National Exams December 2005

98-Civ-B5/Env-B2, Water Supply & Wastewater Treatment

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is an OPEN BOOK EXAM.
   Any non-communicating calculator is permitted.

3. Answer all questions in Part A, and either Questions **B1and B2** *OR* **B3 and B4.**

4. Values of all questions are indicated.

5. Most questions require an answer in essay format. Clarity and organization of the answer are important.

PART A (Total = 60 marks) - all questions must be answered - Civ-B5/Env-B2 – 2/5 Dec/05

A1. (12 marks)

a) (3 marks) Define the meanings of the terms *coagulation* and *flocculation* in reference to destabilization of colloidal suspensions and explain how these are implemented in drinking water treatment.

b) (3 marks) The results from a jar test for coagulation of turbid alkaline raw water are given in the table. Each jar contained 1000 ml of water. The aluminum sulfate solution used for chemical addition had a strength such that each milliliter of the solution added to a jar of water produced a concentration of 8.0 mg/l of aluminum sulfate. Based on the jar test results, what is the most economical dosage of aluminum sulfate in mg/1?

Jar	Aluminum Sulfate Solution (ml)	Floc Formulation
1	1	None
2	2	Smoky
3	3	Fair
4	4	Good
5	5	Good
6	6	Very heavy

If another jar had been filled with freshly distilled water and dosed with 5 ml of aluminum sulfate solution, what would have been the degree of floc formation?

c) (6 marks) Treatment of a water supply requires 60 mg/1 of ferric chloride as a coagulant. The natural alkalinity of the water is 40mg/1. Based on theoretical chemical reactions, what dosage of lime as CaO is required to react with the ferric chloride after the natural alkalinity is exhausted?

A2. (12 marks)

a) (4 marks) Why must granular-media filtration in water treatment be preceded by chemical coagulation?

b) (4 marks) What is the major advantage of a dual-media coal-sand filter compared to a conventional sand filter?

c) (4 marks) In a gravity filter, how can the head loss gauge record a 9-ft loss when the water depth above the filter media surface is only 3.5 ft? What is "air binding" in a filter?

A3. (12 marks) Compute the lime dosage needed for selective calcium-removal softening of the water described by the following analysis. What is the finished water hardness?

Ca^{2+} = 63 mg/l Mg^{2+} = 15 mg/l Na^{+} = 46 mg/l
CO_3^{2-} = 16 mg/l HCO_3^{-} = mg/l SO_4^{2-} = 80 mg/l Cl^{-} = 10 mg/l

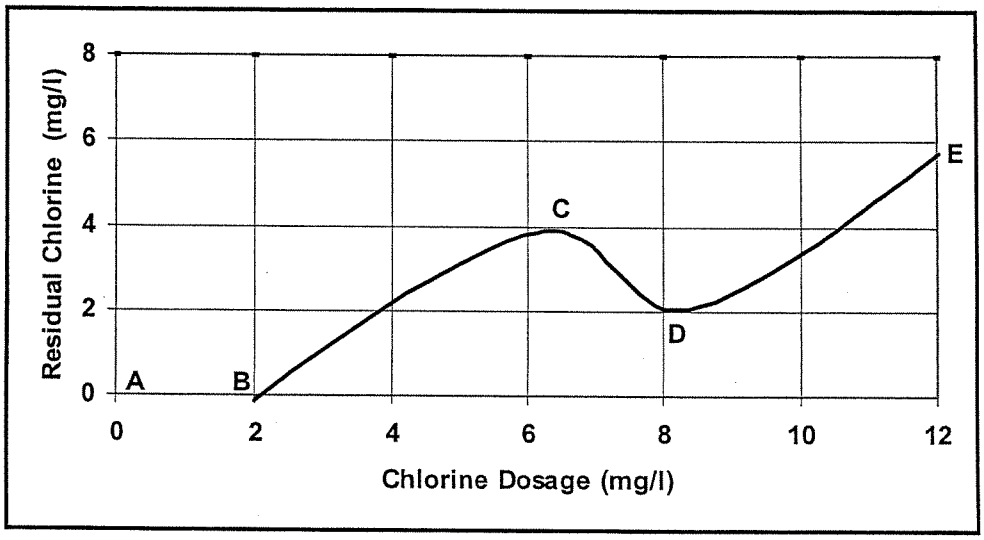
A4. (8 marks) An aerated clarifier-type unit for grit removal is 12 ft square with an 8 ft. liquid depth. The wastewater flow is 0.8 million gallons per day (mgd), with an estimated grit volume of 3 ft^3 /million gal. A separate hopper-bottomed grit storage tank had a usable volume of 3 yd^3. Compute the detention time in the aerated unit and the estimated length of time required to fill the storage tank with grit assuming 90% grit removal efficiency in the unit.

A5. (16 marks) The SWTR specifies a Ct (where C is the concentration of free chlorine and t is the contact time) value of 14mg.min/l for 90% reduction of *Giardia Lamblia* at a temperature of 25°C and pH of 7. Assuming that disinfection reaction rate constant doubles for every 10 C size a chlorine contact chamber to achieve 99.9% removal of *Giardia Lamblia* for a 10,000 m^3/d drinking water plant at neutral pH and a maximum temperature of 35°C assuming a free chlorine dose of 10mg/l. If calcium hypochlorite $Ca(OCl)_2$ is added as a chlorine source what is the daily does required if the minimum water temperature is 5°C what would be the required does of calcium hypochlorite to treat the 10,000 m^3/d flow?

