GX495

OLLSCOIL NA hEIREANN, GAILLIMH
NATIONAL UNIVERSITY OF IRELAND, GALWAY

SUMMER EXAMINATIONS, 2001

THIRD ENGINEERING EXAMINATION
ENVIRONMENTAL ENGINEERING

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Time allowed: *Three* hours.
Attempt *five* questions.

1 (a) Describe the biochemical reactions leading to carbonaceous and nitrogenous oxidation of organic waste in water. Sketch a typical BOD V's Time curve showing both carbonaceous and nitrogenous oxidation.

[8]

(b) The carbonaceous BOD at time 't' can be shown to be given by the following expression:

$$BOD(t) = L_0 K_1 t \left(1 + \frac{K_1 t}{6}\right)^{-3}$$

The BOD test was carried out on a sample of a wastewater and the following results obtained:

Time (Days)	0.5	1	2	3	4	5	7	10	15
BOD (mg/L)	5	37	93	155	205	210	255	280	315

Derive values for the rate reaction constant and the ultimate BOD and then express the BOD at any time in terms of these.

[12]

2 A town is serviced by a combined sewerage system and a secondary level sewage treatment works (STW). The DWF for the system is 5,000m^3/d and during a storm the maximum flow in the sewerage system is 105,000m^3/d.

The STW is located adjacent to a river which has a flow of 5m^3/s and an associated 4mg /L BOD_5 during the storm just upstream of the STW. The river is considered to have a constant cross-section of 16.6m^2.

The wastewater has 400mg/L BOD_5 before it enters the STW and the final effluent has 20mg/L BOD_5. Wastewater exiting from the storm water tanks contains 80% of the original BOD_5.

(i) Draw an outline sketch of the flows through the plant and the river and show locations in the plant where flow separation is required.

[6]

(ii) Determine the BOD_5 in the river just downstream of the STW

[4]

(iii) Using the Streeter-Phelps equation compute the oxygen deficit at a cross-section of the river 10km downstream of the STW for the following conditions:

BOD rate reaction constant = 0.23/day

Reaeration constant = 0.4/day

Temperature of mixture just downstream of STW - 21^{0}C

The dissolved oxygen of the mixture is 6.5mg/L

The Streeter Phelps equation is given by

$$D = \frac{k_1 L_0}{k_2 - k_1}\left(e^{-k_1 t} - e^{-k_2 t}\right) + D_0 e^{-k_2 t}$$

[10]

3 (a) Describe the difference between Type I and Type II settling. Derive an expression for the 'overflow rate' for Type I settling and discuss its significance with respect to the design of a sedimentation tank.

[8]

(b) A settling column analysis on a source of drinking water for a city indicates that an overflow rate of 18m/d will produce satisfactory removal of suspended solids in a 3m deep basin.

If the city requires 30,000m3/d of water design the required long-rectangular sedimentation basins and carry out relevant design checks.

[12]

4 (a) Discuss the relevance of horizontal velocity with respect to the design of grit chambers. Show why the ideal cross-section of a grit chamber is parabolic and outline what cross-section is used in practice.

[10]

(b) A pipe of diameter 1.0m carries a maximum flow of $0.9m^3/s$ into a grit chamber. The water level downstream of the grit chamber is controlled by a flume having a throat width of 0.67m. Design the ideal cross-section of a grit chamber to take all the maximum flow when the horizontal velocity of the water is 0.3m/s. Comment on the cross-section obtained.

If the grit particle has a settling velocity of 0.02m/s determine the length of the grit chamber so that the particle settles out.

Note: Design the above grit chamber cross-section using only 4 widths.

[10]

5 (a) Describe, using the aid of sketches, the operations of both a bio-tower and a rotating biological contactor. Discuss the main advantages and disadvantages of the two systems.

[13]

(b) The effluent from a primary clarifier has a flow rate of $25,000m^3/d$ with an associated soluble BOD of 130mg/L. Determine the plan area, general configuration of a RBC and the BOD loading rate if the final effluent has a soluble BOD of 15mg/L.

