UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: November-2022

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

[Three Hours]

[Answer **all questions**, each question carries **ten marks**]

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

SECTION – A

Q1. Assume that you have been appointed as the project engineer for a new water supply project in a city in the dry zone in Sri Lanka. To investigate the feasibility of this project, relevant water quality data from different sources, census data, and geographical and geological data have also been collected. The water treatment project should be able to cater for the water demand in the year 2050.Table Q1-1 gives the population data of the city.

Table Q1-1: Population data of the city

Year	1971	1981	1991	2001	2011	2021
Population (thousands)	35.2	47.8	59.3	67.9	83.4	95.9

You may assume the following data:

- *Domestic water demand should be based on the census data as in Table Q1-1*
- *Per capita water demand = 110 L /Capita/day*
- *Industrial and commercial water demand by 2050 = 15 % of the Total Water Demand*
- *NRW (by 2050) = 10 % of the Total Water Demand*
- *No fire demand water is considered under this project*

a) i) Calculate the average quantity of domestic water demand by the year 2050. You may use the simple Arithmetical Progression Method given by the following equation: $\mathbf{P_t = P_0 + kt}$ with typical notations.

[2.5 Marks]

ii) Calculate the total average water demand by the year 2050.

[1.5 Marks]

iii) Calculate the design flowrate for the **water distribution system** (the pipe network)

[1.0 Mark]

iv) Generally, three configurations can be adopted in laying the pipes through a water distribution network. With the aid of sketches, briefly explain the differences among these three configurations.

[1.5 Mark]

b) The above water project covers only the city limit and surrounding suburban areas. There is a village far from this city for which the water demand cannot be covered by this water project. Authorities have identified deep groundwater as the potential water source to construct a water supply scheme for this village. Table Q1-2 shows the average concentrations of the key water quality parameters of this groundwater. A young engineer suggests having the following treatment train in a water treatment plant aimed at supplying water to this village:

- *Screening*
- *Aeration*
- *Coagulation and Flocculation*
- *Sedimentation*
- *Filtration*
- *UV treatment*

This groundwater should be treated to satisfy SLS-614 considering engineering, economic and energy factors. Do you agree with the suggested treatment train? Rationalize your answer with explanation for each unit process.

Table Q1.2: Average concentrations of water quality parameters

DO, mg/L	pH	Turbidity, NTU	Conductivity, µS/cm	Fe, mg/L	Mn, mg/L	Total Coliform, MPN/100 mL	Fecal Coliform, MPN/100 mL
5.8	6.8	3	180	6	5	0	0

[3.5 Marks]

Q2. a) i) As explained in Q1, the proposed water treatment includes coagulation and flocculation processes followed by sedimentation. Alum is proposed as the primary coagulant for this water treatment plant. However, design engineers of this treatment plant suggest using "Coagulation aids" as well. Explain the role of the "Coagulation aids" in the process of coagulation and flocculation in water treatment. Give two (2) examples of commonly used coagulation aids.

[3.0 Marks]

ii) Briefly explain the objectives of having a separate tank for each of coagulation and flocculation unit processes.

[1.0 Mark]

b) A coagulation tank is designed to process the flow rate calculated in Q1-a)-ii). A square-shaped rapid-mixing basin with a depth of water being equal to the width will be used for the coagulation process in this proposed water treatment plant as in Q1. The velocity gradient and the hydraulic retention time will be 900/s and 30 s, respectively. Assume that the flow is turbulent inside the mixing basin and the absolute viscosity of the water is 0.00131 $N.s.m^{-2}$.

i) Determine the possible dimensions for the mixing tank

[1.0 Mark]

ii) Calculate the power requirement (in kW) for the mixing tank. Hence, determine the turbine diameter. Assume that a turbine with a shaft speed of 125 rpm and an impeller constant of 3.5 is used to provide the necessary power for rapid mixing. Check the compatibility of the turbine diameter with the tank dimensions. The following equation with typical notations is applicable for the power imparted to water by turbine mixers:

For a turbulent flow, $P = k.\rho.n^3.D^5$

[2.5 Mark]

c) "Camp No." is used as a design parameter in designing a flocculator. Rationalize the fact that the flocculator is designed with the optimum 'Camp No".

