Cork Institute of Technology

Bachelor of Engineering in Chemical & Process Engineering - Award

Summer 2001

CE4.4 Treatment & Disposal Technologies

(Time: 3 Hours)

Instructions
Answer any FOUR questions. Use separate answer books for each Question.
All questions carry equal marks.

Examiners: Dr. D. Glass
Mr. D. Fitzgerald
Dr. A. O'Gorman
Mr. P. Kennedy
Mr. I. O'Sullivan

Q1. (a) For the activated sludge process shown in Figure Q1 calculate the theoretical oxygen requirement for the aeration basin, and the SOR under field conditions and the volume of air required. Check the volume of air per Kg BOD_5 removed, per m^3 of wastewater treated and per m^3 of aeration tank volume (SOR, standard oxygen requirement)

Given: O_2 (kg/d) = $\dfrac{N}{\left[\left(C_{sw}\beta Fa - C\right)/C_{sw}\right]\left(1.024\right)^{T-20}}$

O_2 kg/d = $\dfrac{Q(S_o - S)}{BOD_5 / BOD_L}$ - 1.42Px

Fa = $\left(1 - \dfrac{altitude, m}{9450}\right)$

Px = Y_{obs} Q (S_o-S) $\left(kg/d\right)$

C = 1.5 mg/L

α = 0.95

β = 0.90

Elevation = 500m

BOD_5/BOD_L = 0.68

Aeration Basin Temperature = 24°C

Atmospheric Pressure = 102063 Pa

Density Hg = 13600 Kg/m^3

Density Air = 1.201 Kg/m^3

Diffuser Efficiency = 8%

Design Air = 1.5 (Theoretical Air)

Air contains 23.2% O_2 by weight

(b) Calculate the design flow to the four secondary clarifiers. Prepare a solids flux curve and hence determine the limiting solids loading rate given the following data.

solids concentration X, g/m^3	1000	1500	2000	3000	4000	5000	6000	7000	8000	9000
initial settling rate Vi M/L	4.40	4.20	2.80	1.30	0.67	0.34	0.2	0.1	0.05	0.03

Determine the area and diameter of the secondary clarifiers, and the overflow rate. Does the clarification meet design criteria?

Given $A = \dfrac{Q'X}{SF}$

Q2. (a) For the rotating biological contactor shown in Figure Q2 show that

$$Q(So-Se) = 2PN\pi(r_o^2 - r_u^2)\frac{Se}{Ks+Se}$$

where $P = \dfrac{(\mu_{max})_A X_f d}{Y_A}$

Note:

V_A = volume of active attached biological growth.

V_S = liquid volume of reactor

X_f = active biomass per unit volume of attached growth

X_S = active biomass per unit volume of suspended growth

μ_A = specific growth rate of attached biomass

μ_s = specific growth rate of suspended biomass

Y_A = theoretical yield coefficient for attached growth

Y_S = theoretical yield coefficient for suspended growth

N = number of disks.

d = film thickness. (20 Marks)

(b) Assume a single stage R.B.C. is to be constructed to treat a waste water flow of 0.1 MGD with a strength of 250 mg/l BOD_5 A treatability study has revealed that P = 2500 mg/ft^2 day and K_S = 100 mg/l. How much surface area will be required if a soluble effluent BOD_5 of 15 mg/l is desired? (5 Marks)

Q3. (a) (i) Figure Q3(a) describes a trickling filter process. Derive an expression to allow calculation of the ratio Se/Si. Se is the effluent concentration and Si is the influent concentration.

(ii) Size a two stage trickling filter system to treat a waste water flow of 2MGD with a strength of 400 mg/l BOD_5. Each filter is to be 8ft deep and operated at a recirculation ratio of 4 : 1. A 90% BOD_5 removal is desired. For the most effective design, the volume of the two filters should be approximately the same.

