GX491

OLLSCOIL NA hÉIREANN, GAILLIMH

NATIONAL UNIVERSITY OF IRELAND, GALWAY

FIRST SEMESTER EXAMINATIONS, 2000

B.E. DEGREE EXAMINATION

ENVIRONMENTAL ENGINEERING SYSTEMS

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Professor P. O'Donoghue;
Dr. M. Rodgers.

Time allowed: *Two* hours.
Attempt *three* questions.

Access to a computer with Excel will be provided for each candidate. Candidates using Excel must clearly present equations used in their Excel worksheets.

1. (i) Write detailed notes on the use of activated carbon in treating wastewaters in batch and continuous flow adsorbers.

   (ii) Adsorption pilot plant experiments were conducted on three 1 m high, 60 mm diameter, activated carbon columns in series. The influent had a COD concentration, C_o, of 85 g/m^3 and a continuous flow of 14 litres/hour. It took 70, 175 and 280 hours to reach a breakpoint concentration, C_b, of 10 g/m^3 in the 1st, 2nd and 3rd columns respectively. Estimate the size of column required to treat the same wastewater with a flow of 250 litres/min. at a loading rate of 2 litres/m^2.sec. for one month before a breakpoint of 10 g/m^3 is attained. The time to reach breakpoint, t_b, can be given by the equation:

   $$t_b = (C_u^o.z)/(C_o.u_s) - Ln(C_o/C_b-1)/(k_r.C_o)$$

   where z is the bed height, u_s is the wastewater velocity, C_u^o is the initial adsorptive capacity of the carbon and k_r is an adsorptive parameter.

2. (i) Write notes on the uses of biofilms. A biofilm reactor is repeatedly immersed into wastewater and taken out into air. Illustrate what can happen to the oxygen and chemical oxygen demand (COD) concentrations in the biofilm during one cycle of immersion and emergence.

   (ii) A biofilm, 500 μm thick, is immersed for 15 seconds in wastewater with an oxygen concentration of 5 g/m^3. On immersion, the oxygen concentration in the biofilm is as follows:

Biofilm depth (μm)	0	100	200	300	400	500
Oxygen (g/m^3)	10	9	8	7	7	7

The base material, to which the biofilm is attached, is impermeable. The rate of utilisation of oxygen by the biofilm, r, is modelled by the following equation:

$$r = \mu.X.(Y-1).S_o/(Y.(K_o+S_o))$$

where μ is the maximum specific growth rate of the biofilm, X is the concentration of microorganisms in the biofilm, Y is the stoichiometric yield constant, S_o is the dissolved oxygen concentration and K_o is the saturation coefficient for dissolved oxygen. Assume that μ is 2 /day, X is 10,000 g/m^3, Y is 0.6 and K_o is 0.1 g/m^3. The diffusion coefficient of oxygen, D, through the biofilm can be taken as 2000 μm^2/s. Using a finite difference technique with a time interval of 1 second, calculate the new oxygen concentrations in the immersed biofilm after each of three consecutive time intervals.

3. (i) What two objectives should be met in the design of clarifiers for an activated sludge wastewater treatment plant? Describe with the aid of sketches how zone settling occurs in a batch column test. Write notes on the sludge volume index test, giving typical values of the index.

(ii) The flow from an activated sludge reactor is 8500 m^3/d with a solids concentration of 3000 g/m^3. Samples of activated sludge were examined in batch column settling tests and the results were as follows:

Concentration (g/m^3)	1400	3000	4050	4950	6500	7950	9450
Settling velocity (m/h)	2.91	1.20	0.54	0.26	0.14	0.08	0.05

Determine the area of the clarifier that would thicken the solids to 11,000 g/m^3. Will the calculated area give a clarified effluent?

4. (i) Write detailed notes on the biological removal of nitrogen and phosphorus in wastewater treatment processes. Show that ammonium-nitrogen can have a high demand on oxygen in receiving waters.

(ii) A denitrification system, consisting of an anoxic tank, aerobic tanks and a clarifier in series, treats a wastewater flow of 7200 m^3/d. The influent has a substrate chemical oxygen demand, COD, of 600 g/m^3, a biomass concentration of 5 g/m^3 and a nitrate concentration of 1 g/m^3. It flows into the 1200 m^3 anoxic tank where it is completely mixed with a return flow of 21,600 m^3/d from the clarifier. The return flow has a nitrate concentration of 20 g/m^3 and a zero COD concentration. The stoichiometric biomass to substrate yield coefficient, Y, has a value of 0.6 and the specific decay rate of the biomass is 0.1/day. Assume that the growth rate of the biomass, r, in the anoxic tank is given by the following equation:

$$r = K1.\ Sno$$

where K1 is the specific growth rate of the biomass with a value of 600 /day and Sno is the nitrate concentration in the anoxic tank. The stoichiometric nitrate to biomass yield coefficient is given by the expression (1-Y)/(2.86Y). Assume that the biomass concentration is the same in the anoxic and aerobic tanks. Ignore sludge wastage from the system for this analysis. Calculate the concentrations of nitrate and COD in the effluent from the anoxic tank at steady state. Derive any equations you use.

5. (i) Write notes on the mesophilic anaerobic digestion of wastes, paying particular attention to the following processes: hydrolysis, acidogenesis and methanogenesis. Show that 1 gram of methane has a COD of 4 grams and a volume equivalent of 1.4 litres of gas.

(ii) A completely mixed mesophilic anaerobic reactor with a sludge retention time of 25 days is used to treat an organic influent substrate with a concentration of 11,000 g/m^3. Assume that the biological processes in the reactor simply consist of the growth and decay of both acidogens and methanogens. In the digester, the following reactions are assumed to occur: 15 g of influent substrate are used in the growth of 1 g of acidogens with the remaining 14 g being converted to acetate; 31 g of the acetate product are used to grow 1 g of methanogens and produce 30 g of methane - all the above masses are given in terms of chemical oxygen demand, COD. Assume that the growth rates of the acidogens and the methanogens, r, are both given by the following equation:

$$r = K. S$$

where K is the specific growth rate of both microorganisms with a value of 0.15 /day and S is the appropriate substrate concentration in the reactor.The specific decay rate of the microorganisms is 0.05 /day. Calculate the acidogen, methanogen, organic substrate, acetate and methane concentrations in the digester at steady state. Derive any equations you use.