

**Example 8.4**

In an anaerobic digester primary sludge  $(\text{CH}_2\text{O})_n$  and secondary sludge  $(\text{C}_5\text{H}_7\text{O}_2\text{N})$  are digested. Excess sludge production is  $m_{S_{xv1}} = 0.3 \text{ kg COD.kg}^{-1}$  influent COD in the primary clarifier and  $m_{S_{xv2}} = 0.2 \text{ kg COD.kg}^{-1}$  influent COD for the secondary sludge. If the sludges have concentrations of 40 and 20 g TSS.l<sup>-1</sup> respectively and the removal of the volatile solids in the digester is 40 percent, calculate per unit mass of influent COD:

- (1) Fraction of influent COD that is digested in the system;
- (2) Alkalinity production and alkalinity in the digester effluent;
- (3) Methane and biogas production;

Assume that  $f_{cv}$  is equal to 1.5 g COD.g<sup>-1</sup> VSS for both primary and secondary sludge.

**Solution:**

- (1) In the digester  $0.4 \cdot 300 = 120 \text{ g COD}$  of primary sludge and  $0.4 \cdot 200 = 80 \text{ g COD}$  of secondary sludge will be digested, so that in total  $120 + 80 = 200 \text{ g COD}$  is digested per kg COD influent, or 20 percent of the influent COD;
- (2) During the digestion of secondary sludge, the alkalinity production is equal to  $0.44 \text{ g CaCO}_3.\text{g}^{-1} \text{ VSS}$  or  $0.29 \text{ g CaCO}_3$  per gram digested COD. This results in a production of  $0.29 \cdot 80 = 23.5 \text{ g CaCO}_3.\text{kg}^{-1}$  influent COD. During the digestion of primary sludge, no variation in alkalinity is expected. For the assumed primary and secondary sludge concentrations of 40 and 20 g VSS.l<sup>-1</sup>, the volume of the primary sludge is  $120/(1.5 \cdot 40) = 2 \text{ litre.kg}^{-1}$  influent COD and that of the secondary sludge is  $80/(1.5 \cdot 20) = 2.7 \text{ litre.kg}^{-1}$  influent COD.

Thus, the sludge volume to be digested is  $2 + 2.7 = 4.7 \text{ litre.kg}^{-1}$  influent COD. Since alkalinity production was estimated at a minimum of 23.5 g CaCO<sub>3</sub>, the alkalinity in the digester will increase by at least  $23.5/4.7 = 5000 \text{ mg CaCO}_3.\text{l}^{-1}$ , enough to establish an adequate pH for methanogenesis (van Haandel and Lettinga, 1994);

- (3) Methane production is 25% of the digested COD mass i.e.:  $0.25 \cdot 200 = 50 \text{ g CH}_4.\text{kg}^{-1}$  COD or  $3.12 \text{ mole CH}_4.\text{kg}^{-1}$  applied COD or  $3.12 \cdot 25 = 78 \text{ litre CH}_4.\text{kg}^{-1}$  applied COD. The theoretical CO<sub>2</sub> production will also be  $3.12 \text{ moles CO}_2.\text{kg}^{-1}$  applied COD.

However, as there is an alkalinity production of 23.5 CaCO<sub>3</sub>.kg<sup>-1</sup> influent COD, it may be expected that a stoichiometric fraction (i.e.  $23.5/50 = 0.47 \text{ mole CO}_2$ ) will be absorbed and remain as bicarbonate in the liquid phase. If it is assumed that the concentration of dissolved CO<sub>2</sub> is negligible compared to the bicarbonate concentration, only  $3.12 - 0.47 = 2.65 \text{ mole CO}_2$  or  $2.65 \cdot 25 = 66 \text{ litre of CO}_2$  will desorb per kg of digested COD. Therefore, the total production of biogas may be expected to be  $78 + 66 = 144 \text{ litre per kg digested COD}$  or  $0.2 \cdot 174 = 55 \text{ litre per kg influent COD}$ , having a composition of  $78/144 = 54$  percent of methane. In practice the biogas would probably be richer in methane because:

- Fats will be present so that more methane is generated than carbon dioxide;
- Some alkalinity will be generated due to digestion of primary sludge, resulting in an increase in the CO<sub>2</sub> conversion into bicarbonate;
- Depending on the pH, the dissolved CO<sub>2</sub> concentration may be a significant fraction of the bicarbonate concentration.