GX512

OLLSCOIL NA hÉIREANN, GAILLIMH

NATIONAL UNIVERSITY OF IRELAND, GALWAY

SECOND SEMESTER EXAMINATIONS, 1999

B.E. DEGREE EXAMINATION

ENVIRONMENTAL ENGINEERING SYSTEMS

Professor A.R. Cusens;
Professor P. O'Donoghue;
Dr. M. Rodgers;
Dr. K.McNamara;
Mr. J. Mulqueen.

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

1. (i) Write detailed notes on hazardous wastes in Ireland. Describe an adsorption process for treating hazardous wastes.

(ii) Adsorption pilot plant experiments were conducted on three 1 m high, 50 mm diameter, activated carbon columns in series. The influent had a chemical oxygen demand (COD) concentration, C_o, of 80 g/m^3 and a flow of 10 litres/hour. It took 50, 150 and 260 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) What are the two objectives that 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.

(ii) The flow from an activated sludge reactor is 8000 m^3/d with a solids concentration of 3500 g/m^3. Samples of activated sludge were examined in batch column settling tests and the results were as follows:

Concentration (g/m^3)	1350	2160	2900	3500	4500	5200	6500	8500
Settling velocity (m/h)	2.90	1.80	1.20	0.75	0.4	0.23	0.12	0.07

Determine the size of the clarifier that would thicken the solids to 10,000 g/m^3.

3. (i) Write notes on three different biofilm wastewater treatment systems; illustrate your answer. What are the advantages of biofilm systems over suspended growth systems for the treatment of wastewater.

(ii) A biofilm, 250 μm thick, is taken out of wastewater into air. On emerging, the oxygen concentration in the biofilm is as follows:

Biofilm depth (μm)	0	50	100	150	200	250
Oxygen (g/m^3)	10	5	2	0.5	0	0

When the biofilm is in the air, it is assumed that the oxygen concentration at its surface is 10 g/m^3. The base material, to which the biofilm is attached, is impermeable. The rate of utilisation of oxygen by the biofilm, r, can be modelled by the following equation:

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

where μ is the maximum specific growth rate of the biofilm, X is the concentration of microorganisms in the biofilm and Y is the stoichiometric yield constant. Assume that μ is 3/day, X is 10,000 g/m^3 and Y is 0.6. Mass transfer occurs by diffusion only, and the diffusion coefficient of oxygen through the biofilm can be taken as 2000 $\mu m^2/s$.
Using a finite difference technique with a time interval of 0.1 seconds, calculate the new oxygen concentrations in the biofilm after each of two consecutive time intervals; the biofilm remains in the air during this time. Develop any equation you use.

4. (i) Write notes on biological nitrification and denitrification in wastewater treatment. Sketch a layout of a denitrification treatment system. 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 6000 m^3/d.The influent has a substrate COD of 550 g/m^3, a biomass concentration of 5 g/m^3 and a nitrate concentration of 1 g/m^3. It flows into the 1000 m^3 anoxic tank where it is completely mixed with a return flow of 18,000 m^3/d from the clarifier. The return flow has a nitrate concentration of 22 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:

$$r = K_1 . S_{no}$$

where K_1 is the specific growth rate of the biomass with a value of 100/day and S_{no} is the nitrate concentration in the anoxic tank.The stoichiometric nitrate to biomass yield coefficient is given by the expression (1/Y-1)/(2.86). Assume that the biomass concentration is the same in the anoxic and aerobic tanks. Calculate the concentrations of nitrate and COD in the effluent from the anoxic tank at steady state. Develop any equation you use.

5. (i) Write detailed notes on the characterisation of chemical oxygen demand (COD) and nitrogen substrates in wastewater. Describe the substrates in terms of biodegradable and non-biodegradable components and detail the substrate conversions that take place in treatment processes.

(ii) A completely mixed activated sludge system consisting of an aeration tank and clarifier with recycle and wastage reduces COD in a wastewater flow of 6000 m^3/d. The influent to the aeration tank has a readily biodegradable substrate COD of 240 g/m^3, a slowly biodegradable substrate of 200 g/m^3 and a biomass concentration of 40 g/m^3. The volume of the activated sludge reactor is 1000 m^3 and the sludge retention time is 6 days. The stoichiometric biomass to substrate yield coefficient 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_g, is given by the following equation:

$$r_g = K_1 . S_s$$

where K_1 is the specific growth rate of the biomass with a value of 200/day and S_s is the substrate concentration in the reactor.
Assume that the hydrolysis rate of the biomass, r_h, is given by the following equation:

$$r_h = K_2 . X_s$$

where K_2 is the specific growth rate of the biomass with a value of 40/day and X_s is the substrate concentration in the reactor.
Calculate the biomass, and the readily and slowly biodegradable substrate concentrations in the reactor at steady state. Develop any equation you use.

6. (i) Explain the influence of moisture, temperature and sunlight on the severity of air pollution effects on materials.
(ii) A power plant burns coal at the rate of 11 kg. per second. The coal contains 3.5 % sulphur by weight. If the combustion process is 93 % efficient, (i.e. 7 % ends up as ash), estimate the SO_2 emission, Q, from the power plant stack. The gram molecular weight of sulphur is 32 and that of oxygen is 16.
(iii) The terrain downwind from this power plant is level and uniform and the wind speed at a particular time is 5 m/s. Pasquill's stability category for the atmosphere at the time is estimated to be Category 'E'. The height of the stack is 100 m and the plume rise is 12 m. Use the Gaussian Dispersion Model and the graphs for the dispersion coefficients (given on a separate sheet) to check if the EU Directive concentration of 80 $\mu g/m^3$ is exceeded at ground level at a point 4 km along the plume axis and 0.3 km perpendicular to the plume axis.

7. (i) Write notes on the structure of Environmental Impact Statements

(ii) In the case of the land spreading of pig slurry, name the significant components that could impact on (a) human beings (b) surface water and (c) soil. For any two of (a), (b) and (c), discuss the impact, appropriate mitigation measures and monitoring of effects.

(iii) State the environmental significance of phosphorus and nitrate-nitrogen. In the case of one, mention the transport mechanisms involved and possible control measures.

8. (i) Write notes on percolation tests, soil percolation trenches, intermittent filters and polishing filters. Explain why the results of a soil percolation test cannot be used to design the loading rate of septic tank effluent on the invert of a percolation trench.

(ii) Sketch the essentials of a percolation trench labelling its components. A four-person household produces 0.72 m^3 of wastewater per day. Using percolation trenches 450 mm wide, determine the required length of the trenches if the hydraulic loading rate on the invert of each trench is 20 litres/ m^3.d.

(iii) State why intermittent filters and mechanical aeration systems must be followed by a polishing filter. Determine the thickness of loam soil required to reduce coliforms from 10^5 MPN/100 ml to 10 MPN/100 ml using the equation

$$N = N_o e^{-\lambda z}$$

where N is the concentration of coliforms leaving the filter; N_o is the concentration entering the filter; λ is a filter constant (= 20 for loam soil); and z is the thickness of the filter. Mention disposal routes for the final effluent.