# Sludge residence time and membrane fouling: what is the connection?

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## Introduction

Nowadays, waste activated sludge is more and more regarded as an energy source (through subsequent anaerobic digestion) or even as a potential source of fine chemicals (through subsequent fermentation processes). To this end, the organic content of the activated sludge should remain as high as possible implying short sludge residence times (SRT). However, the settling characteristics of the resulting sludge are most often very poor. This fact is overcome by performing the water-sludge separation by low pressure membrane filtration instead of sedimentation.

This contribution focuses on the impact of the sludge retention time (SRT) on membrane fouling in such low pressure membrane filtration processes. While the disadvantage of a high SRT is indeed the mineralization of the sludge and the higher biomass concentrations in the reactor, often impairing an efficient oxygen transfer, lower membrane fouling rates are observed at higher SRTs. Indeed, a recent review on membrane fouling in MBRs pinpoints the sludge retention time as an important factor influencing membrane fouling (Drews, 2010). At higher SRTs, the activated sludge appears to be more robust and fouling rates are less influenced by variations in temperature or in polysaccharide fractions of soluble microbial products.

Apart from the SRT, also the particle size distribution is known to have a major influence on membrane fouling (Meng and Yang, 2007; Van den Broeck *et al.*, 2010, 2011). Foulants with smaller sizes than the membrane pores may enter the pores and pore blocking can occur. However, MBR activated sludge flocs and free bacteria are considerably larger than membrane pores of membranes used in MBRs, i.e., 10-50 µm and 1-2 µm (Jiang *et al.*, 2003), respectively, compared to 0.01-0.5 µm. The effect of activated sludge particle size distribution can thus be expected at the level of the cake layer resistance rather than pore blocking. Combining the above findings, this contribution focuses on the effect that the SRT has on the flocs' particle size distribution, and, hence, on membrane fouling.

## Materials and Methods

The results obtained in this study were gathered with a pilot-scale MBR. The installation consisted of three separate tanks, i.e., an aerobic reactor (8.04 $m^3$), a non-aerated reactor (4.15 $m^3$) and a separate membrane tank of 2.34 $m^3$. The membrane tank was equipped with 35 $m^2$ flat sheet membranes (Toray, Membray) which were continuously aerated with coarse air bubbles at a rate of 18 $Nm^3/h$ ($SAD_m = 0.514\ Nm^3/m^2$). The pilot-plant has been operated for more than two years during which it was fed with real communal wastewater. During this period, three different SRTs (10 days - 30 days - 50 days) were investigated. For all three SRTs, bioflocculation was closely monitored by means of an automated image analysis procedure (Van den Broeck *et al.*, 2011) while the fouling rate was recorded on-line for different fluxes and different filtration/relaxation cycles. In addition, the Delft Filtration Characterization method ($DFC_m$) was employed to assess the activated sludge fouling propensity (Evenblij *et al.*, 2005; Geilvoet, 2010).

|  | Gross flux [L/m².h] | $T_{fil}/T_{rel}$ [min/min] | Net flux [L/m².h] | dTMP/dt [mbar/d] | $A_f/A_t$ [-] | $D_{eq}$ [µm] | $\Delta R_{20}$ [1/m] |
|---|---|---|---|---|---|---|---|
| SRT 50 days | 20.0 | 8/2 | 16.0 | 0.187 | 0.0240 | 91.3 | $0.038.10^{12}$ |
|  | 20.0 | 9/1 | 18.0 | 0.567 | 0.0259 | 104.9 |  |
|  | 25.0 | 8/2 | 20.0 | 0.625 | 0.0264 | 98.4 |  |
|  | 25.0 | 9/1 | 22.5 | 0.644 | 0.0254 | 102.1 |  |
|  | 30.0 | 8/2 | 24.0 | 0.821 | 0.0260 | 120.5 |  |
|  | 30.0 | 9/1 | 27.0 | 11.15 | 0.0321 | 82.9 |  |
| SRT 10 days | 20.0 | 8/2 | 16.0 | 10.80 | 0.0403 | 73.7 | $4.56.10^{12}$ |
|  | 20.0 | 9/1 | 18.0 | n.a. | n.a. | n.a. |  |
|  | 25.0 | 8/2 | 20.0 | n.a. | n.a. | n.a. |  |
|  | 25.0 | 9/1 | 22.5 | n.a. | n.a. | n.a. |  |
|  | 30.0 | 8/2 | 24.0 | n.a. | n.a. | n.a. |  |
|  | 30.0 | 9/1 | 27.0 | n.a. | n.a. | n.a. |  |
| SRT 30 days | 20.0 | 8/2 | 16.0 | 0.311 | 0.0367 | 110.7 | $0.010.10^{12}$ |
|  | 20.0 | 9/1 | 18.0 | 0.015 | 0.0314 | 118.8 |  |
|  | 25.0 | 8/2 | 20.0 | 0.626 | 0.0366 | 105.5 |  |
|  | 25.0 | 9/1 | 22.5 | 3.370 | 0.0341 | 98.0 |  |
|  | 30.0 | 8/2 | 24.0 | 5.242 | 0.0305 | 113.7 |  |
|  | 30.0 | 9/1 | 27.0 | 38.70 | 0.0280 | 101.1 |  |

n.a.: data not available because of too severe fouling;
$\Delta R_{20} < 0.1.10^{12}.m^{-1}$ = good filterability; $\Delta R_{20} > 1.0.10^{12}.m^{-1}$ = poor filterability

Table 1. Fouling rates and bioflocculation characteristics at the three SRTs and different filtration fluxes with different filtration/relaxation intervals.

## Results

The main results are summarized in Table 1. For the different SRTs and fluxes and the various combinations of filtration/relaxation periods, a clear difference in fouling rate (indicated by the dTMP/dt and $\Delta R_{20}$ values) can be discerned. At higher SRTs the fouling rate is clearly lower and higher net fluxes can be sustained. From the image analysis information that was extracted, the most revealing measurement was the surface covered by the fragments (i.e., very small objects), relative to the surface covered by all the objects in the image ($A_f/A_t$). At high SRTs this ratio was very small, at low SRTs or during process disturbances this ratio was very high. Also hydrophobicity was much higher at the high SRTs (data not shown). Interestingly, the equivalent diameter (Deq) as such, was less indicative to quantify the fouling propensity but these results confirm, anyhow, that the connection between a reduced membrane fouling and a higher SRT is definitely the bioflocculation condition of the activated sludge.

## Conclusions

The here presented results confirm that bioflocculation is much improved at higher SRTs and that the resulting better flocculation prevents severe membrane fouling. The latter is also reported by, e.g., Ma *et al.* (2006) and Meng and Yang (2007). It is, however, not the mere equivalent diameter of the flocs that dictates the fouling propensity of the activated sludge mixture, but the relative abundancy of small flocs or colloids in comparison with the large flocs. Bioflocculation is, hence, as important for conventional activated sludge systems as for MBRs. If *organic* sludge is targeted, a trade-off will have to be made, since the envisaged cost reduction at low SRTs (through lower aeration costs and methane production) might well be overruled by significantly higher operational costs for the filtration. For more details the reader is referred to Van den Broeck *et al.* (2012).

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