

6.5 SLUDGE THICKENERS

A sludge thickener is an auxiliary unit with the specific objective to concentrate the excess sludge, before it is sent to the sludge digester. The supernatant from the thickeners is returned to the aeration tank, so that its quality in terms of suspended solids concentration is of little importance. The size of the sludge flow discharged into the thickener depends on the sludge age of the activated sludge process.

By definition, when the sludge age has a value R_s , a fraction $1/R_s$ of the sludge mass in the process must be discharged daily as excess sludge. Hence, according to Eq. (3.58): $mE_t = mX_t/R_s$, where mE_t equals the suspended solids mass discharged as excess sludge per unit mass of applied COD. The theory for activated sludge settlers derived in the previous sections can also be applied to sludge thickeners. As the sludge concentration at the outlet of a thickener will be high, normally the limiting function will be thickening and the flux that can be transported is given by the limiting solids flux (Eq. 6.18):

$$F_l = X_r \cdot v_0 \cdot (k \cdot X_l - 1) \cdot \exp(-k \cdot X_l) \quad (6.18)$$

The specific solids loading rate of a thickener can be defined as

$$F_{sol} = mE_t/a_{th} \quad (6.44)$$

Where a_{th} = cross sectional thickener area per unit mass daily applied COD

When the solids loading rate is equal to the limiting flux, the specific thickener area can be determined as a function of the thickened sludge concentration X_r :

$$\begin{aligned} a_{th} &= mE_t/F_{sol} = mE_t/F_l \\ &= [(1 - f_{ns} - f_{np}) \cdot (1 + f \cdot b_h \cdot R_s) \cdot C_r/R_s + f_{np}/p] / f_v / [X_{rth} \cdot v_0 \cdot (k \cdot X_{lth} - 1) \cdot \exp(-k \cdot X_{lth})] \end{aligned} \quad (6.45)$$

Where:

X_{rth} = thickened sludge concentration at the exit of the thickener (target concentration)

X_{lth} = limiting sludge concentration in the thickener = $(X_{rth}/2) \cdot [1 + (1 - 4/(k \cdot X_{rth}))^{0.5}]$

When analysing Equation (6.45), it is interesting to observe that a much-applied procedure is to discharge the excess sludge from the return sludge flow, as this contains a higher concentration than the mixed liquor in the aeration tank. The assumption made to justify this procedure is that the higher inlet concentration will automatically lead to a higher outlet concentration in the thickener, so that a more concentrated sludge will be obtained. However, Eq. (6.45) shows that this supposition has no theoretical ground: the thickened sludge concentration is independent of the inlet concentration. It is concluded that there is no clear advantage of using the return sludge flow instead of the mixed liquor in the aeration tank to feed the sludge thickener.

On the contrary, there is a large disadvantage from discharging excess sludge from the return sludge line, as the return sludge concentration fluctuates considerably because of variations in the influent flow and/or sludge settleability. This makes it very difficult to control the mass of daily discharged excess sludge, which is of fundamental importance for adequate management of the sludge age. For a more accurate control of the applied sludge age, it is preferable to discharge the excess sludge directly from the aeration tank, where the variations of sludge concentration are much smaller. When discharging directly from the activated sludge process, a regime called "hydraulic sludge age control" can be applied in which every day a volume of sludge is discharged equal to the total volume of the activated sludge process V_r divided by the sludge age R_s .

Equation (6.45) gives the area of thickener per unit mass of daily applied COD. Hence the required thickener area is proportional to the organic load applied to the activated sludge process and in principle is independent of the hydraulic load. In this respect the thickener is different from the sludge settler: the area of the latter is proportional to the influent flow. Fig. 6.15 shows the minimum thickener area per unit mass daily applied COD as a function of the desired outlet concentration for different values of the mass of excess sludge produced per unit mass applied COD (mE_t) and for different values of the settleability constants k and v_0 .

In practice, the mE_t value varies between $0.5 \text{ mg TSS} \cdot \text{mg}^{-1} \text{ COD}$ (high rate systems; low sludge age) and $0.2 \text{ mg TSS} \cdot \text{mg}^{-1} \text{ COD}$ (low rate systems; high sludge age). As can be observed in Fig. 6.15, the relationship between the thickener area and the desired thickener outlet concentration approximates an exponential relationship for the values that are of practical interest. When sizing a thickener, the following two factors should be taken into consideration:

- (1) A very large thickener area with a concomitant large volume might result in the onset of anaerobic decomposition of the excess sludge, which is undesirable. Therefore the retention time must not exceed 18 to 24 hours;
- (2) The system thickener + digester should be designed for minimum construction costs. This minimum can only be evaluated if the retention time in the digester is known. This retention time, as well as the design optimisation of the thickener-digester system will be discussed in Chapter 8.

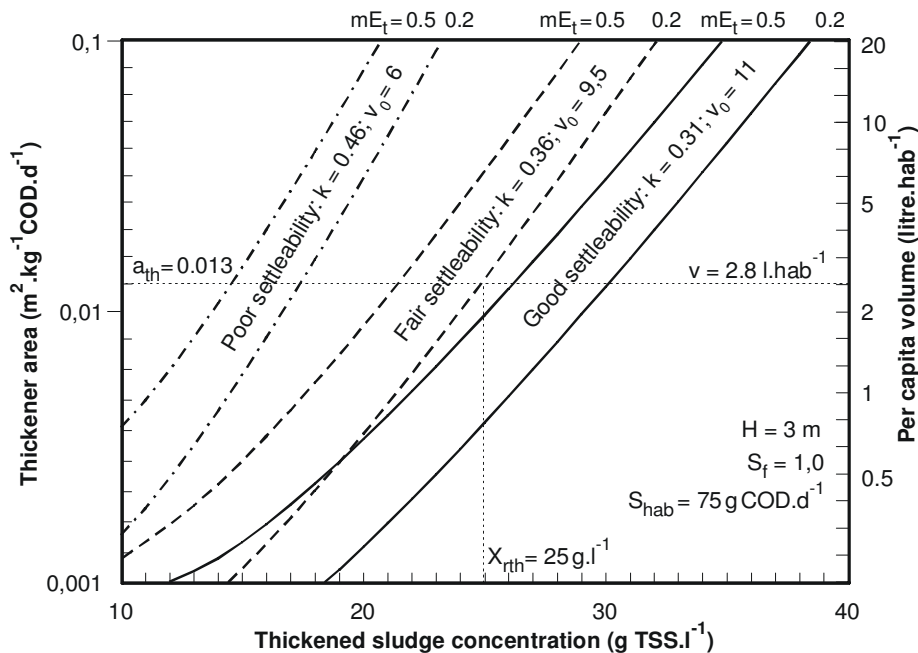


Figure 6.15 Thickener area per unit mass daily applied COD as a function of the target thickened sludge concentration

To complete the thickener design, it is necessary to specify the depth and the safety factor to be applied. The depth in a thickener may be smaller than in a settler, because there is no need to create a storage capacity for sludge. When the thickener is overloaded, the excess load will simply be recycled to the aeration tank, together with the thickener effluent. As the thickeners are much smaller than settlers, the dead volume fraction will be smaller as well so the safety factor to be applied may be less than the value of $S_f = 2$, often adopted for settlers.