[1.5 Marks]

d) Design engineers plan to have Two circular clarifiers with 25m diameter for the treatment plant in Q1. Determine the overflow rate of these clarifiers. You may use the same flow rate calculated in Q1-a)-ii).

[1.0 Marks]

Q3 a) Design engineers of the treatment plant in Q1 are planning to install rapid sand filters downstream of the clarifiers. The design filtration rate is selected to be 150 m^3/m^2. You may use the same flowrate calculated in Q1-a)-ii). The maximum surface area per filter is limited to 35 m^2 and the maximum length and width should be less than 8 m. Design the number and size of filters.

[1.5 Marks]

b) Design engineers suggest that they can use both physical and chemical methods of disinfection for the proposed water treatment plant in Q1. List Two examples for each method of disinfection except Chlorination.

[1.0 Mark]

c) Briefly discuss properties of a chemical used as a disinfectant in water treatment.

[2.0 Marks]

d) Figure Q3 shows the chlorination curve for the raw water, which is going to be used in the proposed water treatment plant in Q1. It is expected to maintain 0.6 mg/L of free chlorine.

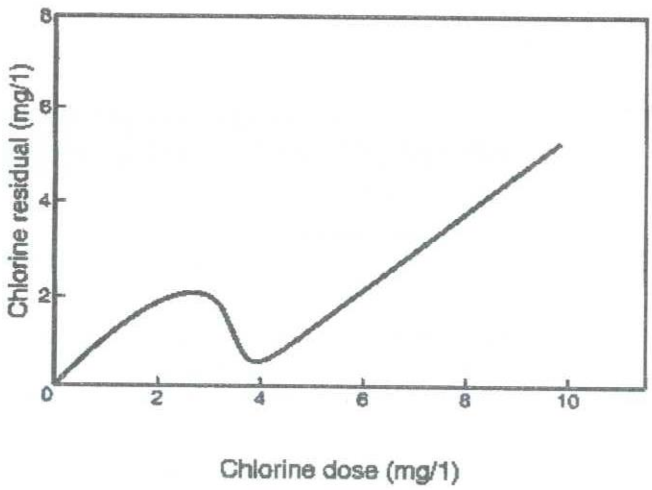

Figure Q3: Chlorination curve

i) Determine the daily requirement of the chlorine for the disinfection process of this water treatment plant.

[1.0 Mark]

ii) If the disinfection is in the form of hypochlorite powder that contains 60% available chlorine, how many kilograms of the hypochlorite powder are required by the proposed water treatment plant per month to treat water? You may use the same flow rate calculated in Q1-a)-ii).

[1.0 Mark]

iii) Experimental studies found that the specific lethality of chlorine (inactivation constant) is 4.2 L/min.mg for one type of Virus. Determine the time required to obtain 4-log inactivation of this Virus using 1.0 mg/L of chlorine solution.

[2.0 Mark]

iv) Some engineers suggested that this proposed water project needs to have a "Re-chlorination" process. Briefly explain the **"Re-chlorination"** process.

[1.5 Mark]

SECTION – B

Q4. a) Name (one parameter for each apparatus) water/wastewater parameter/s that can be measured by the following apparatus.

- *Spectrophotometer*
- *Incubator*
- *Desiccator*
- *Imhoff cone*

[2.0 Marks]

b) Estimate the infiltration flowrate, and its percentage of the peak daily domestic wastewater flows for the following sewer network:
Population = 55,000
Average domestic wastewater flow = 120 L/capita.d
Infiltration flow rate = 120 L/km.d per 1 cm of pipe diameter
Peak factor = 3.0

Table Q 4: Length of sewer network

Type	Diameter (mm)	Length (km)
House sewers	100	65
Building sewers	150	15
Street laterals	200	50
Submains	300	20
Mains	450	10

[4.0 Marks]

c) The forecasted population of a city in the year 2025 is 400,000. If the average per capita water consumption in this city is 200 *L/d*. Determine the size of the trunk sewer required to transport the wastewater in such a way that the solids deposition will be minimized, and the peak flow rate will be satisfied.

The peak factor is 2.25. Assume that the wastewater flows through the trunk sewer at its full velocity equal to 0.6 *m/s* (self-cleansing velocity)

[4.0 Marks]

Q5. a) Explain briefly the Preliminary, Primary, and Secondary levels of wastewater treatment and list key unit operations/processes for each level.

