International Young Water Professionals Conference

Activating secondary settling tank for improved nitrogen removal

G. Kirim [a,b] *, E. Torfs [a,b] **, P. A. Vanrolleghem [a,b] **

[a] model*EAU* - Université Laval, 1065 avenue de la Médecine, Québec G1V 0A6, QC, Canada, gamze.kirim.1@ulaval.ca
[b] CentrEau - Centre de recherche sur l'eau du Québec, 1065 avenue de la Médecine, Québec G1V 0A6, QC.
* Presenting author
** Corresponding author

The results presented demonstrate the potential to exploit biological reactions in secondary settling tanks (SSTs), particularly denitrification to improve overall N removal of WRRFs and to reduce energy and external carbon consumption. The SST denitrification efficiency depends on the water flow through the sludge blanket to the effluent, which warrants a closer look at the design and operation of SSTs.

Keywords: Reactive settling, post-denitrification, energy saving.

Materials and Methods

SSTs are used for gravity-based separation of sludge from WRRF effluents. A significant fraction of the overall sludge inventory can be stored in the bottom of the SST. At long residence times and if incomplete denitrification occurs in the biological reactors, denitrification can take place in the sludge blanket (SB) at the bottom of the settling tank, where the concentration of sludge is high, nitrate levels are still substantial, biomass decay operates, and no oxygen is present (Bürger et al., 2016).

The fact that biokinetic processes and physical settling phenomena occur simultaneously in a settler leads to the concept of so-called reactive settlers and it is a research topic that should be investigated more so as to correctly analyze a WRRF's capacity for optimal nitrogen removal. In theory, exploiting SST denitrification has a great potential for overall N removal and for reaching better effluent quality, and it only requires small operational changes, i.e. it only needs an increase of the sludge blanket height (SBH) to a desirable level. Moreover, through enhanced denitrification in the SST a WRRF requires -for the same N-removal- less internal recycle pumping in the biological reactors resulting in significant energy savings. Moreover, the external carbon needs to reach a desired N removal level, can be (partially) eliminated. In this study, the operation of an ordinary SST was changed into a reactive settler and a detailed measurement campaign was carried out to quantify the nitrate removal potential of SSTs.

Results and Discussion

The objective of the study was to better understand reactive settling and denitrification performance under five different operational scenarios (Figure 1) by increasing the sludge blanket height (SBH) in scenarios 2 to 5, supplementing the sludge entering the SST with extra carbon in scenarios 3 and 5, and increasing the nitrate loading to the settler in scenarios 4 and 5. In Figure 1 the color scale and circle diameters are related to the NO_3-N and TSS concentrations as given in the legend. Scenario 1, the reference scenario was repeated at the beginning and end of the measurement campaign. At the end the SST had returned to its original state.

It is observed that the SB consists of 2 zones in which denitrification occurs at different rates depending on the biomass concentration and the HRT. The upper part, from the feeding point to the top of the SB, acts as an endogenous post-denitrification zone in which NO_3-N removal occurs with relatively low efficiency because of the lower biomass concentration. The lower part of the SB from the feeding point down to the bottom of the SST becomes a high rate reactor with highly concentrated biomass where significant denitrification occurs (Figure 2-right). The results show a consistent 90-95% nitrate removal, even at the high nitrate loading to the SST in scenarios 4 and 5. The overall denitrification performance in the SST can be further improved by increasing the HRT of the up-flowing water through the SB. This could be achieved by feeding the influent of the SST closer to the bottom of the SB (Figure 2-left).

