

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	: CVX7242 - Environmental Engineering Design
Academic Year	: 2023/2024
Date	: 11 ^h March 2025
Time	: 1330-1630hrs
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 an Closed Book Test (**CBT**).
 7. Answers should be in clear handwriting.
 8. Do not use red colour pen.
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Question 1

(a) (i) Explain the law of conservation of mass and its importance in environmental engineering design. Provide an example of how this principle is applied in the design of a wastewater treatment plant.

(ii) Design a primary sedimentation tank (Rectangular) to treat domestic wastewater for a town with a population of 500,000. Assuming the following design criteria:

- Average rate of water supply = 300 lpcd (litres per capita per day)
- Wastewater generation rate = 80% of water supplied
- Suspended solids in wastewater = 350 mg/L
- BOD₅ at 20°C = 250 mg/L
- Surface loading rate (SLR) at daily average flow = 40 m³/m²d
- Detention time = 2.5 hours

[08 marks]

(b) A skimming tank is to be designed for a hotel that produces 600 m³/day of wastewater. The hotel management aims to achieve an oil and grease removal efficiency of 85%.

(i) If the oil and grease concentration in the influent is 250 mg/L and the detention time is 25 minutes, calculate the capacity of the skimming tank.

(ii) Determine the oil and grease concentration in the effluent.

(iii) If the surface loading rate is 300 m³/m²/s, calculate the surface area of the tank.

(iv) Assuming a length-to-width ratio of 4:1, determine the length and width of the tank.

[07 marks]

(c) (i) Discuss the concept of freeboard in the design of treatment units. Why is it important to include freeboard in the design?

(ii) Provide a freeboard of 0.6 m of the above Part (b) and calculate the overall depth and dimensions of the tank.

[05 marks]

Question 2

(a) (i) Explain the law of conservation of mass and its importance in environmental engineering design. Provide an example of how this principle is applied in the design of a wastewater treatment plant.

(ii) Define steady-state conditions in the context of environmental systems. Why is it important to assume steady-state conditions when designing treatment units?

(iii) A lake with a volume of $1,000,000 \text{ m}^3$ receives a polluted stream with a flow rate of $5 \text{ m}^3/\text{s}$ and a pollutant concentration of 50 mg/L . The pollutant decays at a rate of $0.2/\text{day}$. Assuming complete mixing and steady-state conditions, calculate the concentration of the pollutant in the lake

[07 marks]

(b) (i) Explain the concept of materials balance in environmental engineering. How is it used to track pollutants in a system? Provide an example of its application in a wastewater treatment plant.

(ii) A river receives two streams: Stream A has a flow rate of $8 \text{ m}^3/\text{s}$ and a chloride concentration of 25 mg/L , while Stream B has a flow rate of $4 \text{ m}^3/\text{s}$ and a chloride concentration of 40 mg/L . Assuming complete mixing, calculate the chloride concentration downstream of the confluence.

[06 marks]

(c) A factory discharges wastewater containing **Trichloroethylene (TCE)** into a river with an average velocity of 0.8 m/s . The TCE concentration after complete mixing is 0.4 mg/L . A water supply system located 12 km downstream serves a community. Assume a 70 kg person consumes 2 L of water daily for 10 years. The reaction rate coefficient (K) for TCE is $2.1 \times 10^{-4}/\text{day}$.

(i) Estimate the steady-state pollutant concentration at the water intake.

(ii) If the potency factor for TCE is $2.5 \times 10^{-2} (\text{mg/kg-day})^{-1}$, calculate the individual cancer risk due to TCE exposure.

[07 marks]

Question 3

(a) (i) Define surface loading rate (SLR) and explain its significance in the design of sedimentation tanks.

(ii) A sedimentation tank is designed to treat a flow of $12,000 \text{ m}^3/\text{day}$ with an SLR of $30 \text{ m}^3/\text{m}^2\text{d}$. Calculate the surface area of the tank.

[05 marks]

(b) (i) Discuss the role of detention time in the design of treatment units. How does it affect the efficiency of pollutant removal?

(ii) A treatment tank has a volume of $10,000 \text{ m}^3$ and receives a flow of $5,000 \text{ m}^3/\text{day}$. Calculate the detention time of the tank.

[05 marks]

- (c) (i) Explain the purpose of an equalization tank in a wastewater treatment plant.
- (ii) A treatment plant requires an equalization basin with an average daily flow rate of $0.5 \text{ m}^3/\text{s}$. If the overflow rate is $30 \text{ m}^3/\text{m}^2\text{d}$ and the detention time is 2.5 hours, calculate the volume of the primary sedimentation tank. Assume the depth of the basin is 4.0 m.
- (iii) If an equalization tank is installed ahead of the primary sedimentation tank, reducing the average flow to $0.45 \text{ m}^3/\text{s}$, calculate the new overflow rate and detention time of the primary sedimentation tank.

[10 marks]

Question 4

- (a) (i) Explain the concept of volumetric loading in the design of treatment units. How is it related to the capacity of a treatment tank?
- (ii) A treatment tank has a volume of $20,000 \text{ m}^3$ and receives a flow of $10,000 \text{ m}^3/\text{day}$. Calculate the volumetric loading rate of the tank.

[06 marks]

- (b) An aeration system with a hydraulic retention time of 6 hours receives a flow of $2000 \text{ m}^3/\text{day}$ at a BOD of 1400 mg/L . The mixed liquor suspended solids (MLSS) concentration is 4000 mg/L , and the effluent BOD is 25 mg/L .

