UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: September-2023

Module Number: CE4305 **Module Name: Water and Wastewater Engineering**

[Three Hours]

[Answer **all questions**. Questions carry **unequal marks**]

[Use **separate books** to answer **Section-A** and **Section-B**]

SECTION – A

Q1. Assume you have been appointed as the leader of **a new water supply project** to provide water to **a coastal city (City-A)** in Sri Lanka. Your first task is to collect relevant information to plan the water supply scheme with your project members. To investigate the feasibility of this new project, the relevant water quality data from different sources, census data, and geographical and geological data have also been collected.

a) Your project members also noted the following **water-related issues** in some areas in City-A.

- *Some well water samples have high concentrations of Fecal Coliform.*
- *Some well waters near the coastal zone have extremely high conductivity.*
- *One lake in the city has been undergoing high eutrophication.*

Name **possible reason/s** for each of the above issues.

[1.5 Marks]

b) i) Your project members also collected the following data relevant to the City-A:

- *The current population of this city was found to be 55,000 (in the year 2023).*
- *The average population growth rate of this city is found to be 450 per year.*
- *Per capita water demand in the City-A (by 2050) = 120 L /Capita/d*
- *Industrial water demand by 2050 = 10 % of the Total Average Water Demand*
- *Commercial and municipal activities' water demand by 2050 = 1200 m^3/d*

Calculate the **total average daily water demand for the City-A by the year 2050**. You may use the simple arithmetical increase method. You may assume the following:

- *NRW (by 2050) = 12 % of the Total Average Water Demand*
- *No fire demand water is considered under this project.*

[2.5 Marks]

ii) Calculate the **maximum daily demand** and **maximum hourly demand** of a maximum day for the City-A by the **year 2050**.

[1.0 Mark]

iii) Your project members have been discussing to design a "**loop system**" for the water distribution network under the proposed project of City-A. Briefly explain the **advantages and disadvantages** of a "**branching system**" and a "**loop system**" in a water distribution network.

[2.0 Marks]

iv) As mentioned in the Q1-(b-i), "**NRW**" value for the proposed project is assumed to be 12%. Several factors contribute to NRW, and they can vary from one location to another. Briefly explain what is meant by "**NRW**" **and reasons for NRW.**

[1.5 Marks]

c) **River water** has been identified as the potential water source for the above project of City-A, which covers only the city limit and surrounding suburban areas. There is a village far from the City-A for which the water demand cannot be covered by the proposed City-A water project. Your project members have identified deep **groundwater** as the potential water source to construct a water supply scheme for this village.

Table Q1 shows the monthly average concentrations of the key water quality parameters of the river and ground water mentioned above. Draw a schematic diagram of a possible treatment train (to satisfy SLS-614) for each of river and ground water, considering engineering, economic and energy factors. Briefly explain the reasons for the selection of the unit operations in each treatment train.

Table Q1: Average concentrations of water quality parameters.

	pH	Turbidity, NTU	Fe, mg/L	Mn, mg/L	Total Coliform, MPN/100 mL	Fecal Coliform, MPN/100 mL
Ground Water (for village)	7.1	4	10	5	3	0
River Water (for City-A)	6.9	65	4	2	16	5

[3.5 Marks]

d) The water intake structure for the proposed water supply project in City-A is planned to be located approximately 5 kilometers upstream from the city center, along the river. Name **four factors** to be considered in **locating an intake structure** at a river.

[2.0 Marks]

Q2. Government authorities are planning to **upgrade an existing water treatment facility** in another city, called **City-B**. This water treatment facility in the City-B has been designed to treat water with a flowrate of **0.175 m^3/s**. Assume that you have been appointed as a consulting engineer for this project.

a) i) The jar tests conducted on the raw water of the existing water treatment facility indicated that the **best alum dose** for this raw water was **7.5 mg/L**. Determine the **liter per day** setting for the alum solution feeder if the liquid alum contains **0.65 kg of alum per liter** of solution.

[1.0 Mark]

ii) The coagulation basin of this water treatment facility has the dimension of **2.0 m length and 1.5 m width** and contains water to a **depth of 1.5 m**. What is the basin detention time in seconds?

[1.5 Marks]

iii) The power input of this coagulation basin is **6.5 hp**. Find the **Camp No** at a temperature of 30 ° C for this coagulation basin. The absolute viscosity of water is 0.798 x 10^{-3} N.s/m^2 at 30°C. You may consider 1 hp as 746 W.

[1.5 Marks]

iv) Currently, **alum** is used in the coagulation process in this treatment plant of City-B, but there are plans to switch to **polymers** in the future. Explain why '**Polymers**' are considered better coagulants than '**Alum**'.

