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The development of a biofilm membrane bioreactor

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Abstract

Membrane bioreactors (MBRs) are commonly understood as the combination of membrane filtration and biological treatment using activated sludge. Development of a biofilm-MBR has been investigated combining a moving-bed-biofilm reactor with a submerged membrane biomass separation reactor. Treatment efficiencies were found to be high with the production of a consistent high-quality effluent, irrespective of loading rates on the bioreactor or membrane reactor operating modes. Membrane performance (fouling) is a function of the biofilm reactor effluent quality and varies with loading rates (HRT). Sustainable operation was found to correlate to the fate of the submicron particle size fraction throughout the treatment process.

Keywords: Membrane bioreactors; Biofilm; Membrane fouling

1. Introduction

Membrane bioreactors (MBR) are commonly understood as the combination of membrane filtration and biological treatment using activated sludge (AS) where the membrane primarily serves to replace the clarifier in the wastewater treatment system [1,2]. The first generation of MBRs (late 1970s, 1980s) applied the use of cross-flow operated membranes installed in units outside the AS tank with high flow velocity circulation pumps. A disadvantage of the cross-flow membranes is the high energy required to generate sufficient sludge velocities across the membrane surface, and this process option was therefore considered nonviable for treating municipal wastewater. The development of submerged low pressure configurations in the late 1980s–1990s, by immersing the membranes into the AS tank, was an important step in making viable commercial solutions for the MBR process [3–5]. Today a variety of process configurations exist where the membrane is installed either in an external unit or immersed in the aeration tank and where the systems are designed to be operated under low-pressure vacuum. Compared to conventional AS systems,

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several advantages of the AS-MBRs have been identified [6] which have promoted the development of commercial AS-MBR options. These include compact units with small footprints, complete solids removal, effluent disinfection, operation at higher suspended biomass concentrations resulting in long sludge retention times, low sludge production, and no problems with sludge bulking. One of the major drawbacks of AS-MBRs is fouling, which is common for all membrane systems, where the efficacy of the process is constrained by the accumulation of materials on the surface of or within the membrane resulting in a reduction in the membrane permeability. Membrane fouling is caused by different substances and the mechanisms are rather complex and interrelated. Deposition of solids as a cake layer, pore plugging/clogging by colloidal particles, adsorption of soluble compounds and biofouling are some of the main forms of fouling that have been identified [7]. Fouling is particularly a problem in AS-MBRs since the process deals with liquors having high concentrations of total solids as well as dissolved compounds such as extracellular polymeric substances (EPS). Fouling is defined as reversible, i.e. can be removed by backwashing strategies, or as irreversible, i.e. fouling which is only recoverable by chemical cleaning, where the dominating fouling mechanism subsequently determines the performance of the process. Optimizing fouling control and cleaning strategies is therefore an important aspect of developing and designing MBR processes.

An alternative to the AS-MBR is combining a biofilm reactor with membrane separation of the suspended solids (BF-MBR) which may reduce the effect of membrane fouling by high biomass concentrations [8,9]. Although efficient in removing soluble organic matter, biofilm reactors designed as trickling filters or submerged filters using granular media are prone to clogging when the wastewater contains high loads of particulate matter. Consequently, there is a limit to the loading rate that can be applied to such processes, often necessitating a pretreatment step for particle removal prior to the biofilm unit. The moving-bed-biofilm reactor (MBBR) is an alternative process design which utilizes the advantages of a biofilm reactor and which at the same time can handle high loads of particles. The objective of this study has been to develop and investigate the potentials of a BF-MBR combining the MBBR with membrane separation.

2. Materials and methods

A schematic of the BF-MBR process concept is shown in Fig. 1, where the treatment train consists of two reactors, the MBBR followed by a membrane reactor with submerged modules and the process can therefore be defined as a

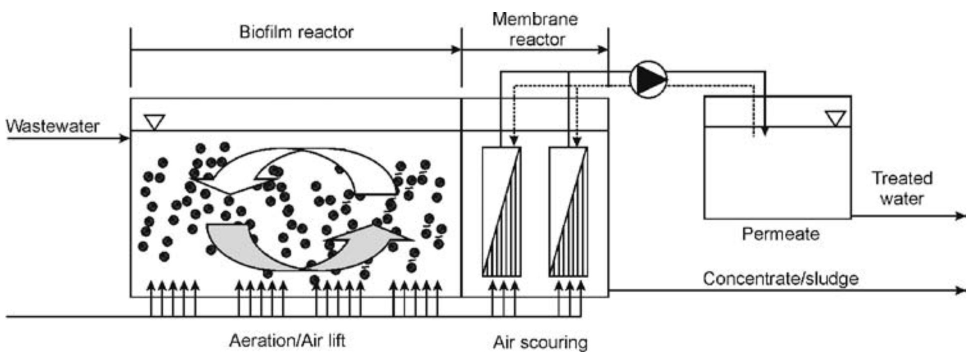

Fig. 1. Schematic of biofilm-MBR process concept.