UNIVERSITY OF RUHUNA

Faculty of Engineering

Semester 4 Examination in Engineering: February 2020

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

[Three Hours]

[Answer all questions. Each question carries **TEN** marks]

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

All Standard Notations denote their regular meanings

SECTION - A

Q1. A new water supply scheme has been proposed to provide water to a rural community with 20,000 population in Southern Sri Lanka. Assume that the above proposed water supply scheme will only supply water for domestic uses, and the per capita water demand is 120 L/capita/d. Also assume the population of the community remains constant during the design period of the project.

a) Assume that the above proposed water supply scheme will only supply water for domestic uses, and the per capita water demand is 120 L/capita/d. Also assume the population of the community remains constant during the design period of the project.

Calculate;

i) Population is an influential factor in determining demand. List three other factors that will be influential on the demand from a water supply scheme.

[1.0 Mark]

ii) Briefly describe two possible reasons for loss of water from a water supply scheme.

[1.0 Mark]

b) Two water sources have been identified as the potential water sources for the above water supply scheme. Table Q1-1 shows the average concentrations of the key water quality parameters and water quantity that can be absorbed from each source in dry weather conditions. Select a suitable water source for the project and justify your selection.

[4.0 Marks]

c) Show the flow diagram of a suitable treatment train for the proposed water supply project, considering the source selected in the part (b).

[2.0 Marks]

d) Describe two factors that should be considered in locating the intake structure in a stream, if a stream is selected as the source for a water supply scheme.

[2.0 Marks]

Q2. a) In a certain water supply scheme, it is recommended that the unit process "aeration" is not necessary. Explain possible reasons for this recommendation.

[2.0 Marks]

b) In the coagulation process, rapid mixing is used while in the flocculation process, gentle mixing is used. Clarify the necessity of this difference.

[2.0 Marks]

c) A water treatment plant has been designed to process 20,000 $m^3.d^{-1}$ of water. The treatment plant consists of the unit operations, namely a coagulation tank, a flocculation tank and a sedimentation tank. The dynamic viscosity of water is 0.00131 $N.s.m^{-2}$ at 10 ° C.

i. The coagulation tank has a velocity gradient of 700 s^{-1} and a hydraulic retention time of 30 s. Assuming that the flow inside the coagulation tank is turbulent, determine its volume.

[2.0 Marks]

ii. It is required to design the flocculation tank of the above treatment plant based on a velocity gradient of 25 s^{-1} and an energy dissipation of 1 $J.L^{-1}$. Calculate the dimensions of the flocculation tank if the length to width ratio is 6:1.

[2.0 Marks]

iii. Laboratory analyses show that an overflow rate of 20 $m^3.d^{-1}.m^{-2}$ will produce satisfactory removal of flocculated sediment in a sedimentation tank at a depth of 4.0 m. Taking length to width ratio of the tank as 5:1, determine the size of the required sedimentation tank.

[2.0 Marks]

Q3. a) It is required to design a rapid sand filter to treat water at a flow rate of 25,000 $m^3.d^{-1}$. The filtration rate, length to width ratio, and the filter bed depth are 5,500 $L.m^{-2}.h^{-1}$, 4:1 and 60 cm, respectively. Determine the filter bed dimensions for this filter. Assume that 0.5% of filtered water is needed for the backwashing process, and totally 30 minutes per day is spent for backwashing.

[2.0 Marks]

b) Describe the methods to identify when to clean a rapid sand filter.

[1.5 Marks]

c) Dengue fever and Cholera are two life threatening diseases prevailing in the world at present. Describe their association with water and sanitation.

[2.0 Marks]

d) Describe briefly three characteristics of a chemical used as a disinfectant.

[1.5 Marks]

e) The breakpoint chlorine requirement of filtered water is 3.5 $mg.L^{-1}$. It is expected to maintain 0.8 $mg.L^{-1}$ of free chlorine.

i. Determine the daily requirement of the chlorine for the disinfection process of this water treatment plant if the water production is 24000 m^3/d.

[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 treatment plant per day to treat the water?

[1.0 Mark]

iii. Why residual chlorine should be available in purified water?

[1.0 Mark]

SECTION - B

Q4. a) Name the water/wastewater parameters whose measurement may need the following apparatus?

- Spectrophotometer
- Incubator
- Desiccator
- Imhoff cone

[2.0 Marks]

b) Two primary settling basins are 26 m in diameter with a 2.1 m side water depth. There are single effluent weirs on the peripheries of the tanks. For a wastewater flow rate of 26,000 m^3/d, calculate the overflow rate, detention time, and weir loading rate.