Note: Use 3.7m diameter disks on 7.6m shafts – each shaft contains $10,000m^2$ of surface area.

[7]

6 (a) Sketch a schematic diagram of a typical secondary wastewater treatment system works. What is meant by the each of the following terms: preliminary, primary and secondary treatments.

[11]

(b) During the log-growth phase of biomass in a biological reactor the growth rate constant is given by the Monod equation. Explain, by means of a sketch, the parameters of the Monod equation.

Using this equation, derive an expression for the growth rate in terms of the change in biomass over time if endogenous decay is ignored and there is an excess of food. Determine a value for the maximum growth rate when biomass doubles over a ten hour period.

[9]

7 (a) Considering that the centerline dilution of a sewage effluent plume is given by:

$$S = 0.38 g_1^{1/3} d / q^{2/3}$$

a pipeline / diffuser system is constructed to obtain good dilution of an effluent in the sea. If the pipeline is being laid over a very gently sloping beach develop an expression for the ratio

$$R = R_{Lo} / R_L$$

where

R_{Lo} is the rate of change of dilution with respect to pipeline length

R_L is the rate of change of dilution with respect to diffuser length

What is the significance of the ratio in R in relation to the design of an outfall diffuser ?

[12]

(b) An outfall pipeline is to be laid on a beach sloping offshore at 10°. A 30m long diffuser is located in 35m deep water. If the maximum total flow through the outfall is 3.6m3/s, the seawater density is 1000kg/m3 and the density difference between the effluent and the seawater is 40 determine:

(i) The centerline dilution at the surface above the outfall and comment on the dilution value.

(ii) Whether the rate of dilution increases faster by increasing the length of the outfall or increasing the length of the diffuser.

[8]

ADDITIONAL INFORMATION

$k_1(T°C) = k_1(20°C) \times (1.047^{T-20})$

$k_2(T°C) = k_2(20°C) \times (1.016^{T-20})$

$BOD(t) = L_0 (1 - e^{-k_1 t})$

Temperature (°C)	**Oxygen Concentration (mg/L)**
14	10.37
15	10.15
16	9.95
17	9.74
18	9.54
19	9.39
20	9.17
21	8.99
22	8.83

Equilibrium concentration of dissolved oxygen as a function of temperature

Activated-Sludge Design Parameters	
Mean Cell Residence time (d)	4 - 15
Food-to-Mass Ratio	0.2-0.5
Hydraulic Retention Time (hr)	3 - 5
MLSS (mg/L)	3000-6000
Recycle Ratio	0.25 – 1.0

ADDITIONAL INFORMATION (Cont'd)

Filtration Design Aids:

$$h_f = \frac{L(1-e)V_s^2}{e^3 g} \sum \left(\frac{f_{ij} X_{ij}}{d_{ij}} \right)$$

$$f_{ij} = \frac{150(1-e)}{\text{Re}} + 1.75$$

$$\text{Re} = \frac{\phi \rho V}{\mu} d_{ij}$$

Flocculator Design Aids:

$$P = D\, v_p$$

$$D = (C_d\, A_p\, V^2_p) / 2$$

$$G = \left(\frac{p}{V\mu} \right)^{\frac{1}{2}}$$

$$C_d = 1.8$$

Water Characteristics:

$$\rho = 1000 \text{kg/m}^3$$

$$\mu = 1.085 \times 10^{-3} \text{ N.s/m}^2$$

Flume Formula:

$$Q = 1.71\, b\, H^{3/2}$$

Grit Chamber Formula:

$$W = 4.92\, Q/H$$

Monod Equation:

$$k = \frac{k_0\, S}{k_s + S}$$

ADDITIONAL INFORMATION (Cont'd)

Sedimentation Basin Design Factors:

Retention Time	2 - 4hrs
Horizontal Velocity	< 36m/hr
Weir Overflow Rate	< 14m^3/hr per m run
Width	< 17m

ADDITIONAL INFORMATION (Cont'd)