

**Example 8.7**

Design an anaerobic digester to process the excess sludge produced from an activated sludge process treating sewage ( $f_{ns} = f_{np} = 0.1$  and  $f_v = 0.75$ ) at a sludge age of 5 days (with and without primary settling). Thickening to 25 g TSS.l<sup>-1</sup> and an operational temperature of 20 °C are assumed, so that the retention time is calculated using Eq. (8.59):

$$R_{di} = 20 \cdot (1.1)^{(20-T)} + 5 = 20 + 5 = 25 \text{ days}$$

**(a) Without primary settling:**

It is calculated that in the case of raw sewage treatment ( $R_s = 5$  days), the excess sludge production is 0.26 kg VSS.kg<sup>-1</sup> COD and 0.35 kg TSS.kg<sup>-1</sup> COD. Hence for the thickened sludge concentration of 25 g TSS.l<sup>-1</sup> the excess sludge flow is given by:

$$mq_{th} = 0.35/25 = 0.014 \text{ m}^3 \cdot \text{kg}^{-1} \text{ COD}$$

Therefore for the calculated retention time of 25 days the volume of the digester will be:

$$V_{di} = R_{di} \cdot mq_{th} = 0.014 \cdot 25 = 0.35 \text{ m}^3 \cdot \text{kg}^{-1} \text{ COD} \cdot \text{d}^{-1}$$

In comparison, for an assumed sludge concentration in the aeration tank of 3.5 g TSS.l<sup>-1</sup> (a typical value for the mixed liquor concentration), the required reactor volume is:

$$v_r = mX_t/X_t = 0.35 \cdot 5/3.5 = 0.5 \text{ m}^3 \cdot \text{kg}^{-1} \text{ COD} \cdot \text{d}^{-1}$$

It is concluded that under the given circumstances the digester volume is 0.35/0.50 = 70% of the aeration tank volume. For processes involving nutrient removal, this ratio would be much lower as the operational sludge age in the activated sludge process will be higher.

**(b) With primary settling:**

In this case, a production of 0.22 g VSS.g<sup>-1</sup> COD of primary sludge and 0.16 g VSS.g<sup>-1</sup> COD of secondary sludge are calculated, resulting in a total excess sludge production of:

$$mE_t = (mE_{v1} + mE_{sv})/f_v = (0.22 + 0.16)/0.75 = 0.51 \text{ g TSS.g}^{-1} \text{ COD}$$

Hence after thickening the flow of sludge will be:

$$mq_{th} = 0.51/25 = 0.020 \text{ m}^3 \cdot \text{kg}^{-1} \text{ COD} \cdot \text{d}^{-1}$$

For the calculated retention time of 25 days this results in a digester volume  $v_{di} = 0.51 \text{ m}^3 \cdot \text{kg}^{-1} \text{ COD}$ . This value is significantly larger than in the configuration without primary settling. On the other hand, the reactor volume will be smaller. If again a mixed liquor concentration of 3.5 g TSS.l<sup>-1</sup> is assumed, the aeration tank volume after primary settling is calculated as:

$$v_r = mX_t/X_t = 0.16 \cdot 5/3.5 = 0.23 \text{ m}^3 \cdot \text{kg}^{-1} \text{ COD} \cdot \text{d}^{-1}$$

The total volume in the case of primary settling equals  $0.23 + 0.51 = 0.74 \text{ m}^3 \cdot \text{kg}^{-1} \text{ COD} \cdot \text{d}^{-1}$ , which is slightly smaller than in the configuration without primary settling:  $0.51 + 0.35 = 0.86 \text{ m}^3 \cdot \text{kg}^{-1} \text{ COD} \cdot \text{d}^{-1}$ . However, it was assumed that the sludge age in the aeration tank would be the same for both cases: i.e.  $R_s = 5$  d. In practice this assumption may not always be justified.