[1.5 Marks]

v) You must explain to your young engineers the **five reactions** involved in the **bridging mechanism** between colloidal particles and **polymers.** Provide a brief explanation of each mechanism.

[2.5 Marks]

b) The water treatment plant in City-B has **two clarifiers**. Each clarifier is **6m wide, 30m long, and 4m deep**. Determine the following parameters for each basin:

i) Detention time

[1.0 Mark]

ii) Overflow rate

[1.0 Mark]

iii) Horizontal velocity

[1.0 Mark]

iv) Weir loading rate, assuming the weir length is **2.5 times the basin width**

[1.0 Mark]

Q3 a) In the existing water treatment plant in City-B in Q2, there are **6 filter units**, each of which has dimensions of **3m and 8m** as the width and length, respectively. Each filter unit is **backwashed for 15 minutes per day**, and **1% of the filtered water** is used for backwashing of all the filters. What is the **average filtration rate** of this existing treatment plant.

[1.5 Marks]

b) Currently, **chlorination** is used as the disinfection process for the water treatment plant at City-B. **50 kg** of chlorine is used **daily** to disinfect the water. The **residual chlorine** after **30 min** contact time was found as **0.5 mg/L**. Determine the **chlorine dosage** and **chlorine demand** of the water.

[1.0 Mark]

c) One engineer suggested upgrading the existing plant to **UV treatment** instead of chlorination. However, most engineers still prefer chlorination for a few reasons. Briefly explain the possible reasons for their decision.

[1.5 Mark]

SECTION – B

Q4. a) The average wastewater flow to a channel-type grit chamber is 10,000 m^3/d. The peak factor is 2.5. The horizontal component of the velocity vector of the wastewater through of the grit chamber is 0.3 m/s. The average grit size (diameter) is 0.2 mm. The detention time is equal to 1 minute. Determine the dimensions (the maximum water depth, width, and length) of the grit chamber. The relative density of sand is 2.65, the dynamic viscosity of water is 1.518×10^{-3} kg/s/m, and the gravitational acceleration is 9.81 m/s^2.

[2.0 Marks]

b) Estimate the infiltration flow rate, and its percentages of the average daily and peak daily domestic wastewater flows for the following sewer network:

Sewered population = 70,000
Average domestic wastewater flow = 110 *L/capita.d*
Infiltration flow rate = 100 *L/km.d* per 1 *cm* of pipe diameter
Peak factor = 2.5

Table Q4(b) shows the relevant sewer data.

Table Q4 (b): Sewer data

Type	Diameter (*mm*)	Length (*km*)
House sewers	100	80
Building sewers	150	55
Street laterals	200	80
Submains	300	40
Mains	450	20

[4.0 Marks]

c) Consider a sedimentation tank having the following conditions.

- Flow rate = 1.5 MGD (1 MGD = 1,000,000 gal/d)
- Overflow rate = 500 gal/ ft^2/d
- Weir loading = 15,000 gal/ft/d
- Number of tank = 3 Nos.
- Detention time = 4 h
- Length of the tank is equal to 4 times the width
- Flow through velocity should be less than 0.5 ft/min
- Assume 1 ft^3 = 7.48 gallons

Based on the above information answer the following

(i) Calculate the required surface area of one tank in **ft^2**
(ii) Calculate the required volume of one tank in **ft^3**
(iii) Calculate the depth of one tank in **ft**
(iv) Calculate the tank width and length in **ft**

(v) Calculate the flow through velocity in **ft/min**, and check whether it is acceptable
(vi) Calculate the weir length in **ft**

[4.0 Marks]

Q5. a) Using a fully labeled chart, briefly describe the growth pattern of microorganisms and food in an activated sludge system.

[2.0 Marks]

b) Considering a completely mix batch reactor system, the growth rate of microbes can be written as the equation (A).

$$\frac{dX}{dt} = \mu X \qquad (A)$$

Where,
X is microbes present at the time and μ is specific growth rate in $time^{-1}$.

This μ is not a constant and μ is a function of substrate concentration (S) as well as environmental conditions. By assuming that the environmental condition is fixed, μ can be calculated empirically using the equation (B).

$$\mu = \frac{\mu_{max} \cdot S}{k_s + S} \qquad (B)$$

i) Explain the terms, 'μ_{max}' and 'K_s' using a labeled chart.
ii) Derive a formula, which shows the microbial growth patten for each of the following cases: substrate is limited and unlimited.
Elaborate the two formulae derived above.

Hint: You may use formulate (A) and (B).

