

OLLSCOIL NA hÉIREANN, GAILLIMH  
NATIONAL UNIVERSITY OF IRELAND, GALWAY

**SECOND SEMESTER EXAMINATIONS, 2000**

**B.E. DEGREE EXAMINATION**

**DESIGN OF WATER/WASTEWATER TREATMENT SYSTEMS**

Professor R.A. Falconer;  
Professor P. O'Donoghue;  
Dr. M. Rodgers;  
Dr. M. Hartnett;  
Mr. B. Gallagher M.Eng.Sc;

Time allowed: *two* hours.  
Attempt *four* questions.

1. (i) Illustrate the operation of the following biofilm systems: fluidised bed, moving bed and submerged stationary biofilter. Distinguish between hydraulic erosion and complete sloughing off of biofilms. Show, using neat sketches, how (a) oxygen and (b) organic substrate can be rate limiting in a biofilm.
- (ii) A trickling stone filter with recycle has a diameter of 10 m and a height of 3 m, and is loaded with 200 m<sup>3</sup>/d of mixed and industrial wastewater having a biochemical oxygen demand (BOD) of 500 g/m<sup>3</sup>. If the hydraulic surface loading rate is 1.2 m/h, find the volumetric loading rate and the recycle flow.  
In order to eliminate the recycle, it was proposed to replace the stone media with plastic media having a surface area of 150 m<sup>2</sup>/m<sup>3</sup> and an organic areal loading rate of 5 g BOD/m<sup>2</sup>.d. Calculate the new height of filter required.
2. (i) Illustrate in detail a nitrification-denitrification activated sludge system using (a) the influent wastewater as the organic substrate for denitrification and (b) methanol as the substrate. Comment on why methanol may be required.
- (ii) A denitrification activated sludge system, consisting of a completely mixed anoxic tank, a completely mixed aerobic tank and a clarifier in series, with return of nitrate to the anoxic zone, treats an influent wastewater flow of 12,000 m<sup>3</sup>/d. The influent has a substrate biochemical oxygen demand (BOD) of 0.25 kg/m<sup>3</sup> and a total nitrogen concentration (TN) of 0.05 kg/m<sup>3</sup>. The effluent has a BOD of 0.020 kg/m<sup>3</sup> and a TN of 0.005 kg/m<sup>3</sup>. The stoichiometric yield constant for heterotrophs is 0.8 in terms of BOD, and for autotrophs is 0.2 in terms of nitrogen. The amount of nitrogen used in cell synthesis is 0.05 kg N/kg suspended solids (SS). The volatile suspended solids (VSS) in the anoxic zone is maintained at 4 kg/m<sup>3</sup> and the denitrification rate is 0.5 g N/kgVSS.h. Calculate the anoxic tank volume. Show how you would obtain the recycle ratio for the system. State any assumptions you make.

3. (i) Write detailed notes on the biological removal of phosphorus in an activated sludge system. Illustrate your answer with a line diagram of a suitable system. Describe what happens in both the anaerobic and aerobic zones of the system. What effect would the introduction of nitrate to the anaerobic zone have on the phosphorus removal.  
  
(ii) Wastewater, with an acetic acid concentration of  $60 \text{ g/m}^3$ , flows into the completely mixed anaerobic tank of an activated sludge biological phosphorus removal system at a rate of  $3000 \text{ m}^3/\text{d}$ . The volume of the tank is  $200 \text{ m}^3$ . Using a Monod expression to model the uptake of acetic acid to cell storage, calculate the concentration of acetic acid in the effluent from the anaerobic tank. Assume that the maximum uptake rate of acetic acid is  $1.5 \text{ kg/m}^3 \cdot \text{d}$  and that the saturation constant for the acetic acid in the Monod expression is  $3 \text{ g/m}^3$ .
4. (i) Illustrate the following anaerobic digesters: (a) an upflow fixed film reactor, (b) a fluidised bed reactor and (c) a completely mixed reactor with recycle. Write notes on anaerobic digestion, paying particular attention to hydrolysis, acid production, methane production, temperature, pH and operational problems.  
  
(ii) A wastewater with a biodegradable COD of  $3 \text{ kg/m}^3$  and a flow of  $1400 \text{ m}^3/\text{d}$  is to be treated in a biofilm anaerobic digester to give a final effluent with a biodegradable COD of  $0.3 \text{ kg/m}^3$ . The sludge concentration in the digester is  $10 \text{ kg/m}^3$  and the removal rate is assumed to be  $0.5 \text{ kg COD for every kg of sludge}$ . If the biofilm media has a specific surface area of  $100 \text{ m}^2/\text{m}^3$ , calculate the total area of media required.
5. (i) Describe how the composition of industrial wastewaters may differ from that of municipal wastewater. Make reference in your answer to specific industrial wastewaters.  
  
(ii) Discuss why phosphorus is of concern in Ireland in terms of our rivers and lakes, making reference to the main sources of phosphorus discharged to our inland waters. What legislative and technical measures are available to reduce the effect of phosphorus on our rivers and lakes?
6. (i) Briefly discuss the process of coagulation as applied to the treatment of potable water; in particular, make reference to the coagulants used, pH buffering and temperature effects.  
  
(ii) Design a three-compartment flocculator having the general configuration shown in Figure 1. It is required to design the details for the first compartment only.

