Computational Analysis of Activated Sludge Lamella Sedimentation

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Introduction

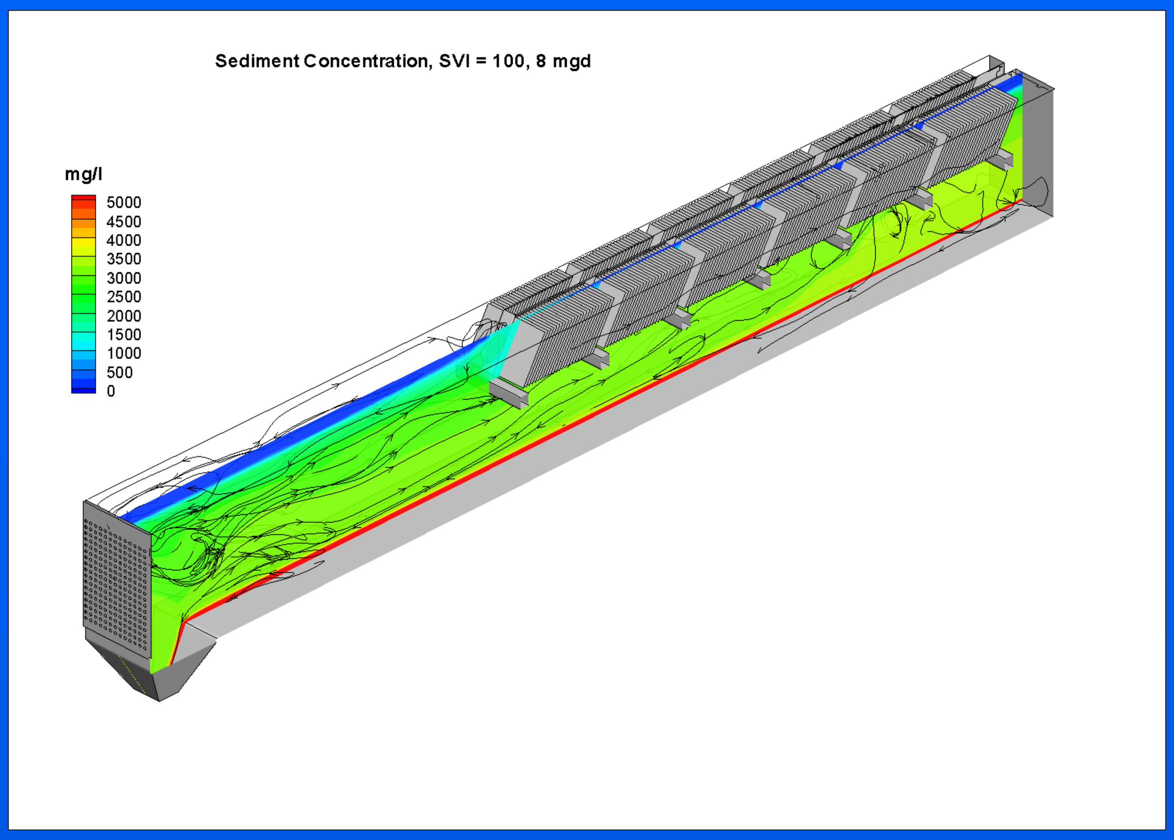

Figure : Three dimensional model of the lamella sedimentation tanks

A.E. Boycott (1920) presented observations that blood corpuscles seemed to settle much faster in an inclined tube than in a vertical one. The "Boycott effect" may be considered as the appearance that settling rates are greater in inclined tubes than in tubes aligned vertically, proportionate to the ratio of the projected area of the inclined tube to the horizontal area of the vertical tube. In applications of lamella sedimentation this ratio can be relatively large, on the order of seven to ten times larger than the horizontal area projection of the vertical tube. Ponder (1925) and Nakamura and Kuroda (1937) independently proposed a model of settling in inclined tubes (the PNK theory) suggesting that settling is enhanced proportionately to the projected area. Xu and Michaelides (2005) recently proposed a lattice Boltzmann model of a single tube undergoing batch settling which resulted in an estimate of particle velocity approximating that predicted by the PNK theory. The question at issue in the current research was whether the PNK theory is valid for continuous flow tanks with lamella plates for activated sludge service.

