Artificial Intelligence (AI) - Based Reverse Osmosis Water Desalination Models

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AbSTRACT

Desalination of brackish water and seawater are the main sources of many countries which afflict rainwater scarcity and are deprived of lakes and rivers. There are several methods for desalination of water such as membrane distillation, solar evaporation, electrodialysis reversal, multi-stage flash distillation, reverse osmosis, etc. Reverse osmosis is more popular because of its simple design and economic factors such as require low energy, minimal operating temperature, and low water production costs. In the current study, artificial intelligence (AI)-based reverse osmosis water desalination models have been developed using AI techniques viz. artificial neural networks (ANN) and support vector regression (SVR). The input parameters of the models include sodium chloride concentration, feed temperature and pressure. The permeate rate is used as the output parameter. The developed AI-based models are evaluated and validated against the reported experimental data present in the literature. These AI-based models are then further compared with the widely used multiple linear regression (MLR) over the virgin test (unseen) dataset based on statistical measures like average absolute relative error (AARE), coefficient of determination (R^2), etc. The SVR-based model exhibits a low value of AARE of 1.95% and a value of high R^2 of 0.9963 while the corresponding values for ANN and MLR models are 9.35%, 52.04%, 0.9899 and 0.9157, respectively. Thus, the structural risk minimization (SRM) principle based SVR model is found to be the best, more accurate and generalized in comparison to the empirical risk minimization (ERM) based MLR and ANN models for the permeate rate prediction. Furthermore, through these AI techniques, excellent predictions can be made for the unseen data which not only reduces the number of experiments to be done but also helps the more effective design and fabrication of membrane-based desalination unit.

Keywords *: Reverse osmosis; SVR; ANN; R^2; AARE.*

1. INTRODu CTION

Seawater and brackish water are considered to be the main source of water in most of the countries which incur from rainwater and lack rivers and lakes. Various desalination technologies are used for the removal of excess salts and mineral from water into potable water. Desalination technology is broadly classified into thermal and membrane desalination technology. Thermal desalination technology contains vapor compression evaporation, multi-stage flash distillation, cogeneration, multi-effect distillation, and solar water desalination while membrane desalination technology comprises of electrodialysis, reverse osmosis and membrane distillation. Reverse osmosis (RO) is found to be an effective and economical method for the treatment of sea and brackish water. In a typical RO process, salty water flows through a semipermeable membrane under pressure as the driving force. Pure water passes through the membrane and the more concentrated salt is left behind. Seawater RO plant recovers around 20 to 40% of the feed water accompanying 90 to 98% salt rejection. For brackish water RO plants, recovery rates vary from 50 to 80% of the feed water accompanying 90 to 98% salt rejection.

Artificial neural networks (ANN) has been utilizing in the past for the desalination process (Khayet et al., 2011; Salgado-Reyna et al., 2015). But, recently, support vector regression (SVR) has appeared as an excellent artificial intelligence (AI) technique offering many advantages over the conventional neural network (ANN) and other regression technique such as optimal, global and unique solution for the convex optimization problem, kernel parameter and upper bound are only the two parameters that is required. Furthermore, structural risk minimization (SRM) principle of SVR offers excellent generalizability.

In this research paper, AI-based models viz. SVR and ANN models is well developed to predict the permeate rate for reverse osmosis water desalination unit. The developed models are then compared with the widely utilized multiple linear regression (MLR) model.

2. Su PPORT VECTOR REGRESSION (SVR)

Support vector machines (SVMs) application is not limited to classification but also, has been extended to regression (Gunn, 1997; Parveen et al., 2017; Smola and Schölkopf, 2004). Training dataset for a given regression problem