Statistical modelling of a semi-industrial scale membrane bioreactor using fuzzy inference methods

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Summary:

Membrane bioreactors (MBR) are recently used in large scale wastewater treatment plants. The modelling of the functioning of such a process could be used as the base of a control strategy. In this study, a fuzzy inference method is used to i) simulate a 4,5 months campaign of a semi-industrial MBR traiting rejection water from sludge treatment, ii) discriminate the influence of the functioning parameters in the fouling of the membrane. The results show not only a good representation of the permeability evolution, but also coupled influences of sludge properties and operating parameters.

Keywords: Wastewater treatment plant, membrane bioreactor, simulation

Introduction

Membrane bioreactors (MBR) are recently used in large scale wastewater treatment plants (Krzeminski et al. 2017). Fouling control is of prime importance for full-scale membrane bioreactor operation to limit energy consumption or to maintain production capacity. Model developments are needed to describe and interpret the mechanisms inducing the fouling but also to predict and optimize the operation of such treatment unit at large scale. While deterministic models allow a better understanding of fouling with detailed parameters, statistical approaches could represent an efficient alternative for this application (as regression model tree (Dalmau *et al.*, 2015) or multivariate linear correlations (Philippe *et al.*, 2013)). In order to reduce operating cost with the development of control strategies, the double objective of this study is to model daily permeability evolution (dPe) of semi-industrial filtration pilot and to understand the influence of different operating parameters on this permeability. For these objectives, fuzzy inference methods (Zahed, 1965), suitable for complex system modelling were used. It is uncommon to date for MBR fouling control.

Material and Methods

Studied unit and data collection: Data have been collected on a filtration pilot supplied by a MBR treating rejection water from digested sludge dewatering after their thermic treatment (about 10,000 m^3/d) in the Seine Aval wastewater treatment plant (Paris suburbs, France). The biological treatment unit is composed of 4 biological tanks (anoxic zone 7500 m^3 and oxic zone 2600 m^3 each) and 6 separated membrane tanks (15000 m^2 of membrane KMS Puron® each). Defoamer is added during the pretreatment stage. The filtration pilot is a semi-industrial PVC reactor (V_{liquid}=2.0 m^3, L×l×h_{liquid} (m)=1.23×0.70×2.40) equipped with three hollow fiber membrane modules (KMS Puron, PSH 34, filtration surface=3×34m^2=102m^2). Each membrane module consists of nine fiber bundles. The reactor was continuously filled with activated sludge and filtration occurred at a liquid flow rate of 1.3 m^3/h. The study was carried out on a dataset of campaign lasting 4.5 months. The semi-industrial pilot was operated for 13 different conditions, from 1 to 2 weeks of operation each. The modified parameters were aeration (air flow rate, sequenced aeration timing, number of aerated modules) or filtration conditions (filtration cycle duration, backwashing/relaxation conditions). Activated sludge properties (conductivity, pH, dissolved oxygen, temperature, MLSS and supernatant COD) were measured daily (data collected from probes recorded every minute). Transmembrane pressure (TMP), temperature, permeate and air flow rates are recorded every five seconds. Transmembrane pressure (TMP), permeate and air flow rates are recorded every five seconds. The permeability of the membranes is calculated using permeate flux and TMP measurements.

Fuzzy inference method: After parameter selection using statistical analysis, the inference system was developed using the Fispro Open-Source Software[1]. Hierarchical Fuzzy Partitioning (HFP) was used to select appropriated numbers of fuzzy sets for the partition step and rules were learned from the obtained dataset. Partitions and rules were manually adjusted. A more complete description of the fuzzy logic and the FisPro tool is proposed by Guillaume & Charnomordic (2011). This inference system was applied either to the whole campaign in order to simulate the evolution of the process or to specific periods with evolution of some parameters related to aeration conditions in order to understand their influence.

Results

The measured permeability of membrane corrected with temperature and the permeability estimated from the inferred dPe presented in Figure 1 show a good matching. The fuzzy decision tree presented in the Figure 2 shows that the effect of aeration flowrate is not similar for small, medium or high ΔDCO and medium, high or very high concentration of MLSS: if an increase of the aeration flowrate reduces the drop of permeability at medium ΔDCO and MLSS, it has nearly not effect at other values.

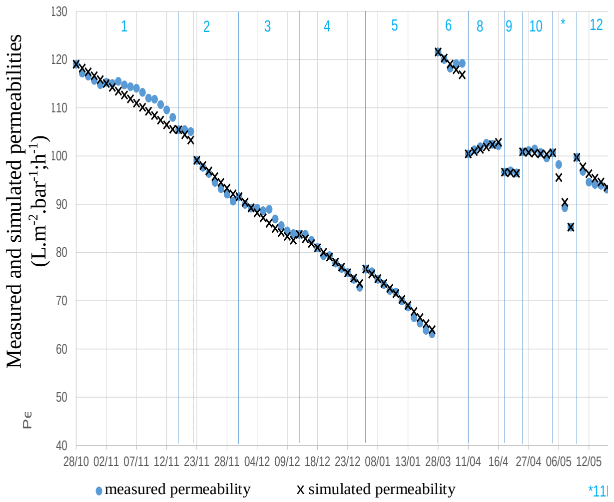

Figure 1: Measured and simulated permeabilities corrected with temperature along the campaign, using 80% of the data for learning and 20% for simulation

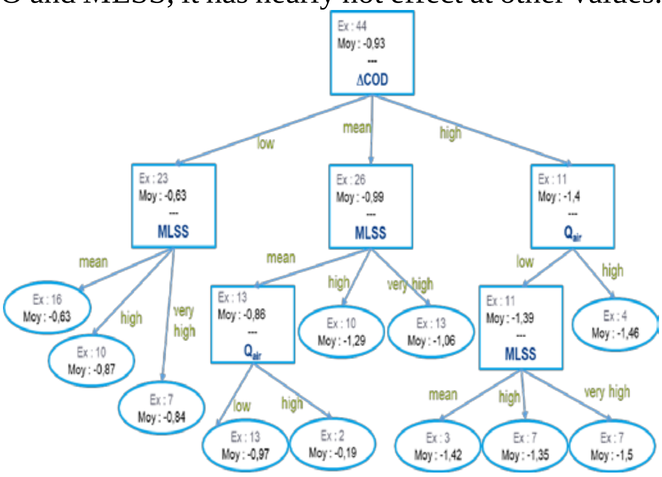

Figure 2: Fuzzy decision tree [dPe = daily permeability evolution at 20°C (L/m^2/h/bar)/ ΔCOD = difference between the supernatant COD in membrane tank and the permeate COD (mg/L)/ MLSS = Mixte Liquor Suspended Solid (g/L)/ Q_{air} = aeration flowrate] for periods of aeration study

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[1] Fuzzy Inference System Professional (https://www7.inra.fr/mia/M/fispro/fispro2013_en.html)