Simulating the soluble microbial products in a membrane bioreactor system and their impact on membrane fouling

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Introduction

MBRs (membrane bioreactors) are a recent innovation of the activated sludge process, which eliminates many constraints associated with the traditional gravity settling. Nevertheless, it suffer membrane fouling. The colloidal and macromolecular fraction of MBR sludge has been reported as the main foulant of MBR systems. SMP can be classified into BAP (biomass associated products) and UAP (utilization associated products) according to their sources (Namkung and Rittmann (1986)). However, the quantification of SMP in a MBR system under various operation conditions remains a challenge. The goal of this study is to: (i) model the SMP production and degradation in MBR systems and (ii) study the filterability of SMP.

Methods

A lab-scale membrane bioreactor (108 L/day) was set up at Ghent University, Belgium for biological nitrogen and phosphorus removal. The lab-scale MBR was fed with a synthetic municipal wastewater (Boeije et al. (1999)) and run at a constant temperature of 15 °C. The bioreactor consisted of an anaerobic compartment (8L) and an anoxic/aerobic compartment (17L) established by alternating aeration. The biomass was separated by a side-stream tubular membrane module (X-Flow, 0.03 µm in pore size). Periodically, the membrane was backwashed for fouling control. pH, ORP, DO and pressure data were collected online and all processes were controlled automatically by a computer running on LabVIEW.

In addition to the online data, offline COD and nutrient monitoring, special attention was paid to SMP and sludge filterability. The COD, protein and polysaccharide in both the sludge (filtered by 0.45 µm filter) and the effluent were measured. The colloidal/soluble fraction (i.e., sludge water) was produced by a 0.45 µm filter. Three types of sludge water (SMP, BAP and UAP) were filtered through a 0.03 µm flat-sheet PVDF membrane (same as MBR membrane) by a stirred cell at a constant pressure (14 kPa).

Results and discussion

ASM2d_SMP model

The BAP is produced during the biomass decay in a small fraction (f_{BAP}) and can be "reused" for biomass growth in a slower growth rate (μ_{BAP}). The UAP is produced in a small fraction (f_{UAP}/Y_H) during the biomass growth and can be "reused" for biomass growth in a slower growth rate (μ_{UAP}). These SMP associated processes were introduced into the standard IWA ASM2d model (Henze et al. (1999)) in a optimal way taking care of both the reality and model identifiability. However, the key of this ASM2d_SMP model is the parameter estimation. Careful designed bath experiments were performed to facilitate the model calibration.

Filterability of SMP

The filtration of three types of sludge water (SMP, BAP and UAP) showed that both BAP and UAP played important roles in MBR fouling. The cake filtration was identified as the main fouling mechanism and most fouling is reversible by backwashing.

Simulation of SMP concentration and membrane fouling

The simulation of the SMP showed that many factors can influence the SMP concentration in a MBR. However, the most important ones are the sludge retention time (SRT) and hydraulic retention time (HRT). A high SRT and low HRT resulted in a high SMP (mostly BAP) concentration due to the biomass decay. However, a low SRT and HRT resulted in a high SMP (mostly UAP) concentration as well due to the rapid biomass growth.

The ASM2d_SMP model is able to simulate the SMP concentration in a MBR reactor and the SMP concentration is well correlated with the MBR fouling.

Conclusions

An ASM2d_SMP model was successfully developed. In addition to its power to model nitrogen and phosphorus removal, the extended ASM2d model has the ability to model the SMP production and consumption, which was proven to have a significant impact on MBR fouling.

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