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Desalination of raw water using a polyamide hollow fiber membrane

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Abstract

An aromatic polymide hollow fibre membrane designed for a reverse osmosis system of 35,000 ppm total dissolved solids in take water was subjected to a low salinity of around 3000 ppm. The applied pressure and feed water temperature were varied to study their effects on permeation and salt rejection. The salt rejection was between 97 and 98%. High quality drinking water was produced at a pressure of 100 psig and room temperature (28–32°C). The performance of aromatic polyamide hollow fibre membrane manufactured by Horizon Desalinators (designed for seawater) was compared with Dow Chemicals thin film composite type spiral wound membrane made of aromatic polyamide (designed for brackish water). The performance of the hollow fibre membrane was better.

Keywords: Desalination; Membrane permeation; Salt rejection

1. Introduction

In the Middle East water is a precious resource and due to a rapid increase in population many countries of this region are facing difficulties in meeting their domestic and industrial requirements. Currently the Saline Water Conversion Corporation of Saudi Arabia (SWCC) has 23 desalination plants in operation at 15 sites producing a total of approximately 2 Mm^3/d. Nineteen of the plants are located on the Red Sea coast and four are on the Arabian Gulf coast. The reverse osmosis plants operating in Saudi Arabia are designed to a specific seawater analysis as the salinity of seawater along the Arabian Gulf is much higher than on the Red Sea coast. The salinity in terms of total dissolved solids (TDS) along the Arabian Gulf coast is between 65,000 and 75,000 mg/l [1]. Desalination performed by reverse osmosis involves the use of a synthetic semi-permeable membrane and a high pressure hydraulic membrane. Reverse osmosis is a physical process in which a proportion of water from a

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pressurized supply (feed water) is forced through a semi-permeable membrane (permeator) to become product water (permeate) leaving behind almost all of the impurities in the remaining water (concentrate). Previous studies [1] show that an aromatic polyamide hollow fiber membrane performs well when subjected to high salinity feed water. However, it is not known how a membrane designed for a specific seawater requirement would respond if subjected to very low salinity (feed) water. Raw water (ranging between 2600 and 3300 mg/I TDS) was used as feed water and an aromatic polyamide membrane of tubular configuration (Horizon Reverse Osmosis Desalinators) [2] designed for 35,000 ppm TDS was used as a semi-permeable membrane.

2. Materials and methods

2.1. Experimental system

Fig. 1 shows the flow diagram of the system. The system was equipped with: (1) a coarse strainer to trap large particles; (2) two filters to remove particles as small as twenty microns; (3) a vacuum gauge to measure the suction by high-pressure pump to pull the water through the pre-filtration subsystem; (4) a pump and motor as an integrated unit to draw water into the system through the pre-filtration at a constant rate; (5) a pressure vessel with an enclosed membrane. A product flow controller, pressure gauge, high-pressure switch, flow meter, salinity probe, diversion valve, brine water outlet and a product water outlet were attached to the vessel. The diversion valve is solenoid-operated and actuates to route the flow to the fresh-water tank when the safe water lamp lights. In the event of a valve solenoid failure, the solenoid-energizes, and the system shuts down within 5 min. The low-flow switch controls low flow that could result from losses due to a ruptured hose, broken fittings, a loose hose clamp, pump motor failure or an obstruction in the flow path. An ultraviolet sterilizer was attached with product water line to eliminate bacteria. All filtration units before reverse osmosis constitute a pretreatment system which has been in use smaller RO plants for seawater desalination [3]. Though a coarse strainer is not required in the case of raw water (feed water), it provides good protection of RO membranes during operation.

The specification given by the permeator manufacturer for a salt concentration of 35,000 ppm is: pH range 2–11, maximum operating pressure 800 psig, recommended operating temperature range 2–45 °C, free chlorine tolerance and tolerance to oxidants <0.1 ppm, and maximum feed flow of 20 l/min.

2.2. Experimental procedure

The valve on the feed water tank was opened. The product flow controller was turned fully counter-clockwise and the system was turned on. When product water flow was stabilized, the product flow controller was slowly turned until the desired pressure on the pressure gauge was achieved. During all experiments, a pressure range of 100–800 psig was maintained.

2.3. Feedwater preparation

The membrane module system 9/200, designed and manufactured by Horizon Reverse Osmosis Desalinators, with a capacity of 750 l/d of potable water under a maximum operating pressure of 800 psig, was used for this study. For each experiment the raw water was continuously supplied to the 4550 L capacity feed tank to maintain the continuous feed flow of around 14 l/min, which enabled continuous operation for a period of 4–6 h.

Low temperatures, between 17°C and 20°C, were obtained by adding a known volume of ice made from sweet water. For high temperature (i.e. between 34°C and 35°C) experiments, the feed water was heated by a heating coil.