

Example 8.2

Calculate the values of X_{vd} , N_{nd} , Alk_d and O_{tda} in the two digesters of the above example for fair sludge settleability (Fig. 8.10):

Solution:

(1) Determine the required retention time in the aerobic digesters:

For the calculated optimal sludge age $R_s = 3.5$ d, one has $f_{ai} = X_a/X_v = 0.68$. Thus, using Eq. (8.40):

$$R_d = N/b_h \cdot \left[\frac{[1/f_{ae} + f - 1]^{1/N}}{[1/f_{ai} + f - 1]} \right] - 1$$

$$R_d = (2/0.24) \cdot \left[\frac{((1/0.1 + 0.2 - 1)/(1/0.66 + 0.2 - 1))^{0.5} - 1}{1} \right]$$

$$= 21.6 \text{ days and } R_{d1} = R_{d2} = 10.8 \text{ days}$$

(2) Determine the concentration of digested active sludge X_{ad} and the active sludge concentration in the first and second digester X_{a1} and X_{a2} :

For the given thickened sludge concentration X_{th} of $22.0 \text{ g TSS.l}^{-1}$ and a volatile sludge fraction f_v of 0.75, the active thickened sludge concentration X_{ai} can be calculated as $0.75 \cdot 0.66 \cdot X_{th} = 10.9 \text{ g VSS.l}^{-1}$. The digested active sludge concentration in the digesters is calculated as:

$$X_{ad} = X_{ai} \cdot (1/f_{ai} - 1/f_{ae}) / (1 - f - 1/f_{ae})$$

$$= 10.9 \cdot (1/0.66 - 1/0.10) / (1 - 0.2 - 1/0.1) = 10.9 \cdot 0.92 = 10.1 \text{ g VSS.l}^{-1}$$

$$X_{a1} = X_{ai} / (1 + b_h \cdot R_1) = 10.9 / (1 + 0.24 \cdot 10.8) = 3.0 \text{ g VSS.l}^{-1}$$

$$X_{a2} = X_{a1} / (1 + b_h \cdot R_2) = 2.9 / (1 + 0.24 \cdot 11.4) = 0.8 \text{ g VSS.l}^{-1}$$

It can now be verified that indeed:

$$X_{ad} = 10.1 = X_{ai} - X_{a2} = 10.9 - 0.8 = 10.1 \text{ g VSS.l}^{-1}$$

(3) Determine the values of X_{vd} , N_{nd} , Alk_d and O_{tda}

With the values of X_{ai} , X_{a1} and X_{a2} calculated above, the operational parameters of the digesters can now easily be calculated and are shown in Table 8.3.

Table 8.3 Operational parameters of the optimised digester system of Fig. 8.10

Parameter	UoM	Excess sludge	Digester	
			1	2
f_{ai}	(-)	0.66	0.29	0.1
X_{ad}	g VSS.l ⁻¹	-	7.9	2.2
X_{ai}	g VSS.l ⁻¹	10.9	3.0	0.8
X_{vi}	g VSS.l ⁻¹	16.5	10.1	8.4
X_{ti}	g TSS.l ⁻¹	22	15.7	12.9
NO ₃ ⁻ -N	g N.l ⁻¹	-	630 (*)	824 (*)
Alkalinity	mg CaCO ₃ .l ⁻¹	-	2250 (*)	2906 (*)
OUR	mg O ₂ .l ⁻¹ .h ⁻¹	-	46.0	13.2
BOD	g O ₂ .l ⁻¹	12.0	3.2	0.8
BOD	g O ₂ .g VSS ⁻¹	0.73	0.32	0.1
Retention time	days	-	10.8	11.4

(*) = variation in the digesters independent of the concentration in the excess sludge

It is interesting to calculate the ratio between the oxygen demand in the digester and the organic load to the activated sludge process. The volume of the two digesters is 0.38 m³.kg⁻¹ COD.d⁻¹ (Fig. 8.10a): i.e. 0.19 m³.kg⁻¹ COD.d⁻¹ for each digester. The oxygen uptake rates are 46.0 and 13.2 mg O₂.l⁻¹.h⁻¹ or 1.10 and 0.32 g O₂.l⁻¹.d⁻¹ respectively (Table 8.3) so that:

$$mS_{od} = 0.19 \cdot (1.10 + 0.32) = 0.27 \text{ kg O}_2 \cdot \text{kg}^{-1} \text{ COD}$$

Where mS_{od} = fraction of influent COD oxidised in the digester

The calculated oxygen demand of 0.27 kg O₂.kg⁻¹ COD applied is very significant in economical terms. The oxygen consumption for the oxidation of organic material in the aeration tank is calculated from Eq. (3.43) for the optimal sludge age of $R_s = 3.5$ days:

$$mS_o = (1 - f_{ns} - f_{np}) \cdot (1 - f_{cv} \cdot Y + f_{cv} \cdot (1 - f) \cdot b_h \cdot C_r) = 0.46 \text{ kg O}_2 \cdot \text{kg}^{-1} \text{ COD}$$

It is concluded that under the specified conditions the oxygen demand in the digesters of 0.27 kg O₂.kg⁻¹ COD (assuming nitrification of the liquefied nitrogen) is more than fifty percent of the oxygen consumption in the aeration tank of 0.46 kg O₂.kg⁻¹ COD (when no nitrification is assumed).