

### 4.1.2 Mass balance of nitrogenous matter

Fig. 4.1 shows that nitrogen may leave the activated sludge process in one of the following forms:

- As solid matter in the excess sludge ( $N_1$ ). Depending on the liquid-solid separation efficiency of the secondary settler, part of the nitrogen in the excess sludge may actually leave with the effluent suspended solids ( $N_{oep}$ ). However, as  $N_{oep} \ll N_1$ , for mass balance purposes  $N_1$  is not corrected for the value of  $N_{oep}$  (the consequences of this choice are discussed later);
- As dissolved matter in the effluent: ammonium ( $N_{ae}$ ), nitrate/nitrite ( $N_{ne}$ ) and soluble organic nitrogen ( $N_{oe}$ , or actually  $N_{oes}$ );
- As gaseous material (molecular nitrogen) to the atmosphere ( $N_2$ ).

In Fig. 4.1 the possibility of ammonium volatilisation is not considered because this process can only have importance when the pH approaches a value of 9 or more and a significant fraction of the ammonium is present in the unionised form. In practice such a situation can only develop under very special conditions.

Although the quantity of particulate nitrogen leaving with the effluent may be ignored for mass balance purposes, in those cases where strict nitrogen limits apply, the contribution of  $N_{oep}$  to the total nitrogen effluent concentration may in fact be quite significant. The volatile suspended solids concentration in the effluent of a well designed final settler is typically between 5 - 10 mg VSS.l<sup>-1</sup>, resulting in an particulate organic nitrogen concentration between 0.5 and 1.0 mg N.l<sup>-1</sup>.

Using the concepts developed in mass balance calculations for organic material, the nitrogen recovery factor can be defined as the ratio of the nitrogen mass fluxes leaving and entering the activated sludge process:

$$B_n = (MN_1 + MN_{te} + MN_d) / MN_{ti} \quad (4.4)$$

Where:

- $B_n$  = recovery factor for nitrogenous material (-)
- $MN_1$  = flux of nitrogenous matter in the excess sludge (kg N.d<sup>-1</sup>)
- $MN_{te}$  = flux of nitrogenous matter in the effluent (kg N.d<sup>-1</sup>)
- $MN_d$  = flux of denitrified nitrogen (kg N.d<sup>-1</sup>)
- $MN_{ti}$  = flux of nitrogenous matter in the influent (kg N.d<sup>-1</sup>)

Eq. (4.4) is only useful, when the different fluxes are formulated in terms of measurable parameters, so that the  $B_n$  value can be determined experimentally and compared to its theoretical value of one. For the nitrogen flux in the excess sludge, an expression was already derived in the previous chapter:

$$MN_1 = f_n \cdot MX_v / R_s \quad (4.5)$$

The fluxes in the influent and the effluent are easily calculated as:

$$MN_{ti} = Q_i \cdot (N_{oi} + N_{ai} + N_{ni}) = Q_i \cdot N_{ti} \quad (4.6)$$

$$MN_{te} = Q_e \cdot (N_{oe} + N_{ae} + N_{ne}) = Q_e \cdot N_{te} \quad (4.7)$$

Where:

$$\begin{aligned} N_t &= \text{total nitrogen concentration (mg N.l}^{-1}\text{)} \\ N_a &= \text{ammonium nitrogen concentration (mg N.l}^{-1}\text{)} \\ N_o &= \text{organic nitrogen concentration (mg N.l}^{-1}\text{)} \\ N_n &= \text{nitrate nitrogen concentration (mg N.l}^{-1}\text{)} \end{aligned}$$

The indices “i” and “e” refer to influent and effluent respectively. In Eqs. (4.6 and 4.7) the nitrite concentration is assumed to be insignificant, which is usually justified in practice. If this is not the case, then this indicates a process disturbance that should be remedied.

In order to calculate the denitrified nitrogen flux, the process configuration must be taken into consideration. When the objective of the process is nitrogen removal, there will be anoxic zones where denitrification takes place. The flux of removed nitrogen is calculated as the product of the flow passing through the anoxic reactor and the decrease of the nitrate nitrogen concentration in it. Hence:

$$MN_{dk} = Q_k \cdot \Delta N_{nk} \quad (4.8)$$

Where:

$$\begin{aligned} MN_{dk} &= \text{flux of denitrified nitrogen in anoxic reactor “k” (kg N.d}^{-1}\text{)} \\ Q_k &= \text{flow rate to reactor “k” (m}^3\text{.d}^{-1}\text{)} \\ &= \text{influent flow plus return sludge and possible other recycle flows} \\ \Delta N_{nk} &= \text{nitrate-N concentration difference between inlet and outlet in anoxic reactor “k”} \end{aligned}$$

If a system has a total number of “k” anoxic reactors, the total denitrification nitrogen flux can be expressed as:

$$MN_d = \sum_{k=1}^K MN_{dk} = \sum_{k=1}^K (Q_k \cdot \Delta N_{nk}) \quad (4.9)$$

Now, using the expressions of Eqs. (4.5, 4.6, 4.7 and 4.9):

$$B_n = (f_n \cdot MX_v / R_s + Q_f \cdot N_{te} + \sum_{k=1}^K Q_k \cdot \Delta N_{nk}) / (Q_i \cdot N_{ti}) \quad (4.10)$$

In Eq. (4.10) all parameters on the right hand side are measurable so that it is possible to calculate the nitrogen recovery factor based on experimental data.