

Application of Bayesian Belief Networks to identify factors affecting log removal values of microbial indicators through membrane bioreactors

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Abstract

In order to provide instruction on what operational conditions need to be set in a validation protocol for membrane bioreactors (MBRs) to ensure appropriately conservative performance testing, factors affecting log removal values (LRV) of microbial indicators by MBRs need to be identified. Microbial indicators of concern in this study include F RNA bacteriophage and somatic coliphage as indicators for virus, Escherichia coli (E. coli) as an indicator for fecal bacteria, and clostridium perfringens as an indicator for protozoa. A large sampling programme was conducted covering 5 full-scale MBRs with various design and operational conditions across Australia. During the full-scale site investigations, the density of microbial indicators in influent, mixed liquor and permeate of the MBRs were assayed, and corresponding sets of operational parameters were also collected. A Bayesian Belief Network (BBN) was constructed from a dataset of 312 cases from which 80% of the data was used to learn the structure and estimate the parameters, and 20% of the data was used for final testing. The network structure was defined by automated structure learning using the bnlearn 3.8.1 package in R. Domain expert knowledge was also introduced in the structure learning in the form of whitelist and backlist. The variables were discretised by density approximation and validation was performed in BayesiaLab 5.4.3. The ROC score was from 70 to 92% for the indicators. The BBN was then used to identify factors influencing LRV of microbial indicators by MBRs by using "Influence path to target" and "Correlation with target node" functions in the BayesiaLab 5.4.3. The results show that membrane age, membrane pore size, permeability and solid retention time are important factors affecting LRV of microbial indicators by MBRs. To the best of the authors' knowledge, this was the first time that BBN was used for such application. The results have been used to form the basis of the validation protocol for MBRs in Australian water recycling schemes that will ensure consistent accreditation and appreciation of risk.

Keywords: Bayesian Belief Networks, membrane bioreactors, validation guideline, microbial indicators, wastewater treatment