[3.0 Marks]

c) 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
Table Q4-1 gives the length of sewer network
Peak factor = 3.0

[5.0 Marks]

Q5. a) Draw a schematic flow diagram of a wastewater treatment plant, and categorize the unit operations/processes into preliminary, primary and secondary treatment.

[2.0 Marks]

b) What is the objective of the recirculation system in a complete-mix activated sludge process?

[2.0 Marks]

c) A complete-mix activated sludge process (Figure Q5-1) is to be designed to treat a wastewater flow of 10 ML/d. The influent BOD_5 at the average flow conditions will be 200 mg/L. The BOD_5 removal efficiency after the primary treatment is 30 percent. The effluent BOD_5 is expected to be 10 mg/L or less. Following data are available:

- Influent volatile suspended solids to the reactor is negligible
- Ratio of MLVSS (Mixed Liquor Volatile Suspended Solids) to MLSS (Mixed Liquor Suspended Solids) is 0.8.
- Return sludge concentration is 10,000 mg/L of SS.
- MLVSS to the reactor is 4200 mg/L.
- Design Mean Cell Residence Time (θc) is 10 d
- Hydraulic regime of reactor is complete mix.
- Kinetic coefficients, 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 10 mg/L of biological solids, of which 60% 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 the biological growth.

Based on the above information, compute the following:

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

[6.0 Marks]

Q6. a) A wastewater flow of 10,000 m^3/d is received at a sewage treatment plant. This flow rate includes the flow generated by a population equal to 40,000 and a few industries. If the total BOD_5 of the influent wastewater is 400 mg/L. Estimate the BOD_5 due to each of domestic sewage and industries. Assume that the maximum BOD_5 value of the domestic wastewater is 54 g/capita/d.

[2.0 Marks]

b) Following test results depict the characteristics of a wastewater sample. All the tests were performed for a sample volume of 50 mL. Determine the concentrations of the 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

[3.0 Marks]

c) A coarse bar rack is placed vertically against the approaching flow in a wastewater treatment plant. Table Q6-1 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
v. Head loss when the screen is half clogged

[5.0 Marks]

Figures

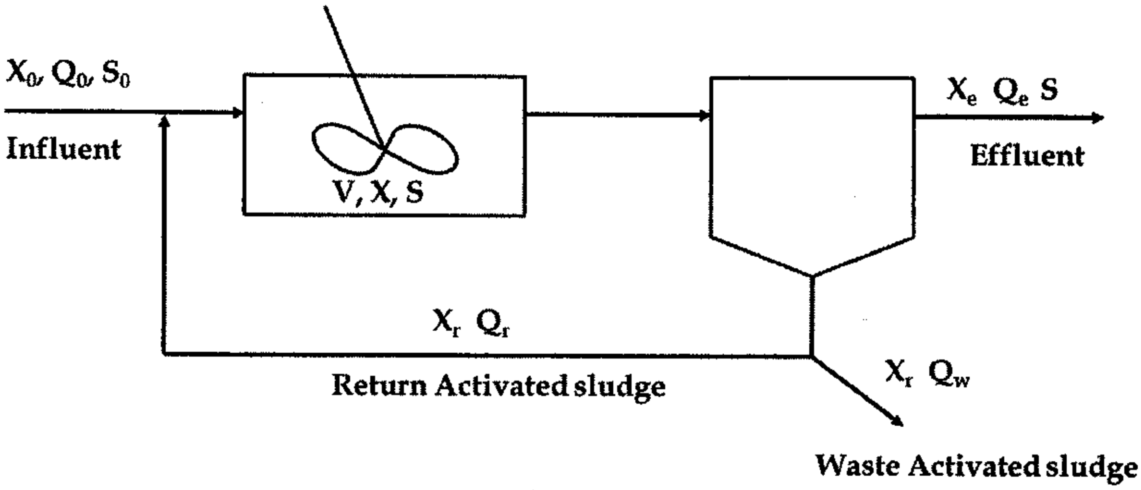

Fig Q5-1: Schematic diagram of the complete- mix activated sludge process

Tables

Table Q1-1: Characteristics of potential water sources

Source	Dry weather yield (m^3/day)	pH	Turbidity (NTU)	Fe (mg/L)	Mn (mg/L)	Total Coliform (MPN/100 mL)	Fecal Coliform (MPN/100 mL)
A	1000	6.8	15	7	4	20	6
B	2500	7.2	60	3	1	85	10

Table Q 4-1: 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

Table Q6-1: Operating data

Parameter	Unit	Value
Flow rate	L/d	80 x 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

Equations

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

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

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

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

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

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

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

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

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

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

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

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

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

$$Q_0 = Q_e + Q_w$$

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

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

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

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

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