Given:

$$V_1 = 0.0263 Q So \frac{(1+0.1R)^2}{1+R} \left[\frac{E_1}{1-E_1} \right]^2$$

$$V_2 = 0.0263 Q S_1 \frac{(1+0.1R)^2}{1+R} \left[\frac{E_2}{(1-E_1)(1-E_2)} \right]^2$$

(13 marks)

(b) Briefly describe the functions of the various physical and chemical operations and processes used for wastewater treatment which are listed below. Indicate whether these operations and processes are used in primary, secondary or tertiary treatment.

Operation / Process

Coarse screening (3 marks)

Flocculation (3 marks)

Sedimentation (3 marks)

Chemical Precipitation (3 marks)

Q4. (a) Draw a labelled schematic diagram of an aerated grit chamber. (4 marks)

(b) Discuss the operation of this type of grit chamber. (2 marks)

Include the following items in your discussion:

(i) removal of particles (2 marks)

(ii) velocity of roll or agitation (2 marks)

(iii) flow pattern of the wastewater in the chamber (2 marks)

(iv) grit collection (2 marks)

(c) Design an aerated grit chamber for the treatment of municipal wastewater. The average flow rate is 0.6 $m^3 s^{-1}$. Assume that the peaking factor is 2.5. (Refer to table 1 for further data).

(i) Calculate the peak design flow rate (1 mark)

(ii) Calculate the grit chamber volume. It will be necessary to drain the chamber for routine maintenance. (2 marks)

(iii) Calculate the dimensions of the grit chamber. Use a width to depth ratio of 1.2 : 1.

(3 marks)

(iv) Calculate the air supply requirement. (2 marks)

(v) Estimate the average quantity of grit that must be handled per day. (3 marks)

Table 1. Typical Design Information for Aerated Grit Chambers

Item	Value: Range	Value: Typical
Detention time at peak flowrate, min	2–5	3
Dimensions:		
Depth, ft	7–16	
Length, ft	25–65	
Width, ft	8–23	
Width-depth ratio	1:1–5:1	1.5:1
Length-width ratio	3:1–5:1	4:1
Air supply, ft^3/min · ft of length	2.0–5.0	
Grit quantities, ft^3/Mgal	0.5–27	2.0

Note: ft × 0.3048 = m
ft^3/min · ft × 0.0929 = m^3/min · m
ft^3/Mgal × 0.00748 = $m^3/10^3 m^3$

Q5. (a) Why is it necessary to conduct wastewater characterisation studies? (5 marks)

(b) Discuss the procedures for wastewater sampling under the following headings:

(i) Sampling techniques (4 marks)

(ii) Sampling locations (4 marks)

(iii) Sampling intervals (4 marks)

(iv) Sampling equipment (4 marks)

(v) Sample preservation (4 marks)

Q6. You have just been appointed to the position of Environmental Director with Lone Ranger Chemicals, a Multinational Conglomerate. Your new employers have recently been severely punished in a number of countries as a result of non-compliance with air pollution licences due to gaseous emissions. What advice would you give to your fellow directors on the options available to the company if it wishes to avoid non-compliance in the future? (25 Marks)

