

National Examinations, May 2004
98-Env-A4, Physical, chemical and Biological Processes
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 clean statement of any assumptions made.
2. This is an open-book exam. Only **ONE** textbook of their choice is allowed but no notes.
3. Any non-communicating calculator is permitted
4. Do Questions 1 and 2 plus any three of questions 3 to 6. Therefore, you should answer a total of five (5) questions. If you answered more than five questions, only the first five of them will be marked.
5. All questions are of equal value (20% of the total mark for each question).

Front Page

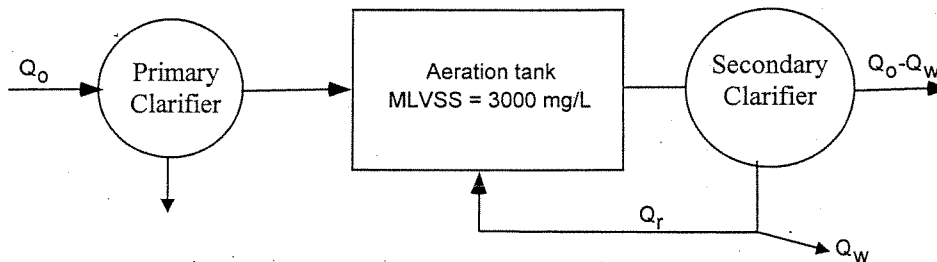
QUESTION 1

Laboratory studies on a municipal wastewater showed that the COD biodegradation follows Monod model with the following kinetic parameters:

saturation coefficient $K_s = 170$ mg/L of BOD₅,
 maximum substrate utilization rate coefficient $k = 4.5$ d⁻¹,
 yield coefficient $Y = 0.45$ mg VSS/mg COD,
 decay rate constant $k_d = 0.05$ d⁻¹,

The COD in the influent is 375 mg/L, of which 15 mg/L is non-biodegradable. The suspended solids in the influent is negligible.

- Design a completely mixed activated sludge system with sludge recycle as shown below to achieve an overall COD removal efficiency of 95%. Additional design criteria are: hydraulic capacity = 10,000 m³/day, mean hydraulic detention time = 6 hours, and mixed liquor volatile suspended solids (MLVSS) in the aeration tank = 3000 mg/L. Estimate the aeration tank volume, sludge retention time, daily sludge production rate, oxygen utilization rate and sludge recycle ratio.
- If biological nitrification is to be added to this plant, quantitatively explain what effects would be expected on sludge production rate, oxygen utilization rate, and mixed liquor suspended solids.

**QUESTION 2**

A two-stage high-rate trickling filter plant is to be designed to treat a municipal wastewater with a flow rate of 5,000 m³. Pertinent data are: temperature = 20 °C, influent BOD₅ = 220 mg/L, filter bed depth = 2 m, first- and second-stage filters have same BOD₅ removal efficiency, recycle ratio = 1.2 for each filter. The effluent BOD₅ must be 20 mg/L or less.

- Determine the surface areas of these filters using NRC method.
- List at least three common operational problems when the trickling filters are used in cold regions.

QUESTION 3

A particle-size distribution has been obtained from a sieve analysis of sand particles as summarized below. The average settling velocity for each weight fraction has been calculated based on Stoke's law at 20 °C.

Remaining weight fraction, %	0.55	0.46	0.35	0.21	0.11	0.03
Settling velocity, m/min	3.0	1.5	0.60	0.30	0.22	0.15

- What is the overall removal in an ideal settling tank for an overflow rate of 3000 m³/m²/d?
- Whether the removal efficiency will increase, decrease or not change, if: 1) the surface area of the sedimentation tank is reduced, or 2) the tank depth is increased from 2.5 to 3.0 m

QUESTION 4

A dual medium filter used in a water treatment plant is composed of 0.4m anthracite placed over a 0.5m layer of sand. Their main properties of media are summarized below:

Sand: diameter = 0.5mm, porosity = 0.45, sphericity factor = 0.80, density = 2650 kg/m³
 Anthracite: diameter = 1.0mm, porosity = 0.50, sphericity factor = 0.70, density = 1500 kg/m³

- Suggest the diameter of anthracite medium to prevent excessive medium intermixing after backwash.
- Calculate the headloss in the clean filter bed, assuming a filtration rate of 8 m/h.

QUESTION 5

A water treatment plant plans using excess lime-soda ash softening process to reduce hardness. Its partial analysis shows the following composition:

pH	7.0
Temperature	20 °C
Alkalinity	220 mg/L @ CaCO ₃
Calcium ions	100 mg/L
Magnesium ions	12.2 mg/L
Sodium ions	12.5 mg/L
Chloride	36.5 mg/L

- Determine the lime and soda ash dosage required to soften the water.
- Estimate the hardness in the treated water.

QUESTION 6

A surface water treatment plant employs the direct filtration, followed by chlorination to treat cold, low-turbidity water with a capacity of 10,000m³/d at a design temperature of 0.5 °C. The filtered water has a turbidity of less than 0.1 NTU, and pH of 7.5. The residual chlorine from the chlorine contactor must be 1.0 mg/L or higher. The previous tracer study showed that the chlorine contactor can be represented by two CSTR-in-series.

- a) What would be the volume of the chlorine contactor and the applied chlorine dose to meet a 99.9% removal of an indicator microorganism? Assume that chlorine decay rate constant is 2 day⁻¹ and the disinfection kinetics for the indicator microorganism is:

$$-\frac{dN}{dt} = KCN$$

where N is the number of living microorganisms, t is contact time, min, K is rate constant (= 0.015, (mg/L)⁻¹ · min⁻¹) and C is chlorine concentration, mg/L.

- b) Based on the above calculation, what would you suggest to improve the performance of the existing disinfection system?

MARK SCHEME

All the problems are of equal value, i.e., 20% of the total mark for each problem. Specifically, the suggested marking scheme is:

1. (a) 15 marks, (b) 5 marks.
2. (a) 14 marks, (b) 6 marks.
3. (a) 10 marks, (b) 10 marks.
4. (a) 10 marks, (b) 10 marks.
5. (a) 15 marks, (b) 5 marks.
6. (a) 15 marks, (b) 5 marks.