Simulated Suspended Solids Concentrations of Secondary Clarifiers in the Activated Sludge Process Using Comsol Multiphysics Program

Article

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Simulated Suspended Solids Concentrations of Secondary Clarifiers in the Activated Sludge Process Using Comsol Multiphysics Program

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Abstract: The purification stations for waste-waters are dynamical systems, being under important and uncontrolled variations of the debit, concentration and composition of the polluting substances. Mathematical models are essential for describing, predict, and control the results of this process. The aim of this article is to describe the modelling and simulation of activated sludge processes, using COMSOL Multiphysics Program.

Keywords: secondary clarifier, activated sludge processes, numerical model, COMSOL.

1. Introduction

The activated process is the most frequently used system to purify wastewater (Horan, 1991; Metcalf & Eddy, 1991). It is estimated that in the European Community alone a daily volume of $40 \cdot 10^6 m^3$ is processed (Lens & Verstraete, 1992). An activated sludge system accomplishes an enhanced biological purification of the wastewater. A conventional system can always be subdivided in two major units (Figure1).

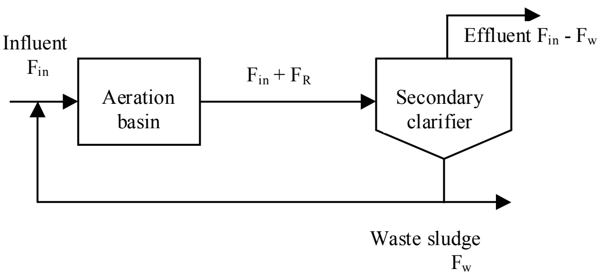

Figure 1. Schematic overview of the conventional activated sludge process.

- **Aeration basin**: Pre-treated wastewater is mixed with activated sludge, containing the micro organisms which transform and eliminate the organic pollutants in the wastewater by means of bio catalysis. Oxygen must be supplied. Usually this is accomplished by blowing air in the mixed liquor (the mixture of water and activated sludge)
- **Secondary clarifier**: The activated sludge is separated from the purified water under the influence of gravitation. The major part of the settled sludge is sent back to the aeration basin. Part is wasted to keep the growing biomass in the system at certain level.

2. Modelling of secondary clarifiers

The dynamics of the solids – liquid separation processes is as follows. The proposed models are most often based on mass balances ("continuity equation") and on the solid flux theory.

$$F(z,t) = u \cdot C + v \cdot C$$

Where:
u - is the bulk velocity,
v - is the settling velocity,
C - is suspended solids concentration.

The dynamical model in its simplest form is written as follows:

$$\frac{\partial C}{\partial t} = -\frac{\partial F}{\partial z}$$

The question that arises is "Is it possible to derive the mass balance model such that a limitation of flux is implicitly included? A possible solution to the above question and to that of the presence of spatial gradient in settlers is indeed to introduce a second order derivative term with respect to z in the mass balance model. A possible interpretation of such a term is that it represents diffusion following Fick's law. In such a case, the flux F is written as follows:

$$F = u \cdot C - v \cdot C - D_a \cdot \frac{\partial C}{\partial z}$$

and the mass balance model becames:

$$\frac{\partial C}{\partial t} = -u \cdot \frac{\partial C}{\partial z} + \frac{\partial (v \cdot C)}{\partial z} + D_a \cdot \frac{\partial^2 C}{\partial z^2}$$

If $v = v_0 \cdot e^{-a \cdot C}$, $v_0, a > 0$ (Vesilind model) then

$$\frac{\partial C}{\partial t} = -\left[u - (1 - a \cdot C) \cdot e^{-a \cdot C}\right] \cdot \frac{\partial C}{\partial z} + D_a \cdot \frac{\partial^2 C}{\partial z^2}$$

Equivalent with:

$$\frac{\partial C}{\partial t} + \left[u - (1 - a \cdot C) \cdot e^{-a \cdot C}\right] \cdot \frac{\partial C}{\partial z} = D_a \cdot \frac{\partial^2 C}{\partial z^2}$$

The modelling is based on the measurements made in the purification stations for waste-waters IAWPRC (Henze et al. 1992) and CEIT, San Sebastien, Spania. Several zones can be distinguished in a secondary clarifier (Figure 2). The height of each zone can be calculated separately using empirical formula (Billmeier 1992).

For the clarifier zone,

$$u = u_0 = -\frac{F_{in} - F_w}{A_{se}},$$

with A_{se} the cross-sectional surface of the circular clarifier, and the boundary conditions are:

$$C(H_1, t) = C_{in}, \qquad C(H_2, t) = 0$$

For the feed zone $u = u_0 - u_b$.