B1. (20 marks)

a. (10 marks) For the breakpoint chlorination curve shown below, determine:

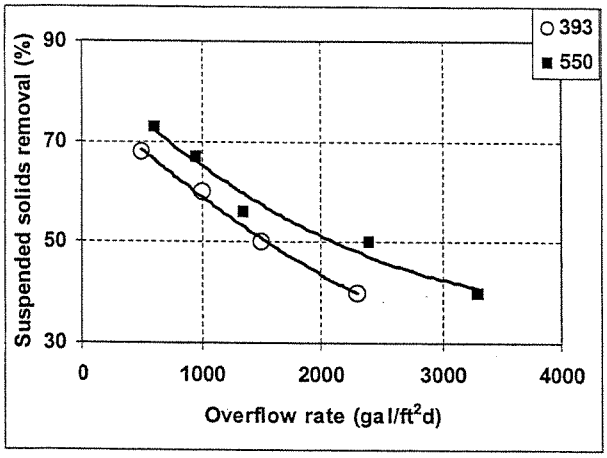
i) The chlorine demand exerted by reduced inorganic species i.e. Fe^{2+}, S^{2-}
ii) Chlorine demand at breakpoint
iii) The highest combined chlorine residual
iv) The chlorine dose needed to achieve a free residual of 2 mg/l and the total residual at that dose

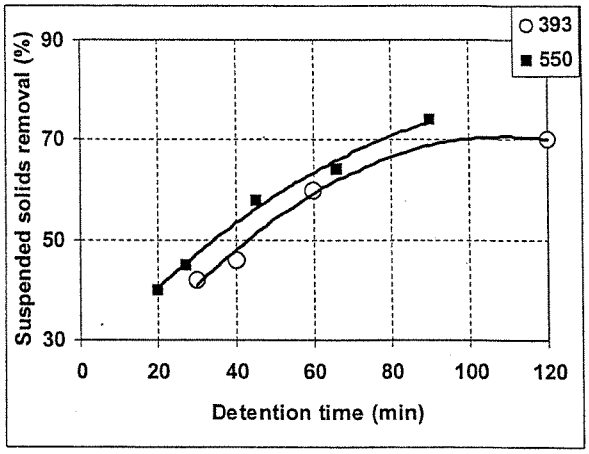


b. (3 marks) What are the effects of pH on the disinfection power of Cl_2 ?

c. (7 marks) What average intensity must be provided in a UV system to achieve 99.99% removal of an indicator organism with an inactivation rate constant of 0.001 m^2/J and detention time of 2 minutes in the UV zone? What would the removal efficiency after 5000 hours of operation, if the system was designed to meet the 99.99% efficiency after 10,000 hours of operation. Assume lamp output decreases by 20% and 28% respectively after 5,000 and 10,000 h of operation respectively.

B2. (20 marks) An industrial wastewater from a paper-mill had initial suspended solids concentration of 393-550 mg/l. The settling characteristics, as derived form a laboratory flocculent settling column data of the wastewater, are shown below. The design of the downstream biological treatment system is based on a TSS concentration not exceeding 150 mg/L. Determine the surface area, depth, and detention time of the primary clarifier to achieve the required TSS removal efficiency for a wastewater flow rate of 1 million US gallons per day. Assume a safety factor of 1.5 and 1.75 for scale-up design over flow rate and detention time respectively.





Note: gal/ft^2.d = 4.07 x 10^{-2} m^3/m^2.d

B3. (25 marks) You are to design a completely-mixed activated sludge system to treat 2300 m^3/d of filtered tomato-processing wastewater with the following characteristics:

COD = 5000 mg/l BOD = 3000 mg/l TKN =100 mg/l

To achieve effluent COD = 150 mg/l, TSS = 50mg/l, and VSS = 40mg/l. The facility has an existing clarifier which is intended for use a secondary clarifier' however in order to meet the effluent VSS criterion of 40mg/l, the feed to the clarifier shall not exceed 4500 mg VSS/l. Respirometry conducted on the wastewater revealed the following biokinetic coefficients

μ_{max} = 2.0 d^{-1} K_d=0.05d^{-1} Y=0.45 mg VSS/mg COD K_s=100mg COD/L

Calculate the following:

i) hydraulic retention time in aeration tank and volume of aeration tank
ii) design biological solids residence time (SRT) and minimum SRT
iii) quantity of waste sludge in kg/d
iv) food-to-microorganism ratio
v) aeration requirements in kg O_2/d
vi) nitrogen requirement for biomass synthesis.
Is there sufficient N in the wastewater?

B4. (15 marks). A city has a population of 5000 persons and is to be served by a high-rate trickling filter with a recycle ratio of 2. Pertinent data for the plant are: wastewater flow = 380 L/cap.d, primary effluent BOD_5 = 150 mg/l, final effluent BOD_5 = 25mg/l. Treatability constant (k) derived from pilot studies using a 20 ft deep filter at 20°C is 0.1 (gal/min)$^{0.5}$ft. The minimum and maximum operating temperatures are 10°C and 30°C respectively. You are to design a 25 ft deep rock circular filter, calculate the following:

a) filter area b) organic loading c) final effluent BOD during summer