Fabrication of electrospun anti-fouling membranes for emulsified oil-in-water separation

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The separation of emulsified oils from water represents a significant challenge for water reclamation and clean-up, because such droplets remain suspended for long periods of time. Membrane technology offers a solution to such separations, but their major drawback is the requirement for frequent cleaning to remove foulants, which reduces membrane lifetime and incurs additional economic and environmental costs. Therefore, there's motivation to design membranes with better robustness against fouling for the technique to be more competitive in the field. There are generally two approaches to reducing the detrimental effects of membrane fouling. One way is to improve the effectiveness of foulant removal during membrane regeneration, so that a larger proportion of the original permeate flux can be recovered. The second approach is to improve the resistance against foulant deposition, so that the decrease in permeate flux is less severe. In this work, we look into both approaches to improve the anti-fouling properties of membranes used for the treatment of emulsified oily wastewater.

We first investigate the feasibility of using thermal treatment to improve the effectiveness of foulant removal. We have identified a commercially available copolyimide called P84 to be a promising candidate due to its excellent thermal stability. The separation performance of fibrous membranes made of P84 was examined, and the effectiveness of different foulant removal methods was evaluated. Electrospun P84 membranes offer significant advantages over other materials for the separation of oil-in-water emulsions. In particular, the decline in permeate flux due to fouling is comparable to that observed for more oleophobic polymers like polyacrylonitrile (PAN), and less severe than that observed for several other commonly used polymers. More importantly, the P84 membranes also exhibit essentially 100% flux recovery through thermal treatment, with no influence on the separation performance of the membranes. This work demonstrates the feasibility of using thermal treatment as an effective method to regenerate membranes with good thermal stability.

We next look into strategies to improve the resistance against foulant deposition. Here we present an approach to fabricate liquid-infused membranes (LIMs) as the separator of a stable oil-in-water emulsion. We show that with the right chemistries, infusing the membrane with an inert lubricant improves the selectivity of the membrane. The presence of the stable infused-liquid layer coating on the pore wall also successfully prevents the interaction between foulants and the pore wall, and therefore eliminates the deposition of foulant. We then study the transport mechanism of the dispersed oil phase through LIMs using confocal laser scanning microscopy (CLSM) with an aim to further improve the permeate flux. We find that the transport of the oil phase includes the coalescence of dispersed oil droplets on the surface of the LIM and the formation of oil channels through the LIM. By conducting a parametric study combined with image analysis, we identify factors affecting the permeate flux through LIMs, and provide guidelines to improve permeate flux. In summary, this work demonstrates the feasibility of using LIMs to separate stable oil-in-water emulsions and their potential to eliminate membrane fouling. It also provides some design guidelines to prevent fouling and to improve the permeate flux through the LIMs.

Overall, these works provide new approaches to ameliorate the effect of membrane fouling during the treatment of emulsified oily wastewater.