[4.0 Marks]

c) A complete-mix activated sludge process (the waste sludge is withdrawn from the recycle line) will be used to treat a wastewater flow of 100 m^3/h with BOD_5 of 250 *mg/L*. Calculate the effluent substrate (BOD_5) concentration and volume of the aeration tank using the design criteria as follows:

Yield coefficient (Y) = 0.4
Maximum rate of substrate utilization (k) = 8 d^{-1}
Endogenous decay coefficient (k_d) = 0.1 d^{-1}
Half velocity constant (K_s) = 75 *mg/L*
Mean Cell Residence Time (θ_c) = 5 *d*
Mixed Liquor Volatile Suspended Solids concentration (X) = 2000 *mg/L*

[4.0 Marks]

Q6. A municipal wastewater treatment plant processes an average flow of 14,000 m^3/d. The peak flow is 1.75 times the average flow.

a) Draw the schematic flow diagram of a wastewater treatment plant that includes a coarse bar screen, a primary sedimentation tank, a channel type grit chamber, a completely mixed activated sludge process, a disinfection unit, and an equalization tank. Categorize the above unit processes into preliminary, primary, and secondary levels of treatment in the flow diagram. Briefly state the purpose/s of each unit process.

[2.0 Marks]

b) **Table Q6(b)** gives the data for the coarse bar screen of the above wastewater treatment plant.

Table Q6(b): Data for the coarse bar screen

Parameter	Value
Velocity through the screen	0.6 m/s
Bar width	1.5 cm
Clear spacing between the bars	4.5 cm
Inclination angle	55°
Horizontal channel width	0.8 m
Gravitational acceleration (g)	9.81 m/s²

(i) Calculate the cross-section area and the minimum height of the screen.

(ii) Calculate the head loss through the screen when the screen is half-clogged.

[4.0 Marks]

c) The following test results were obtained from a wastewater quality analysis for a wastewater sample. All the tests were performed using a sample of 50 mL. Determine the concentration of suspended solids, volatile suspended solids, total solids, and total volatile solids. The samples used in the solids analyses were all either dried after evaporation or ignited to a constant weight.

- Mass of the evaporating dish is 51.5323 g
- Mass of the evaporating dish plus residue after evaporation at 105 °C is 51.7243 g
- Mass of the evaporating dish plus residue after ignition at 550 °C is 51.6231 g
- Mass of the filter paper is 1.5321 g
- Mass of residue and the filter paper after drying at 105 °C is 1.5671 g
- Mass of residue and the filter paper after drying at 550 °C is 1.5531 g

[4.0 Marks]

Equations

$$\theta_C = \frac{V\,X}{Q_w X_r + Q_e X_e}$$

$$Q_r = \frac{Q_0\,X}{X_r - X}$$

$$X = \frac{\theta_c}{\theta} \frac{Y (S_0 - S)}{1 + k_d \theta_c}$$

$$Y_{obs} = \frac{Y}{1 + k_d \theta_c}$$

$$S_e = \frac{K_S(1 + k_d \theta_c)}{\theta_c (Yk - k_d) - 1}$$

$$P_x = Q_0 \frac{Y (S_0 - S)}{(1 + k_d \theta_c)}$$

$$\frac{F}{M} = \frac{S_0}{X \theta}$$

$$s = \sqrt{\left(\sum (X - \bar{X})^2\right) / (n-1)}$$

$$WLR = \frac{Q_0}{Perimeter\ of\ the\ weir}$$

$$Mode = 3\ (Med) - 2\bar{x}$$

$$Y_T = Y_{20}\ (1.056)^{T-20}$$

$$k_{d\,@T} = k_{d\,@20}\ (1.056)^{T-20}$$

$$A = \frac{Q_0}{S.L.R}$$

$$Q_0 = Q_e + Q_w$$

$$V_s = \frac{g(\rho_s - \rho_L) d_p^2}{18\,\mu}$$

$$h_L = \frac{1}{C}\left(\frac{V^2 - U^2}{2g}\right)$$

$$Recirculation\ ratio = \frac{Q_r}{Q_0}$$

$$U = V \frac{(s)}{(s + w)}$$

$$\frac{A_{net}}{w + s} = \frac{A_E}{s}$$

$$h_L = \frac{1}{0.7} \times \left(\frac{V^2 - U^2}{2g}\right)$$

$$n = \frac{A_{net} - A_E}{Area\ of\ bars} = \frac{A_{net} - A_E}{Area\ of\ bars}$$

$$U = V \left(\frac{Bar\ spacing}{Bar\ spacing - Bar\ width}\right)$$