CHAPTER 7

CONCLUSIONS

In this chapter, the importance of the research work is discussed, its major contributions are summarized and the possible directions for safe practices are indicated.

7.1 STATUS OF DESALINATION

The desalination of sea water has been considered as one of the most efficient techniques for supplying fresh water to regions suffering from water scarcity. Sea water desalination has been gaining popularity for potable water production, as the available inland water sources are gradually depleting due to water scarcity as well as quality deterioration. The water desalination industry was started in the early 20th century, but the true expansion and spread of this industry occurred in the early 1960s. Reverse osmosis is one of the major technologies for medium and large sized desalination plants, because it produces high quality water from sea water with lower energy consumption. High pressure reverse osmosis (RO) is the technology of choice in many countries in the world. The market share of RO desalination was 43% in 2004 that increased upto 61 % in 2015. This is because RO has many advantages including low energy requirement, low operating temperature, modular design, low water production cost, less space requirement and less maintenance cost. The performance of the reverse osmosis process is dependent on the concentration of dissolved solids in the feed-water, feed-water pressure, and the membrane strength to withstand
EXPERIMENTAL STUDIES OF THE RO DESALINATION PROCESS

The steady state and transient behaviour of a large scale Reverse osmosis process has been studied to model different units of the plant. The main units are the mixing tank, HP pump, RO section, Brine tank and permeate tank. The plant set up was described in the line diagram and each unit operation was explained. A schematic process flow sheet describes the flow rates, pressure and the TDS of different streams in the entire plant. The technical details of the plant are tabulated. The input and output data such as the flowrate, TDS, pressure and pH are recorded from these units, and graphs are plotted to predict the performance of these units under the steady state and dynamic conditions. From the collected data the rejection of the solute was estimated as 95% and the recovery of the permeate was found to be around 40 to 45%.

MATHEMATICAL MODELLING OF THE REVERSE OSMOSIS DESALINATION PROCESS

The models used in the literature have been summarized. The normal operation conditions of the plant have been described. A comprehensive mechanistic mathematical model representing individual units of the desalination process is formulated from the first principles of mass transfer. The modelling of each unit of the RO desalination was done using mass balance continuity and the PDE equation. The integrated system is of the multivariable type and is represented as having two inputs, namely, pump pressure and ratio of the flow rates of sea water feed to that of the brine stream; and three outputs, namely, permeate concentration, flowrate and pH.
The steady state and transient behaviour of the model are validated using practical industrial data. Permeate flowrates are calculated from the steady state model equations for different values of pump pressures to validate the steady state behaviour of the process, by comparing the industrial data obtained practically. Similarly, the flowrates and concentrations of the permeate stream are calculated for step changes in inputs using the transient model, and are validated using similar recorded data from the experiment. Thus, the developed model has been validated. The construction of the model for the large scale SWRO plant has the advantage of reducing the unit potable water cost, including both capital and maintenance/operating cost, so that it becomes more useful for society.

7.4  STATISTICAL MODELING OF RO SYSTEMS

In the statistical analysis a good correlation between the input (pump pressure and feed ratio) and output (permeate flow rate, TDS and pH) of the RO section in a desalination plant is formulated, using the 2nd degree polynomial by the data, collected from the inlet and exit stream of the RO. The statistical model of the RO developed is useful for planning, monitoring and analysis of the present separation system. The statistical model of the RO is obtained after a multivariable analysis, resulting in P values smaller than $\alpha < 0.052$, indicating independently distributed residuals with mean residual values for confidence levels of 95% and 99% being negligible. This validation supports the present statistical model of RO for the use of prediction.
7.5 IDENTIFICATION OF THE TRANSFER FUNCTION MODELS OF THE RO DESALINATION PROCESS

The review of the identification used in the RO model was presented in chapter 5. The RO non-square model was predicted from the ARX model structure, and the nonlinear least square (NLLS) algorithm. The identification method for the ARX model is the least square method, which is a special case of the prediction error method. The state and the graphical models are predicted from the Extended Kalman Filter (EKF). The predicted models are as accurate as the experimental FOPDT and experimental graphical models.

7.6 CONTROL OF THE RO PROCESS USING MODEL BASED CONTROL

The developed linearized model is useful for further study, for safe operation and control of the process. The design equation and MIMO model is used for the model based control system in the closed loop control system. The closed loop control system was developed using the Laurent IMC PI centralized and decentralized controllers, and with the decoupler. The performance revealed that the centralised closed loop system showed less raise time, less time constant and fast setting time, compared to that of the decentralized controller. But for the load change, the decoupler has higher sensitivity than the centralized controller. The values of the permeate TDS, permeate flowrate and permeate pH rises by 10% for a 10% rise in the feed TDS value (load) in the centralized closed loop system. The performances of both the control systems for the servo operation were analyzed using the IAE criteria.
7.7 FUTURE SCOPE OF THIS WORK

There are ample scope of improvement on the modelling, identification and control of desalination process. It is suggested that the tannery waste water can be considered as the raw feed water instead of sea water where the characteristic of feed is completely different and the technology can be redesigned for the new process. New identification techniques like ARMA method and Subspace identification can be used to identify the MIMO process model structures. Considering the model as non-linear, heuristic control strategies (ANN, Fuzzy control strategies) can be developed and new optimization techniques can be used to find optimal controller parameters for safer control practices.