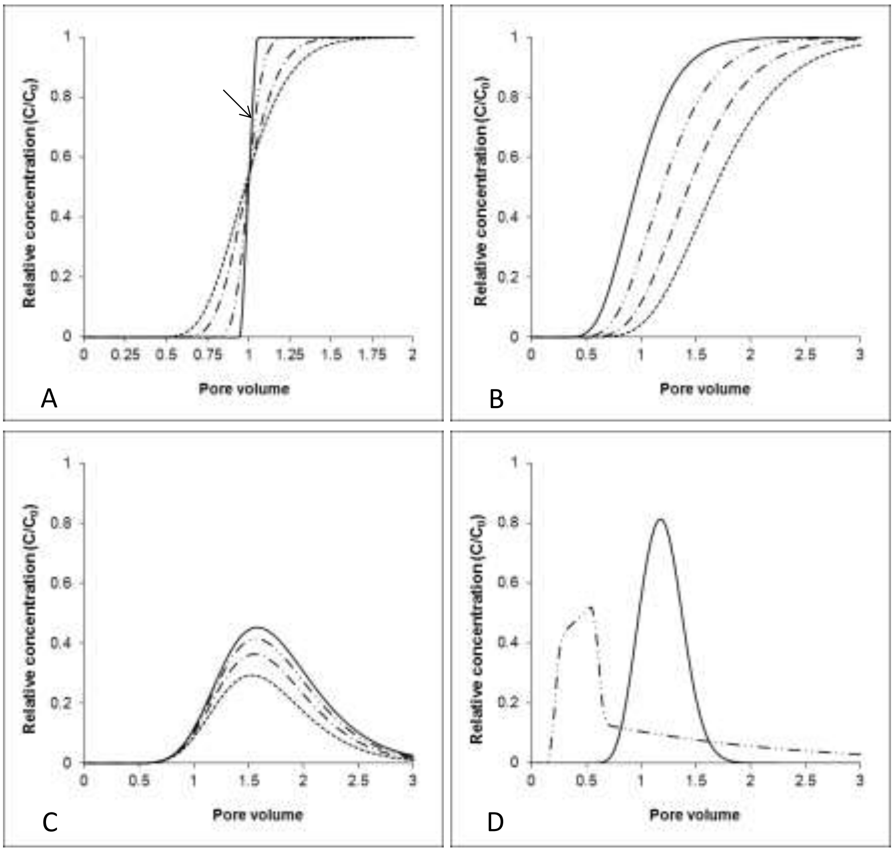

Fig. 6-3: Solute breakthrough curves for various conditions

Answer:

a. The breakthrough curves represented in the top left graph are characteristic of non-sorbing and non-degrading solutes, when the solute is continuously applied to the surface of a soil column. The observed concentrations in these breakthrough curves would come from the effluent exiting the bottom of the soil columns. The variation in the curves is due to dispersive processes. When there is no dispersion (D = 0), all solutes move at the same velocity, and the front arrives as a square wave (see arrow), termed “piston flow”. The dispersion of a solute in a flow path can result from velocity variations within a pore, pore size differences, or path length differences. Breakthrough curves characterized by increased dispersion will be spread out along the x-axis, resulting from increased variation in solute arrival times (or pore volumes) around the idealized piston flow arrival value. Nevertheless, the inflection point of all curves, representing 50% displacement of the non-sorbing and non-degrading solute, should occur at about one pore volume.

b. The breakthrough curves represented in the top right graph are characteristic of sorbing solutes, when the solute is continuously applied to the surface of a soil column. The observed concentrations in these column breakthrough curves would come from the effluent exiting the bottom of the soil columns. Retardation factors (R) in the soil may result in breakthrough curves similar to those displayed in the top right graph.

$R = 1 + \dfrac{\rho_b K_d}{\theta}$, where K_d is the distribution coefficient, ρ_b is bulk density, and θ is volumetric water content. If there is no adsorption, then K_d = 0 and R = 1, which would represent the curve furthest to the left. As adsorption increases (i.e. K_d > 0) the breakthrough time increases (moves right) and the curve spreads more across the x-axis.

c. The breakthrough curves represented in the bottom left graph are characteristic of degradable or volatile solutes such as ammonia (NH_3). The solute for these breakthrough curves was applied as a pulse of solution where water was applied after the pulse application was discontinued. The observed concentrations come from the effluent exiting the bottom of the soil columns. The greater the rate of degradation, the smaller the peak of the curves.

d. The solute for these breakthrough curves was applied as a pulse of solution where water was applied after the pulse application was discontinued. The observed concentrations come from the effluent exiting the bottom of the soil columns. The more symmetrical shape of the breakthrough curve results from a more uniform pore size distribution and the concomitant removal of large pores. In the second case, early breakthrough of the solute is made possible by solute moving at higher convective velocity through more mobile areas (e.g. root holes, cracks).