[3.0 Marks]

b) A complete-mix activated sludge process (ASP) (Figure Q5) is designed to treat a primary settled wastewater flow of 0.15 m^3/s. The influent soluble BOD_5 to the ASP is 200 *mg/L* at the average flow conditions. The effluent BOD_5 is expected to be
20 *mg/L*. Following data are available for the ASP:

- Hydraulic regime of the reactor is complete mix.
- Influent volatile suspended solids to the reactor is negligible.
- Mixed Liquor Volatile Suspended Solids (MLVSS) is 3500 *mg/L* in the reactor.
- Ratio of VSS (Volatile Suspended Solids) to SS (Suspended Solids) is 0.8.
- Return sludge concentration is 12,000 *mg/L* of SS
- Design Mean Cell Residence Time (θ_c) is 10 *d*
- Kinetic coefficients at 20 ^0C:
  Yield Coefficient (Y) = 0.65 *g cells/g* BOD_5 *utilized.*
  Endogenous Decay Coefficient (k_d) = 0.06 d^{-1}
- It is estimated that the effluent will contain about 20 *mg/L* of biological solids, of which 70% is biodegradable.
- Ultimate carbonaceous biochemical oxygen demand (BOD_L) of cell is equal to 1.42 times the concentration of cells.
- $BOD_5 = 0.68 \times BOD_L$
- System temperature is 20 °C.
- Wastewater contains adequate nitrogen, phosphorus, and other trace nutrients for biological growth.

Compute the following:

i. Soluble BOD_5 in the effluent
ii. Hydraulic Retention Time (HRT)
iii. Reactor volume
iv. Recirculation ratio
v. Biomass production rate

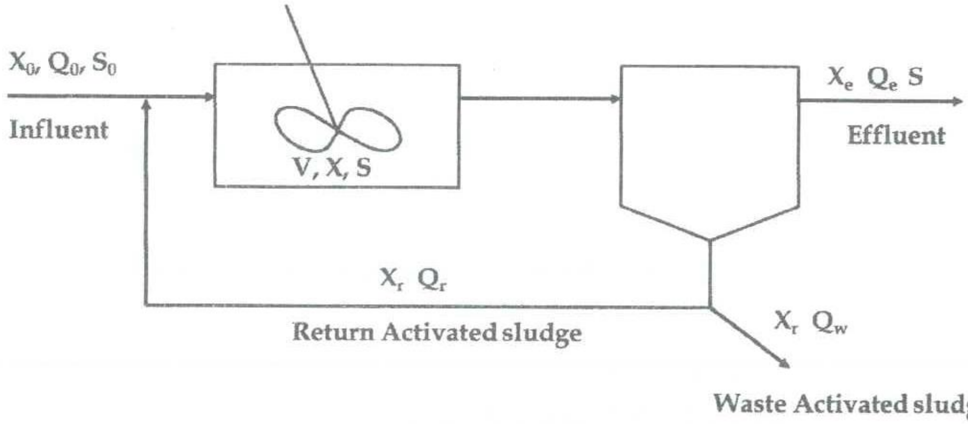

Figure Q5: Schematic of the ASP

[7.0 Marks]

Q6. a) Name **two** wastewater parameters belonging to each of physical, chemical, and biological wastewater characteristics

[3.0 Mark]

b) A coarse bar rack is placed vertically against the approaching flow in a wastewater treatment plant. Table Q6 gives the operating data.
Calculate the
(i) cross-sectional area;
(ii) number of bars;
(iii) width and height of the screen;
(iv) the initial head loss through the screen; and
(v) head loss when the screen is half clogged.

Table Q6(b): Operating data

Parameter	Unit	Value
Flow rate	L/d	80×10^6
Bar width	cm	1
Clear spacing between the bars	cm	5
Initial channel width	m	0.75
Velocity of the flow through the opening of the bars	m/s	0.6
Gravitational acceleration (g)	m/s^2	9.81

[7.0 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=√ ((∑(X-X¯)²)/(n-1))

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

Mode=3 (Med)-2x¯

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

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

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

$$Q_0 = Q_e + Q_w$$

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

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

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

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

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

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

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