

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⁻¹ 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⁻¹ 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 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⁻¹, 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 CaCO₃, 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 CO₂ 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 CaCO₃.kg⁻¹ 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 CO₂ 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 CO₂ conversion into bicarbonate;
- Depending on the pH, the dissolved CO₂ concentration may be a significant fraction of the bicarbonate concentration.