CEE 371	November 23, 2009

Exam #2

Please grade the following questions:

1, 2, 3
6, 7, 8

Circle two from each row. You must answer 4, 5, 9 and 10

Closed Book, two sheets of notes allowed
Please answer questions 4, 5, 9 and 10. In addition, answer two questions from 1-3 and two from 6-8. The total potential number of points is 100. Show all work. Be neat, and box-in your answer.

A. Water Quality & Regulations: Answer any 2 of the following 3 questions (5 points each)

1. Standards

What does the multiple barrier approach refer to? Explain. (5 points)

2. Definition 1

How are primary and secondary drinking water standards different? Give two examples of each. (5 points)

3. Definition 2

Define the term "pathogen", and give two examples. (5 points)

B. Disinfection: Answer both question #4 and question #5 (30 points total)

4. Disinfection Effectiveness (7 points)

Name 4 different disinfectants used in drinking water treatment. Discuss the relative efffectivenss of each and the pros and cons of using the 4 you have named. (7 points)

5. Tracer Problem (23 points)

The hydraulics of the disinfection contact tank at a water treatment plant are described by Figure 1 showing continuous (or step) input tracer study results (C_{out}/C_0 vs. time) for a flow of 1.5 MGD at a mean hydraulic detention time of 42 minutes. Some US EPA stipulated requirements for "Ct" values are described in Table 1.

Figure 1. Normalized Tracer Study Results

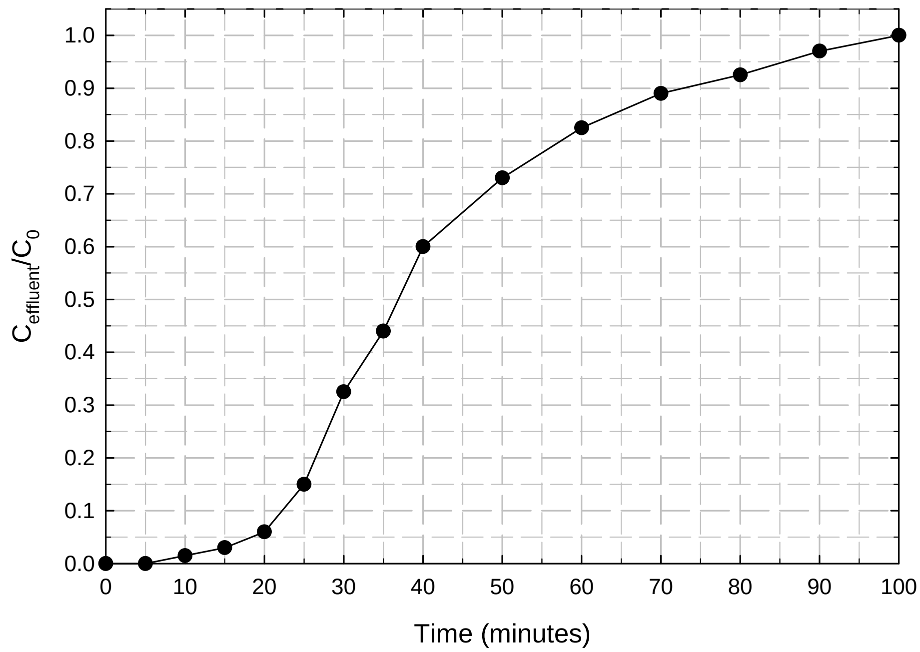

Table 1.

