Membrane bioreactor biomass characteristics and microbial yield at very low mean cell residence time

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Abstract

Membrane bioreactors (MBRs) are an exciting and evolving technology that replaces gravity sedimentation with micro- or ultra-filtration. MBRs are typically operated at low mean cell residence times (MCRTs), but there are cases when operating at very low MCRT may be more beneficial. In this study, a laboratory-scale MBR and SBR were operated in parallel and at very low MCRTs (3 d, 2 d, 1 d and 0.5 d) to assess the relative bioreactor performance, biomass characteristics, and microbial yield. This study confirmed that the MBR maintains higher solids levels and better overall effluent quality than conventional bioreactors at all MCRTs tested. The MBR biomass particles were approximately 10 µm, which was significantly smaller than those of the SBR under all operating conditions tested. The MBR sludge typically did not dewater as well as that of the SBR. As the MCRT was decreased, the SBR particle size became smaller and the dewaterability improved, which supports the notion that smaller particles dewater better because there is less bound water present. The MBR sludge was more hydrophobic, which should result in more sorption of organic micro-pollutants like pharmaceutical compounds. These experiments also showed that the MBR biomass true yield was higher than that of the SBR. This study expands the MBR dataset available for very low MCRT operation.

Keywords: membrane bioreactors; microbial yield; biomass characteristics

Introduction

Membrane bioreactors (MBRs) are an evolving wastewater treatment technology that uses a suspended growth bioreactor, like in conventional activated sludge, but replaces gravity sedimentation with micro- or ultra-filtration. The membrane filtration unit allows for nearly complete retention of particles, high MLSS concentrations and production of an effluent very low in total suspended solids (TSS) and turbidity. It eliminates the need for secondary clarification, which in turn allows the overall treatment process to be sited on a much smaller footprint. MBRs are now becoming more common due to these operating advantages.

MBRs tend to operate at long mean cell residence times (MCRTs) in order to maintain high MLSS concentrations and to support nitrification, but under these operating conditions the aeration requirements pose a serious process limitation because of the high oxygen demand and the need to scour the membrane to slow the rate of fouling. Another concern at long MCRT is the production of soluble microbial products which can cause membrane fouling and produce too much colour (Rittmann and McCarty, 2001). MBR operation at low MCRT may be a prudent option for facilities that wish to avoid these disadvantages, reduce energy requirements, or reuse waste biosolids for the production of renewable resources like methane gas or biodegradable biopolymers (i.e. polyhydroxyalkanoates).

Currently there are very few data available concerning MBR operation at low MCRT. To date, Ng and Hermanowicz (2005) have provided the only available study of MBR operation at low MCRT. They operated a laboratory-scale MBR and conventional activated sludge system at MCRTs ranging from 5 d to 0.25 d. They found that the MBR achieved superior removal of COD and lower levels of effluent TSS. They also found that the MBR biomass was composed of fairly small, weak, and uniformly sized particles with a high fraction of non-flocculating organisms and very little exocellular polymer. The biomass in the conventional activated sludge system was composed of relatively large flocs when the MCRTs was greater than 2.5 d, but the floc was much smaller and weaker when the MCRT was shorter. They also found that the MBR microbial yield was greater than that of the conventional activated sludge system, in spite of the fact that both systems were operated under the same conditions (i.e. same MCRTs, electron donors and acceptors). Ng and Hermanowicz (2005) presented important data regarding MBR operation at low MCRT; however, critical information is still needed. In addition to confirming their overall conclusions related to process performance and microbial yield, there is a need for more information about the MBR sludge characteristics (e.g. particle size, hydrophobicity and dewaterability) at low MCRT conditions.

Previous work shows that particle size affects dewaterability. There is a common notion that dewaterability is negatively affected by small particle size because the high specific surface area increases the frictional resistance to the withdrawal of water. Karr and Keinath (1978) corroborated this idea by showing that too many solids in the 1 to 100 µm range were detrimental to dewaterability. However, more recently, Jin and Lant (2004) showed that floc size correlates negatively with dewaterability for floc sizes between approx. 50 and 200 µm, and they postulated that larger particles contained more bound water and were therefore more difficult to dewater. It is possible to reconcile these two studies by postulating that particles smaller than 50 µm negatively affect dewaterability; this issue directly affects MBR operation, because MBRs are known to operate with particles smaller than 50 µm (Yi and Harper, 2005;

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