For the settler zone,

$$u = u_b = -\frac{F_R + F_w}{A_{se}},$$

and the boundary conditions are:

$$C(H_1, t) = C_{in}, \qquad C(0, t) = C_R$$

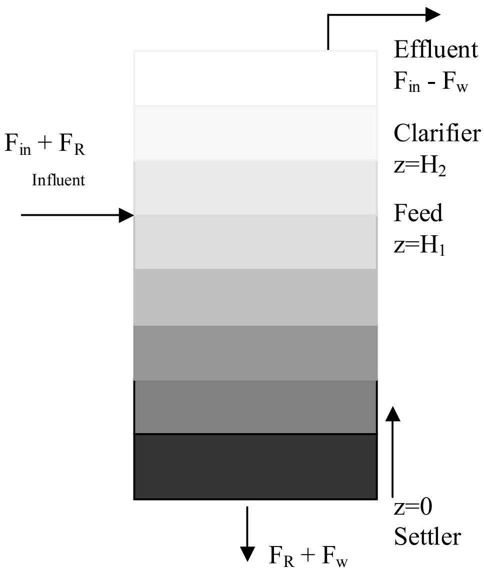

Figure 2. The different zones in a secondary clarifier

3. Simulated suspended solids concentrations

The COMSOL Mutiphysics program is used to simulate the suspend solids concentrations which correspond to the numerical solution of these model equations. We select **3D** as the **Space Dimension**, then in the list of Physical Models we select **Chemical Engineering Module>Mass Balance>Convection an Diffusion**. We build the geometry of the model, and then we fixed the boundary settings, the mesh parameters (Figure 3) and compute the final solution (Figure 4).

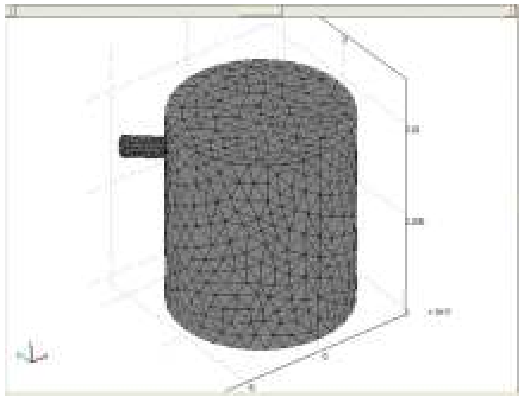

Figure 3. The geometry and the mesh of the model in COMSOL Multiphysics.

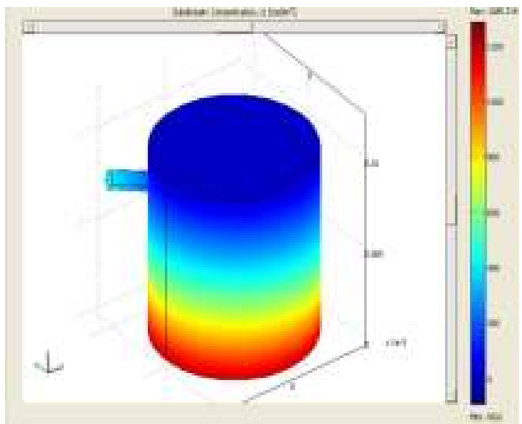

Figure 4. Results from the compute solution in COMSOL Multiphysics.

The streamline concentration contour for the model are presented in Figure 5.

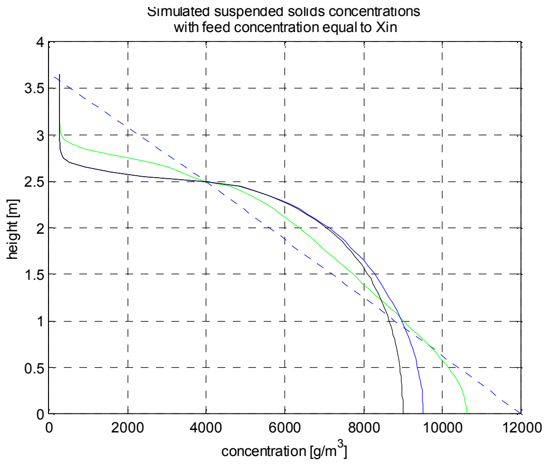

Figure 5. Simulated suspended solids concentrations, for various concentrations.

Example: $u_0 = 17.6 \quad m/d, \quad u_b = 16.5 \quad m/d,$
$D_a = 13 \quad m^2/d, \quad v_0 = 370 \quad m/d, \quad a = 4.16 \cdot 10^{-4} \quad m^3/g$
$H_1 = 2.51 \quad m, \quad H_2 = 3.66 \quad m$

In this study model parameters were assessed based on an analysis of field and pilot-scale experimental data. Results of the analysis are presented in Figure 6, where the logarithm of the solids concentration is plotted as a function of depth. A logarithmic scale was chosen for the solids concentration to provide more detail at lower concentrations.

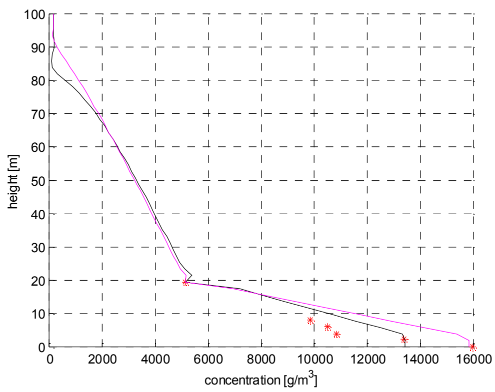

Figure 6. Simulated suspended solids concentrations with experimental dates.

4. Conclusions

In this paper, we have demonstrated the versatility of COMSOL Multyphisics with regard to the modelling and simulation of activated sludge processes in the secondary clarifiers. A multi-layer model of the clarification/ thickening process was presented. Based on the solid flux concept and a mass balance around each layer of a one-dimensional settler, the model is designed to predict the solids profile along settling column, including the effluent and underflow suspend solids. The model was applied to the one pilot scale and full scale experimental data with good results.

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