

High Efficiency Forward Osmosis Membrane Treatment Using Seawater

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Summary

Forward osmosis is an excellent technology for concentrating various solutions at low pressures. For example, it is possible to concentrate urban wastewater without using high pressure, and biogas can be produced from this concentrated urban wastewater by more efficient anaerobic digestion, such as methane fermentation. However, the support layer of commercially available forward osmosis membranes is 50-150 μm thick, and as the treatment progresses, the internal concentration polarization increases, reducing the actual osmotic pressure difference that determines the water flux. This study aimed to develop an ultra-thin polyamide forward osmosis membrane using a very thin polyimide membrane with a thickness of 25-40 μm and cylindrical pores as the support layer.

First, when the m-phenylenediamine (MPD) concentration was fixed at 3 wt% and the trimesoyl chloride (TMC) concentration was increased from 0.1 to 0.2 wt%, the water permeation flux also increased slightly from 13.2 L/m²h to 16.2 L/m²h. In contrast, the reverse diffusion flux of salt decreased from 72.6 g/m²h to 4.5 g/m²h with increasing TMC concentration. Second, when the MPD concentration was increased from 0.5 to 3.0 wt% while keeping the TMC concentration fixed at 0.15 wt%, the water permeation flux decreased from 20.1 L/m²h to 14.1 L/m²h. Similarly, the reverse diffusion flux of salt also decreased significantly from 20.3 g/m²h to 1.7 g/m²h with increasing MPD concentration. In summary, an MPD concentration of 2.0 wt% and TMC concentration of 0.15 wt% are suitable for forward osmosis membranes. A cross-section of the polyamide skin layer formed on the polyimide support membrane was also observed. As a result, a polyamide skin layer several hundred nanometers thick was confirmed, and cavities and folds were formed in the skin layer. The cavities were several tens to several hundred nanometers in size, and the thickness of the folds was 20–40 nm.

The pores of the polyimide support membrane, which is the support membrane, have been commonly used up to now, and it is possible that these pores have a significant effect on the performance of the forward osmosis membrane. As a result of comparing three types of polyimide support membranes with different pore sizes, the water permeation flux of the forward osmosis membrane decreased with the increase in the pore size of the polyimide support membrane (from 17.2 L/m²h to 9.8 L/m²h). On the other hand, the reverse salt flux did not depend significantly on the pore size of the support membrane, and only differed from 1.9 g/m²h to 3.6 g/m²h. When evaluated using J_w/J_s , which considers the water permeation flux and reverse salt flux, the forward osmosis membrane with a pore size of 0.08 μm had the lowest value, indicating that a pore size of 0.08 μm is optimal. The S value of the forward osmosis membrane developed in this study (193 μm) was lower than that of most other forward osmosis membranes reported in the literature. This study highlights the advantages of the developed forward osmosis membrane