

ABSTRACT

Salinity is one of the most critical environmental problems for water scarce countries, deteriorating water quality and threatening economic and social consequences. This research encompasses the investigation of a system to appropriately manage concentrated aqueous brines. Membrane distillation and crystallisation is a useful adjunct to seawater and other desalination processes in order to further process the resulting brine streams. This technique becomes particularly valuable when treating solutions of extremely high concentration which other processes such as reverse osmosis are incapable of handling. The process uses low grade heat (which is often present in excess in many industries) and operates at about atmospheric pressure. This work demonstrates how membrane distillation and crystallisation was used to obtain pure crystalline products and water from solutions of sodium chloride and magnesium sulphate of concentrations near to saturation (exceeding 5 m).

A problem that is faced during membrane distillation is that of a rapid decline in distillate flux once crystal disengagement begins, after which the flux diminishes to zero. In order to gain a better understanding of the process, a new approach to the modelling of the membrane distillation process enables the prediction of driving force for the process by estimating the vapour pressure from chemical speciation calculations. The measurement of the vapour pressure is not readily achieved during the course of the experiment itself. The calculations were verified by performing experimental vapour pressure measurements in a dynamic vapour liquid equilibrium still.

The modelling of vapour pressures and hence driving force enabled it to be compared with the distillate flux. The thermodynamics of high ionic strength solutions were used to arrive at this correlation. This comparison revealed a marked similarity between driving force and distillate flux implying that reduction in the driving force is one of the mechanisms which causes the distillate flux to fall zero, along with membrane fouling and crystallisation on the membrane. Further simulations were performed which illustrates how membrane distillation could be used to recover solid products from a mixed solution of salts whilst maintaining a positive driving force at extremely high solute concentrations thus reducing both the cost and environmental impacts of brine disposal while being an energy conserving process. It was found that in order for reverse osmosis to operate at these concentrations, pressures exceeding 45 MPa have to be applied in order to overcome the osmotic pressure barrier.