

4.3.4 Denitrification capacity

In practice, the most important parameter in a nitrogen removing activated sludge process is the amount of nitrate that can be removed per litre of influent. This parameter is called the denitrification capacity and can be determined from Eqs. (4.46, 4.47 and 4.55) as shown below.

4.3.4.1 Denitrification capacity in a pre-D reactor

If the volume of a pre-D reactor is insufficient for complete removal of the easily biodegradable material, the removed nitrate mass can be expressed as:

$$MN_d = r_D \cdot V_1 = (K_1 + K_2) \cdot X_a \cdot V_1 \quad (V_1 < V_{min}) \quad (4.56)$$

Where:

MN_d = mass of removed nitrate per time unit
 V_1 = pre-D reactor volume

Knowing that the volume of influent entering into the pre-D reactor per time unit is equal to the influent flow Q_i , the removed nitrate per litre of influent is given as:

$$D_{c1} = MN_d / Q_i = (K_1 + K_2) \cdot X_a \cdot V_1 / Q_i \quad (4.57)$$

Where D_{c1} = denitrification capacity in the pre-D reactor ($V_1 < V_{min}$)

Substituting for X_a from Eq. (3.29) one has:

$$D_{c1} = (K_1 + K_2) \cdot C_r \cdot S_{bi} \cdot V_1 / V_r = (K_1 + K_2) \cdot C_r \cdot f_{x1} \cdot S_{bi} \quad (f_{x1} < f_{min}) \quad (4.58)$$

Where f_{x1} = sludge mass fraction in the pre-D reactor

If the retention time in the pre-D reactor is sufficient for complete removal of the easily biodegradable material and if enough nitrate is available, the denitrification capacity can be calculated by considering separately the denitrification due to both easily biodegradable and slowly biodegradable material. In so far as the easily biodegradable material is concerned, the following stoichiometric relationship can be used (Eq. (4.51)):

$$MN_{Ds} = (1 - f_{cv} \cdot Y) / 2.86 \cdot MS_{bsi} = f_{dn} \cdot f_{sb} \cdot S_{bi} \cdot Q_i \quad \text{or} \quad N_{Ds} = MN_{Ds} / Q_i = f_{dn} \cdot f_{sb} \cdot S_{bi} \quad (4.59)$$

Where:

MN_{Ds} = removed nitrate mass per time unit, associated to the utilisation of easily biodegradable material
 N_{Ds} = nitrate removal in mg N per litre of influent, associated to the utilisation of easily biodegradable material

The mass of removed nitrate per time unit due to the utilisation of slowly biodegradable material in a pre-D reactor can be calculated as:

$$MN_{Dp} = K_2 \cdot X_a \cdot V_1 \quad (4.60)$$

Now, using the same procedure as above, the removed nitrate concentration (expressed as mg N.l⁻¹ influent) due to the utilisation of slowly biodegradable material, N_{Dp} is:

$$N_{Dp} = K_2 \cdot C_r \cdot f_{x1} \cdot S_{bi} \tag{4.61}$$

The denitrification capacity of the pre-D reactor is the sum of the values of N_{Ds} and N_{Dp}. From Eqs.(4.59 and 4.61) one has:

$$D_{c1} = N_{ds} + N_{dp} = (f_{dn} \cdot f_{sb} + K_2 \cdot C_r \cdot f_{x1}) \cdot S_{bi} \text{ for } f_{x1} > f_{min} \tag{4.62}$$

4.3.4.2 Denitrification capacity in a post-D reactor

$$D_{c3} = K_3 \cdot C_r \cdot f_{x3} \cdot S_{bi} \tag{4.63}$$

Where:

- D_{c3} = denitrification capacity of a post-D reactor (mg N.l⁻¹ influent)
- f_{x3} = sludge mass fraction in the post-D reactor

In Fig. 4.17 the denitrification capacities of a pre-D and a post-D reactor are plotted as a function of the anoxic sludge mass fraction. The values of D_{C1} and D_{C3} have been calculated for a sludge age of 10 days and under the following conditions: S_{bi} = 400 mg COD.l⁻¹; T = 20 °C; f_{sb} = 0.24. The ratio D_C/S_{bi} is also indicated (on the right hand scale).

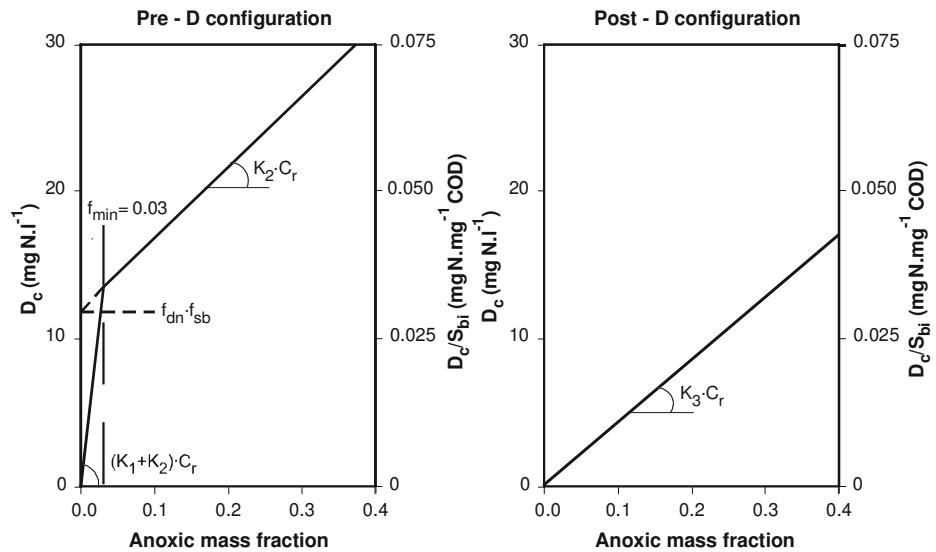


Figure 4.17 Denitrification capacity as a function of the anoxic sludge mass fraction for a sludge age of 10 days in a pre-D and a post-D anoxic reactor

It can be observed that the denitrification capacity depends on the following factors:

- Concentration and composition of the influent organic material, i. e. the values of the fractions f_{ns} , f_{np} and f_{sb} ;
- Sludge age: the value of $C_r = Y \cdot R_s / (1 + b_h \cdot R_s)$ increases at higher sludge age and thus the value of D_c will be higher as well;
- Temperature: the values of the denitrification rate constants K_2 and K_3 increase at higher temperatures, resulting in an increase of D_c . On the other hand, the value of the decay constant b_h will be higher as well, which reduces the overall temperature effect;
- Anoxic sludge mass fractions: when the anoxic sludge mass fractions f_{x1} and f_{x3} increase in size, so does the denitrification capacities D_{c1} and D_{c3} . In practice, the values of f_{x1} and f_{x3} are limited by the conditions that efficient nitrification and good sludge settleability must be maintained.