Problem Set 7 Draft

Water Treatment
CEEG 340–Introduction to Environmental Engineering
Instructor: Deborah Sills
21 October, 2019

Due Date: Wednesday, 30 October.

Learning Goals:

1. Apply water treatment design parameters to size the unit processes used for coagulation, flocculation, sedimentation, filtration, and disinfection.

Problems:

Submittal Process: Please submit this assignment as two separate hard copies–i.e., PS 7–Part 1 and PS 7–Part 2. I'm grading Part 1 and one of the course graders is grading Part 2. In addition, I recommend that you type your response to Part 1. Thank you!

Part 1

1. *(20 pts)*Please submit this question separately, typed out. Read the linked article about bottled water, and refer to the ASCE code of ethics, Canon 1. Write a short (one paragraph) response to the following scenario based on these two sources: You are an city engineer working for the City of Charleston West Virginia after the water was contaminated with MCHM. After the water is safe to drink (i.e., all the MCHM has washed out) residents, claiming they no longer trust the water, want to continue to use bottled water. The mayor asks you to provide guidance to residents as a news brief, explaining what people should do. Should they use tap water or bottled water?

Part 2

1. *(10 pts)* **FE Formatted (multiple choice) Question—Filtration**
   Determine the number of rapid-sand filters to treat a flow rate of $75.7 \times 10^3 \ \frac{\mathrm{m}^3}{\mathrm{d}}$ if the design [hydraulic] loading rate is 300 $\frac{\mathrm{m3}}{\mathrm{d} \times \mathrm{m}^2}$. The maximum dimension is 7.5 m, and the length to width ratio is 1.2:1.

   (a) 4 filters
   (b) 3 filters
   (c) 6 filters
   (d) 5 filters

   Show your work even though you wouldn't have to for the FE.

2. *(10 pts)* **Disinfection**
   A contact tank that uses 2 mg/L of free chlorine for disinfection was designed to achieve a 3-log inactivation of *Giardia* cysts at T= 10 ^{0}C, and pH = 6.0. The upstream treatment process is scheduled to change, and the water entering the contact tank will have a pH of 7.

(a) Using Table 1, describe (with numbers) how this change in pH will affect the required Ct for the contact tank?

(b) Describe three ways the water treatment plant can accommodate this change in pH?

Table 1: **Ct values (in $\frac{\text{mg}\times\text{min}}{\text{L}}$) for a 3-log inactivation of *Giardia* cysts by free chlorine at 10 ^{0}C** (adapted from EPA, 1991).

Chlorine Concentration (mg/L)	pH = 6	pH = 7
1.8	86	122
2.0	87	124
2.2	89	127
2.4	90	129
2.6	92	131

3. **Conceptual Design of Water Treatment Plant**

You have been asked to design a water treatment facility to meet the following criteria:

- Design capacity = 3.25 MGD
- Source is river water with an initial turbidity of 10 NTU, an alkalinity concentration of 50 mg/L as $CaCO_3$, at 10 ^{0}C, with dynamic viscosity of $1.307 \times 10^{-3}\ \frac{\text{N}\times\text{s}}{\text{m}^2}$ and pH = 7.
- Unit operations: coagulation (rapid mix), flocculation, sedimentation, rapid sand filtration, and disinfection, based on the design parameters presented in Table 1.
- Additional constraints: (1) Units must be sized according to acceptable ranges (see Table 1); (2) Design must accommodate maintenance and repair—i.e., the option for one or more units to be out of service (O.O.S.); (3) Design should consider cost–i.e., lowest cost.
- Complete the design according to the following sequence:

(a) *(10 pts)* ***Coagulation.*** Optimal alum dose was determined to be 35 mg/L. Calculate tonnes of alum and tonnes of alkalinity (in units of as CaCO3)—if needed—required per year. Determine the size of mixing tanks, and power of mixing motors. State the number of tanks, and mixers in service and on site.

(b) *(10 pts)* ***Flocculation.*** Use tanks with triple sections in series, with one horizontal paddle mixer in each section (let me know in class if you don't know what this means), and allow for one tank (including mixer) to be out of service. Determine size of flocculation tanks, and power of mixing motors. State the number of tanks, and mixers in service and on site.

(c) *(10 pts)* ***Sedimentation.*** Determine the number of tanks on site, and area of each tank. Allow for one tank to be out of service. Note that common length-to-width ratios for settling are between 2:1 and 5:1, lengths seldom exceed 100 m, and a minimum of two tanks is always provided. You do not need to design the weir boxes for this assignment.

(d) *(10 pts)* ***Rapid Sand Filtration.*** Determine the number of filters on site, and the area of each filter. Assume that the duration of backwash is eight hours—this means that the design should allow for 2 filters to be out of service (one undergoing backwash and one maintenance).

(e) *(10 pts)* ***Disinfection.*** Determine the size and number of contact tanks, reactor type, and chlorine dose to maintain 2 mg/L residual with 40% on-site consumption due to oxidation and side reactions. Design should allow for one contact tank to be out of service. Design for average hourly flow.

(f) *(10 pts)* Prepare a computer generated block-flow diagram (in Autocad) of necessary unit operations with dimensions, in proper order.

Table 2: **Typical values used in design of water treatment systems** (adapted from our textbook).

Unit Operation	**Design Basis**	**Calculate**
Coagulation–rapid-mix tank	$\theta = 1$–2 min $\bar{G} = 600$–$1000\ s^{-1}$ Coagulant type	Volume Number of tanks Mixing Power (P) Coagulant dose Alkalinity req'd
Flocculation Tanks	$\theta = 10$–30 min $\bar{G} = 20$–$50\ s^{-1}$ (horiz. paddle) $\bar{G} = 10$–$80\ s^{-1}$ (vertical shaft)	Volume Number of tanks Mixing power (P)
Sedimentation Tanks	$\theta = 2$–4 h OFR = 700–1400 gpd/ft^2 Weir loading rate = 20,000 gpd/ft	Area Number of tanks
Filtration (Rapid Sand)	Hyd. loading rate = 2–6 gpm/ft^2 Depth = 2–6 ft	Area Volume Number of filters
Chlorination	$\theta_{min} = 15$ min (at peak hourly flow) $\theta_{min} = 30$ min (at average hourly flow)	Volume Chlorine dose