A Bayesian belief network analysis to infer an ultrafiltration membrane condition

Guido Carvajal *[1], David Roser [1], Stuart Khan [1]
1. Water Research Centre, University of New South Wales, Sydney, NSW 2052, Australia

Ultrafiltration is one the most common unit operations used in the tertiary treatment of wastewater. From a risk management viewpoint, it is considered an important step because it can be credited with reduction values for pathogens including viruses. Monitoring of ultrafiltration membranes includes measurement of indicator parameters such as turbidity, direct integrity test, permeability and challenge testing. By observing these parameters an operator should be able to infer the condition of the membrane and determine if corrective actions are required. However, there is a lack of available models able to deal with multiple indicators in a probabilistic fashion. Bayesian networks show great potential for addressing this where inference of a condition or state is required from multiple indicator parameters.

The aim of our study was to investigate the use of Bayesian networks for monitoring the condition of ultrafiltration membrane module based on permeability, direct integrity tests and challenge testing using two microbial indicators (one spore former bacterium and one virus). The network was constructed from expert knowledge in BayesiaLab 5.4.3 considering five candidate variables. The variables were discretised using equal frequency method in three states for all variables except from the microbial indicators node which only had two states. Prospective parameters were determined by EM algorithm and net evaluation was performed using 5-fold cross validation. Our analysis indicated that the model had an overall accuracy of 80% with and AUC score greater than 0.90 for five different seeds. The contingency table fit which measures the quality of the representation of the joint probability distribution with respect to the fully connected network was 83%. These results indicated that using a Bayes Net model membrane condition could be reliably inferred from any of the three indicators and that for the bacterial indicator a damaged membrane had a greater impact than for virus. This can be explained by the smaller size of the virus compared to the nominal pore size of the membrane.

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*Corresponding author: Guido Carvajal. E-mail: guido.carvajal@unsw.edu.au. Water Research Centre, University of New South Wales, Sydney, NSW 2052, Australia

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