10.2.4 System C1: Tertiary treatment with nitrogen removal

If nitrogen removal is to be achieved, the system configuration has to be modified to include non-aerated zones for denitrification. Another important change is that the sludge age is no longer set by the requirements for good organic material removal: now the sludge age will depend on the constraints from the nitrification and denitrification processes. In Chapter 4, a method was presented to calculate the minimum sludge age required to achieve complete removal of nitrate in an activated sludge system Eq. (4.71 or 4.72). This minimum sludge age depends on various parameters, whose values are required for the design process:

- Nitrification constants: μ_m, K_n, b_n, f_{max} and N_{ad};
- Denitrification constants K_2 and K_3;
- Easily biodegradable COD fraction f_{sb}.

The procedure for optimised design for activated sludge systems with nitrification and denitrification is as follows:

Step 1 Determine the sludge age and the aerobic and anoxic sludge mass fractions

Determine the minimum sludge age required in a Bardenpho configuration to achieve both efficient nitrification (i.e. the concentration of residual ammonia equals N_{ad}) and complete removal of nitrate. Use an iterative calculation Eq. (4.72) or a graphic analysis (Fig. 4.21). If complete removal is not possible for a sludge age lower than a specified maximum (for example R_s = 20 days), then use Eq. (4.75) to calculate for this sludge age the largest extent of nitrogen removal possible and the resulting residual nitrate concentration in the effluent. Once the sludge age is established, the anoxic pre-D sludge mass fraction (f_{x1}) and post-D sludge mass fraction (f_{x3}) are calculated, using Eqs. (4.69 and 4.70) for complete removal of nitrate or Eq. (4.76) for incomplete removal.

Steps 2 - 9 Optimise the system design

Using the sludge age determined in Step 1, the system design is finalised using essentially the same procedure as in Example 10.2. A problem is that the removal of nitrogen is calculated for the concentration that is present in the influent. However, the excess sludge will be digested and in the process of mineralisation of the volatile sludge, a considerable quantity of nutrients will be released to the liquid phase and may be returned to the biological reactor. The effect of the solubilisation of nutrients can be included in the calculation through the addition to the influent nitrogen concentration of an amount equivalent to the soluble nitrogen mass generated in the anaerobic digester. Therefore the optimisation of the system design will be done in two steps:

(1) The system is optimised for the nitrogen concentration present in the influent and the mass of nitrogen liberated during digestion is calculated;
(2) The calculations are repeated with the estimated nitrogen mass released during digestion added to the influent nitrogen concentration. If the resulting values of the optimal sludge ages from step 1 and 2 deviate significantly, then a third iteration may be required.