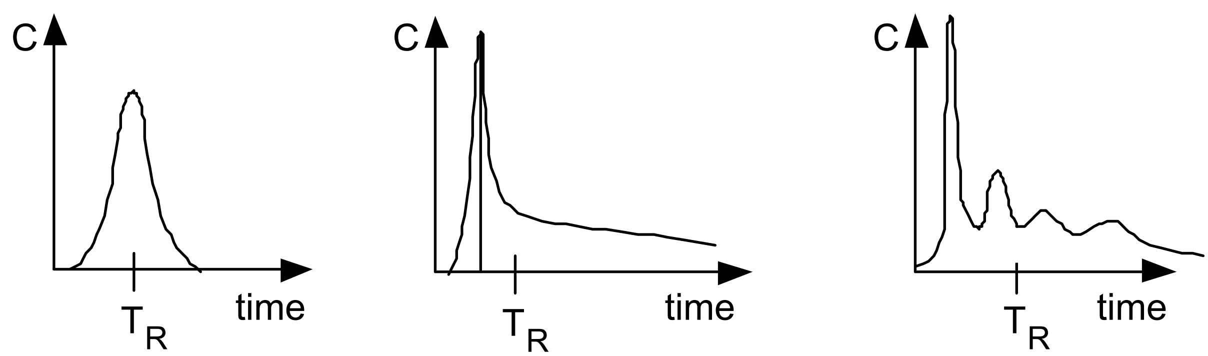
Answer 2.4

a) *Estimate the concentration of phosphorus at the exit as a fraction of the inlet concentration, C_e/C_o. Give a minimum and maximum expected value.*

First, we estimate the nominal residence time, $T_R = bLh/Q = (40m)(100m)(0.5m)/(0.01m^3s^{-1}) = 2x10^5$ s = 2.3 d. The *minimum* exit concentration is achieved by plug flow, for which $C_e/C_o = \exp(-kT_R) = \exp(-(1x2.3)) = 0.1$, which corresponds to 90% removal. Circulation that approaches a stirred reactor would yield $C_e/C_o = (1+kT_R)^{-1} = (1+2.3)^{-1} = 0.31$, or 69% removal. Higher exit concentrations could occur if the dead-zone volume was large and short-circuiting was pronounced, as the practical detention time, T_{det}, would be diminished relative to the nominal residence time, T_R. Theoretically, if all the water were to short-circuit, it could remain in the wetland for such a short time that C_e/C_o would approach 1. This is the theoretical maximum exit concentration.

b) *Sketch the concentration distribution, C(t), that you would expect to observe at the exit of each wetland*



Case 1 Case 2 Case 3

Case 1: The baffles prevent short-circuiting and ensure that the flow travels through the entire volume, *i.e.* it prevents the formation of dead-zones. This system is the closest to plug-flow. The center of mass arrives at the exit at T_R, and the distribution of mass around T_R is small.

Case 2: Most of the flow stays in the channel, effectively short-circuiting. This creates a peak concentration at the exit earlier than T_R. Some dye moves into the vegetation and then is slowly released creating the long tail observed in C(t).

Case 3: Through each channel the travel time to the exit is different, creating multiple peaks in C(t). Some of these peaks arrive before T_R.

c) *Which condition is closest to achieving the minimum exit concentration, as described in part a.*

Case 1 is closest to plug-flow (see description above) and so comes closest to achieving the minimum exit concentration, or maximum removal.