Euromembrane Conference 2012

[P1.004]

Aeration for fouling control in submerged membrane bioreactors for wastewater treatment : Shear simulation and experimental validation

E. Braak[1], S. Schetrite[1], D. Anne-Archard[2], C. Albasi*[1], M. Alliet[1]

[1]*Laboratoire de Génie Chimique, France,* [2]*Institut de Mécanique des Fluides de Toulouse, France*

Aeration for fouling prevention in SMBRs represents a great part of energy consumption of the process (Gil *et al.*, 2010 ; Racault *et al.*, 2010). To decrease it a better understanding of the impact of aeration on filtration performances is required. In spite of its beneficial effect (shear stress on membrane surface, turbulences...), the aeration has an impact on a potential destructuration of mixed liquor that could be detrimental to filtration (Meng *et al.*, 2008). Our study aims at estimating this impact for SAD_m and SAD_p close to those used in full scale plants.

To do so work was separated in two main parts:

- Hydrodynamics characterisation to quantify shear stresses imposed to mixed liquor through Computational Fluid Dynamics (CFD) simulations validated by bubble velocity measurements obtained by visualisation on a dedicated experimental device.
- A pilot campaign to assess experimentally the impact of aeration on mixed liquor parameters. The hollow fibre membranes (polysulfone, 0.225m^2) are operated in dead end filtration in a cylindrical carter located outside the MBR into which the mixed liquor circulates at low velocity (Lorain *et al*, 2010).

The aim is to link air flowrate (operational parameter) to fouling through local mechanism induced by aeration: shear stresses imposed to mixed liquor and the induced variations of floc size and Extracellular Polymeric Substances (EPS) concentrations.

A high-speed camera was used to characterize hydrodynamics, focusing on gas phase. Three airflow rates were tested: 0.075, 0.1125 and 0.225 $m^3.h^{-1}$ corresponding respectively to SAD_m values of 0.33, 0.5 and 1 $m^3.h^{-1}.m^{-2}$. The liquid used was tap water. Only slug bubbles were tracked as they were considered as responsible for the main shear contribution given the confined configuration of the flow. Image processing was realized with Matlab and bubbles were characterized by their position, dimension and shape.

The hollow fibre membrane bundle was simulated as a cylindrical wall and consequently bubbles and liquid flowed through cylindrical annulus geometry. Bubbles were initialized at the bottom of the annulus without any velocity. The value of bubble velocity obtained experimentally enabled us to validate our CFD model for water/air flow. The first developments of this model have already been presented (Braak *et al.*, 2011). Simulations have been improved since that time, particularly with the introduction of a rheological law that characterizes the fluid to take into account the real behaviour of activated sludge.

To set the parameters of this rheological law, some experiments were led using already developed protocols (Günther *et al.*, 2011). Most of the time, SMBR activated sludge presents a pseudo-plastic profile and it was simulated with Carreau model which matched rather well to experimental values as shown on Figure 1.

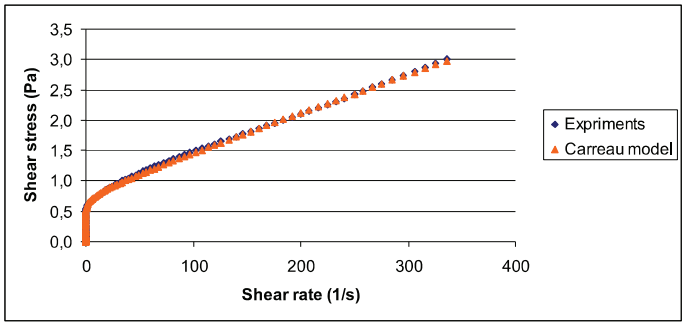

Figure 1 : SMBR activated sludge rheogram

To estimate shear stress faced by biological aggregates, particles will be injected at t=0 at various locations of the module and shear stress will be estimated for these particles at various times. The results obtained for ten particles which were injected along module length (particle 1 at the bottom and particle 10 at the top of the module) on a vertical line passing through initial bubble centre are presented on Figure 2, for tap water. A next step of investigation will be to propose similar results taking into account the rheological properties by the above validated law.

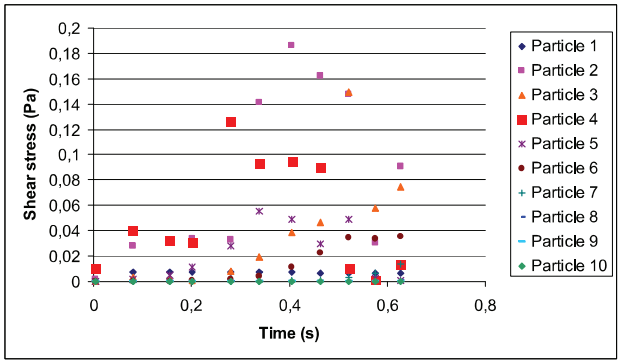

Figure 2 : Variations of shear stress faced by particles with time for air/water flow

To assess experimentally the effect of aeration on mixed liquor a SMBR pilot of 15L fed with screened wastewater was run for various aeration parameters settings. TransMembrane Pressure (TMP) and mixed liquor parameters (particularly EPS concentrations and floc morphology) were monitored in order to link aeration, biological media characteristics and fouling behaviour. The SMBR was run with 2 airflow rates: 0.075 $m^3.h^{-1}$ and 0.225 $m^3.h^{-1}$. It was operated with 5 mn cycles with 75 s of filtration and 225 s of relaxation/aeration. The instantaneous filtration flux was set to 24 $L.h^{-1}.m^{-2}$ which corresponds to mean flux of 6 $L.h^{-1}.m^{-2}$. TMP results are presented on Figure 3.

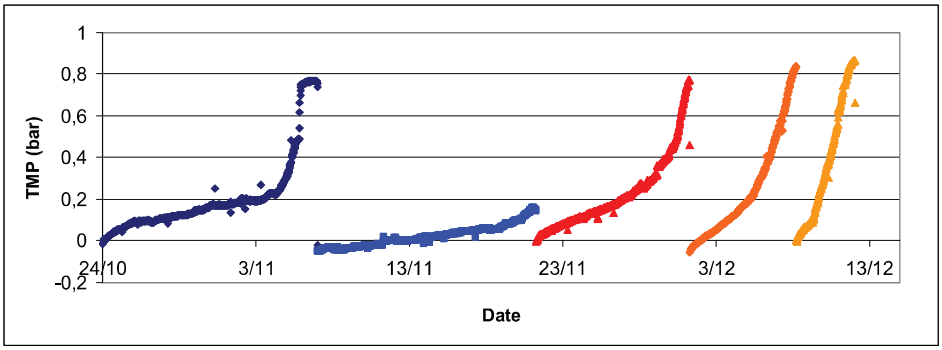

Figure 3 : TMP variations with time

Experimental pilot results will then be checked against CFD simulation outputs and rheological experiments. Given the accurate characterisation of hydrodynamics provided by adapted CFD simulations, this work provides further insight into the understanding of the impact of aeration on mixed liquor characteristics. It enables to link air flowrate, shear stresses, mixed liquor characteristics and finally fouling behaviour for a range of SAD_m rather close to those used in full scale plants, and to conclude whether or not aeration may influence mixed liquor and be detrimental to filtration performances. Next work could consider the industrial scale.

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Keywords: Submerged Membrane Bioreactor, Computational Fluid Dynamics, Rheology, Shear Stress