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The Open University of Sri Lanka

Faculty of Engineering Technology

Department of Civil Engineering

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: CVX4348 - Water and Wastewater Engineering**
Academic Year	: 2023/2024
Date	: 12th March 2025
Time	: 0930 hrs-1230hrs
Duration	: **3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **seven (7)** questions in **six (6)** pages.
3. Answer any **Five (5)** questions only. All questions carry equal marks.
4. Answer for each question should commence from a new page.
5. Relevant charts / codes / equations are provided in last page
6. This is a Closed Book Test **(CBT).**
7. Answers should be in clear handwriting.
8. Do not use the red colour pen.

Question 1

(a) (i) Explain why a protected water supply is essential for a community. Provide at least three reasons.

(ii) Explain the difference between shallow wells and deep wells in terms of water quality and the layers from which they draw water. (3 Marks)

[05 marks]

(b) (i)Explain the importance of aeration in water treatment. What are the main purposes of aeration in a water treatment plant?

(ii) Describe the role of sedimentation and filtration in a typical water treatment process. How do these processes contribute to making water safe for consumption?

(iii) If the surface loading rate (SLR) for a sedimentation tank is 25 $m^3/m^2/day$ and the average daily wastewater flow rate is 10,000 m^3/day, calculate the required surface area of the tank.

[08 marks]

(c) (i) Explain the purpose of a distribution reservoir in a water supply system. List at least three functions it serves.

(ii) A town has an annual water consumption of 5,000 ML for a population of 50,000. Calculate the average daily per capita water supply rate and the total quantity of wastewater generated per day, assuming 80% of the water supplied is converted to wastewater

[07 marks]

Question 2.

(a) (i) A town has a population of 50,000, and the average daily water demand is 200 liters per capita. Calculate the total daily water demand for the town. If the town uses a Circular or Ring System for water distribution, explain why this system is beneficial for firefighting purposes.

(ii) What are the main functions of gate valves in a water distribution system?

[06 marks]

(b) (i)Explain the working principle of a cascade aerator. How does it facilitate the removal of gases like CO_2 and H_2S from water?

(ii)Explain the purpose of pre-chlorination in water treatment. Under what conditions is pre-chlorination most effective?

(iii)Describe the effects of hardness in water. Why is it important to remove hardness from water used in industrial processes?

[06 marks]

(c) (i) Discuss the importance of rapid mixing in the coagulation process and how poor mixing can affect the performance of the process. (2 marks)
(ii) Explain how the jar test helps in determining the optimal coagulant dose for a water treatment plant.
(iii) Calculate the power dissipated (P) in a mixing tank if the flow rate (Q) is 0.05 m^3/s and the head loss (ΔH) is 0.3 m. Use the formula:
$P=\rho \cdot g \cdot Q \cdot \Delta H$ where $\rho=1000$ kg/ and $g=9.81$ m/s^2

[08 marks]

Question 3

(a) A horizontal flow settling tank has the following dimensions:

- Length (L) = 40 m
- Width (B) = 10 m
- Height (H) = 3 m
- Flow rate (Q) = 0.4 m^3/s

(i) Calculate the surface loading (q) of the tank.

(ii) Determine the critical settling velocity (v_{so}) for this tank.

(iii) If the settling velocity of a particle is 0.0006 m/s, will this particle be completely removed in the tank? Justify your answer.

(iv) Explain how turbulence affects the settling of particles in a horizontal flow settling tank.

[07 Marks]

(b) A city water treatment system requires a settling tank to handle a maximum flow rate of 0.6 m^3/s. The design overflow rate is 30 $m^3/d \cdot m^2$.

(I) Calculate the required surface area (A_s) for the settling tank.

(II) If the tank is to be divided into 4 equal-sized tanks, calculate the surface area for each tank.

(III) Assuming a width of 5 m for each tank, determine the length (L) of each tank and check if the length-to-width ratio is acceptable (acceptable range: 6:1 to 12:1).

[06 Marks]

(c) A rapid sand filter is designed to handle a flow rate of 0.5 m^3/s. The filtration rate is 10 m/h.

(I) Calculate the required surface area (A) of the filter.

(II) If the filter is divided into 4 equal-sized tanks, calculate the surface area for each tank.

(III) Assuming a width of 5 m for each tank, determine the length (L) of each tank and check if the length-to-width ratio is acceptable (acceptable range: 6:1 to 12:1).

(IV) Explain the phenomenon of "sand boil" and how it can be prevented.

[07 Marks]

Question 4.

(a) (i) Explain the concept of breakpoint chlorination and sketch a breakpoint chlorination curve, labeling the axes, breakpoint, and regions of predominantly combined and free residual chlorine.

(ii)Calculate the chlorine demand for a water sample if the applied chlorine dose is 5 mg/L and the residual chlorine is 0.2 mg/L.

(iii) Describe the disadvantages of using ozone as a disinfectant.

[07 marks]

(b) (i) Explain the difference between granular activated carbon (GAC) and powdered activated carbon (PAC) in water treatment.

(ii) Calculate the amount of GAC required for a water treatment plant with a flow rate of 10,000 m^3/day, assuming a GAC usage rate of 0.5 g/m^3.

(iii) Describe the advantages of using GAC over PAC for taste and odour control.

[06 marks]

(c) (i) Explain the concept of breakpoint chlorination and sketch a breakpoint chlorination curve, labeling the axes, breakpoint, and regions of predominantly combined and free residual chlorine.