Disinfectant	**Ct values (mg L^{-1} min) for *Giardia* Inactivation, water temp of 5ºC**	
	1 log	**3 log**
Free Chlorine, pH=6.0	35	105
Free Chlorine, pH=8.0	72	216
Chlorine Dioxide	8.7	26
Ozone	0.63	1.9
Chloramine	735	2200

(Ignore any chlorine concentration effects on Ct.)

a) **(7 Pts)** Name the two chemical forms of free chlorine. Calculate the ratio of the concentrations of the two forms at pH 6 and also at pH 8.

b) **(7 Pts)** If you needed to achieve 1 log inactivation of *Giardia*, how much of a dose would you need if you were going to use chlorine at pH 8. Assume the reactor hydraulics shown in Figure 1 represent those of your contact tank. Also, assume that the chlorine demand is 0.9 mg/L and you're calculating this for a water temperature of 5 ºC.

c) **(5 Pts)** Assume you're treating a groundwater with 1.2 mg/L of ferrous iron. Also assume you have essentially no other reduced substances, nor any appreciable organic carbon. Estimate the chlorine demand. Show your work.

d) **(2 Pts)** What are the two most commonly used secondary disinfectants?.

e) **(2 Pts)** Name two specific treatment processes that can be used to provide a barrier against pathogen contamination of drinking water without the addition of treatment chemicals.

C. Coagulation and Flocculation: Answer any 2 of the following 3 questions (6 points each)

6. Coagulants (6 points)

The design flow for a water treatment plant (WTP) is 0.5 MGD (1.9×10^3 m^3/d). Jar testing shows that the best alum dosage will be 40 mg/L. What is the quantity of alum needed on a daily basis in kg/d? Name one other common coagulant that you might want to test with this water.

7. Power (6 points)

What power input (in kW) is required to achieve a mixing intensity (G) of 550 sec^{-1} in a mechanical rapid mixing tank with a mean hydraulic detention time of 50 seconds at a water flow of 0.5 MGD (1.9×10^3 m^3/d)? Assume a water temperature of 10 ºC.

8. Flocculation Design (6 points)

Consider the flocculation process used in drinking water treatment:

a) What is the main objective of this treatment process, and what is a typical design value for the mean hydraulic detention time of the process?

b) Name three different ways you can increase the degree of mixing in a flocculation tank with horizontal shaft paddle flocculators

D. Settling and Filtration: Answer both question #9 and #10 (48 points total)

9. Settling (30 points)

A single rectangular sedimentation basin is to be designed to treat a water flow of 0.5 MGD at the design overflow rate of 800 gpd/ft^2 .

a) **(10 Pts)** Determine the basin dimensions (width, length, depth) for a detention time of 5 hours and a length to width ratio of 3 to 1. (use English units)

b) **(10 Pts)** Assuming the sedimentation tank behaves like an ideal plug flow reactor, determine the diameter that corresponds to a particle that will be 50%

removed by this tank. Assume your particle has a density of 1100 kg/m^3 and tha the water temperature is 10 ºC.

c) **(5 Pts)** If the flow rate to the sedimentation tank doubled, and if the depth of the tank was doubled as well, would the particle removal efficiency decrease, stay the same, or increase? Briefly explain.

d) **(5 Pts)** Suppose you decided to convert the gravity settling tank to a dissolved air flotation process, incorporating a flotation tank the same size as the settling tank. Would the efficiency of particle removal, increase, decrease or stay the same. Explain your answer.

10. Filtration (18 points)

Consider the design and use of a dual media filter for drinking water treatment with the following characteristics:

• <u>Anthracite Layer</u> 24 inch depth	<u>Sand layer</u> 12 inch depth
Effective Size (ES): 1.1 mm	ES: 0.50 mm
d_{60} size: 1.45 mm	d_{60} size: 0.60 mm
Porosity: 0.40	Porosity: 0.38

a) **(2 Pts)** What is the value of the Uniformity Coefficient for the anthracite media?

b) **(3 Pts)** If the design hydraulic loading rate is 5 gpm/ft^2, what is the approach, or superficial, velocity? <u>Express in units of ft/min</u>.

c) **(4 Pts)** Calculate the detention time (in minutes) throught the entire depth of the filter at the design hydraulic loading rate of 5 gpm/ft^2.

d) **(7 Pts)** At the design hydraulic loading rate, what is the clean bed head loss for the for the entire filter for a water temperature of 60 ºF? Use the Carmen-Kozeny equation with k = 5, and use the d_{60} value for media size.

e) **(2 Pts)** What is the unit filter run volume (UFRV) if the filter run length is 48 hours?