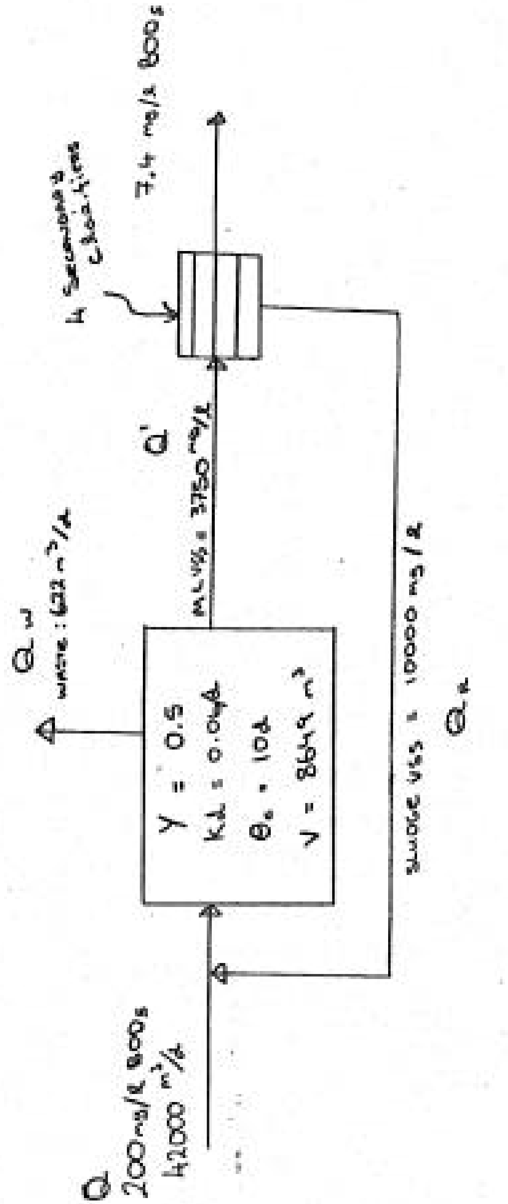


Figure Q1

TABLE [illegible]

Dissolved-oxygen concentration in water as a function of temperature and barometric pressure (salinity = 0 ppt)[a]

Temp, °C	Dissolved-oxygen concentration, mg/L									
	Barometric pressure, millimeters of mercury									
	735	740	745	750	755	760	765	770	775	780
0	14.12	14.22	14.31	14.41	14.51	14.60	14.70	14.80	14.89	14.99
1	13.73	13.82	13.92	14.01	14.10	14.20	14.29	14.39	14.48	14.57
2	13.36	13.45	13.54	13.63	13.72	13.81	13.90	14.00	14.09	14.18
3	13.00	13.09	13.18	13.27	13.36	13.45	13.53	13.62	13.71	13.80
4	12.66	12.75	12.83	12.92	13.01	13.09	13.18	13.27	13.35	13.44
5	12.33	12.42	12.50	12.59	12.67	12.76	12.84	12.93	13.01	13.10
6	12.02	12.11	12.19	12.27	12.35	12.44	12.52	12.60	12.68	12.77
7	11.72	11.80	11.89	11.97	12.05	12.13	12.21	12.29	12.37	12.45
8	11.44	11.52	11.60	11.67	11.75	11.83	11.91	11.99	12.07	12.15
9	11.16	11.24	11.32	11.40	11.47	11.55	11.63	11.70	11.78	11.86
10	10.90	10.98	11.05	11.13	11.20	11.28	11.35	11.43	11.50	11.58
11	10.65	10.72	10.80	10.87	10.94	11.02	11.09	11.16	11.24	11.31
12	10.41	10.48	10.55	10.62	10.69	10.77	10.84	10.91	10.98	11.05
13	10.17	10.24	10.31	10.38	10.46	10.53	10.60	10.67	10.74	10.81
14	9.95	10.02	10.09	10.16	10.23	10.29	10.36	10.43	10.50	10.57
15	9.73	9.80	9.87	9.94	10.00	10.07	10.14	10.21	10.27	10.34
16	9.53	9.59	9.66	9.73	9.79	9.86	9.92	9.99	10.06	10.12
17	9.33	9.39	9.46	9.52	9.59	9.65	9.72	9.78	9.85	9.91
18	9.14	9.20	9.26	9.33	9.39	9.45	9.52	9.58	9.64	9.71
19	8.95	9.01	9.07	9.14	9.20	9.26	9.32	9.39	9.45	9.51
20	8.77	8.83	8.89	8.95	9.02	9.08	9.14	9.20	9.26	9.32
21	8.60	8.66	8.72	8.78	8.84	8.90	8.96	9.02	9.08	9.14
22	8.43	8.49	8.55	8.61	8.67	8.73	8.79	8.84	8.90	8.96
23	8.27	8.33	8.39	8.44	8.50	8.56	8.62	8.68	8.73	8.79
24	8.11	8.17	8.23	8.29	8.34	8.40	8.46	8.51	8.57	8.63
25	7.96	8.02	8.08	8.13	8.19	8.24	8.30	8.36	8.41	8.47
26	7.82	7.87	7.93	7.98	8.04	8.09	8.15	8.20	8.26	8.31
27	7.68	7.73	7.79	7.84	7.89	7.95	8.00	8.06	8.11	8.17
28	7.54	7.59	7.65	7.70	7.75	7.81	7.86	7.91	7.97	8.02
29	7.41	7.46	7.51	7.57	7.62	7.67	7.72	7.78	7.83	7.88
30	7.28	7.33	7.38	7.44	7.49	7.54	7.59	7.64	7.69	7.75
31	7.16	7.21	7.26	7.31	7.36	7.41	7.46	7.51	7.46	7.62
32	7.04	7.09	7.14	7.19	7.24	7.29	7.34	7.39	7.44	7.49
33	6.92	6.97	7.02	7.07	7.12	7.17	7.22	7.27	7.31	7.36
34	6.80	6.85	6.90	6.95	7.00	7.05	7.10	7.15	7.20	7.24
35	6.69	6.74	6.79	6.84	6.89	6.93	6.98	7.03	7.08	7.13
36	6.59	6.63	6.68	6.73	6.78	6.82	6.87	6.92	6.97	7.01
37	6.48	6.53	6.57	6.62	6.67	6.72	6.76	6.81	6.86	6.90
38	6.38	6.43	6.47	6.52	6.56	6.61	6.66	6.70	6.75	6.80
39	6.28	6.33	6.37	6.42	6.46	6.51	6.56	6.60	6.65	6.69
40	6.18	6.23	6.27	6.32	6.36	6.41	6.46	6.50	6.55	6.59

