# Effects of shear forces on the particle size distribution and viscosity of activated sludge from an MBR pilot plant

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## Introduction
In a world driven towards sustainability, energy savings are nowadays a priority and that is no different in wastewater treatment systems. Interestingly, viscosity is known to affect several of the most energy requiring steps of wastewater treatment plant (WWTP) processes, among which mixing, filtration, aeration (Fabiyi & Novak, 2008; Seyssiecq et al., 2003) and activated sludge (AS) pumping (Tchobanoglous et al., 2003). Since AS is a particulate suspension, its viscosity is observed to vary with the suspended solids content (Rosenberger et al., 2011). However, being a colloidal system, its rheological behaviour is also determined by the dispersing flow features, dispersed phase characteristics and the magnitude of the particle interactions characterizing it as a non-Newtonian fluid. This work aims at coupling rheological measurements of AS from an MBR pilot plant with particle size analysis (PSA) as an initiating and knowledge building step in the framework of developing a generally accepted and improved mathematical model with respect to AS viscosity (Ratkovich et al., 2013).

## Materials and methods
AS samples were taken from the bioreactor of a full scale MBR pilot plant located at the Osnabrück WWTP and fed with pre-treated sewage (for details see Rosenberger et al., 2011). A PSA was carried out with the laser channel of the EyeTech (Ankersmid) before (reference sample) and after applying a defined shear rate. A rotational rheometer (MCR101, Anton Paar) with a double gap cylinder was used. In order to investigate the influence of shear rate and shear duration, each AS sample was subjected to a predefined shear rate (100, 1000, 10000 $s^{-1}$) for a predefined duration (5, 20, 30 minutes). Temperature was set to 20℃. The effect of dilutions (necessary for the PSA) was also studied including three different dilution rates. Moreover, for visual validation of the PSA results, microscopic images were taken using a binocular microscope (Zeiss) equipped with image acquisition and processing software. Total suspended solids (TSS) of the AS samples were also measured according to standard methods.

## Results and discussion
The particle size distribution (PSD) results are presented in percentage of deviation from the reference distribution (making the latter coincide with the horizontal axis). In Figure 1 the volume based percentages are given for three different measurements (for completeness, number based distributions will be provided in the full paper). As expected, the application of the highest shear rate (10000 $s^{-1}$) for the longest period (30 minutes), caused overall break-up of the bigger and medium sized flocs producing smaller flocs (< 10 μm). On the other hand, the application of the lowest shear rate (100 $s^{-1}$) for 30 minutes provided the opposite effect (i.e. aggregation). The smallest sized flocs decreased, whereas the medium and large sized particles

increased. Remarkable is the appearance of particles in the range of 80 to 90 µm. The black line, indicating the effect of a shear rate ramping up from 100 up to 10000 $s^{-1}$ and ramping down in a 30 min timeframe, demonstrates the hysteresis effect of deflocculation by increasing shear rate, followed by a partial recovery through aggregation when decreasing the shear rate. These results can be observed in both the 150 and 250 dilution rates. However, two main effects can be recognized as mere outcomes of increasing dilution: less appearance of big particles for the low shear rate and the ramp (hindered flocculation), higher formation of small sized particles for the highest shear rate (enhanced deflocculation).

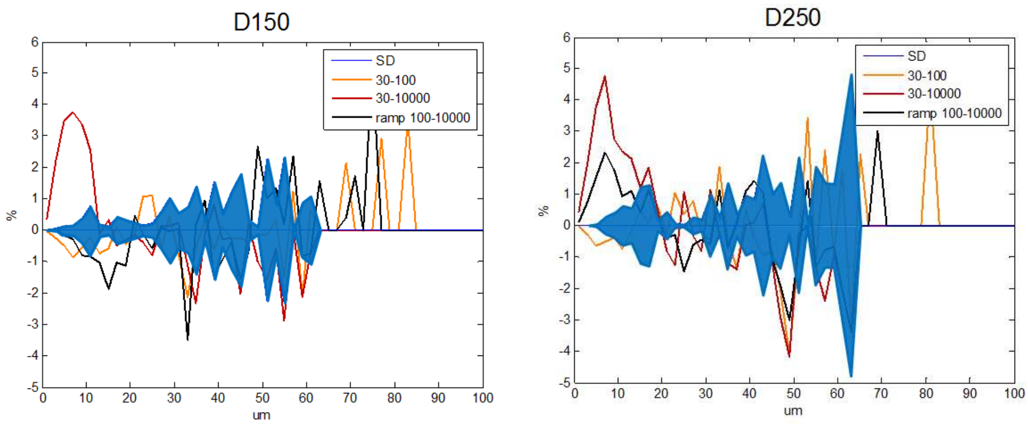


**Figure 1 - Volume-based PSD measured at a dilution ratio of 150 (left) and 250 (right). Standard deviation (SD) of three reference distributions is given as the blue shaded area. PSA results for constant shear application are noted by their shear time (min) – shear rate ($s^{-1}$) combination while for the ramp the shear rate variation range is given.**

More PSA results will be presented in the full paper together with viscosity measurements and microscopic pictures.

## Conclusions

The applied shear forces affected the AS composition and its PSD, and therefore its structure. It was found that high shear forces tend to break-up particles, while low shear forces appear to enhance aggregation. Most importantly, these changes in PSD were measurable, opening the field for the development of a monitoring system of AS via its PSD for the control, and maybe even prediction of its rheological state. Moreover, dilution effects, necessary for PSA, appeared to be quantifiable and therefore likely to be predictable following further experiments. As these changes in the AS have effects on viscosity, it can be stated that the development of a new possible mathematical model for AS rheology should consider to include the floc size as one of the constituent variables. This is an important prerequisite for e.g. energy models based on viscosity or models used in system design.

## References

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