Good stuff to know

Conversions

7.48 gallon = 1.0 ft^3 1 gal = 3.7854×10^{-3} m^3

1 MGD = 694 gal/min = 1.547 ft^3/s = 43.8 L/s

1 ft^3/s = 449 gal/min

g = 32 ft/s^2

W=γ = 62.4 lb/ft^3 = 9.8 N/L

1 hp = 550 ft-lbs/s = 0.75 kW

1 mile = 5280 feet 1 ft = 0.3048 m

1 watt = 1 N-m/s

1 psi pressure = 2.3 vertical feet of water (head)

At 60 ºF, $\nu = 1.217 \times 10^{-5}$ ft^2/s

Water Properties:

At 60 ºF, $\nu = 1.217 \times 10^{-5}$ ft^2/s , $\mu = 2.359 \times 10^{-5}$ $lb\text{-}sec/ft^2$, $\gamma = 62.4$ lb/ft^3

At 10 ºC, $\nu = 1.306 \times 10^{-6}$ m^2/s , $\mu = 1.307 \times 10^{-3}$ kg/m-s , $\rho = 999.7$ kg/m^3

Chemistry

K_a for free chlorine is $10^{-7.5}$

PHYSICAL AND CHEMICAL CONSTANTS

Avogadro's number	$\mathcal{N} = 6.022 \times 10^{23}$ mol^{-1}
Elementary charge	$e = 1.602 \times 10^{-19}$ C
Gas constant	$R = 8.314$ J mol^{-1} K^{-1}
	$= 1.987$ cal mol^{-1} K^{-1}
	$= 0.08205$ L atm mol^{-1} K^{-1}
Planck's constant	$h = 6.626 \times 10^{-34}$ J s
Boltzmann's constant	$\mathbf{k} = 1.381 \times 10^{-23}$ J K^{-1}
Faraday's constant	$F = 9.649 \times 10^{4}$ C mol^{-1}
Speed of light	$c = 2.998 \times 10^{8}$ m s^{-1}
Vacuum permittivity	$\varepsilon_0 = 8.854 \times 10^{-12}$ J^{-1} C^{2} m^{-1}
Earth's gravitation	$g = 9.806$ m s^{-2}

CONVERSION FACTORS

1 cal	= 4.184 joules (J)
1 eV/molecule	= 96.485 kJ mol^{-1}
	= 23.061 kcal mol^{-1}
1 wave number (cm^{-1})	= 1.1970×10^{-2} kJ mol^{-1}
1 erg	= 10^{-10} kJ
1 atm	= 1.01325×10^{5} Pa
1 Å	= 10^{-10} m
1 L	= 10^{-3} m^3

PROPERTIES OF WATER

T(°C)	ρ, Density (kg · m^{-3})	μ Viscosity (kg · m^{-1} · s^{-1})	σ, Surface Tension against Air (J · m^{-2})	ε Dielectric Constant (C · V^{-1} · m^{-1})	pK_w, Ionization Constant (mol^2 · L^{-2})
0	999.868	0.001787	0.0756	88.28	14.9435
5	999.992	0.001519	0.0749	86.3	14.7338
10	999.726	0.001307	0.07422	84.4	14.5346
15	999.125	0.001139	0.07349	82.5	14.3463
20	998.228	0.001002	0.07275	80.7	14.1669
25	997.069	0.0008904	0.07197	78.85	13.9965
30	995.671	0.0007975	0.07118	77.1	13.8330

SI PREFIXES

Multiplication Factor	Prefix	Symbol	Multiplication Factor	Prefix	Symbol
10^{12}	tera	T	10^{-2}	centi	c
10^{9}	giga	G	10^{-3}	milli	m
10^{6}	mega	M	10^{-6}	micro	μ
10^{3}	kilo	k	10^{-9}	nano	n
10^{2}	hecto	h	10^{-12}	pico	p
10^{1}	deka	da	10^{-15}	femto	f
10^{-1}	deci	d	10^{-18}	atto	a