Modelling Chemically Enhanced Primary Settlers for Resource Recovery Purposes

Emma Lundin[1], Magnus Arnell[1,2], Robert Sehlén[3], Sovanna Tik[4], Peter A. Vanrolleghem4, Bengt Carlsson[5]

[1] SP Urban Water Management, Sweden.
[2]Department of Biomedical Engineering, Lund University, Sweden.
[3] Tekniska Verken in Linköping AB, Sweden.
[4] ModelEAU- Department of civil engineering and water engineering, Laval University, Canada.
[5] Department of Information Technology, Uppsala University, Sweden.

Corresponding author: Emma Lundin, emma.lundin@sp.se, +46 70 -690 90 06

Research Objectives

Wastewater treatment plant (WWTP) operation is slowly shifting from simply focusing on effluent qualities towards becoming resource recovery plants and viewing wastewater as a carrier of nutrients and source of renewable energy. The primary settling tanks (PSTs) serve as the most important sludge producers and are therefore crucial for the biogas production as well as for the whole plant's energy consumption. In this work the separation model for solids in the PST has been extended within the activated sludge model framework, IWA Benchmark Simulation Model no. 2 (BSM2). Modelling the separation of solids from wastewater has been shown to be difficult when the concentration and the flocculent nature vary between the layers of the tank.

Case Study

The PSTs in the plant-wide model for the Linkoping WWTP based on BSM2 were developed based on characterization of the wastewater particles through settling velocity distribution with the ViCA's protocol, developed by Chebbo and Gromaire (2009). In the study, the settling velocity distribution was described by five particle classes, each given a specific experimentally found settling velocity, vs, the geometrical mean of vc,min and vc,max for each class (also done by Bachis et al., 2014). The primary clarifier model was developed similarly to the secondary settler in BSM2, with ten layers of constant thickness continuously predicting the sludge concentration in each layer by calculating the mass balance around each layer. The specific settling velocity of each particle class was used to calculate the gravitational flux of particles between layers. The fraction of particles in each class was predicted as a function of chemical dosage and time, given by the coefficient model derived from statistical analysis of the experimental data.