(ii)Calculate the chlorine demand for a water sample if the applied chlorine dose is 5 mg/L and the residual chlorine is 0.2 mg/L. (2 marks)

(iii)Describe the disadvantages of using ozone as a disinfectant.

[07 Marks]

Question 5.

(a) (i) Explain why BOD and SS are important parameters in wastewater treatment.

(ii) A residential community generates 120 L/person/day of wastewater with a BOD concentration of 200 mg/L and suspended solids (SS) concentration of 240 mg/L. Calculate the total BOD and SS generated per capita per day.

(iii) Calculate the BOD equivalent population for this industrial wastewater, assuming an average BOD contribution of 40 g/person/day.

[06 marks]

(b) (i)A metal plating industry discharges wastewater with a COD of 800 mg/L and a BOD_5 of 250 mg/L. Calculate the COD/BOD_5 ratio and interpret whether the waste is easily biodegradable or not.

(ii) Identify three major pollutant categories found in rivers and explain their impact on water quality. Provide at least one source for each pollutant.

(iii) A wastewater sample has an ultimate BOD (Lo) of 250 mg/L and a BOD rate constant (k) of 0.23 day^{-1}. Calculate the (BOD_5) after 5 days.

[06 marks]

(c) A wastewater treatment plant receives an average daily flow of 25,000 m^3/d. The peaking factor is 2.5. Design a horizontal flow grit chamber using the following criteria:

- Detention time at peak flow = 60 seconds
- Flow-through velocity = 0.3 m/s
- Number of channels = 2
- Width of each channel = 1.2 m

(i) Calculate the dimensions (length, width, depth) of one grit chamber channel. Assume a freeboard of 0.3 m and a grit storage depth of 0.2 m.

(ii) Check the surface loading rate (SLR) at peak flow and determine if it meets the typical design range (1,200–1,700 $m^3/m^2 \cdot d$).

(iii) If the grit accumulation rate is 0.05 m^3/1,000 m^3 of flow, calculate the volume of grit accumulated in one channel after 3 days.

[08 marks]

Question 6.

(a) A trickling filter has a diameter of 25 m and **a** depth of 3 m. If the influent BOD is 200 mg/L and the flow rate is 10 MLD, calculate:

(i). The total organic load in kg/day.

(ii). The organic loading rate in kg BOD/m^3/day.

[06 marks]

(b) A primary sedimentation tank is to be designed for a wastewater flow of 50,000 m^3/d. Assume:

- Surface loading rate (SLR) at average flow = 40 $m^3/m^2 \cdot d$
- Detention time = 2 hours
- Weir loading rate (WLR) ≤ 250 $m^3/m \cdot d$

(i) Calculate the required surface area, diameter, and side water depth (SWD) for a circular tank.

(ii) Determine the total weir length needed and propose a design modification if the initial weir length is insufficient.

[08 marks]

(c) A wastewater treatment plant uses a completely mixed activated sludge system to treat an influent with the following characteristics:

- Flow rate (QQ) = 0.2 m^3/s
- Influent soluble BOD55 ($SoSo$) = 220 mg/L
- Effluent total BOD55 requirement = 25 mg/L
- Allowable BOD55 from suspended solids = 10 mg/L
- MLVSS (XX) = 2,500 mg/L
- Growth constants: μm=3.0 d^{-1}, Ks=60mg/L, kd=0.06d−1, Y=0.5mg VSS/mg

(i) Calculate the mean cell residence time (θc) required to achieve the effluent quality.

(ii) Determine the hydraulic retention time (t) and volume (V) of the aeration tank.

[06 marks]

Question 7.

(a) (i) Explain the difference between granular activated carbon (GAC) and powdered activated carbon (PAC) in water treatment.

(ii) Calculate the amount of GAC required for a water treatment plant with a flow rate of 10,000 m^3/day, assuming a GAC usage rate of 0.5 g/m^3.

(ii) Describe the advantages of using GAC over PAC for taste and odour control.

[07 marks]

(b) A wastewater treatment plant discharges effluent into a river. The river has a saturation dissolved oxygen (DOs) of 9 mg/L, and after mixing, the actual DO concentration is 4.5 mg/L.

(i). Calculate the DO deficit after mixing.

(ii). Explain the significance of this deficit for aquatic life.

[06 marks]

(c) A canary industry treatment plant processes 5,000 m^3/day of wastewater with an influent BOD_5 of 380mg/L. The mixed liquor suspended solids (MLSS) concentration in the aeration tank is 3,500 mg/L, and the hydraulic retention time (HRT) is 7 hours.

(i) Estimate the capacity of the tank.

(ii) Calculate the F/M ratio for the treatment system.

(iii) If the operator wants to adjust the F/M ratio to 0.25 d^{-1}, what should the new MLSS concentration be?

[07 marks]

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Supplementary

$$r_u = -\frac{\mu_m S X_{avg}}{K_s + S}$$

$$\frac{1}{\theta_c} = \frac{Y\mu_m(S_o - S)}{(S_o - S) + (1+\alpha)K_s ln(S_i/S)} - k_d$$

$$\frac{F}{M} = \frac{QS_0}{\forall X}$$

$1.47\ Q\ (S_0\text{-}S) - 1.42V(x/\theta_c)$

[$k=k_{20}\vartheta^{(T-20)}$; $BOD_5 = Lo\ (1- e^{-kt})$; $\vartheta = 1.047$]