[a]From Colt, J.: "Computation of Dissolved Gas Concentrations in Water as Functions of Temperature, Salinity, and Pressure," *American Fisheries Society Special Publication 14*, Bethesda, MD, 1984.

Note: ppt = parts per thousand

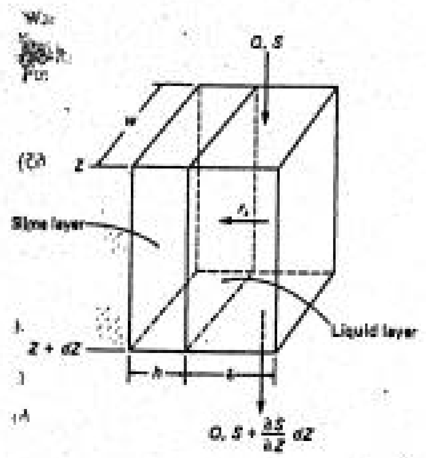
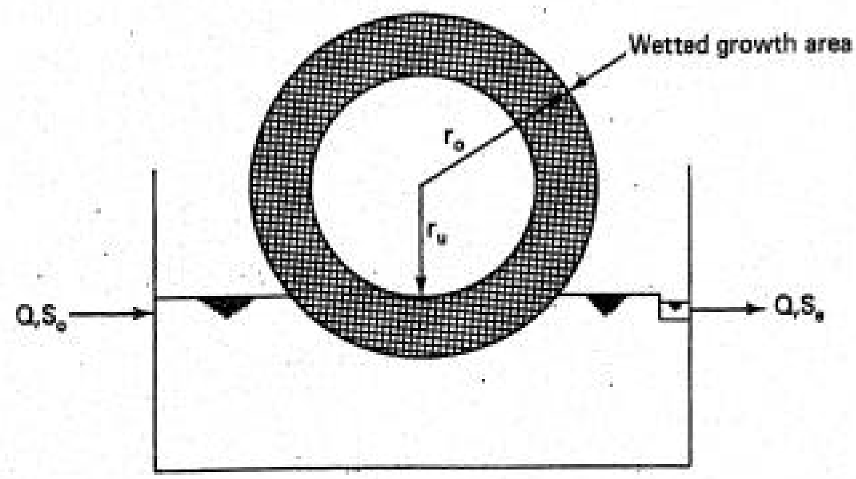


Figure Q3(a)



Rotating Biological Contactor.

Figure Q2