Department of Biochemical Engineering and Biotechnology

BEL715: Biological Waste Treatment

Major Examination

26th November, 2008
13.00 – 15.00 Hrs.
Venue: WS-101

Answer all questions. Maximum marks 40.

1. 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)

2. Write short notes on (i) sanitary land-filling (ii) biological treatment of waste waters containing toxic compounds.

(4 marks)

3. Explain the basic concepts applied in the biological nutrient removal processes targeting nitrogen and phosphorus removal.

(4 Marks)

4. 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% at a dissolved oxygen concentration of 2 mg l^{-1}. The sludge generated in the activated sludge treatment plant is stabilized through a thermophilic aerobic digestion process operating at 60°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.

(4 Marks)

(ii) What will be the percentage savings in net energy to be supplied to the activated sludge process if oxygenation is done using oxygen-enriched air containing 50% oxygen? 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 overall oxygen transfer efficiency increases linearly with the oxygen transfer rate (OTR).

(8 Marks)

(iii) If the waste activated sludge solids are 90% biodegradable, calculate the maximum aeration rate (expressed in volume per volume per minute, vvm) at which the aerobic sludge digestion can operate as an autothermal unit. 10% of the biological heat generated is lost as sensible heat for the incoming sludge and air. The consistency of the sludge fed to the digester is 4% (w/v) and the sludge residence time in the digester is 4 days. 50% saturated air (density = 1.3 $g.l^{-1}$) is used for aerating the sludge and leaves the digester almost saturated with moisture (0.02 kg moisture per kg air). Latent heat of vaporization of water may be taken as 540 $cal.g^{-1}$.

(8 Marks)

(iv) 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.

(4 Marks)

(v) 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.

(4 Marks)

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.

(4+8+8+4+4=28)