8.3.6 Design and optimisation of anaerobic digesters

The most important parameter involved in the design of an anaerobic digester is the operational temperature. In accordance with Eq. (8.59), the retention time in the digester depends on this parameter, whereas Eqs. (8.60a and b) show that the volatile solids removal efficiency is also affected. For design of unheated digesters, the average temperature of the coldest month may be taken. Once the operational temperature is known, the retention time can be calculated. With the daily (thickened) excess sludge flow rate, the required digester volume is established. As in most waste waters, organic matter is predominantly of a particulate nature while nitrogen is mostly dissolved (ammonium), and during the primary settling process a large proportion of organic matter will be removed. This will result in an increase in the TKN/COD ratio of the pre-settled influent. Thus, if nitrogen is to be removed in the activated sludge system, in general the required sludge age in a system treating settled waste water will be longer than in a system treating raw waste water.

This increase in sludge age leads to a larger aeration tank volume. The effect of the increase of the TKN/COD ratio can only be assessed quantitatively with the aid of the kinetics of nitrification and denitrification as explained in Chapter 4.

Once the minimum sludge age of the activated sludge process has been established, it is a relatively simple matter to optimise the entire treatment system. For the optimisation of the activated sludge system with anaerobic sludge stabilisation, the construction and the operational costs must be taken into consideration. The construction costs are mainly determined by the volume of the main treatment units: primary settler, aeration tank, final settler, thickener, digester and liquid-solid separation unit for the digested sludge.

Furthermore, the required oxygenation capacity is an important item in construction costs. The operational costs mainly depend on the power consumption for aeration, methane production (if it is flared: when used for power generation it will be a cost reducing factor), the temperature in the digester (heating or not) and the concentration- and mass of stabilised sludge, which partially determine the cost for final disposal. The procedure for optimisation of the activated sludge system with stabilisation of activated sludge can be summarised as follows:

(a) For primary sedimentation

(1) For the TKN/COD and P/COD ratio of the waste water after settling, determine the minimum sludge age necessary to achieve the desired level of biological nutrient removal;
(2) Determine the mass and production of sludge for the calculated sludge age;
(3) Determine the required retention time in the digester for the operational temperature with Eq. 8.59;
(4) Determine the optimal volume for the sludge thickener and the digester for the known or assumed settling characteristics of the excess sludge;
(5) Use the settling characteristics to determine the optimal volumes of the aeration tank and the final settler;
(6) Determine the volume of the primary settler (normally a residence time of about two hours is adopted).

(b) For raw sewage treatment

Repeat (1) to (5) for raw waste water.

Finally, taking into consideration the construction and operational costs, it will be decided which of the two options is most attractive from a total cost point of view.