

**Example 5.3**

Assuming that  $f_m$ , the non-aerated sludge mass fraction, is 50 percent in Example 5.2, estimate the possible denitrification (1) in a pre-D system and (2) in a Bardenpho system with two denitrification zones of equal size. Calculate this for two different values of  $f_{pd}$ , the fraction of PAO capable of denitrification: i.e. 0.8 and 1.0. Assume  $K_2 = 0.10$  and  $K_3 = 0.08 \text{ mg N} \cdot \text{mg}^{-1} \text{ VSS} \cdot \text{d}^{-1}$ .

**Solution:**

The anaerobic mass fraction is 0.15 and the aerobic mass fraction is 0.5, therefore the anoxic mass fraction is equal to 0.35. Using Eqs. (5.9 to 5.12), the following influent composition can be calculated from the data of the previous example:

$$\begin{aligned} S_{bsp} &= 100 - 2 \cdot 16.7 = 66.6 \text{ mg COD} \cdot \text{l}^{-1} \rightarrow f_{bsp} = 0.67 \\ S_{bsh} &= 2 \cdot 16.7 = 32.6 \text{ mg COD} \cdot \text{l}^{-1} \rightarrow f_{bsh} = 0.33 \\ S_{bp} &= S_{bsp} = 67.4 \text{ mg COD} \cdot \text{l}^{-1} \rightarrow f_{bp} = 67.4/400 = 0.17 \\ S_{bh} &= 400 - 67.4 = 332.6 \text{ mg COD} \cdot \text{l}^{-1} \rightarrow f_{bh} = 0.83 \end{aligned}$$

**(1) Pre-D configuration**

Using Eq. (5.9) for  $f_{pd} = 0.8$ :

$$\begin{aligned} D_{c1} &= [f_{dn} \cdot (f_{bsp} \cdot f_{pd} + f_{bsh}) \cdot f_{sb} + K_2 \cdot f_{x1} \cdot (C_{rh} \cdot f_{bh} + C_{rp} \cdot f_{bp} \cdot f_{pd})] \cdot S_{bi} \\ &= [0.11 \cdot (0.67 \cdot 0.8 + 0.33) \cdot 0.25 + 0.10 \cdot 0.35 \cdot (1.32 \cdot 0.83 + 3.21 \cdot 0.17 \cdot 0.8)] \cdot 400 \\ &= 31.3 \text{ mg N} \cdot \text{l}^{-1} \end{aligned}$$

For  $f_{pd} = 1.0$ , the value of  $D_{c1}$  is equal to  $34.3 \text{ mg N} \cdot \text{l}^{-1}$ . In comparison, when the denitrification capacity is calculated under the hypothesis of Clayton, the PAO do not exhibit anoxic activity. Instead the value of  $K_2$  increases from 0.10 to  $0.25 \text{ mg N} \cdot \text{mg}^{-1} \text{ VSS} \cdot \text{d}^{-1}$  and the value of  $D_{c1} = 0.25 \cdot 1.32 \cdot 0.35 \cdot 0.83 \cdot 400 = 38.6 \text{ mg N} \cdot \text{l}^{-1}$ .

**(2) Bardenpho configuration**

In the case where the anoxic sludge mass is equally divided over the pre-D and post-D reactors, both will have an anoxic mass fraction of  $0.35/2 = 0.175$ .

For  $f_{pd} = 0.8$  the denitrification capacity will be equal to:

$$\begin{aligned} D_{c1} &= [0.11 \cdot (0.67 \cdot 0.8 + 0.33) \cdot 0.25 + 0.10 \cdot 0.175 \cdot (1.32 \cdot 0.83 + 3.21 \cdot 0.17 \cdot 0.8)] \cdot 400 \\ &= 20.6 \text{ mg N} \cdot \text{l}^{-1} \end{aligned}$$

And using Eq. (5.11):

$$\begin{aligned} D_{c3} &= K_3 \cdot f_{x3} \cdot (C_{rh} \cdot f_{bh} + C_{rp} \cdot f_{bp} \cdot f_{pd}) \cdot S_{bi} \\ &= 0.08 \cdot 0.175 \cdot (1.32 \cdot 0.83 + 3.21 \cdot 0.17 \cdot 0.8) \cdot 400 = 8.6 \text{ mg N} \cdot \text{l}^{-1} \end{aligned}$$

The combined denitrification capacity  $D_{c1} + D_{c3} = 29.1 \text{ mg N} \cdot \text{l}^{-1}$ . For  $f_{pd} = 1.0$  the combined denitrification capacity  $D_{c1} + D_{c3} = 22.8 + 9.2 = 32.0 \text{ mg N} \cdot \text{l}^{-1}$ . Under the hypothesis that PAO do not exhibit anoxic activity, the denitrification capacity will be:

$$D_{c1} = 0.25 \cdot 1.32 \cdot 0.175 \cdot 0.83 \cdot 400 = 19.3 \text{ mg N.l}^{-1}$$

$$D_{c3} = 0.12 \cdot 1.32 \cdot 0.175 \cdot 0.83 \cdot 400 = 9.3 \text{ mg N.l}^{-1}$$

$$D_{c1} + D_{c3} = 19.3 + 9.3 = 28.6 \text{ mg N.l}^{-1}$$

It can be observed that the expected denitrification capacity for the bio-P removal system, with 80 to 100% of the PAO capable of denitrification, corresponds very well with the denitrification capacity calculated under the assumption that only the normal heterotrophic biomass is able to denitrify, i.e. with an increased  $K_2$  and  $K_3$  value.