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Ragging and Sludging Measurement in Membrane Bioreactors

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Abstract : Membrane bioreactor (MBR) technology is challenged by the tendency for the membrane permeability to decrease due to 'clogging'. Clogging includes 'sludging', the filling of the membrane channels with sludge solids, and 'ragging', the aggregation of short filaments to form long rag-like particles. Both sludging and ragging demand manual intervention to clear out the solids, which is time-consuming, labour-intensive and potentially damaging to the membranes. These factors impact on costs more significantly than membrane surface fouling which, unlike clogging, is largely mitigated by the chemical clean. However, practical evaluation of MBR clogging has thus far been limited. This paper presents the results of recent work attempting to quantify sludging and clogging based on simple bench-scale tests. Results from a novel ragging simulation trial indicated that rags can be formed within 24-36 hours from dispersed < 5 mm-long filaments at concentrations of 5-10 mg/L under gently agitated conditions. Rag formation occurred for both a cotton wool standard and samples taken from an operating municipal MBR, with between 15% and 75% of the added fibrous material forming a single rag. The extent of rag formation depended both on the material type or origin – lint from laundering operations forming zero rags – and the filament length. Sludging rates were quantified using a bespoke parallel-channel test cell representing the membrane channels of an immersed flat sheet MBR. Sludge samples were provided from two local MBRs, one treating municipal and the other industrial effluent. Bulk sludge properties measured comprised mixed liquor suspended solids (MLSS) concentration, capillary suction time (CST), particle size, soluble COD (sCOD) and rheology (apparent viscosity μ_a vs shear rate γ). The fouling and sludging propensity of the sludge was determined using the test cell, 'fouling' being quantified as the pressure incline rate against flux via the flux step test (for which clogging was absent) and sludging by photographing the channel and processing the image to determine the ratio of the clogged to unclogged regions. A substantial difference in rheological and fouling behaviour was evident between the two sludge sources, the industrial sludge having a higher viscosity but less shear-thinning than the municipal. Fouling, as manifested by the pressure increase $\Delta p/\Delta t$, as a function of flux from classic flux-step experiments (where no clogging was evident), was more rapid for the industrial sludge. Across all samples of both sludge origins the expected trend of increased fouling propensity with increased CST and sCOD was demonstrated, whereas no correlation was observed between clogging rate and these parameters. The relative contribution of fouling and clogging was appraised by adjusting the clogging propensity via increasing the MLSS both with and without a commensurate increase in the COD. Results indicated that whereas for the municipal sludge the fouling propensity was affected by the increased sCOD, there was no associated increased in the sludging propensity (or cake formation). The clogging rate actually decreased on increasing the MLSS. Against this, for the industrial sludge the clogging rate dramatically increased with solids concentration despite a decrease in the soluble COD. From this was surmised that sludging did not relate to fouling.

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