M. Sc. in Civil Engineering December 22, 2023 (Friday)/Afternoon

ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)

ORGANISATION OF ISLAMIC COOPERATION (OIC)

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

TERM: SEMESTER FINAL EXAMINATION WINTER SEMESTER: 2022-2023
COURSE NO.: CEE 6303 TIME: 3 Hours
COURSE TITLE: Municipal Wastewater Treatment and Process Design FULL MARKS: 150

There are **6 (Six)** questions. Answer **ALL** questions. Programmable calculators are not allowed. Do not write on this question paper. The figures in the right margin indicate full marks. Symbols convey their usual meanings. Assume reasonable values for any necessary design data where required.

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1. (a) Describe the trickling filter process used in wastewater treatment with diagrams of single stage and two-stage. **(7)**

(b) Analyze a single stage rock-media trickling filter process for secondary treatment in a wastewater treatment plant. The wastewater flow rate is 2000 m^3/d with a BOD_5 concentration of 400 mg/L. Primary clarification removes 30% of the BOD_5. The filter diameter is 12 m and depth is 1.5 m. Direct recirculation pump operates at 2.78 m^3/min to the filter. Wastewater temperature is 20°C. Determine the hydraulic loading rate, organic loading rate, filter efficiency, effluent BOD_5 concentration and overall plant efficiency. **(18)**

How the hydraulic and organic loading rates to trickling filter can be reduced?

Do you think that wastewater treatment with trickling filter(s) only is a standalone technique? Justify your answer.

2. (a) Draw a flow diagram to treat a wastewater that has a high concentration of suspended solids, organic matter, pathogens and a high concentration of ammonia–nitrogen. Describe briefly. **(7)**

(b) As a design engineer, you can predict the methane gas production rate from an anaerobic reactor operated at 35°C. It processes a wastewater stream with a flow of 3000 m^3/d and a bsCOD concentration of 5000 g/m^3. Assume that 1.42 g COD/g biomass VSS, 64 g COD/mole CH_4, universal gas constant (R) is 0.082057 atm.L/mole.K and atmospheric pressure (P) is 1.0 atm. At 95% bsCOD removal and a net biomass synthesis yield of 0.04 g VSS/g COD used, what is the amount of methane produced in m^3/d? **(18)**

Is it important to determine the volume occupied by the gas at the actual operating temperature? Why?

3. (a) Why is Zero Liquid Discharge (ZLD) needed to save our environment? Sketch a diagram to discuss it. **(5)**

(b) A three-cell lagoon system is to be designed for municipal wastewater treatment for a small community with a population of 2500. The wastewater design flow is 400 Lpcd with a BOD load of 70 g/capita·d. It is desired to use a three-cell system where the first two cells used as primary lagoons in parallel with an equal area and a secondary lagoon with the same area. The allowable BOD loading is 2.2 $g/m^2 \cdot d$. Assume that the high-water level is 2 m, freeboard is 1 m and low water level is 0.6 m. **(20)**

i. Calculate the area of the lagoon system.
ii. Design and sketch the diagram of three-cell system.

iii. Sketch a diagram of lagoon cross-section showing high and low water levels.
iv. Calculate the winter storage available in number of days if no losses.
v. Calculate the winter storage available in number of days if losses due to evaporation and seepage are 0.5 mm/d.
vi. Calculate the winter storage available in number of days if losses due to evaporation and seepage are 0.5 mm/d and rainfall is estimated as 0.1 mm/d.

4. **(a)** Describe briefly the water reclamation from wastewater to recharge groundwater aquifers with a process flow diagram. **(7)**

(b) Estimate the daily required chlorine dosage and the resulting buildup of total dissolved solids (TDS) when breakpoint chlorination is used for the seasonal control of nitrogen. Assume that the flow rate is 1 MGD (3800 m^3/d), mass ratio of chlorine to ammonia is 9:1 and the TDS increase per mg/L ammonia consumed is 6.2. The effluent characteristics are: BOD_5 = 20 mg/L, suspended solids = 25 mg/L and NH_3-N concentration = 23 mg/L. The required effluent NH_3-N concentration is 1 mg/L. Determine the annual cost of the plant if the chlorine price is BDT 200/lb. **(18)**

5. **(a)** Differentiate between adsorption and desorption with a diagram. **(5)**

(b) Determine the Freundlich and Langmuir isotherm coefficients using appropriate graphs for the following activated carbon adsorption test data. The liquid volume used in the batch adsorption tests is 1 L. The initial concentration of the adsorbate in solution is 3.37 mg/L. Equilibrium is obtained after 7 days as shown below. **(20)**

Mass of GAC, m (g)	Equilibrium concentration of adsorbate in solution, C_e (mg/L)
0	3.37
0.001	3.27
0.01	2.77
0.1	1.86

6. **(a)** Explain the SBR used in wastewater treatment with a diagram. **(5)**

(b) Estimate the mass and volume of sludge produced from untreated wastewater without and with the use of ferric chloride ($FeCl_3$) for the enhanced removal of TSS. Also estimate the amount of lime required for the specified $FeCl_3$ dose. Assume that 60% of the TSS is removed in the primary settling tank without the addition of chemicals, and that the addition of ferric chloride results in an increased removal of TSS to 85%. Also assume that the following data apply to this situation: wastewater flowrate = 1000 m^3/d, TSS = 220 mg/L, alkalinity as $CaCO_3$ = 136 mg/L, $FeCl_3$ added 40 kg/1000 m^3, raw sludge specific gravity = 1.03 and moisture content = 94%, chemical sludge specific gravity = 1.05 and moisture content = 92.5%. **(20)**

Prepare a summary table of sludge masses and volumes without and with chemical precipitation.

What is the percentage of sludge increment in mass and volume due to use of chemical?

Formulae

$$F = \frac{1+R}{(1+0.1R)^2}$$

$$E_1 = \frac{100}{1+0.4432\sqrt{\frac{W_1}{VF}}}$$

$$\frac{X}{M} = \frac{abC_e}{1+bC_e} \text{ where, a, b= empirical constant}$$

$$\frac{C_e}{\frac{X}{M}} = \frac{1}{ab} + \frac{1}{a}C_e$$

$$m/V = (C_o - C_e)/q_e \qquad q_e = x/m = (C_o - C_e).V/m \qquad q_e = X/M = x/m = K_f C_e^{1/n}$$