Secondary settling tank modelling and design Part 1: Review of theoretical and practical developments

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Abstract

An overview of theoretical and practical developments in modelling and design of secondary settling tanks (SST) is presented. Historically, to overcome the lack of simple, reliable measures of sludge settleability and to incorporate sludge settleability into the design of the SST, two approaches were taken:

- in English-speaking countries the flux theory was adopted and the required flux theory constants (V_o and n) were determined from empirical relationships linking these constants to the simpler SSVI or DSVI sludge settleability measures;
- in Europe (Germany and Holland) empirical design equations were developed from observed full-scale SST performance.

The former approach provides only a surface area whereas the latter recognises sludge transfer to the SST and also provides depth, maximum underflow concentration and SST sludge storage concentration, all as functions of sludge settleability. It was noted that local conventions in (he design of the internal SST features (e.g. inlet, outlet, sludge collection and baffling arrangement) which are known to influence SST performance via secondary effects such as hydraulic turbulence and density currents, are implicitly incorporated in local design procedures. In English-speaking countries, this has occurred through the verification/calibration process of the flux theory against observed full-scale SST performance, whereas, in Europe, this has occurred through the establishment of empirical design equations based on observed full-scale SST performance.

In order to bring theoretical and practical developments closer together, it was identified as necessary to establish to what extent the information embodied in the European empirical design relationships flows naturally from a dynamic SST model based on the flux theory. The outcome of this evaluation is presented in three sequel papers.

Introduction

Over the past few decades, work on secondary settling tanks (SSTs) has progressed along two parallel but distinct paths. One path has focused mainly on empirically based procedures for SST design and operation. The other path has focused on developing the flux theory and incorporating it into models of varying complexity for SST steady state, transient and dynamic simulation. Until recently, not much integration between the two paths has taken place, with the result that theoretical developments in SST modelling have not been well integrated into design and operation practice.

In this paper the basic developments in the two parallel paths are reviewed so that the principle objective of this series of four papers i.e. greater integration of theory and practice, will come into focus.

Chronological review

Theoretical developments have centred mainly on the flux theory as a means of understanding and describing the solids sedimentation process taking place in the SST and on developing mathematical models for simulation based on this theory. This flux approach presumes that the solids sedimentation and transport processes through the SST dominate the behaviour and hence performance of the SST and that these processes alone give an adequate description of the behaviour of the SST. Other processes, such as hydraulic effects, turbulence and density currents, mixing, flocculation, and influences of inlet and outlet configurations and baffling, even though they are known to take place, are assumed to be minor and not to influence the SST performance significantly. The validity of this assumption is considered in this series of papers which evaluate the flux theory as a design procedure.

At its root, the flux theory is relatively simple. Originally conceived by Coe and Clevenger in 1916 from observations on inorganic mining slurries and formally set out mathematically by Kynch (1952), it states, from a material balance, that, under ideal conditions, the rate of accumulation of material (in our case, activated sludge solids) in a particular layer over an interval of time is equal to the difference between the rates of material entering and leaving the layer i.e.

$$\frac{\delta}{St}(Xdz)dt = G(z + dz)dt - G(z)dt \qquad \textbf{(1)}$$

which, after simplifying, yields the idealised mass balance partial differential equation (PDE):

$$\frac{5X}{St} = \frac{8G}{8z} \qquad (2)$$

where
X = solids concentration. (kg TSS-m^{-3})
t = time (h)
z = depth (m)
G = solids flux (kgTSS-m^{2}-h-^{1})
= $V_s X$
V_s = solids zone settling velocity (ZSV) (m-h^{1})

While the principle embodied in Eq. (2) can be applied to SST modelling without undue difficulty, its application is complicated

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