Problem 1. Bacterial Remediation

(i) During the exponential growth phase of bacteria you observe that on day 0 you start with $5mg/l$. You measure every day for 6 days and observe concentrations of [10.5850 22.4084 47.4387 100.4277 212.6054 450.0857] mg/l. What is the growth rate of this colony?

(ii) Calculate the size of the population after 10 days, assuming that logistic growth is followed and that the carrying capacity is 10,000 mg/L.

(iii) When your colony starts to die (food source removed) you observe that its population dies by a quarter every day. What is the death rate of this colony?

(iv) From other studies you know that this bacteria has a $G = 0.1mg/l$ value (Recall G is concentration of the limiting resource when the growth rate is half the maximum). You wish to use this specific colony in a steady state remediation (as discussed in the lecture notes). What is the lowest concentration that one could attain?

(v) *Conceptual*: Imagine this concentration has to be 10 times less. What characteristic of the bacteria would you change if you could only change one. Justify why you chose this particular one.

Problem 2. Kinetic Batch Bimolecular Reactions

Consider the chemical reaction $A + B \rightarrow C$ at reaction rate k in a well mixed batch reactor such that the governing equation for concentration is

$$\frac{dC_A}{dt} = -kC_A C_B \tag{1}$$

In class we considered the case where at initial time $t = 0$ we have equal concentrations of both reactant and we obtained the solution in the lecture notes. Now assume that initially you do not have equal amounts of A and B, but rather $C_A(t = 0) = C_0$ and $C_B(t = 0) = C_0 + \Delta C$.

(i) Can you solve for the evolution of the concentration of C_A over time. You may need to use Mathematica - look back to HW1 for guidance.

(ii) *Conceptual*: Compare the expression you get to the one we derived in class for equal concentrations and discuss any significant differences e.g. is it faster/slower? (as well as others that you notice).

(iii) Now consider a case of a confined and sealed part of an aquifer where you wish to remediate a contaminant. Initially there is a uniform concentration of 1 $mol\ m^{-3}$. You inject in another solute that reacts with the contaminant to neutralize it and mix it uniformly (for example using chaotic advection - not important for the question, but just if you want know how one might achieve this) at a concentration of 2 $mol\ m^{-3}$. The rate of reaction is 0.1 m^3 s^{-1} mol^{-1}. How long does it take to remove 99% of the contaminant?

Problem 3. Instantaneous Chemical Reactions

You are in an aquifer and may consider the system as one dimensional. The aquifer is virtually flat in terms of head and there is next to no advection in the system. There has been a spill of a contaminant of 1 mole located at a certain point. You wish to remediate this contaminant by injecting in another chemical that will instantaneously react with it to form a harmless byproduct. However you cannot access it directly and the best thing you can do is inject the remediant chemical at a distance of 0.2 meters away. The remediant itself is not the nicest compound and so you do not want to inject more than you need. They react in a ratio of 1 to 1 and so you inject 1 mole of remediant at your desired location. You may assume that the spill occurs at the same time as the injection of the remediant.

(i) Draw a conceptual diagram of the setup

(ii) Write the governing equations for transport of the species and the reactant - state any assumptions you are making explicitly.

(iii) Now calculate how long it will take to remove 10, 25, 50, 90 and 95% of the contaminant. You may assume a diffusion coefficient for both substances of $1 \times 10^{-6} m^2/s$

Conceptual Question: What changes if you go to 2d? Everything else stays the same. Draw a figure to help you explain your reasoning.

Problem 4. Creative Project

Update me on your project. Have you met your milestones? If not, are you on track to catch up or have you modified your approach and goals...