SOLUTIONS TO QUIZ #3 QUESTIONS

31¢ + TAX

PART A - *Short* Answer (point form acceptable)

1. RAPID ROUND:

a) Name one oxygen source and 1 oxygen sink that are not included in the basic Streeter-Phelps DO sag model.

source: PHOTOSYNTHESIS

sink: NBOD, RESPIRATION, BENTHIC DEMAND

b) What is the main factor affecting the saturation concentration of dissolved oxygen in water? TEMPERATURE

c) What is the principal driving force behind dispersion? CONCENTRATION GRADIENTS

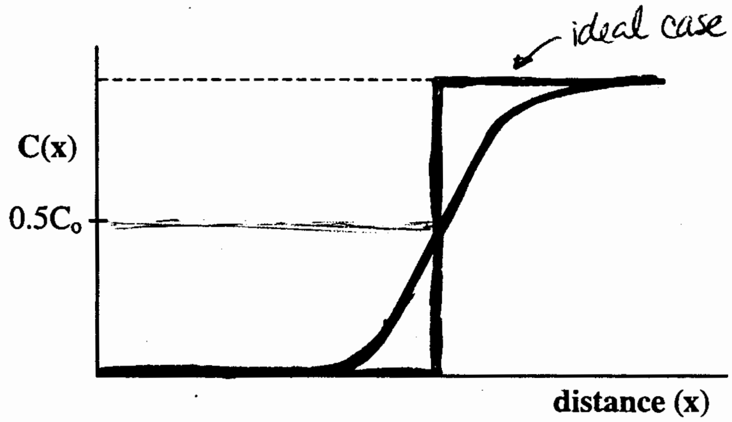
2. What 2 main assumptions are required to define an ideal CFSTR?

- COMPLETE DISPERSION OF FLUID PARTICLES THROUGHOUT REACTOR
- EFFLUENT CONC. = CONC. IN REACTOR

3. How do dead zones affect the detention time of a CFSTR?

DEAD ZONES REDUCE THE DETENTION TIME OF A CFSTR.

4. The diagram at right illustrates the distribution of a plug flow front of a step input of contaminant which has undergone some dispersion. Show how the front would look if the system exhibited ideal plug flow.



5. Is disposal of biodegradable wastes in Canadian streams a bigger problem in winter or summer? Why?

SUMMER — GREATER MICROBIAL ACTIVITY AT HIGHER TEMPERATURES (↑k's) MEANS THERE WILL BE GREATER OXYGEN DEMANDS (D.O. DEFICITS) DURING THE WARM SUMMER MONTHS THAN IN WINTER.

ICE COVER SLOWS REAERATION IN WINTER, BUT BIOACTIVITY IS SO LOW AT < 1°C THAT THERE IS LITTLE O_2 CONSUMPTION TO COMPENSATE FOR (PARDON MY GRAMMAR)

6. Is NBOD included in the Streeter-Phelps DO sag model? For what type of waste is NBOD a significant contributor to the oxygen demand in streams?

NO.

MUNICIPAL WASTES (SEWAGE), OR OTHER WASTES HIGH IN AMMONIA OR ORGANIC NITROGEN.

PART B - Numerical Problems

7. A particular first order reaction with rate constant k of 0.05 hr^{-1} can be accomplished using either a single PFR or 3 identical CFSTRs in series. Calculate the relative steady state % treatment efficiency of each process type assuming an influent concentration of 100 mg/L and a total detention time in either case of 1.5 days.

t_o PFR = 1.5d
t_o CFSTRs = 0.5d for n = 3

PFR: $C = C_o e^{-kt_o} = 100 mg/L\, e^{-(0.05 hr^{-1})(1.5d)(24hr/d)} = 16.5 mg/L$

$\%\ efficiency = \left(\frac{100-16.5}{100}\right) = 83.5\%$

3-CFSTRs: $\frac{C}{C_o} = \frac{1}{(1+kt_o)^n} = \frac{1}{(1+(0.05hr^{-1})(24hr/d)(0.5d))^3} = 0.244$