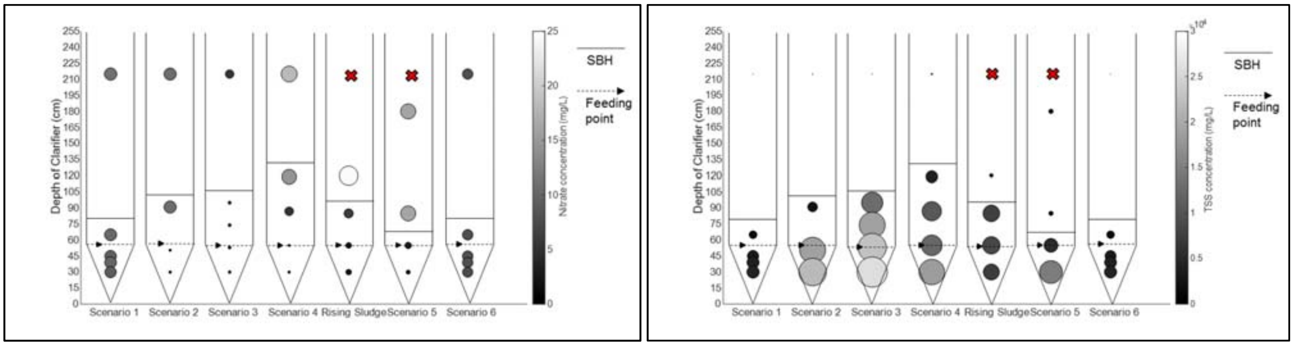

Figure 1. SST NO_3-N (left) and TSS (right) concentration profiles (samples could not be taken at the **X** points due to rising sludge).

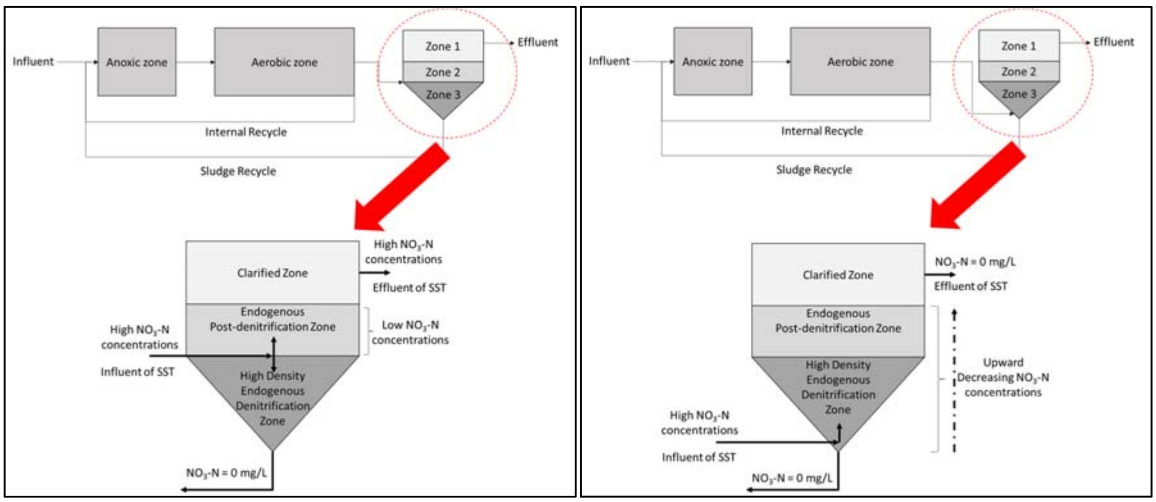

Figure 2. SST denitrification efficiency depending on current feeding point (right) and modified bottom feeding (left).

Settled sludge at the bottom of the SST may start rising depending on the NO_3-N load and the biomass activity. This undesirable condition was observed at an inlet NO_3-N concentration of 20 mg/L (Scenario 4 – Rising Sludge, Figure 1) where the sludge started to rise due to the release of nitrogen gas. This effect became even more pronounced when external carbon was added (Scenario 5). Clearly, adequate process control will be needed to properly exploit SST-denitrification.

Contributions of the work

This study focused on data collection to monitor the reactive settling process and to support the calibration of a reactive settler model. The unique experimental results showed a great potential for improved N-removal through reactive settler operation while reducing pumping energy and external carbon requirements. Moreover, the study also conceived the idea of bottom feeding to improve overall N removal since SST denitrification efficiency can be linked to increasing the HRT of the up-flowing water through the SB, a condition that can be achieved by feeding the influent closer to the bottom of the tank. However, strong denitrification during overloaded clarifier conditions were shown detrimental to the plant's efficiency since it may lead to N_2-bubble induced sludge rising. To conclude, since the efficiency of denitrification in the SST highly depends on the biomass concentration, nitrate load and the hydraulic retention time (HRT) in the SST, research is required to link the settling behavior of activated sludge and its denitrification efficiency, to operational and control conditions.

References

Bürger, R., Careagaa, J., Diehl, S., Mejías, C., Nopens, I., Torfs, E. & Vanrolleghem, P. A. (2016). Simulations of reactive settling of activated sludge with a reduced biokinetic model. *Computers & Chemical Engineering,* 92, 216-229.