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The effect of feed ionic strength on salt passage through reverse osmosis membranes

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Abstract

Several parameters are known to influence the passage of salts through a reverse osmosis membrane. These parameters include characteristics of both the membrane and the feed water. Of these parameters, the least understood is the effect feed water concentration has on salt passage. At high and very low feed salinities, salt passage can increase by a factor of two or more. As an increasing number of RO systems are designed to treat water at these salinity extremes, a better understanding of this salinity effect is necessary to accurately predict the permeate quality of these systems. This study seeks to demonstrate and characterize the salinity effect on different RO elements treating different feed waters. The magnitude of the salinity effect at any given feed salinity is shown to be influenced by membrane charge and feed water composition. The results of the study on individual elements are used to accurately predict the salt passage in an existing full scale RO system.

Keywords: RO membranes, Feed water, Salt passage

1. Introduction

It is well known in the membrane industry that salt passage through a reverse osmosis membrane is affected by both membrane and feed water characteristics. Specifically, membrane age, chemistry, thickness, pore size, and charge density as well as feed water temperature and composition all contribute in varying degrees to the passage of ions through the membrane. But less widely

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recognized is the role feed salinity has on salt passage. Though this feed salinity effect has appeared in experimental and theoretical studies, only in the past few years has it been acknowledged by the industry when projecting membrane performance. As demand for RO treated water increases, an increasing number of brackish systems are being designed to treat higher salinity waters at higher recoveries. For this reason, a practical understanding of the effect of feed salinity on salt passage is essential for predicting and optimizing the design and operation of these RO systems.

The experiments presented in the paper will investigate the effect feed salinity has on salt passage. Six membranes will be tested over a range of salinities on two different feed waters consisting of sodium chloride and concentrated city water. A consistent trend will be shown in which salt passage increases at very low and high feed salinities. The increase in salt passage can be as high as four times the salt passage at standard test conditions.

2. Theoretical Background

A typical RO membrane allows only a small percentage of the feed ions to pass. Given the concentration of salt in the permeate (Cp) and in the feed (Cf), the salt flux is given as:

$$Js = B\ (Cf - Cp) \tag{1}$$

where B, referred to as the salt permeability coefficient or simply the *B*-value, is a function of the membrane thickness and the membrane's diffusivity. Salt permeability is specific to different membrane types and is arrived at by analytical methods.

The passage of salt through a membrane is expressed as a percentage using the following equation

$$SP\% = (Cp/Cf) \times 100 \tag{2}$$

In a single spiral wound element, the concentration on the feed side increases as the stream flows from the feed end to the brine end of the element and volume is reduced due to the removal of permeate. Salt passage through an element is measured using the average of the feed concentration and brine concentration (Cfb) so that Eq. 2 becomes:

$$SP\% = (Cp/Cfb) \times 100 \tag{3}$$

Though the actual mechanism of membrane salt passage is not well understood, theories have been developed to predict the concentration of salt on the permeate side given the characteristics of the membrane and the feed water. Basic calculations for predicting salt passage treat the membrane as a black box and require little understanding of the transport mechanism within the membrane [1]. These theories consider the following parameters when predicting salt passage:

- Temperature. An increase in feed water temperature will lead to an increase in membrane salt passage. A temperature correction factor is used to compensate for this increase in salt passage when normalizing data of an RO system.
- Membrane type. Brackish membranes, for example, have higher passage rates than seawater membranes. Even among brackish membranes, salt passage varies with the specific membrane chemistry.
- Membrane age. Wearing of the membrane from continuous use and repeated cleanings will increase salt passage over time.
- Feed water composition. Certain ionic species in the feed water, such as monovalent ions, pass more readily than other ions such as the divalent ions.

Given the nature of the membrane and an understanding of the degree that the membrane allows different ions to pass, basic