UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: December 2015

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. A new water supply project has been proposed to provide water to a city in Sri Lanka. As the first step, the relevant information has to be gathered to plan the water supply scheme.

a) List 4 factors, excluding the population, which are considered in calculating the projected water demand of the city.

[1.0 Mark]

b) Calculate the projected water demand of the city. The design period of the proposed water supply scheme is 50 years. Table Q1 (b) shows the census figures.
Assume that the proposed water supply scheme will only supply water for domestic uses and the per capita water demand is 140 L/capita/d.

You may use the Arithmetical Progression Method, $P_t = P_0 + kt$ with typical notations.

Table Q1 (b): Population data.

Year	1965	1975	1985	1995	2005	2015
Population: (thousands)	53	61	69	78	88	101

[3.5 Marks]

c) Both '**river water**' and '**ground water**' have been identified as the potential water sources for the above project.

i. If the key physical, chemical and biological water quality parameters of these water sources have to be analyzed, Name three parameters for each category.

[1.5 Marks]

ii. Table Q1 (c) shows the average concentrations of key water quality parameters of river and ground water. Draw a schematic diagram of a possible treatment train for each of river and ground water, considering the engineering, economic and energy factors. Explain briefly the reasons for the selection of unit operations in each treatment train.

Table Q1 (c): 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	6.5	5	10	5	5	0
River Water	7.1	65	4	2	15	3

[4.0 Marks]

Q2. a) Why are '**polymers**' considered better coagulants than "'inorganic coagulants'"

[1.0 Mark]

b) Explain briefly five reactions involved in the bridging mechanism between colloidal particles and polymers

[2.5 Marks]

c) A water treatment plant is being designed to process 30,000 m^3/d of water. According to the jar test and a pilot plant analysis, the optimum coagulant dosage is 40 mg/L. A square shaped rapid-mixing basin will be used for the coagulation process. The velocity gradient, hydraulic retention time and the operating temperature will be 800/s, 40 s, and 10° C, respectively. The turbine shaft speed is 120 rpm with an impeller constant of 4.5. Assume that the flow is turbulent inside the mixing basin and absolute viscosity of the water is 0.00131 $N.s.m^{-2}$. Following equations are applicable:

$\boldsymbol{P} = \mu . \boldsymbol{G^2} . \boldsymbol{V}$, For turbulent flow, $\boldsymbol{P} = \boldsymbol{k} . \boldsymbol{\rho} . \boldsymbol{n^3} . \boldsymbol{D^5}$

G = velocity gradient, s^{-1}
V = volume of water in the mixing tank, m^3
μ = absolute viscosity, $N.s.m^{-2}$
P = power requirement (W)
k = Impeller constant
ρ = mass density of the fluid (kg/m^3)
D = diameter of impeller (m)
n = revolution per second (rev/s)

Determine;

i. the monthly alum requirement
ii. the power requirement for the mixing basin
iii. turbine diameter and possible dimensions for the tank

[3.0 Marks]

b) It is also planned to design two parallel rectangular sedimentation tanks for the above treatment plant. The column analysis indicates that an overflow rate of 20 m^3/ m^2. d will give a satisfactory removal of particles. If the hydraulic retention time is 2 h, determine the dimensions of a single sedimentation tank. Consider that the length (L)-to-width (W) ratio is 5:1, and the freeboard is 0.5 m. If the weir overflow rate is 200 $m^3/m.d.$, determine the effluent weir length. Explain briefly how to provide the weir length if the calculated weir length is higher than the tank dimensions.

[3.5 Marks]

Q3 a) Explain briefly 'NRW', which the engineers and managers in the water sector around the world have identified as a great issue for water utilities. .

[1.0 Mark]

b) An engineer of a rural water supply project in the southern province of Sri Lanka observed following water related problems:

i) The color of the ground water appeared reddish;
ii) The water of the main river is highly murkier;
iii) A white colored scale appeared in boiling kettles;
iv) One lake showed a high algal blooms;
v) The fishes in another lake died unusually;
vi) The well water samples showed high concentrations of fecal coliform.

What can be the causes for the above problems? You may mention more than one cause if available

[3.0 Marks]

c) When either the head loss or the effluent turbidity reaches a predetermined limit, the granular filters must be cleaned. Explain briefly how to clean a 'slow sand filter' and a 'rapid sand filter'.

[1.0 Mark]

d) 'Chlorination' is one of the most common methods used for disinfection in water treatment. What is meant by **'breakpoint chlorination'**? Explain the answer using a schematic diagram.

[2.0 Marks]

e) A water treatment plant with the total water production is 32,000 m^3/d is expected to maintain 0.4 mg/L of free chlorine. From the laboratory tests, it was found that the chlorine demand for this water is 2.1 mg/L.

i. Determine the required amount of chlorine per day for the disinfection process.

