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The evolution of pore-blocking during the ultrafiltration of anaerobic effluent–like mixtures

Miguel Herrera-Robledo *, Adalberto Noyola

Instituto de Ingeniería, Universidad Nacional Autónoma de México, Ciudad Universitaria, Delegación Coyoacán, México D.F. CP 04510, Mexico

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ABSTRACT

The global market for membrane bioreactor technology (MBR) is growing fast. Membrane biofouling hinders the broader application of MBR because it reduces permeate yield. The main goal of this manuscript was to identify the arrangement of fouling mechanisms during the ultrafiltration (UF) of suspensions comprising extracellular polymeric substances (EPS) and inorganic colloids (IC). Standard blocking (SB) was the main operative fouling mechanism in the early stages of filtration, which eventually shifted to cake filtration (CF). Longer SB stages were observed in UF experiments with a slight electric charge density ratio (ECD). CF was the predominant fouling mechanism with a higher ECD and led to the formation of mineralized-EPS-building blocks (MEBB) within the cake. MEBB accumulation in the membrane produced sharp reductions in filtration performance after 0.5 and 1.5 mM $CaCO_3$ were added. Non-covalent interactions fostered the development of irreversible fouling and biomineral seeds on membranes.

1. Introduction

The global market for membrane bioreactor technology (MBR) is growing fast (15% per year according to [1]), largely because MBR wastewater treatment plants (WWTP) are relatively easy to deploy and capable of producing clean water that meets stringent regulations for direct water reclamation. In comparison to other technologies for municipal sewage treatment, such as activated sludge, MBR WWTPs are not only smaller but also more efficient at removing pollutants and are capable of providing disinfected water [2]. During the last decade, dozens of full-scale MBR plants were installed in Japan, Korea, China, Germany and the USA. This success was the result of strategic partnerships between governments, enterprises and research centers (i.e., MBR-network, E-water, PERMEANT). The knowledge associated with this technological milestone (i.e., optimal strategies in the design, operation and maintenance of the membrane process) has fostered the potential of anaerobic MBR (AnMBR) as a practical alternative for municipal wastewater treatment [3,4].

Although the AnMBR concept was developed more than 30 years ago, its commercial applications have been limited by the efficiency of the membrane process due to fouling. Fouling control, especially in long-term operation, seems to be the most critical constraint for the applicability and feasibility of AnMBR in the growing field of municipal wastewater treatment [3]. So far, membrane fouling in AnMBR has not been fully understood due to the complex nature of anaerobic effluent and the diversity of operational conditions and bioreactor configurations. AnMBR systems will likely benefit from the development of efficient technologies to prevent fouling [4].

Non-covalent interactions (hydrogen bonding, metal coordination, van der Waals forces), between extracellular polymeric substances (EPS) and inorganic colloids (IC) have been identified as potential causes of irreversible fouling during water treatment performed by membranes; Ma et al. [5] suggested that the biomineralization of Fe crystals onto the extracellular matrix was the cause of irreversible scaling during a hybrid (coagulation/UF) desalination plant's pretreatment. Later, Teychene et al. [6] reported that interactions between the acidic chemical groups in EPS (i.e., COO−) and Ca ions were able to enhance the stiffness of fouling layers. Herrera-Robledo et al. argued that metal complexation by EPS fostered the deposition of insoluble deposits in the fouling layers during AnMBR operation [7].

In addition to the abiotic components, several strains of EPS-releasing bacteria have been identified in membrane fouling and could influence the dimensions and structure of the layer [8–11]. In considering biotic/abiotic interactions, other reports concluded that biomineralized deposits are important structural components

* Corresponding author at: Department of Civil and Environmental Engineering, Michigan State University, N. Shaw Lane 427, Room 3502, United States. Tel.: +1 517 355 1288.

E-mail addresses: mherrera@msu.edu (M. Herrera-Robledo), noyola@pumas.iingen.unam.mx (A. Noyola).

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