Dynamic influent model for PST

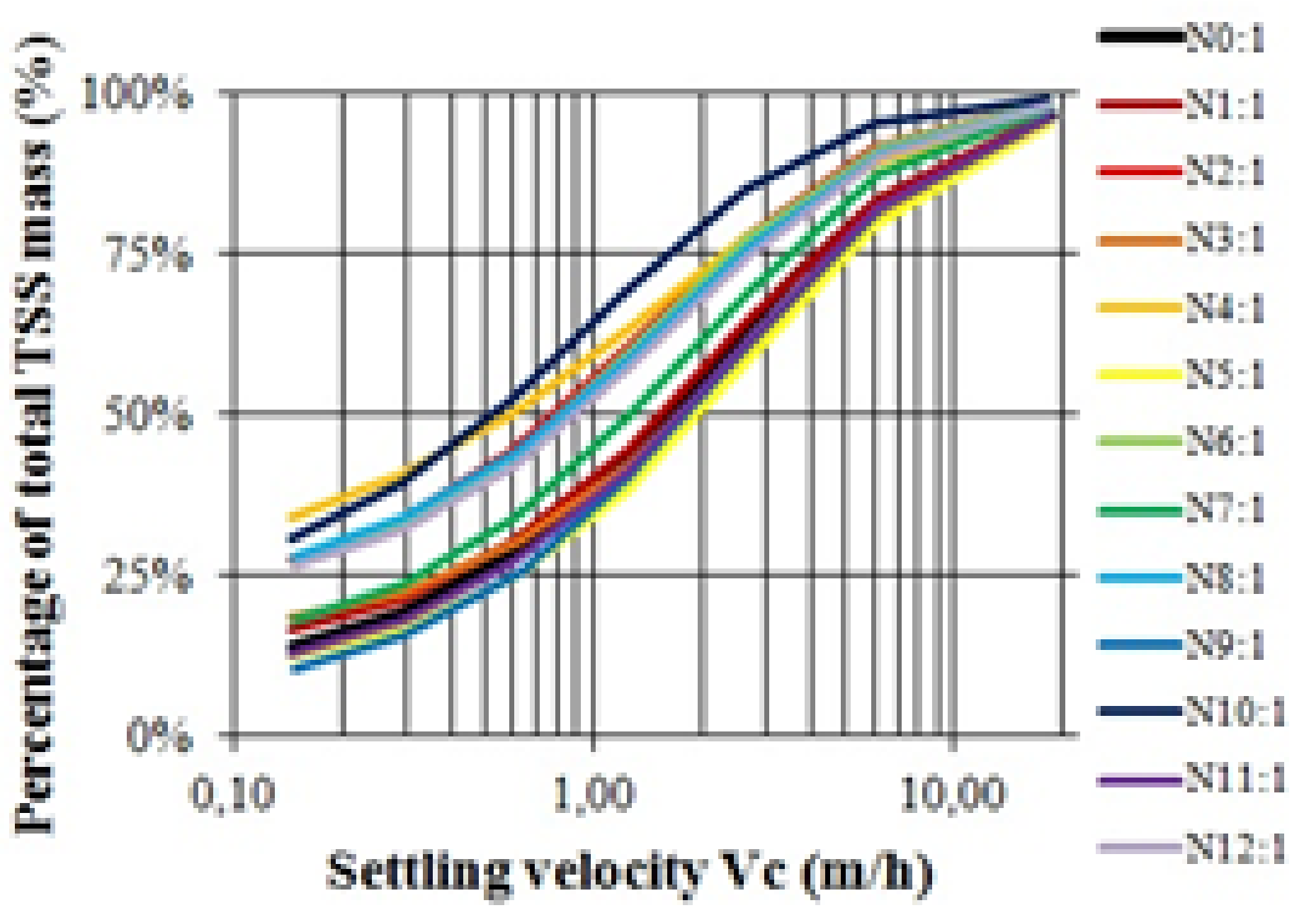

Figure 1. The settling velocity distribution, ViCA's, attained from column experiments. The bottom cluster of curves represents low flow samples and the top cluster high flow samples.

References

- Bachis, G., Maruéjouls, T., Tik, S., Amerlinck, Y., Melcer, H., Nopens, I., Lessard, P., Vanrolleghem, P.A., 2014. Modelling and characterization of primary settlers in view of whole plant and resource recovery modelling. Proc. 4th IWA/WEF Wastewater Treatment Modelling Seminar (WWTmod2014), Spa, Belgium, 30 March – 2 April
- Chebbo, G., Gromaire, M.-C., 2009. VICAS- An Operating Protocol to Measure the Distributions of Suspended Solid Settling Velocities within Urban Drainage Samples. Journal of Environmental Engineering 135: 768-775.
- Lundin, E., 2014. Modelling Chemically Enhanced Primary Settler Treating Wastewater, using Particle Settling Velocity Distribution. Master of Science Thesis. Uppsala, Sweden: Uppsala University, Department of Information Technology.

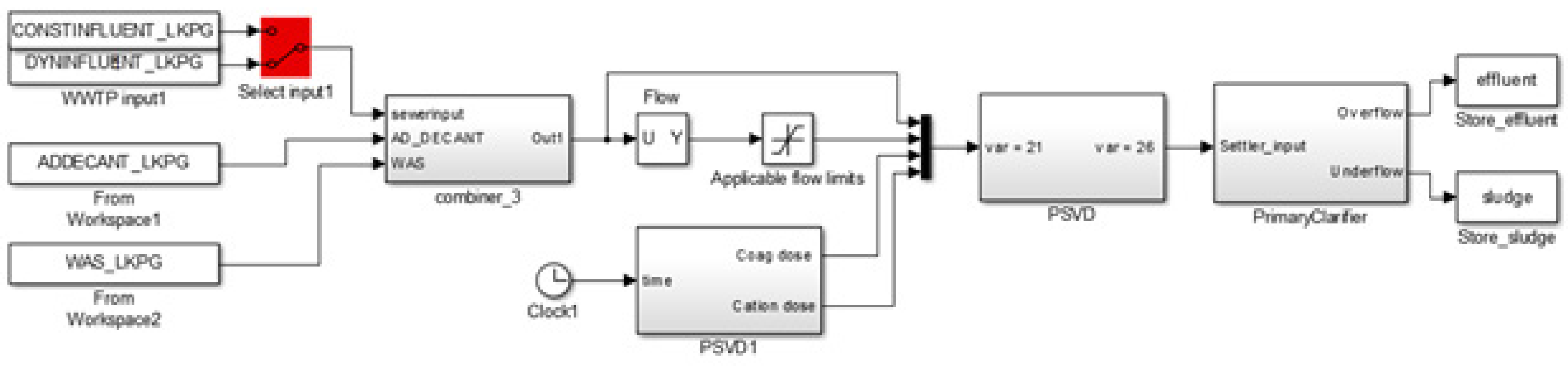

Figure 2. The model of the primary clarifier based on particle settling velocity distribution (PSVD), presented in Simulink.

