INTRODUCTION OF LG CHEM'S NANOH_2O™ RO MEMBRANE

About LG Water Solutions

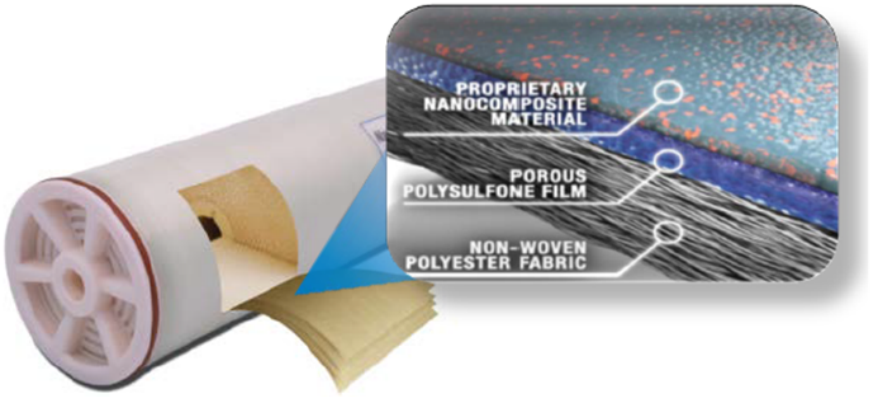
LG Chem Water Solutions develops and manufactures NanoH_2O™ reverse osmosis (RO) membranes that lower the cost of water treatment. Based on breakthrough nano-structured materials and industry-proven polymer technology, LG Chem's NanoH_2O RO membranes dramatically improve desalination energy efficiency and productivity, delivering best-in-class salt rejection and flow. LG Chem's NanoH_2O RO membranes are available in standard 8-inch (20 cm) diameter elements that fit easily into new and existing RO membrane plants, purifying water from a broad range of sources with improved productivity and water quality.

Cheong-Ju, Korea

LG Water Solutions is part of LG Chem, Ltd. LG Chem's expertise in roll-to-roll coating technology and excellence in chemical and polymer manufacturing are key factors in the quality, performance and reliability of its NanoH_2O RO membranes. NanoH_2O membranes are formulated, developed, cast, rolled and wet-tested at the LG Chem manufacturing facility in **Cheong-Ju, Republic of Korea**. LG Chem wet tests each element at industry standard test conditions before shipping the membrane elements to the customer facility.

1. Thin Film Nanocomposite (TFN) Technologies

Since their first introduction over 30 years ago, thin film composite (TFC) membranes are still considered "state-of-the-art" in RO membrane technology. While modern TFC membranes produce clean water from highly contaminated sources (e.g., wastewater, seawater), the high cost of energy required in the production of clean water prevents widespread implementation of RO membrane technology.



The term **"thin-film nanocomposite"** was first used by Los Angeles-based NanoH_2O, Inc. (acquired by LG Chem in April 2014). The company found that by encapsulating benign nanomaterials into the thin-film polyamide layer of a traditional thin-film composite membrane, it was able to increase membrane permeability compared to conventional RO membranes. Benign nanoparticles are introduced during the synthesis of a polymer film and are fully encapsulated when the nanocomposite RO membrane is formed.

The encapsulation of **benign nanoparticles** modifies the property of the thin-film of a conventional RO membrane, allowing more water to pass through the membrane while maintaining high salt rejection. LG Chem's TFN membranes are 50-100% more permeable than conventional membranes while still meeting best-in-class salt rejection. The nanoparticles are encapsulated into LG Chem's patented thin-film polyamide formulation, which makes up the top layer of the thin-film nanocomposite (TFN) membrane.

TFN-based RO membranes are formed using super-hydrophilic nanoparticles. TFN membranes purify water just as well as TFC membranes, with the added benefit of significant energy savings.

2. LG Chem's NanoH_2O RO Membranes with 34 mil spacer

LG Chem's NanoH_2O RO membranes utilize a feed/brine spacer engineered to improve RO system performance by:

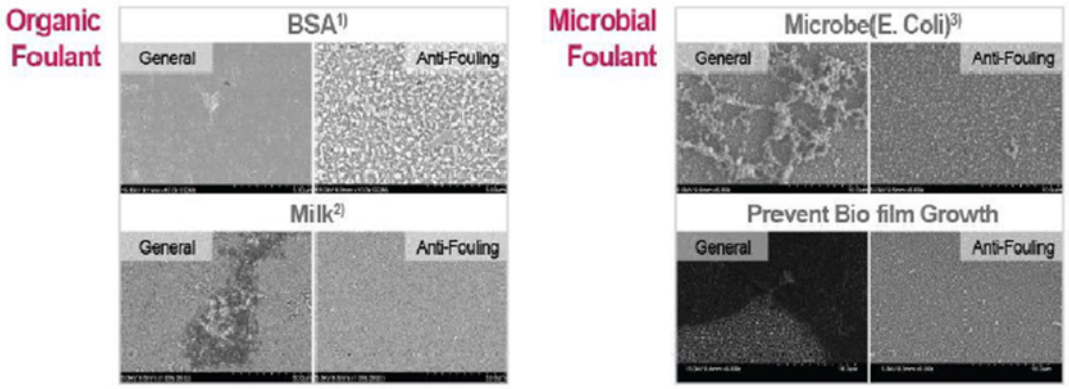
- reducing the rate of fouling due to colloidal material and microorganism
- lowering the energy cost to produce water by reducing the differential pressure
- reducing operating cost by extending membrane life
- decreasing labor and chemical cost by reducing the frequency of chemical cleanings.

LG Chem NanoH_2O RO membranes use a **34-mil thick feed spacer** while still maintaining 400 square feet of active membrane area in an 8-inch diameter (40-inch length) RO element. A 400 square-foot element used to require a thinner 26 or 28 mil feed spacer, but the improvements in material and manufacturing techniques have resulted in the development of a 400 square-foot membrane with a 34-mil feed spacer.

The primary functions of the feed spacer is to separate the opposing membrane leaves of a spiral wound element so feed/concentrate water can flow freely between the membrane leaves. This also promotes a shearing form of turbulence to minimize concentration polarization at the membrane surface by enhancing the back diffusion of salts and foulants from the membrane surface.

3. *Anti-fouling Characteristic Membrane*

Thin film nanocomposite (TFN) technology was originally conceived not as a means to alter flux/rejection, but rather as a method to change surface properties related to fouling. This approach represents the next generation of RO membrane materials because, unlike all other membrane surface modification approaches, it can be immediately incorporated into existing commercial manufacturing facilities. In addition, nanoparticle properties can be selected or modified to impart a wide array of advantageous membrane surface properties.



1) BSA: Bovine Serum Albumin 500ppm, 7day 2) Milk: Dry milk 500ppm, 4day 3) E. Coli: OD 0.1, 20day growth

Characterization of the first generation of low fouling TFN membranes suggests they can produce as good or better product water quality using significantly less pressure (energy), are more resistant to fouling and easier to clean. LG Chem's anti-fouling RO membranes will be introduced mid-2016.