290v An on-Line Study of Progressive Ro Membrane Mineral Scaling by Time-Lapse Photo Microscopy

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Abstract

In recent years there has been a growing interest generating new water drinking sources through membrane desalination of brackish water and in desalination and reclamation of high salinity agricultural drainage water. Most high salinity inland water sources (brackish groundwater and AD water) usually contain high levels of mineral salt ion precursors such as calcium and barium cations and sulfate and carbonate anions. At high product water recovery levels (generally above about 85%), the concentration of ions near the membrane surface increase due to concentration polarization (CP) can exceed the saturation level with respect to the solubility of sparingly soluble mineral salts such as calcium carbonate (typically calcite), calcium sulfate (typically gypsum) and barium sulfate (typically barite). As a consequence, these mineral salts can precipitate in the bulk near the membrane surface as well as crystallize onto the membrane surface, thereby scaling the membrane leading to flux decline and shortening of membrane life. The solubilities of gypsum and barite, unlike calcium carbonate are pH insensitive. Therefore, control of gypsum and barite scaling cannot be achieved by pH control and at present is combated by control of process conditions and use of antiscalant additives. Fundamental understanding of the dynamic formation of surface scale is needed in order to develop predictive models of scale formation, assessing membrane scaling propensity and evaluating scale mitigation strategies. Accordingly, in the present study, an approach is presented of the real-time study of surface crystallization with a focus on gypsum scaling. The present approach enables the study of the kinetic growth of isolated and multiple gypsum rosette structures, the rate of change of the surface number density of growing crystals as well as change in fractional surface area covered by scale. This information can be used directly in scale formation models and assess the impact of RO process operating conditions. The present study was conducted using a small plate-and-frame reverse osmosis cell fitted with a specially designed sapphire optical window capable of withstanding pressures in excess of 300 psi. Specially designed dark field illumination was employed in order to observe the gypsum crystals which typically display low contrast in optical imaging. Images of surface crystals were obtained using an optical microscope fitted with a high resolution digital camera. Membrane scaling studies were conduct6ed by circulating a supersaturated solution containing calcium and sulfate through the membrane channel in a total recycle mode. Retentate filtration with a 0.2 micron microfilter served to remove any bulk crystals that may have formed in the membrane channel. Therefore, using the above approach, the observed surface crystals were primarily due to surface crystallization as verified by previous published studies. Gypsum scale development was evaluated for different levels of concentration polarization (CP) achieved by varying cross-flow velocity and transmembrane pressure. In addition, the rate of gypsum scale development was also investigated at different temperatures and ionic strength. The appearance of surface crystal sites appeared to be random but with a higher frequency at higher CP levels. Surface crystals appeared initially to preferentially grow in the direction opposite to the flow direction. This behavior was attributed to the higher mass transfer coefficient near the stagnation region and its decrease as the concentration boundary layer develops about the crystal formations. Single surface crystal growth kinetics was described by a classical mass transfer growth model which was then utilized to characterize the growth of colonies of crystals. The use of the present data in predictive modeling of scale formation//flux decline will be illustrated using a model recently developed at the UCLA PolySep laboratory. Finally, the potential use of the system for real-time monitoring of mineral salt scaling in RO plants and the evaluation of membrane cleaning strategies will be discussed.