CFD Analysis of the Desalination Performance of Ceramic-based Hollow Fiber Membranes in Direct Contact Membrane Distillation

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Supporting information:

1-Preparation of Ceramic Hollow Fiber Membrane

1.1 Preparation of Ball Clay Powder

Before the fabrication of hollow fibers, the initial ball clay underwent a series of pre-treatment steps aimed at reducing particle size, narrowing distribution, and producing anhydrous ball clay powder. The as-received ball clay was initially dried at 100 ºC for 24 h and subsequently pulverized into a powder using a mortar. To create purified ball clay for membrane fabrication, the raw ball clay powder underwent a purification process outlined in a previous study [1]. The purification involved immersing the raw ball clay powder in distilled water (20 wt.% concentration), vigorously stirring the mixture for 4 h, and allowing it to settle for 24 h. This process effectively removed most soluble impurities and dirt. The resulting clay was then dried at 80 ºC.

The purified ball clay underwent mechanical treatment utilizing a laboratory planetary ball mill machine at 200 rpm, with water as the wet media. The resulting product was identified as milled ball clay. Wet grinding was conducted with a solid density of 50 wt.% in water, using alumina balls (10 mm diameter) as grinding media at a ball-to-powder weight ratio of 6:1, with a grinding time of 6 h. Following grinding, the slurry obtained was dried in an oven at 80 ºC for 24 h. Subsequently, the milled powder underwent calcination at 800 ºC for 3 h in a furnace to eliminate structural water [2], and this product was referred to as calcined ball clay powder.

1.2 Ceramic Hollow Fiber Membranes Fabrication

After the pre-treatment of the raw ball clay, the fabrication of hollow fibers was conducted using the extrusion-based phase inversion method and sintering technique[3, 4]. To create ball clay-based hollow fiber membranes, ceramic suspensions were formulated by combining PEG 30 (1 wt.%) and ball clay powder in an NMP solvent. These mixtures underwent milling for 48 hours. Subsequently, PES was introduced as a polymer binder, and the mixtures underwent an additional 48 hours of milling to ensure homogeneity, maintaining a ceramic powder to PES ratio of 7. The ceramic suspensions were degassed for 1 hour to eliminate entrapped air bubbles prior to spinning.

The degassed suspensions were then transferred into a stainless steel syringe and extruded through a tube-in-orifice spinneret at a constant speed of 10 ml/min at 25 °C, with tap water serving as the bore fluid and coagulant bath. The hollow fiber precursor, with an outer diameter of 2.5 mm and an inner diameter of 0.5 mm, was spun into the coagulant bath. Afterward, the hollow fiber precursor underwent immersion in tap water overnight to complete the solvent/non-solvent exchange. The precursor was then air-dried at ambient temperature and subsequently cut into 20 cm lengths.

The precursors were sintered using a tube furnace (Magna Value, XY-1700). Initially, the precursors were heated from room temperature to 600°C at a rate of 2°C/min and held for 2 hours to ensure the complete removal of the organic polymer binder. The temperature was then further increased to target temperatures between 1150 °C to 1300 °C at a rate of 5 °C/min, maintaining this temperature for 5 hours to consolidate the ceramic hollow fiber membranes. Subsequently, the sintered products were cooled down to 25 °C at a rate of 5°C/min. The chosen sintering process aligns with previous works [5, 6].

References

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