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Review

Do biological-based strategies hold promise to biofouling control in MBRs?

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ABSTRACT

Biofouling in membrane bioreactors (MBRs) remains a primary challenge for their wider application, despite the growing acceptance of MBRs worldwide. Research studies on membrane fouling are extensive in the literature, with more than 200 publications on MBR fouling in the last 3 years; yet, improvements in practice on biofouling control and management have been remarkably slow. Commonly applied cleaning methods are only partially effective and membrane replacement often becomes frequent. The reason for the slow advancement in successful control of biofouling is largely attributed to the complex interactions of involved biological compounds and the lack of representative-for-practice experimental approaches to evaluate potential effective control strategies. Biofouling is driven by microorganisms and their associated extra-cellular polymeric substances (EPS) and microbial products. Microorganisms and their products convene together to form matrices that are commonly treated as a black box in conventional control approaches. Biological-based antifouling strategies seem to be a promising constituent of an effective integrated control approach since they target the essence of biofouling problems. However,

Abbreviations: AHL, acyl-homoserine lactone; AFM, atomic force microscopy; AIP, autoinducer peptide; ARDRA, amplified ribosomal deoxyribonucleic acid restriction analysis; ATP, adenosine triphosphate; CCCP, carbonyl cyanide chlorophenylhydrazone; CLSM, confocal laser scanning microscopy; COD, chemical oxygen demand; DNP, 2,4-dinitrophenol; DOC, dissolved organic carbon; DGGE, denaturing gradient gel electrophoresis; EPBR, enhanced biological phosphorous removal; ED, enzymatic disruption; EEM, excitation emission matrix; EPS, extracellular polymers; EU, energy uncoupling; F/M, food to microorganisms ratio; FISH, fluorescent in situ hybridization; FTIR, Fourier transform infrared; MALDI-TOF, matrix-assisted laser desorption/ionization -time of flight; MBR, membrane bioreactor; MF, microfiltration; MLSS, mixed liquor suspended solids; MS, mass spectrometry; NF, nanofiltration; NMR, nuclear magnetic resonance; NO, nitric oxide; NSM, natural small molecules; PAOs, polyphosphate accumulating organisms; PFU, plaque forming units; QQ, quorum quenching; QS, quorum sensing; RO, reverse osmosis; SEM, scanning electron microscopy; SIMS, secondary-ion mass spectrometry; SMP, soluble microbial products; SRT, sludge retention time; STXM, scanning transmission X-ray microscopy; CS, 3,3′,4′,5-tetrachlorosalicylanilide; TEM, transmission electron microscopy; TOC, total organic carbon; T-RFLP, terminal restriction fragment length polymorphism; UF, ultrafiltration; 2D-PAGE, two-dimensional polyacrylamide gel electrophoresis.

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Membrane performance
Microbial community

biological-based strategies are in their developmental phase and several questions should be addressed to set a roadmap for translating existing and new information into sustainable and effective control techniques. This paper investigates membrane biofouling in MBRs from the microbiological perspective to evaluate the potential of biological-based strategies in offering viable control alternatives. Limitations of available control methods highlight the importance of an integrated anti-fouling approach including biological strategies. Successful development of these strategies requires detailed characterization of microorganisms and EPS through the proper selection of analytical tools and assembly of results. Existing microbiological/EPS studies reveal a number of implications as well as knowledge gaps, warranting future targeted research. Systematic and representative microbiological studies, complementary utilization of molecular and biofilm characterization tools, standardized experimental methods and validation of successful biological-based antifouling strategies for MBR applications are needed. Specifically, in addition, linking these studies to relevant operational conditions in MBRs is an essential step to ultimately develop a better understanding and more effective and directed control strategy for biofouling.

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1. Biofouling problem in MBRs

Membrane bioreactors (MBRs) are now broadly applied as wastewater treatment technology that combines membrane processes and suspended growth bioreactors. Compared to other technologies e.g. activated sludge processes (Kim et al., 2010; Judd, 2008; Visvanathan et al., 2000), MBRs allow smaller footprints, higher-quality effluents, less sludge and complete solid–liquid separation; however, membrane fouling remains in most cases a persistent problem (increasing operating costs and reducing the water quality and quantity) (Wang et al., 2009; Kimura et al., 2009). Fouling results in a lower permeate flux, higher trans-membrane pressure (TMP), frequent membrane cleaning or replacement and overall degraded membrane performance (Mahendran et al., 2011; Liao et al., 2004). Fouling can be organic, inorganic or biological, although the boundary between these classifications is not rigid and the definitions of different fouling types may overlap. For example, inorganic deposition can be a direct consequence of biologically-induced mineralization between biopolymers and salts (Wei et al., 2007; Herrera-Robledo et al., 2011) and internal fouling caused by the adsorption of