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Tubular Membrane Module - The Suitable Configuration for Pervaporation Desalination Membrane

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Seawater desalination has been proved to be an efficient way to alleviate the global water crisis. Among major desalination technologies, membrane separation seems to be the most applicable and economic method because of its high efficiency, small footprint, energy saving, easily scales up etc. Currently, membrane researchers focus on developing better reverse osmosis (RO) and membrane distillation (MD) membranes. RO is the dominate technology for membrane desalination. However, it is difficult to treat high concentrated salt water due to the extremely high osmosis pressure. In a MD process, the driving force lies in the difference of the water vapor pressures between the membrane feed and permeate sides. Theoretically, high concentrated brine water can be easily treated as long as the low water vapor pressure in the permeate side can be maintained either by running a cooling water or applying a low pressure in the membrane permeate side. Literature data show that water flux of 40 to 100 l/m^{2}h (LMH) can be obtained by a MD desalination process at a feed temperature range from 30 to 90°C. However, due to the hydrophobic and porous nature of MD membrane, fouling problem is severe which hinders the industrial application. Recently, our groups have systematically study the feasibility of pervaporation (PV) desalination. Unlike conventional PV membranes which are used for remove trace amount of water from organic solvents, in a PV seawater desalination process, water concentration is usually higher than 90 wt%, which offers 20 times the driving force compared to PV dehydration process. In addition, due to the hydrophilicity of PV membrane, it is easily swollen by water molecule that results in a higher water flux. At the same time, the salt rejection is still high due to its non-volatility. Another advantage of PV membrane over MD is its dense hydrophilic selective layer which greatly mitigates the fouling problem.

To developing high performance PV desalination membrane, researcher need to first fabricate the membrane material with high water permeability and salt rejection and second find the right configuration of membrane module which can optimize the separation performance. Based on our experience, PV desalination process faces significant concentration and temperature polarization problems. In addition, if we want to take the advantage of the anti-fouling property of the PV membrane and use the un-pretreated seawater as the feed, fouling problem is more severe than we thought. All the problems are results from the high water flux of the PV membranes which have water flux around 40~50 LMH at 70°C. And we find that if the PV membranes are in flat sheet, hollow fiber, or spiral would forms, all the above mentioned issues are very difficult to be solved. Therefore, we start to fabricate tubular PV membrane modules because of their unique advantages in the process of separating high concentration and high solid content liquid mixtures. In a tubular membrane module, the feed water flow rate can be easily increased. And a turbulent flow pattern can be realized which greatly reduce the temperature and concentration polarization as well as the fouling problem. In addition, tubular membrane is insensitive to block and easily clean. The pressure drop in the tube side is small in tubular membrane module, and flow rate can be easily adjusted in a wide range. Therefore tubular membrane shows remarkable ability in dealing with high solid contents and high concentration feed liquid. Overall, with simple feed pretreatment and lower operation cost, choosing the tubular module is the key in fabricating PV composite membrane to achieve efficient desalination.