- (i) Calculate the volume of the aeration tank.
- (ii) Determine the F/M ratio (Food to Microorganisms).

[06 marks]

- (c) A city with a population of 200,000 generates an average wastewater flow of 40 MLD. The primary sedimentation tank needs to be designed to remove 60% of the suspended solids. The tank should have a detention time of 2 hours and a surface loading rate (SLR) of $40 \text{ m}^3/\text{m}^2/\text{d}$ at average flow.

- (i) Calculate the surface area and volume of the tank.
- (ii) Determine the dimensions of the tank (diameter and depth) if it is circular.
- (iii) Check the weir loading rate (WLR) and suggest modifications if it exceeds the recommended range.

[08 marks]

Question 5

- (a) A sample of mixed liquor suspended solids (MLSS) from a treatment plant has a concentration of 4,000 mg/L. After 30 minutes of settling in a 1-liter Imhoff cone, the settled sludge volume is 400 mL. Calculate the Sludge Volume Index (SVI) and comment on the settling quality of the sludge. Based on the SVI, suggest possible adjustments to the treatment process to improve sludge settling.

[05 marks]

- (b) The treatment plant processes 5,000 m³/day of wastewater with an influent BOD₅ of 300 mg/L. The mixed liquor suspended solids (MLSS) concentration in the aeration tank is 2,500 mg/L, and the hydraulic retention time (HRT) is 6 hours.

- (i) Calculate the F/M ratio for the treatment system.
- (ii) If the operator wants to adjust the F/M ratio to 0.3 d⁻¹, what should the new MLSS concentration be?
- (iii) Discuss the long-term implications of operating a treatment plant with an F/M ratio that is too high or too low. How might this affect sludge production, oxygen demand, and effluent quality?

[08 marks]

- (c) Some landfills are operated as bioreactors, where leachate is recirculated to accelerate waste decomposition.

- (i) What are the advantages and disadvantages of operating a landfill as a bioreactor?
- (ii) How does leachate recirculation impact the design and operation of a landfill?
- (iii) After a landfill is closed, the land can be repurposed for various uses, such as parks, golf courses, or even construction sites. What are the key challenges associated with reusing a closed landfill site?

[07 marks]

Question 6

- (a) A city is planning to implement an Integrated Solid Waste Management (ISWM) system to manage its municipal solid waste (MSW). The city manager is considering the hierarchy of waste management strategies, including source reduction, recycling, combustion, and landfilling.

- (i) Explain why source reduction is considered the most desirable option.
- (ii) A city generates 1000 tonnes of municipal solid waste (MSW) per day. The city is planning to implement a recycling program that aims to recycle 30% of the waste. Calculate the amount of waste that will be sent to the landfill if the recycling program is successful.

[06 marks]

- (b) A stack emits gas at a velocity of 5 m/s through a stack diameter of 3 meters. The average wind speed is 7 m/s, and the temperature of the stack gas is 150°C, while the ambient temperature is 20°C. The atmospheric stability is neutral.

- (i) Calculate the plume rise (Δh) using the Briggs model.
- (ii) What is the effective stack height (H) if the physical stack height is 80 meters?

[08 marks]

- (c) With increasing concerns about climate change and air quality, new technologies are being developed to control emissions more effectively.

- (i) Discuss the potential role of carbon capture and storage (CCS) in reducing greenhouse gas emissions from industrial stacks.
- (ii) How can renewable energy sources (e.g., solar, wind) contribute to reducing the need for traditional stack emissions?
- (iii) What are the challenges and opportunities in transitioning to cleaner emission control technologies?

[06 marks]

Question 7

- (a) (i) A treatment plant operator notices that the sludge in the secondary clarifier is not settling properly, leading to high suspended solids in the effluent. The operator suspects that the F/M ratio might be too high or too low. Explain how the F/M ratio affects sludge settling and suggest how the operator could adjust the F/M ratio to improve sludge settling.

- (ii) A wastewater treatment plant is required to remove nitrogen from the effluent to meet regulatory standards. Explain the role of anoxic processes in nitrogen removal and how you would design a treatment system to incorporate both aerobic and anoxic processes for effective nitrogen removal.

[08 marks]

- (b) With increasing concerns about urban noise pollution, new technologies are being developed to control noise more effectively.

- (i) Discuss the potential role of active noise control (e.g., noise-canceling technologies) in reducing highway noise.

- (ii) How can urban planning (e.g., green spaces, building design) contribute to reducing noise pollution in cities?

- (iii) What are the challenges and opportunities in transitioning to calmer (quieter) urban environments?

[07 marks]

- (c) Noise barriers are often constructed along highways to reduce noise pollution, but they are not always effective for all residents. Discuss the limitations of noise barriers and propose alternative or complementary solutions that could enhance their effectiveness.

[05 marks]

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Supplementary

$$CDI \text{ (mg/kg/day)} = \text{Total dose(mg)} / [\text{Body weight(kg)} * \text{Life time (days)}]$$

$$Risk = CDI \times \text{potency factor}$$

$$C(t) = C(0)e^{-Kt}$$

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

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

$$O_2 \text{ required per day} = 1.47 Q (S_o - S) - 1.42 V(x/\vartheta_c)$$

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

$$DO = DO_s - \left[\frac{k_d L_0}{k_r - k_d} (e^{-k_d t} - e^{-k_r t}) + D_0 e^{-k_d t} \right]$$

$$t_c = \frac{1}{k_r - k_d} \ln \left\{ \frac{k_r}{k_d} \left[1 - \frac{D_0 (k_r - k_d)}{k_d L_0} \right] \right\}$$