GX510

OLLSCOIL NA hÉIREANN, GAILLIMH

NATIONAL UNIVERSITY OF IRELAND, GALWAY

SECOND SEMESTER EXAMINATIONS, 2001

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 a nitrification-denitrification activated sludge system using the influent wastewater as the organic substrate for denitrification.
Comment on: (a) the effect of high oxygen concentrations in the return flow, and (b) the magnitude of the return flow in terms of nitrate removal.
(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 20,000 m^3/d.The influent has a substrate biochemical oxygen demand (BOD) of 0.28 kg/m^3 and a total nitrogen concentration (TN) of 0.06 kg/m^3. The effluent should have a BOD of 0.020 kg/m^3 and a TN of 0.005 kg/m^3. 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^3 and the denitrification rate is 0.5 g N/kgVSS.h in the absence of any oxygen. Calculate the anoxic tank volume.
If the activated sludge in the anoxic zone is mixed by a stirrer with an oxygen mass transfer coefficient, K_la, of 4/day, determine the reduced denitrification rate due to the presence of the oxygen, if for every gram of oxygen in the anoxic zone 0.35 grams of nitrate nitrogen are not used up. The saturated concentration for oxygen in the wastewater is 11 g/m^3. State any assumptions you make.

2. (i) For the nitrification of a municipal wastewater, illustrate the operational cycle of a single sludge activated sludge system in two reactors with alternating flows. Comment on: (a) the effect of organic carbon on nitrification and (b) the oxygen demand by ammonium-nitrogen.
(ii) The wastewater flow into an alternating activated sludge facility is 2000 m^3/d with a concentration of 0.25 kg BOD/m^3. The sludge concentration in the facility is 5 kg SS/m^3 and the effluent concentration is to be 0.02 kg BOD/m^3. The activated sludge is aerated for 3 hours out of a total 8 hour cycle. The stoichiometric yield constant, Y, is 0.8 in terms of BOD. Calculate (a) the activated sludge volume needed to carry out the required carbonaceous oxidation and full nitrification if the necessary aerobic sludge age is 14 days, and (b) the hydraulic retention time.

3. (i) Illustrate three types of contact stabilisation system that can be used to upgrade an activated sludge plant. Which is the more rational basis for the preliminary design of a wastewater treatment system: volumetric loading or sludge loading? Give a reason for your selection.

(ii) An oxidation ditch plant has a volume of wastewater of 1500 m^3 just after withdrawal of settled effluent. The plant operates as follows: 2.5 hours aeration, 0.5 hours settling and 1 hour withdrawal of settled wastewater. The continuous flow into the plant is 50 m^3/hour, organic matter is 0.28 kg BOD/m^3 and the sludge concentration during aeration is 5.5 kg SS/m^3. Calculate the sludge loading rate in terms of BOD. What BOD removal efficiency could be expected from this loading rate? Explain any equation used.

4. (i) Illustrate an activated sludge system for biological phosphorus removal Describe what happens in both the anaerobic and aerobic zones of the system. Give an estimate on the amount of dissolved phosphorus that may be removed in relation to readily biodegradable organic substrate.

(ii) Wastewater, with an acetic acid concentration of 80 g/m^3, flows into the completely mixed anaerobic tank of an activated sludge biological phosphorus removal system at a rate of 4000 m^3/d. The volume of the tank is 250 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 kg/m^3.d and that the saturation constant for the acetic acid in the Monod expression is 3 g/m^3. Develop any equation used and explain each term.

5. (i) 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?

(ii) In a municipal wastewater treatment plant with a flow of 1000 m^3/d, phosphorus concentration is to be reduced from an influent concentration of 12 g P/m^3 to an effluent concentration of 1.0 g P/m^3 using ferric chloride.
It is assumed that the effluent suspended solids have a concentration of 20 g/m^3 with a phosphorus content of 3%. Calculate the amount of ferric chloride required in the precipitation process if a molar ratio, Fe/P, of 1.2 is used in the metal dosing. The atomic weights are P = 31, Cl = 35.5 and Fe = 55.9.
As an alternative to chemical precipitation in the plant, 10,000 m^2 of land having a 1.0 m depth of soil are available for percolation of the effluent; the soil has an adsorption capacity of 100 mg P/kg soil and a density of 1800 kg/m^3. How many days would elapse before the adsorption capacity of the soil is used up.

6. (a) Carry out a power balance on a control volume to determine an expression for velocity gradient in terms of power and dynamic viscosity – refer to the sketch in Figure Q6.

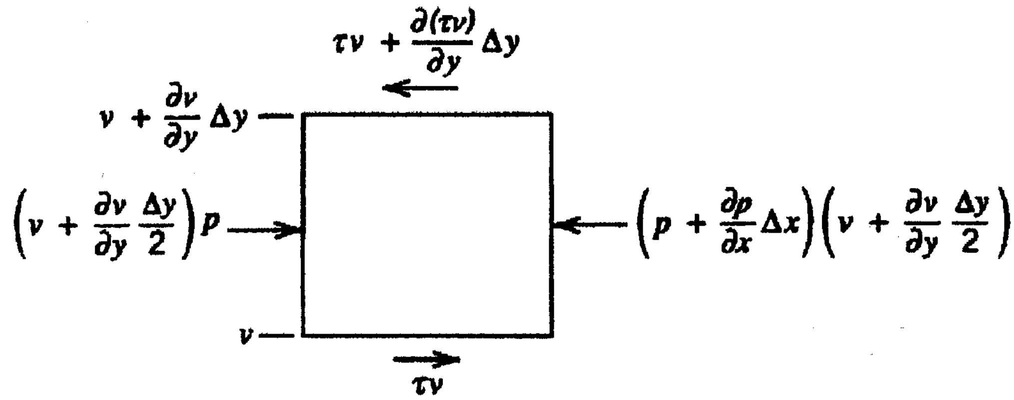

Figure Q6

Notes: (i) From a power balance it can be shown that

$$\frac{\partial p}{\partial x} = -\frac{\partial \tau}{\partial y}$$

(ii)

$$\tau = -\frac{\partial v}{\partial y}$$

(b) Design and sketch a weir to provide good mixing in a water treatment plant for the following conditions:

- $G = 1100 s^{-1}$
- Minimum downstream velocity 0.5m/s
- Flow $Q = 25{,}000 m^3/d$
- Channels are rectangular
- Water temperature is 20^0C

Notes: (i) Power = $\rho g Q h_L$

(ii) At 20^0C $\rho = 998.2 kg/m^3$ & $\mu = 1.002 x 10^{-3} N.s/m$

(iii) Weir formula $Q = \frac{2}{3} C_d w \sqrt{2gh}$ where $C_d = 0.62$