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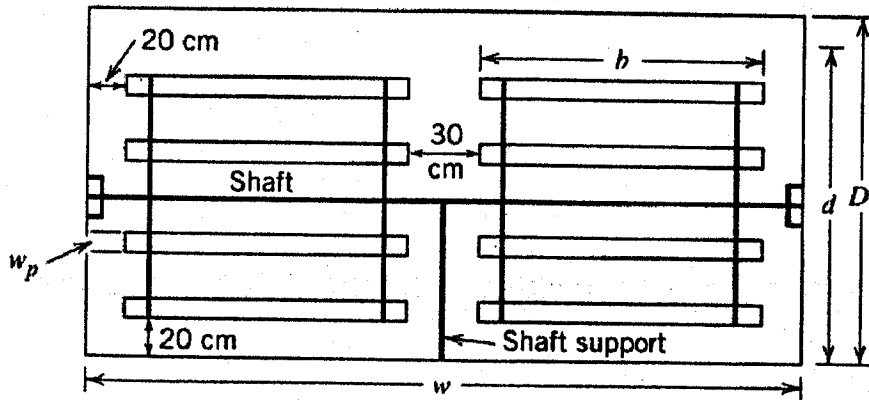


Figure 1

The flocculator must be designed for the following conditions:

Design flow	20,000 m <sup>3</sup> /d
G values	30, 20, 10
Max paddle length	4.2 m
Min paddle clearances	20 cm
Total detention time	25 mins
Shaft supports	30 cm spacing
Lowest temperature	10°C
Max depth	4.1 m

### Flocculator Design Aids

#### General

Peripheral speed of paddles	0.09 m/s - 0.9 m/s
k	0.25
C <sub>D</sub>	1.8 for flat blades

#### Area of Blades

Paddles oriented normal to flow:

15 - 20% of the tank cross-sectional area

Paddles oriented parallel to flow:

15 - 20% of the tank side area

#### Depth - Area Ratio

No specific limits -- Max depth < 5 m

#### Freeboard

0.5 m

#### Width

Paddle width, 10 cm < w < 20 cm

Basin width, same width as sedimentation basin

#### Water Properties @ 10°C

$$\rho = 999.7 \text{ kg/m}^3$$

$$\mu = 1.307 \times 10^{-3} \text{ N.s/m}$$

#### Power Requirements

$$G = \sqrt{\frac{P}{\mu V}}$$

$$P = (1.44 \times 10^{-4}) \rho C_D b [N(1 - k)]^3 (r_o^4 - r_i^4)$$

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**SECOND SEMESTER EXAMINATIONS, SUMMER 2000**

**B.E. Degree**

**Offshore and Coastal Engineering II**

Professor R. A. Falconer

Professor P. O'Donoghue

Dr. T. P. Mullarkey

Time allowed: *Two* hours

Answer *three* questions

Relevant set of graphs and formulas are available from the invigilator

1. (a) Define the following terms which are of importance in the case of floating bodies:

Centre of buoyancy;  
Centre of rotation;  
Centre of floatation;  
Centre of gravity;  
Metacentric heights; and  
Metacentres.

- (b) A barge of length 18.3 m, width 6.1 m, and depth 3 m is loaded with sand up to 1.2 m from the barge bottom. Find the waterline; the metacentric height with respect to rotation about the longitudinal axis; and the applied moment for a rotation of  $3^\circ$  about the longitudinal axis. The weight of the barge is 133.44 kN, and the unit weight of sand is  $15.708 \text{ kN/m}^3$ .

2. (a) Evaluate the magnitude of the maximum and minimum force imparted to a moored ship by an ocean current whose speed is 1 m/s and whose direction coincides with the longitudinal direction of the ship. The length of the ship is 260m, its beam is 37 m, and its draft is 14 m maximum and 5 m minimum.

(b) Two concrete dolphins, each of length 13 m, are placed in front of a petroleum hose-handling platform. The dolphins are supported on steel piles and protected with cylindrical rubber fenders. The area is exposed to offshore winds of 33.5 m/s. Compute the fender dimensions in order that the dolphins may cater for the docking of a ship with a displacement of 700,000 kN and an approach speed of 0.1 m/s normal to the face of the dolphin. The area of the ship exposed to the wind is

3,800 m<sup>2</sup>. The docking force should not exceed the wind force.

(c) Write notes on bulk cargo and container terminals.

3. (a) A design wave with a height of 10.0 m and period of 10 seconds in a depth of 25.0 m acts on a pile with a diameter of 1.25 m. Find the total force on the pile when the crest is 40 m in front of the pile. Take  $C_D=0.7$  and  $C_M=1.5$ .

(b) A 33.5 metric ton concrete armour unit is required for the protection of a rubble-mound structure against a given wave height in salt water. The unit weight of water is 10 kN/m<sup>3</sup>. The unit weight of concrete used is 22.8 kN/m<sup>3</sup>. Find the required weight of armour unit for concrete with

- (i) unit weight of 22 kN/m<sup>3</sup> and
- (ii) unit weight of 26.7 kN/m<sup>3</sup>.

(c) Describe the method for the evaluation of wave forces and moments on smooth vertical walls. Distinguish breaking from non-breaking waves.

4. (a) Outline with sketches the basic aspects of three wave focusing techniques by which wave power from large sections of coastal waters are focused on conversion devices occupying relatively small regions.

(b) Show with sketches the arrangement used in the cavity resonator to maintain unidirectional flow past the turbine.

(c) Describe with sketches self-rectifying turbines whose operation is independent of the axial flow direction.

(d) Find the fundamental period of oscillation for an open basin of length 500 m and depth 10 m.