

## 1.85 WATER AND WASTEWATER TREATMENT ENGINEERING HOMEWORK 1 – DUE FEBRUARY 10, 2005

You may collaborate in working on the homework, but the work you submit should be your own. Questions are by design open-ended: you may need to make assumptions or develop your own approach.

### Question 1 (2 points)

This question relates to professional practice rather than water or wastewater treatment. It is intended to stimulate some thought about how to communicate technical information effectively.

Consider the following two passages:

1. Galactic dark matter may consist of weakly interacting particles which can be captured and trapped in stars, and which would then contribute to the transfer of energy. A special class of these particles (“cosmions”), with weak cross-sections that are larger than standard has been invoked as a solution of the solar-neutrino problem, and also as a means of suppressing convection in the cores of horizontal-branch stars.
2. Subduction of the Juan de Fuca and Gorda plates has presented earth scientists with a dilemma. Despite compelling evidence of active plate convergence, subduction on the Cascadia zone has often been viewed as a relatively benign tectonic process. There is no deep oceanic trench off the coast; there is no extensive Benioff-Wadati seismicity zone; and most puzzling of all, there have not been any historic low-angle thrust earthquakes between the continental and subducted plates.

Which of these two passages is easier to read? Why?

ANSWER. See pages 29-30 of: Montgomery, S. L., 2003. *The Chicago Guide to Communicating Science*. The University of Chicago Press, Chicago. Montgomery explains that the second passage is much easier and more interesting reading. It using diverse and interesting vocabulary and the pattern of the passage – some medium-length sentences, some short – is good. In short, the second passage does a better job of drawing in the reader.

### Question 2 (4 points)

What happens to your wastewater? Describe the wastewater treatment facilities that service your residence at either home or school. The description should list the individual unit processes that comprise the treatment system and what each process accomplishes.

### Question 3 (4 points)

Where does your drinking water come from? Describe the source of your water at either home or school, how it is treated, and how it is conveyed from the source to the distribution system.

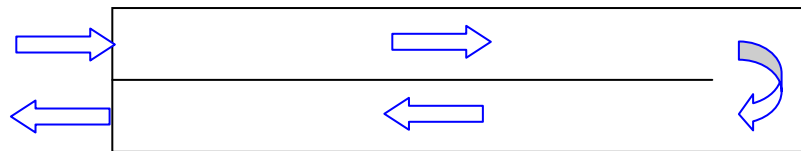
ANSWER: The answer to Questions 2 and 3 obviously will vary. The expectation is that by research on the internet, through phone calls, or from other sources, you gathered information on your water supply and wastewater treatment.

Question 4 (5 points total, 1 point each part)

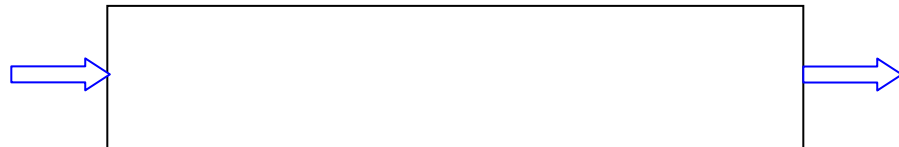
A waste treatment system is to be designed for a raw wastewater containing 200 mg/L of carbonaceous oxygen demanding material (BOD). The wastewater flow rate of 0.2 million gallons per day (mgd) is to be introduced into a reactor tank having a theoretical detention time of 1 day. The organic matter is oxidized at the rate of  $1.0 \text{ day}^{-1}$  (first-order rate constant). Note that  $1 \text{ mgd} = 1.55 \text{ ft}^3/\text{sec}$ .

Compare the relative steady-state treatment efficiencies of the following tank configurations all having the same total theoretical detention time:

- A fully-mixed circular tank, 80 feet in diameter, with inflow at center and outflow along the perimeter. Specify the tank depth.
- A rectangular dispersed-flow tank, 100 feet long and 50 feet wide, containing a central longitudinal baffle. Specify the tank depth.



- A dispersed-flow tank of the same shape as in part b, but without the central baffle.



- Three fully-mixed circular tanks of equal size in series. Specify the tank diameters and depths.
- Which configuration would you recommend and why?

ANSWER: Solution follows.

