Activated sludge settling Part II: Settling theory and application to design and optimisation

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Abstract

Activated sludge settlers perform both clarification and thickening. Depending on the operational conditions of a settler and sludge settleability characteristics, either one of these processes may limit the solids loading rate. Assuming the validity of Vesilind's (1968) equation, expressions are derived for the limiting sludge loading rates for clarification and for thickening. Based on settling theory an optimisation procedure for the design of the reactor-settler system was developed. For optimal design the mixed liquor concentration and recycle ration must be chosen such that these limiting loading rates are equal. For any specified sludge settleability the design procedure based on theory gives virtually the same results as empirical procedures suggested by Dutch and German research organisations (STORA, 1981; ATV, 1976)

Introduction

Activated sludge settlers have two simultaneous functions:

- clarification, i.e. the separation of the solid and liquid phases of mixed liquor, necessary to produce an effluent free of suspended solids; and
- thickening, i.e. the increase of total suspended solids (TSS) concentration from its value in the mixed liquor to that in the return sludge.

Depending on the settleability of the sludge and on the operational conditions in the settler (notably the incoming and outgoing flow rates and TSS concentrations), either one of these two functions may limit the solids handling capacity per unit area, which in turn determines the minimum surface area and hence the volume of the settler.

In this paper equations are derived for the maximum loading rate of final activated sludge settlers, both for clarification and for thickening. These equations are used for the optimisation of activated sludge process design. It is demonstrated that the design resulting from the developed theory is virtually identical to that of existing empirical models.

Sedimentation in a continuous settler

In the activated sludge process the final settler receives a flow of mixed liquor and discharges a clarified effluent, while a (more concentrated) return sludge is recirculated to the aeration tank. In order to describe the behaviour of a final settling tank the following suppositions and approximations will be made (see also Fig. 1):

- The flow rate of the mixed liquor entering the settler is the sum of the influent flow rate (which initially will be assumed to be constant) and the return sludge flow. Hence the mass flows in and out of the settler are:

$$F_{in} = X_t(Q_a + Q_r) \quad (1a)$$

and

$$F_{out} = (X_r Q_r) \quad (1b)$$

where:
F_{in} and F_{out} = incoming and outgoing mass flows (kg TSS/h)
X_t = mixed liquor concentration (kg TSS/m^3)
X_r = return sludge concentration (kg TSS/m^3)
Q_a = influent flow rate (mVh)
Q_r = return sludge flow rate (m^3/h)

If it is assumed that no accumulation of sludge takes place in the settler, then:

$$F_{in} = F_{out} \quad (2a)$$

and

$$X_r = X_t(Q_a + Q_r)/Q_r = X_t(s + 1)/s \quad (2b)$$

where:
s = recirculation factor = Qr/Qa

- The flow in the settler has a vertical direction. The incoming flow is uniformly distributed at a certain depth where an interface is formed between a supernatant with no suspended solids at the top part and settling sludge at the bottom part. In the top part there is an upflow velocity equal to the overflow rate:

$$T_s = Q_a/A \quad (3)$$

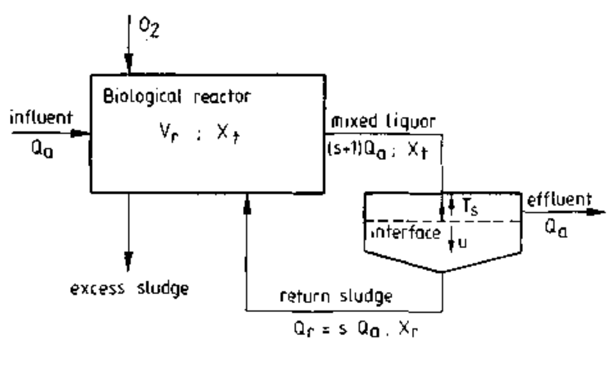

Figure 1
Schematic representation of an activated sludge process with a final settler

Received 1 August 1991; accepted in revised form 11 February 1992.