Prediction of permeate flux decline in Crossflow membrane filtration of colloidal suspension: a radial basis function neural network approach

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Microfiltration (MF) and ultrafiltration (UF) are pressure-driven membrane processes which are widely used in order to remove colloidal particles and microorganisms in water and waste water treatment systems. The filtration performance is, however, often hampered by the buildup of retained particulate matters on the membrane surfaces, which causes the deleterious permeate flux decline. Conversely, the retained particles form a cake layer between the concentration polarization (CP) layer and membrane surface provides significant resistance to water permeation.

Many theoretical models have been proposed to predict the permeate flux decline (stemmed from the cake formation) with physical, chemical, and hydrodynamic modeling parameters, such as particle size, zeta potential, Hamaker constant, transmembrane pressure, solution pH, ionic strength, temperature, and so forth. The complexity of the micro-scale phenomena often propels deviations of theoretical predictions from observations of experimental data. Such deviations imply that fundamental theoretical models sometimes do not have sufficient capabilities that describe real phenomena occurring on the membrane surface although they implement well scientific and engineering mechanisms. Therefore, as opposite to the fundamental approach, a purely empirical model, which can be built with specific experimental data (even from a single testing pilot plant) and then used to predict the system performance, appear to be a new challenging alternative.

In this study, we used an Artificial Neural Network as the alternative approach to predict the long term flux decline due to colloidal cake formation as a function of transmembrane pressure, particle size, solution pH, ionic strength, and elapsed operation time during crossflow MF/UF membrane filtration. Other conditions such as temperature, feed concentration, and axial velocity (shear rate) are set constant for the experiments and ANN simulations. The emphasis of the present work is, first, to minimize the amount of training data sets with a small network configuration in terms of the number of hidden layers and the number of neurons in each layer, and second, to predict new data sets that may not be originally available by giving the operation conditions belonging to the training data sets. To obtain the optimal network structure for prediction, various ANN network structures were investigated, and the performance of the ANNs are evaluated by estimating the difference between the predicted output and the target output in terms of root mean square error (RMSE).

Modeling results generated by the developed network show excellent agreement with experimental data. The effects of the solution pH, ionic strength, and transmembrane pressure on the permeate flux are accurately demonstrated by the ANN simulations. The initial permeate flux decline is governed by the intrinsic membrane hydraulic permeability, and as filtration proceeds, the effect of the particle deposition becomes significant. As the ionic strength increases, the ANN produces decreasing permeate flux which stems from formation of a dense cake layer comprised of less repulsive particles due to suppression of the electrostatic double layer.

In this study, the capability of a radial basis function neural network (RBFNN) to predict long-term permeate flux decline in crossflow membrane filtration was investigated. Operating conditions of transmembrane pressure and filtration time along with feed water parameters such as particle radius, solution pH, and ionic strength were used as inputs to predict the permeate flux. Simulation results indicated that one single RBFNN accurately predicted the permeate flux decline under various experimental conditions of colloidal membrane filtrations and eventually produced better predictability compared to those of the regular multi-layer feed-forward backpropagation neural network (BPNN) and the multiple regression (MR) method. We believe further development of the artificial neural network approach will enable us to design and analyze full scale processes from results of lab and/or pilot scale experiments.

We conclude that the artificial neural network approach can be effectively used for optimal operation and management of membrane filtration systems by well predicting the system performance after a proper training process is completed. The authors acknowledge Water Resources Research Center (WRRC), University of Hawaii at Manoa, and SAEHAN Industries, Seoul, Korea for their support in the accomplishment of this presentation.