Results from two different CFD models were compared. A custom two-dimensional model was used for initial testing. A coarse rectangular grid was used for initial testing of the problem. The settling model was the five-component model of McCorquodale et al. (2006). The commercial CFD model Fluent was also used to model tank flow in both two and three dimensions. The Fluent models incorporated user-defined functions (UDF) to simulate density coupling, solids transport, and solids settling using the Vesilind equation. These models are further described in Samstag and Wicklein (2009). Results from the two independent models were used to obtain critical comparison, since field test data were unavailable.

Results & Discussion

The custom model was tested at overall tank overflow rates of 1, 2, and 3 m/hr. Figure 1 presents a schematic of the lamella configuration simulated in a coarse grid in the custom model. The figure shows the predicted concentration profile for the test domain at 1 m/hr overflow rate. An overall recirculation eddy is present, which causes flow to be predominantly downward in the lamella zone nearest to the inlet. This is in contrast to the equally divided and uniform upflow pattern assumed in the PNK theory. Table 1 presents a summary of effluent concentrations from modelling five different configurations with and without lamella plates. The lamella configuration did not perform significantly better than a configuration with no plates at all. The simulation with the same flow, but the projected area of the lamella plates with no plates included, outperformed all others.

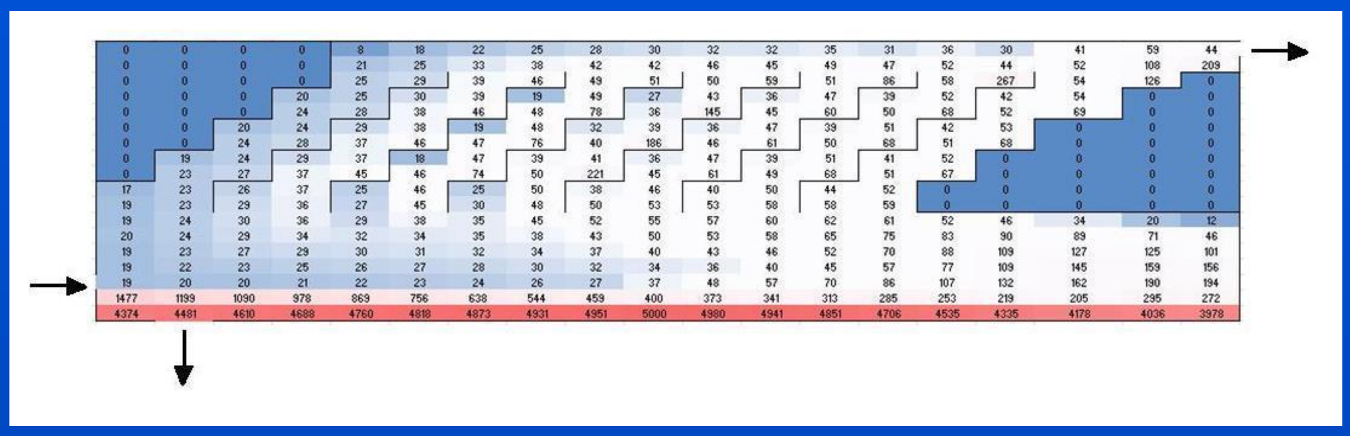

Figure 1: Custom model schematic (solids concentration)

Table 1: Comparison of predicted effluent concentrations for custom CFD model

Tank Configuration	Steady State Effluent Solids (mg/L)		
	1 m/hr Lamella Tank Overflow	2 m/hr Lamella Tank Overflow	3 m/hr Lamella Tank Overflow
Lamella plates and end baffles	40	>500	650
End baffles but no interior lamella plates	20	> 90	> 250
No end baffles or lamella plates	80	10	600
Stamford baffle in upper discharge	40	10	600
Projected area of lamella plates	8	30	80