[2.0 Marks]

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 week to treat the water?

[1.0 Mark]

SECTION - B

Q4. a) Name two methods of measuring the organic compounds in wastewater

[1.0 Mark]

b) Define the term' Biochemical Oxygen Demand (BOD)'.

[1.0 Mark]

c) A wastewater sample is placed in a closed container and inoculated with bacteria. Describe the relationship between the oxygen consumed and time. Draw typical graphs of 'BOD remaining versus time', and 'oxygen consumed versus time'. Indicate the ultimate carbonaceous BOD and five day BOD on the graphs.

[3.0 Marks]

c) The following information is available for a seeded 5 d standard BOD test conducted on a wastewater sample. 30 mL of the wastewater sample was added directly into a 300 mL BOD incubation bottle. The initial DO of the diluted sample was 8.5 mg/L an final DO after 5 days was 2.5 mg/L. The corresponding initial and final DO of seeded dilution water was 9.2 mg/L and 8.0 mg/L, respectively. The seed control had the standard volume of 300 mL.

i. Write a formula to obtain BOD value for the above sample giving the notations used.

[2.0 Marks]

ii. Calculate the 5 d BOD (BOD_5) of the above sample using the formula in the part (i).

[3.0 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) 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

[2.0 Marks]

ii. Reactor volume

[1.0 Mark]

iii. Hydraulic Retention Time (HRT)

[1.0 Mark]

iv. Sludge retention rate

[1.0 Mark]

v. Biomass production rate

[1.0 Mark]

Q6 a) The following test results were obtained 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]

b) Consider that a primary sedimentation tank which is to be designed, will have following conditions:

- The average wastewater flow to be treated is 15,000 m^3/d
- The peak factor is 2.5
- The over flow rate (surface loading rate) is 40 $m^3/m^2.d$
- The number of channels is 2 (Both are circular)
- The hydraulic retention time is 2 h.

Based on above information compute the following:

i. Surface area of each tank.

[1.0 Mark]

ii. Diameter of the tank (d).

[1.0 Mark]

iii. Volume of each tank.

[1.0 Mark]

iv. Side water depth (SWD) in the tank.

[1.0 Mark]

v. Weir loading rate (WLR).

[1.0 Mark]

vi. Comment on the SWD and WLR.

[1.0 Mark]

Consider that the recommended design rage for SWD is 3-5 m ;WLR is 124 - 496 $m^3/m.d$

Tables, Figures and Equations

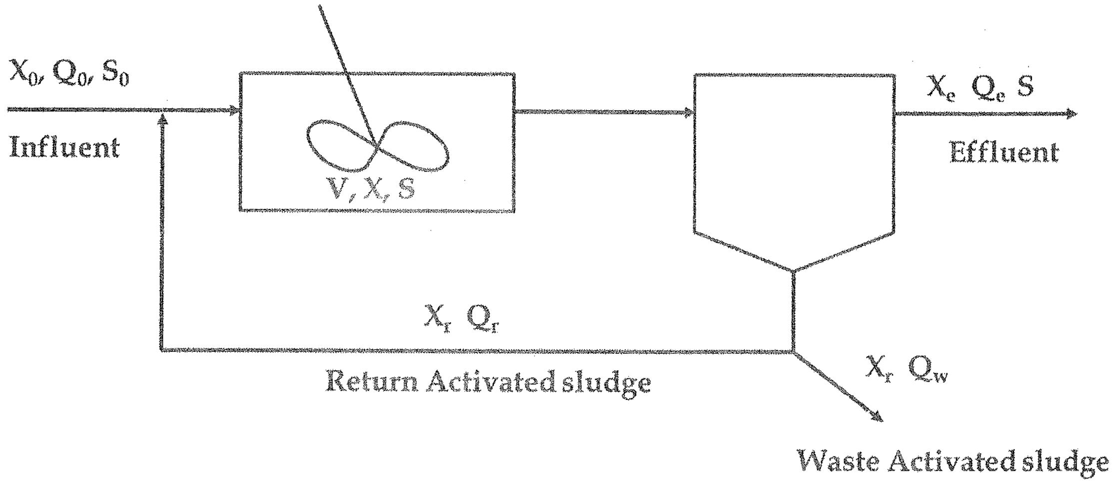

Figure Q5: Schematic diagram of the complete- mix activated sludge process

Equations to be used in the calculations

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

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

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

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

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

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

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

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

$$\theta = \frac{V}{Q}$$

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

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

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

$$Q_0 = Q_e + Q_w$$

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

$$\eta_{BOD5_{Soluble}} = \frac{(S_0 - S)}{S_0}$$

$$\eta_{BOD5_{Total}} = \frac{(S_0 - S_{total})}{S_0}$$