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Live membrane filters with immobilized quorum quenching bacterial strains for anti-biofouling☆

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ABSTRACT

Membrane filters are core materials for water treatment, reuse, and desalination. However, their fouling caused by biofilm growth is a major challenge, needing resolution. Here, we report the new strategies and efficacy of anti-biofouling membranes fabricated through the immobilization of quorum quenching (QQ) bacterial strains (*Rhodococcus* sp. BH4). The QQ cells are not attached to the membrane by direct phase inversion. However, they anchor to the membrane with its incubation in the presence of hydrophilic polymers (polyvinyl alcohol and alginate) as evidenced in the spectroscopic and morphological observations. Membrane filters with live QQ bacteria can degrade a signal molecule (N-octanoyl-L-homoserine lactone) with the first-order rate constant of 0.58–0.82 h^{-1} and inhibit the growth of a biofilm-forming bacterium (PAO1) and its secretion of biopolymers. The QQ membrane demonstrates its significant anti-biofouling effect in bioreactors for treating synthetic wastewater (i.e., membrane fouling was delayed by 57–67% compared to the naked membrane), although the initial water permeabilities are reduced with surface modification by 34–47% compared to pristine condition. The findings of this work bring the broad potential for material fabrication requiring biofouling control, encountered in our daily lives and mechanical, marine, and medical industries in addition to membrane filters.

1. Introduction

The United Nations World Water Development Report states that as of 2018, 3.6 billion people suffer from water scarcity for at least a month in a year [1]. The World Health Organization also reported that in 2017, 29% of the world population lacked access to safely managed drinking water services [2]. Besides, anthropogenic pollution by effluents from domestic, agricultural, and industrial practices deteriorates water sources' quality [3,4]. These threats draw our attention to more practical and reliable treatment options. Membrane filters, which can separate and eliminate contaminants by rated pore sizes [5,6], are vital in water management, accounting for ~53% of the total number of world treatment processes [7]. Furthermore, membrane technologies are sustainable, environmentally friendly, flexible, and resilient in the circular economy because they can selectively extract valuable resources such as nutrients, metals, and energy from wastewater effluents in addition to water [3].

Precisely, a membrane bioreactor (MBR) technology, based on a synergistic combination of biodegradation and physical separation, is considered as one of the most efficient and popular approaches for wastewater reclamation and reuse, targeting alternative water resources [8,9]. Despite the advantages of the MBR technology, membrane fouling, particularly biofilm growth on the membrane filter (biofouling caused by quorum sensing (QS) mechanisms), is one of the most serious issues, needing resolution [8]. Several physicochemical methods have been developed to solve biofouling problems, such as air scouring [10], permeate backwashing [11], chemically enhanced backwashing [12], subcritical flux membrane filtration [13,14], membrane vibration [15], membrane reciprocation [16], or their combination [15]. However, biofouling, which naturally occurs on the solid's surface (membrane surface) via cell-to-cell communications (quorum sensing) [17,18], is inevitable, thus requiring novel approaches for anti-biofouling.

Since 2009, quenching bacterial signaling at the membrane surface has been reported using signal molecule-degrading enzymes, quorum

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