Department of Biochemical Engineering and Biotechnology

BE 711 / BEL715: Biological Waste Treatment

Major Examination

30th November 2006
13.00 – 15.00 Hrs.
II - 378

Answer all questions. Maximum marks 40.

1. Explain the principle behind biological phosphorus removal processes. How does the side-stream phosphorus removal differ from the main-stream phosphorus removal?

   (4 marks)

2. Why is it necessary to treat wastewater treatment sludges before disposal? State the ways and means by which these objectives can be achieved.

   (4 marks)

3. Write short notes on (a) land-filling of solid wastes (b) biological treatment of wastewaters containing toxic compounds.

   (4 marks)

4. A fermentation industry produces 10,000 litres of effluent per day, having a BOD_5 of 400 $mg.l^{-1}$. This is being treated using a sequencing batch reactor (SBR) so as to result in an effluent having no suspended solids and BOD_5 not exceeding 30 $mg.l^{-1}$. The reactor has a square cross section with each side measuring 2 metres, and each cycle of operation lasts 24 hours, with two-third (66.67%) of the total volume being decanted at the end of this period.

   A laboratory batch fermentation experiment using the same aerobic mixed microorganisms consumed all the substrate present in a 1 litre batch reactor containing a medium with 1% (w/v) glucose as the sole carbon souree, producing 4 grams of biomass (dry weight) in the process. Similar growth pattern of the mixed eulture is expeeted to be taking place in the SBR also. The ultimate BOD of 1 g glueose is 1.0667g and the ratio of ultimate BOD to BOD_5 is 0.8.

   The design F/M ratio for the SBR immediately following a sludge wastage operation is 0.08 g BOD_5. (g MLVSS) $^{-1}$. d^{-1} and the specific oxygen uptake rate of the mixed aerobic culture is 0.008 g O_2 (g VSS)$^{-1}$. h^{-1}. When aeration was started, the dissolved oxygen (D.O) concentration was recorded as zero in the initial few seconds, but started increasing gradually. The equilibrium dissolved oxygen concentration at the temperature of operation is 8.0 $mg.l^{-1}$ and its variation over the time of the year is negligible.

This industry has decided to expand its operations and the result will be the production of 45,000 litres of effluent per day, of the same characteristics as at present. The management wants to treat the entire effluent stream to the present discharge level by converting the effluent treatment plant into an activated sludge process with completely mixed aeration tank. However, the aeration tank and oxygen supply system will be the existing reactor and accessories only. The proposed plant will have a design SRT of 4 days.

(a) Calculate the MLVSS concentration in the aeration tank, sludge production rate and theoretical rate of oxygen transport required in the proposed process.

(b) If the geometry and operating conditions in the aeration tank are maintained the same as in the case of the SBR, comment on the adequacy of the oxygenation system for the modified plant.

(c) If you want to overcome possible oxygen transport problems by employing O_2-enriched air instead of normal air, calculate the level of oxygen enrichment required so as to provide a steady state D.O concentration of 2 mg.l^{-1} inside the aeration tank. The equilibrium dissolved oxygen concentration is related to the partial pressure of oxygen in air through the relation

$$c^* = 8.0 + 10.0\,(p - 0.21)$$

where c^* is the equilibrium dissolved oxygen concentration in mg.l^{-1} and p is the oxygen partial pressure.

The BOD(ultimate) of 1g VSS may be taken as 1.42.

(12 Marks)

5. An industry produces 2,000,000 litres of effluent per day, with an average BOD_5 of 50,000 mg l^{-1}. This is being treated in an anaerobic filter to such an extent that the gas produced in the process reduces the furnace oil consumption in the boilers by 50%. After the anaerobic treatment stage, the effluent is further treated in an activated sludge process to bring down the BOD_5 to 30 mg l^{-1}. The activated sludge process uses a system of diffused air aeration with an overall oxygen transfer efficiency of 8%. The sludge generated in the activated sludge treatment plant is stabilized through a thermophilic aerobic digestion process operating at 20°C. The treated effluent from the activated sludge process has a residual ammonia nitrogen of 40 mg l^{-1} and is further treated in a separate stage nitrification process.

   (i) Compute the energy recovery in terms of biogas and comment on it with respect to the energy required for aeration in the activated sludge process.
   (ii) If the waste activated sludge solids are 90% biodegradable, specify the conditions to be satisfied for the aerobic sludge digestion to operate as an autothermal unit.
   (iii) If the separate stage nitrification is designed at a factor of safety of 2.0, calculate the ammonia nitrogen concentration in the treated effluent coming out of the nitrification tank.
   (iv) If the maximum feasible specific ammonia nitrogen utilization rate is 0.1 (gNH_4-N) (gMLVSS)$^{-1}$ d^{-1}, calculate the MLVSS concentration required to be maintained in the nitrification reactor.

The following data is available on the treatment plant:

Ratio of BOD_5 to ultimate BOD in the raw effluent = 0.80
Normal (average) consumption of furnace oil in the boilers = 40,000 litres per day
Calorific value of furnace oil = 30,000 Btu. l^{-1}
Calorific value of methane = 1000 Btu. ft^{-3}(at STP)
Maximum possible methane generation = 350 litres (at STP) per kg ultimate BOD removed
Observed yield of biomass based on substrate (for aerobic heterotrophs) = 0.5
Power required for aeration system compressors = 2 kWH per kg of air delivered
Air contains 23% oxygen by weight.
Biological heat generated by aerobic digestion = 15,000 J (g biodegradable VSS)$^{-1}$
Minimum expected temperature in the nitrification reactor = 20°C
Design residual DO concentration in the nitrification reactor = 2 mg l^{-1}
Yield of biomass based on substrate for autotrophs = 0.2 g VSS (g NH_4-N)$^{-1}$
k_d for the autotrophs = 0.05 d^{-1}

$K_N = 10^{0.051T - 1.158}$
1 Btu = 2.93×10^{-4} kWH
$\mu_m' = \mu_m e^{0.098(T-15)} [DO/(DO+Ko_2)]$

$\mu_m = 0.5 d^{-1}$
$Ko_2 = 1.2$ mg l^{-1}
Hydraulic retention time in the nitrification reactor = 8 hours.

(16 marks)