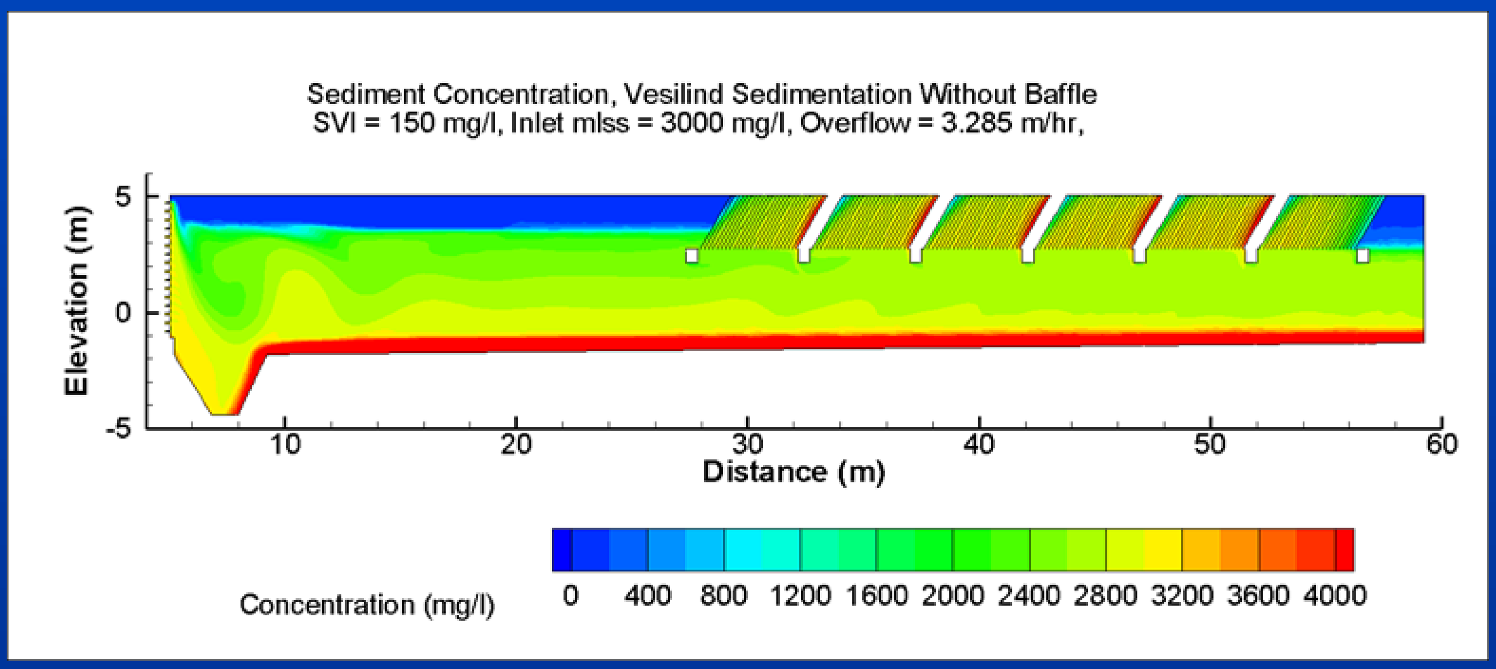

Figure 2: Solids profile results from the commercial CFD model at 3.2 m/hr with plates

Additional modelling was conducted using commercial CFD software from ANSYS (Fluent). Both two-dimensional and three-dimensional hexahedral grids were used to model the geometry of a tank design proposed for municipal activated sludge application near Seoul, Korea. As shown in Figures 2 and 3, there was no significant improvement in performance for the tank with lamella plates compared to the tank with no lamella plates at all.

