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B.Sc. Engg. (CEE)/7th Sem. **December 23, 2023 (Saturday)/Morning**

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 4733 — TIME: 3.0 Hours

COURSE TITLE: Industrial Wastewater Engineering — 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 and corresponding CO and PO in the brackets. Symbols convey their usual meanings. Assume reasonable values for any necessary design data where required.

1. (a) Draw a process flow diagram for treatment of wastewater that has a high concentration of herbicides, as well as suspended solids and organic matter. Describe briefly. **(5)** (CO1,PO1)

   (b) A municipal wastewater treatment plant is planning to upgrade to a nitrogen removal plant. It is successfully incorporated nitrification with BOD removal in the existing activated sludge process. The plant wants to add a separate denitrification system consisting of two identical anoxic tanks followed by two identical clarifiers. Design a suspended growth denitrification system for the plant using methanol as a carbon source. Determine the tank volume and daily methanol dose required to achieve an effluent NO_3–N concentration of 3 mg/L. Wastewater effluent characteristics from nitrification system are: Flow rate = 3000 m^3/d, temperature = 20°C, NO_3–N = 30 mg/L, TSS = 20 mg/L, denitrification kinetic coefficients with methanol at 20°C: μ_{max} = 1.3/d, k_d = 0.04/d, k_s = 4 mg bsCOD/L, Y = 0.35 kg VSS/kg bsCOD, COD equivalent of methanol = 1.5 kg COD/kg methanol, MLSS in denitrification tank = 2500 mg/L, SRT = 6 d, HRT = 2 h and overflow rate in clarifier = 24 $m^3/m^2 \cdot d$. **(20)** (CO3,PO3)
   Estimate the annual cost if the price of methanol is BDT 100/kg.
   Design and sketch the anoxic tanks and clarifiers with proper dimensions.
   Sketch the process flow diagram of this nitrification-denitrification system.

2. (a) Sketch a diagram to discuss resource recovery from wastewater treatment facilities. **(5)** (CO1,PO1)

   (b) Design a two-stage trickling filter using the National Research Council (NRC) equations for treating a municipal wastewater having a BOD of 200 g/m^3 is to be treated by a two-stage trickling filter. The desired effluent quality is 25 g/m^3 of BOD. If both of the filter depths are to be 1.83 m and the recirculation ratio is 2:1. Determine the i) required filter diameters, ii) BOD loading to each filter, and iii) hydraulic loading to each filter. Assume that the flow rate = 7570 m^3/d, wastewater temperature = 20°C and E_1=E_2. **(20)** (CO3,PO3)
   Design and sketch the trickling filters with proper dimensions.
   Estimate the BOD removal efficiency if the wastewater temperature is 25°C.

3. (a) Explain the electrodialysis process used in wastewater treatment with a diagram. **(5)** (CO1,PO1)

   (b) Design an electrodialysis unit for an industry in Tongi area to treat its process wastewater. Determine the area, side dimensions and power required to demineralize 4000 m^3/d of treated wastewater to be used for industrial cooling water using an electrodialysis unit comprised of 240 cells. Assume that the following conditions **(20)** (CO3,PO3)

apply: total dissolved solids (TDS) concentration = 2568 mg/L, cation and anion concentration (Normality) = 0.01 g-eq/L, efficiency of salt removal = 50%, current efficiency = 90%, current density to normality (CD/N) ratio = 500 mA/cm^2.g-eq/L, Faraday's constant = 96,480 A.s/g-eq and resistance = 5 Ω.
Design and sketch the electrodialysis unit with proper dimensions.
Do you think cylindrical design of electrodialysis unit is better and why?
Select the pollutants in wastewater that can be removed by electrodialysis unit and justify your statement.
Estimate the annual cost if the price of electricity is BDT 10/kW.h and the daily utilization time of the electrodialysis unit is 10 h.

4. (a) Sketch diagrams and discuss the followings: osmotic flow, osmotic equilibrium and reverse osmosis. **(7)** (CO1,PO1)

(b) Estimate the quantity and quality of the waste stream, and the total quantity of water that must be processed from a reverse osmosis facility that is to produce 4000 m^3/d of water to be used for industrial cooling operations. Assume that the recovery rate is 90% and rejection rate is 90%, and that the concentration of the feed stream is 400 g/m^3. **(18)** (CO2,PO2)
Determine the overall plant efficiency and solute removal efficiency.
Do you think water and wastewater treatment plants apply reverse osmosis technique and why?
Select the impurities in wastewater that can be removed by reverse osmosis unit and justify your opinion.

5. (a) Differentiate between absorption and adsorption with diagrams. **(5)** (CO1,PO1)

(b) An isotherm test is conducted to find the adsorption of phenol by activated carbon (AC). From a 1000 mg/L solution of phenol, 100 mL is added to each of the 4 beakers containing different amounts of AC. The containers are shaken for 5 days. Then, the samples are filtered and analyzed for phenol concentration (C). Determine the isotherm equations for Langmuir and Freundlich by plotting linearized isotherms using appropriate graphs. **(20)** (CO2,PO2)
Describe the appropriateness of isotherms to predict adsorption of phenol.

Container	AC added (m), mg	C_o, mg/L	C_e, mg/L
1	50	600	450
2	100	600	300
3	200	600	100
4	300	600	33

6. (a) How recycled water can be produced for irrigation from wastewater? Describe briefly with a process flow diagram. **(7)** (CO1,PO1)

(b) Describe briefly the nitrification-denitrification process with reactions that take place with a diagram. **(7)** (CO1,PO1)

(c) Estimate the powdered activated carbon (PAC) adsorption dose and cost for a treated wastewater in a city. The wastewater with a flow rate of 1000 L/min is to be treated with PAC to reduce the concentration of residual organics measured as TOC from 5 to 1 mg/L. Assuming the following data apply, initial concentration, C_o = 5.0 mg/L, final **(11)** (CO2,PO2) concentration, C_e = 1.0 mg/L, PAC density = 450 g/L, compound = mixed organics, Freundlich capacity factor, K_f = 150 (mg/g) $(L/mg)^{1/n}$, and Freundlich intensity parameter, 1/n = 0.5. Determine the PAC requirements to treat the wastewater flow. If PAC costs $0.50/kg, estimate the annual cost for treatment, assuming the PAC will not be regenerated.

Do you apply activated carbon adsorption technique immediately after aeration tank in wastewater treatment and why?

Select the residual constituents in wastewater that can be removed by activated carbon adsorption technique and justify your answer.

Formulae

$$Y_n = \frac{Y}{1 + k_d\,\theta_c} \qquad \text{kg bsCOD/kg NO}_3\text{–N} = \frac{2.86}{1 - 1.42\,Y_n}$$

$$E_1 = \frac{100}{1 + 0.4432\sqrt{\dfrac{W_1}{VF}}} \qquad F = \frac{1 + R}{(1 + R/10)^2} \qquad E_2 = \frac{100}{1 + \dfrac{0.4432}{1 - E_1}\sqrt{\dfrac{W_2}{VF}}}$$

$$E_T = E_{20}\,(1.035)^{T-20} \qquad I = FQN\eta/nE_c \qquad P = R(I)^2$$

$$Q_c = Q_p(1-r)/r\,; \quad C_p = C_f(1-R)\,; \quad C_c = (Q_fC_f - Q_pC_p)/Q_c$$

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

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

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