Equation 1. The equation to calculate the fraction of particles settling within each class used in the PSVD, where A is a constant; B, C and D coefficients for the factors: flow, coagulant dose and cationic dose in named order and E the coefficient for the interaction term.

$$F\,(v_s) = A + B \cdot \text{flow } [m^3/\text{day}] + C \cdot \text{coag. } [g/m^3] + D \cdot \text{cation } [g/m^3] \\ + E \cdot \text{coag} \cdot \text{cation}$$

Equation 2. The equation for settling particles flux in the PrimaryClarifier where v_s was determined experimentally for each particle class. Js – Particle flux due to gravity; vs- settling velocity; X_{SC}- total sludge concentration

$$J_s = v_s\,(X_{SC})\,X_{SC}$$

Results and conclusions

- Knowledge about settling behavior and particle properties can be strengthened by performing ViCA's column tests.
- The settling velocity distribution was shown to be clearly affected by the load of return sludge from the biological treatment step and a greater addition of coagulant increased the class of slowly settling particles due to precipitation of soluble components.
- Modeling provides more knowledge about the capacity of sludge withdrawal from the primary clarifier and how to set the optimal chemical dosage to maximize the reduction of COD and for utilizing wastewater as a resource. The full report (Lundin, 2014) includes simulation results on dynamic influent data; see Figure 3 for a simulation example.

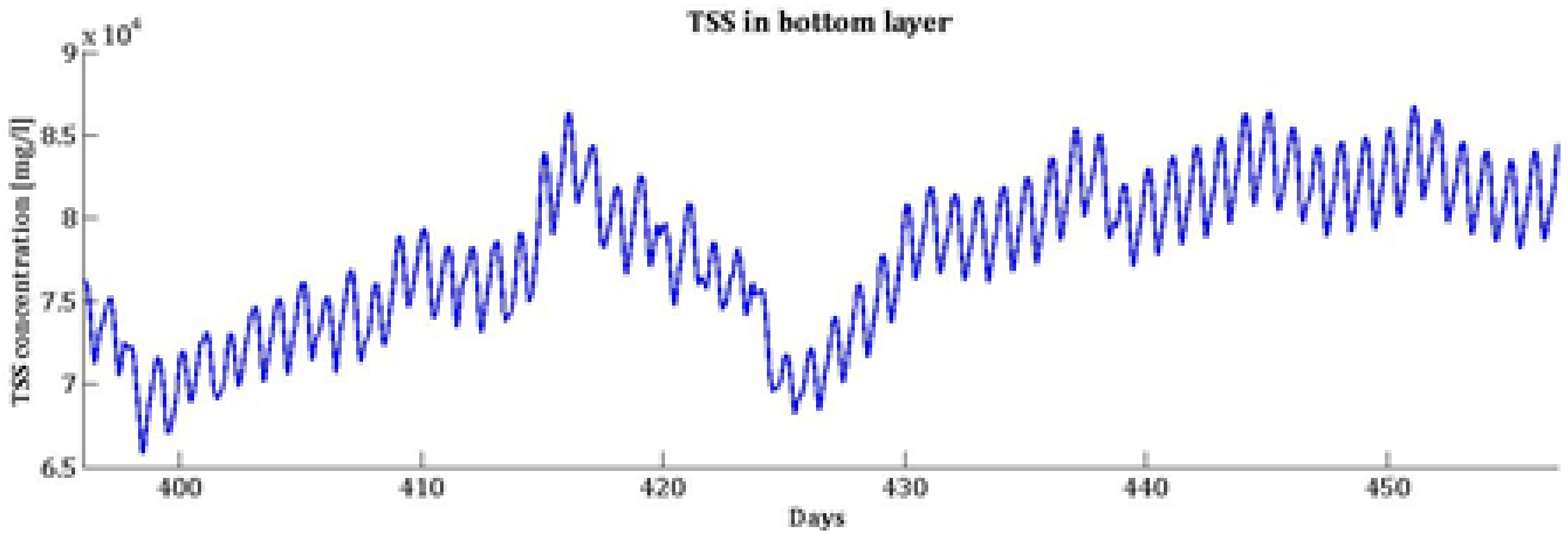

Figure 3. Simulated total suspended solids concentration in the primary settling tank's bottom layer, given using provided influent data for June and July.

Comment: The class boundaries used to create the settling velocity distribution should be calibrated through better matching of simulated data with existing measured data. When the optimal model for the time period June/July is found, the MATLAB/Simulink model should be further testified though confrontation with new data series using cross-validation. How the occurrence of hindered settling in the primary settlers can be implemented in the model should be further investigated. Since the ViCA's method assumes flocculent settling the method needs to be re-evaluated for cases where for example bio-sludge is re-circulated.

SP Technical Research Institute of Sweden
Enhet
Box 857, SE-501 15 Borås, Sweden
Telephone: +46 10 516 50 00 • Telefax: +46 33 13 55 02
E-mail: info@sp.se • www.sp.se

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