## Problem 4

a. Fully-mixed circular tank 80 ft in diameter

$$C = \frac{C_{in}}{1 + Kt_R}$$

$$t_R = \frac{V}{Q} = \frac{\pi r^2 H}{Q}$$

Given:  $Q = 0.2 \text{ mgd}$   
 $C_{in} = 200 \text{ mg/L COD}$   
 $K = 1 \text{ day}^{-1}$   
 $r = 40 \text{ ft}$   
 $t_R = 1 \text{ day}$

$$H = \frac{t_R Q}{\pi r^2} = \frac{1 \text{ day} \cdot 0.2 \times 10^6 \frac{\text{gal}}{\text{d}} \cdot \frac{1}{7.48} \frac{\text{ft}^3}{\text{gal}}}{\pi \cdot (40 \text{ ft})^2}$$

= 5.3 ft deep

$$C = \frac{C_{in}}{1 + Kt_R} = \frac{200 \text{ mg/L}}{1 + 1 \text{ day}^{-1} \cdot 1 \text{ day}} = 100 \text{ mg/L}$$

50% removal

b. Rectangular tank with baffle

$$L = 100 \text{ ft} \quad W = 50 \text{ ft}$$

$$t_R = \frac{L W H}{Q} = 1 \text{ day}$$

$$H = \frac{t_R Q}{W L} = \frac{1 \text{ day} \cdot 0.2 \times 10^6 \frac{\text{gal}}{\text{d}} \cdot \frac{1}{7.48} \frac{\text{ft}^3}{\text{gal}}}{100 \text{ ft} \cdot 50 \text{ ft}}$$

$$= 5.3 \text{ feet deep}$$

Consider as dispersed flow reactor (note, use half-width for baffled tank)

$$\text{Estimate } D = 0.03 \frac{U W^2}{R_h}$$

$$R_h = \frac{\text{area}}{\text{perimeter}} = \frac{5.3 \times 25}{25 + 2 \cdot 5.3} = 3.7 \text{ ft}$$

$$U = \frac{Q}{A} = \frac{0.2 \times 10^6 \frac{\text{gal}}{\text{day}} \cdot \frac{1}{7.48} \frac{\text{ft}^3}{\text{gal}}}{5.3 \times 25 \text{ ft}^2}$$

$$= 200 \text{ ft/d}$$

$$D = 0.03 \frac{200 \text{ ft/d} (25 \text{ ft})^2}{3.7 \text{ ft}}$$

$$= 1000 \text{ ft}^2/\text{d}$$

Steady-state solution:

$$\frac{C}{C_{in}} = \frac{4 a \exp(P/2)}{(1+a)^2 \exp(aP/2) - (1-a)^2 \exp(-aP/2)}$$

$$P = \frac{UL}{D} = \frac{200 \text{ ft/d} \cdot 200 \text{ ft}}{1000 \text{ ft}^2/\text{d}} = 40$$

Note,  $L$  is doubled for baffled tank

$$a = \sqrt{1 + \frac{4 K t_R}{P}}$$

$$a = \sqrt{1 + \frac{4 \text{ 1/day 1 day}}{40}} = 1.05$$

$$\frac{C}{C_{in}} = 0.38$$

$$C = 76 \text{ mg/L} \quad .62\% \text{ removal}$$

If tank is assumed to provide plug flow:

$$\frac{C}{C_{in}} = e^{-Kt_R}$$

$$= 0.37$$

$$C = 74 \text{ mg/L} \quad 63\% \text{ removal}$$

Baffled tank is nearly plug flow!

c.  $H = 5.3$  feet deep (same as Part b)

$$R_h = 4.4 \text{ ft}$$

$$U = 100 \text{ ft/d}$$

$$D = 1700 \text{ ft}^2/\text{d}$$

$$P = 5.8$$

$$a = 1.3$$

$$\frac{C}{C_{in}} = 0.41$$

$$C = 82 \text{ mg/L}$$

59% removal

d. Three circular fully-mixed tanks

$$t'_R \text{ for each tank} = \frac{1}{3} \text{ day}$$

$$\frac{t_R}{3} = \frac{1}{3} \text{ day} = \frac{\pi r^2 H}{Q}$$

Use same depth as single tank =  $H = 5.3 \text{ ft}$

$$r = \left[ \frac{\frac{1}{3} \text{ day} \cdot 0.2 \times 10^6 \frac{\text{gal}}{\text{day}} \cdot \frac{1}{7.48} \frac{\text{ft}^3}{\text{gal}}}{\pi \cdot 5.3 \text{ ft}} \right]^{1/2}$$

$$= 23 \text{ feet}$$

$$\frac{C}{C_{in}} = \frac{1}{(1 + K t'_R)^3}$$

$$= \frac{1}{(1 + 1 \text{ day}^{-1} \cdot \frac{1}{3} \text{ day})^3} = 0.42$$

$$C = 84 \text{ mg/L} \quad 58\% \text{ removal}$$

e. Comparison

	Area (ft <sup>2</sup> )	Effluent conc (mg/L)	% Removal
a	5000	100	50
b	5000	76	62
c	5000	82	59
d	5000	84	58

Option b gives best performance but is much more expensive than c which gives nearly as good performance. Need a cost analysis to decide.