$\%\ efficiency = (1-0.244)\times 100 = 75.6\%$

8. A boat runs aground in the middle of a river and loses a portion of its load of the toxic compound 'MX'. The 'MX' becomes completely dispersed across the river to a concentration of 100 µg/L at a point 3.2 km upstream of an untreated drinking water intake, and the maximum acceptable concentration for 'MX' in drinking water is 10 µg/L. If the mean velocity of the river is 300 m/min and it takes 9.5 minutes before people at the drinking water intake can be notified of the spill, can they still avoid pumping water which has been contaminated above the acceptable limit, or is it too late? Why or why not? [Assume that $D = 1.5x10^3\ m^2/min$.]

x = 3200m v = 300m/min
C = 10µg/L C_o = 100µg/L

$\frac{C}{C_o} = \frac{1}{2}\left[erfc\left(\frac{x-vt}{2\sqrt{Dt}}\right)\right]$ ← assume x, t large ∴ right hand part of full equation → 0

$\frac{10}{100}\times 2 = 0.2 = erfc(\Psi)$ ∴ Ψ (from table @ erfc = 0.2) = 0.90

∴ $0.9 = \frac{x-vt}{2\sqrt{Dt}}$

$1.8\sqrt{Dt} = x - vt$ square both sides

$3.24 Dt = x^2 - 2xvt + v^2t^2$

$3.24(1.5\times10^3)t = (3200m)^2 - 2(3200m)(300m/min)t + (300m/min)^2 t^2$

∴ $0 = \underbrace{1.024\times10^7}_{c} - \underbrace{1.92\times10^6}_{b} t + \underbrace{9.0\times10^4}_{a} t^2$

$t = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$

t = 10 min

∴ They would have 30 seconds to turn off the intake.

9. Wastewater effluent is discharged to a river. Both the effluent and the river upstream of the point of discharge are at 20°C. The river upstream has an ultimate BOD of zero and the DO concentration is at saturation. For the wastewater, the BOD_5 is 100 mg/L and the DO is zero. The wastewater flow is relatively small in relation to the river. $\therefore D_o = C_s - C_s = 0$

The flow in the river upstream of the point of mixing is 3 m^3/s. The depth of the river is 1.5 m and its velocity is 0.2 m/s. In the lab, k was determined to be 0.25 d^{-1} at 20°C. Because of in-stream processes, k_r is 10% greater than k. Reaeration occurs in this stretch with a rate constant k_2 of 0.95 d^{-1}, and C_s = 9.08 mg/L at 20°C. If the critical deficit is 2.0 mg/L and the critical time is 3.0 d, determine the wastewater flow allowable.

$D_c = 2.0\,mg/L \quad t_c = 3.0\,d \quad C_s = 9.08\,mg/L \quad k = 0.25\,d^{-1} \quad k_2 = 0.95\,d^{-1}$

$$k_r = 1.1(k) = 1.1(0.25\,d^{-1}) = 0.275\,d^{-1}$$

L_w:

$$BOD(5) = L_w(1 - e^{-kt}) \quad \therefore L_w = \frac{BOD_5}{1 - e^{-kt}} = \frac{100\,mg/L}{1 - e^{-0.25(5)}} = 140\,mg/L$$

$$D_c = D(3d) = 2.0\,mg/L = \frac{kL_o}{k_2 - k_r}\left(e^{-k_r t_c} - e^{-k_2 t_c}\right) + \cancel{D_o e^{-k_2 t_c}} \quad D_o = 0$$

$$\therefore L_o = \frac{2\,mg/L\,(k_2 - k_r)}{k\left(e^{-k_r t_c} - e^{-k_2 t_c}\right)} = \frac{2(0.95 - 0.275)}{0.25\left(e^{-0.275(3.0)} - e^{-0.95(3.0)}\right)} = 14.2\,mg/L$$

Assume simple mixing model:

$$\frac{Q_w L_w + Q_s L_s}{Q_w + Q_s} = L_o \quad \therefore Q_w L_w + \cancel{Q_s L_s} = Q_w L_o + Q_s L_o \quad (L_s = 0)$$

$$Q_w = \frac{Q_s L_o}{L_w - L_o} = \frac{3.0\,m^3/s\,(14.2\,mg/L)}{140\,mg/L - 14.2\,mg/L}$$

ALLOWABLE WASTEWATER FLOW FOR THESE CONDITIONS. → $Q_w = 0.339\,m^3/s$

BONUS QUESTION

10. The DO sag curve for discharge of a particular biodegradable waste in warm weather conditions is shown below. On this diagram, sketch the general trends in changes to this system if the temperature of the receiving body was to be reduced by several degrees.