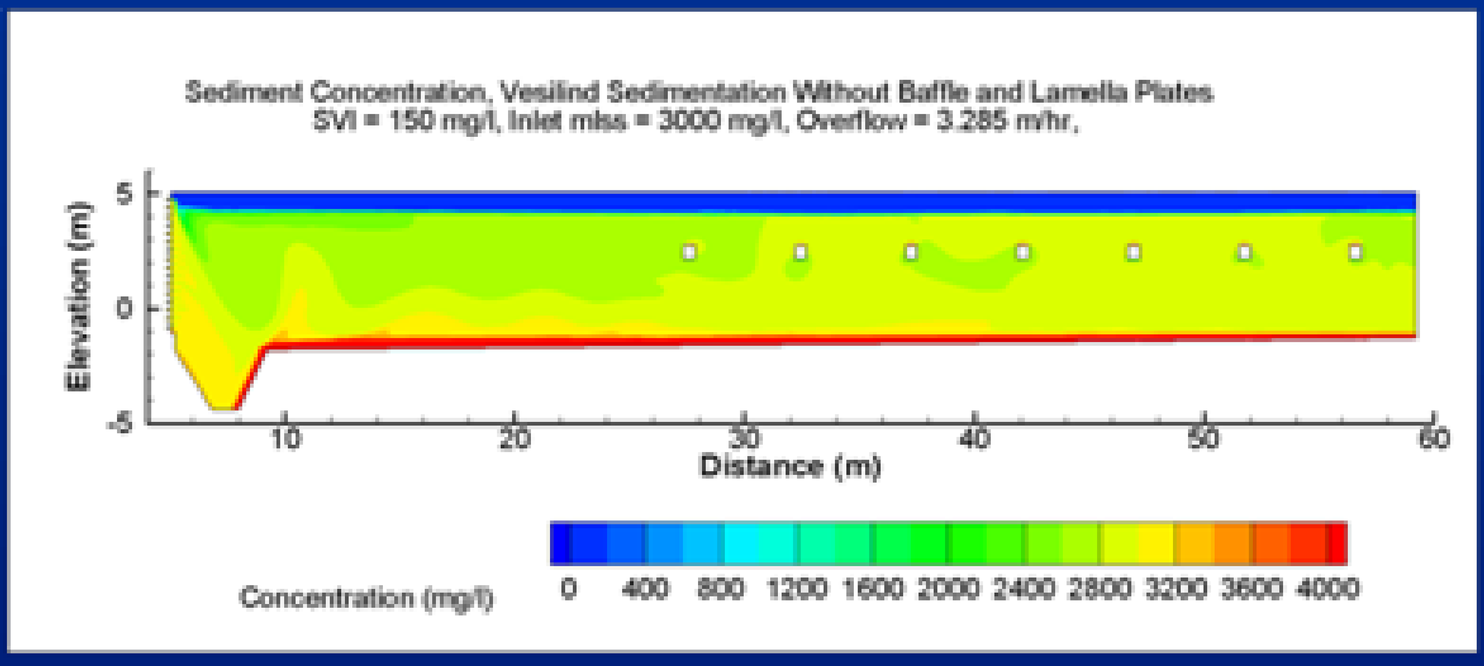

Figure 3: Solids profile results from the commercial CFD model at 3.2 m/hr without plates

Conclusions

Simulation of test cases of activated sludge lamella sedimentation in a coarse grid by a custom two-dimensional CFD program found that rectangular tanks with lamella plates did not have significantly better performance than tanks of the same overall geometry but no lamella plates at all, nor did they perform as well as the projected area theory would suggest. This was confirmed in a commercial CFD package using two and three-dimensional flow simulations and UDF to implement solids transport, settling, and density coupling. The results indicate that the apparent Boycott effect may be the result of internal recirculation within an inclined tube in a batch test rather than of an increase in the particle's undisturbed settling velocity. Two independent CFD models yielded comparable results. These results should be confirmed by lab and full-scale tests with test data published for critical review. We have found no published data presenting detailed results of full or lab scale tests of lamella sedimentation of activated sludge.

The authors gratefully acknowledge funding for this research by Kyonggi University.