STUDENT JOURNALS

water e-journal
Online Journal of the Australian Water Association

ISSN 2206-1991
Volume 7 No 1 2022
https://doi.org/10.21139/wej.2022.009

Managing the risk of Legionella in drinking water treatment aeration systems

Danladi Yunana, University of New South Wales

ABSTRACT

Legionella bacteria in natural and engineering water environments are considered one of the leading causes of waterborne disease outbreaks. Efforts to manage the frequency of Legionnaires' disease outbreaks have been focused on air and water handling systems in buildings, overlooking water treatment assets. This thesis aimed to investigate and develop measures to manage the risk of Legionella in groundwater treatment plants (GWTPs) aerators. This was achieved by: (1) surveying existing aerators for risk factors associated with Legionella growth and exposure, (2) conducting coupon studies to understand temporal changes and biofilm formation, and (3) modelling the risk of Legionella using iterative Bayesian networks (BNs).

FINDINGS

During an initial survey, 13 GWTPs aerators, including tray, open and semi-enclosed spray configurations, were identified to feature design and operational constraints, favouring elevated levels of nutrients, water stagnation, challenging water quality, aerosolisation, and inconsistent operation and maintenance. Legionella enumerated from over 300 samples collected from aerators in five years, revealed sporadic occurrence in influent and effluent at 8 and 15%, respectively, and more frequently in the biofouling collected on the asset surface at 28%. Based on these observations, design considerations for the next generation of safer aerators that can overcome identified Legionella risks factors were outlined.

Temporal changes of the fouling characteristics on two different aerator surfaces showed steady behaviour after six weeks, with significantly higher concentration (277 ng ATP/cm2) on the sprayed (vertically placed) coupon compared to (73 ng ATP/cm2) on the submerged (horizontally laid) sample. Concentrations of dissolved organic carbon (DOC) were statistically similar for the two tested conditions, measuring (6 - 39 µg/cm2) and (4 - 39 µg/cm2) on the sprayed and submerged coupons respectively, as the fouling reached steady state. Comparing fouling characteristics from the lab and full-scale coupons confirmed the significant impact of properties of wettability, surface orientation and influent on biofilm formation. A weak correlation of organic and inorganic parameters and microbial activity was observed for the influent, effluent, and fouling ($r2 \leq 0.7$). NaOCl (concentration ≥ 6%) at 30 min can achieve 99.9% efficiency in biofilm inactivation on aged fouling. Oxalic acid (concentration >1%) significantly removed inorganic materials like iron and manganese. This indicated that combining biocides and antiscalants are important cleaning agents to address fouling challenges in aerators.

Advanced risk assessment techniques were also implemented in this study. First, fishbone diagram and bowtie analysis were used to conceptually frame and split the risk factors into growth and transmission categories. Then, iterative BNs models were developed to integrate and rank the risk of Legionella exposure in each category. The initial BN model estimates a low-risk threshold of Legionella exposure. The Legionella growth sub-model showed weak prediction accuracy with a negative kappa coefficient, signifying inconsistency in predicted and observed Legionella occurrence. Sensitivity analysis of the growth model revealed water quality as the most impactful variable for Legionella occurrence.

Finally, data-driven learning with larger and more diverse historical water quality records was explored to strengthen predictive power of Legionella occurrence modelling. The optimised BN model utilised the Greedy Thick Thinning approach, complemented with domain knowledge, achieved superior performance accuracy exceeding 90%, kappa coefficient above 0.8, sensitivity (true positive rate) greater than 80% and specificity (true negative rate) above 90%. The results indicated that commonly monitored water quality parameters of temperature, total organic carbon, pH, and

heterotrophic plate count, can be utilised for binary tracking of Legionella in water systems. The use of BNs modelling based on risk estimation can significantly improve assessment of Legionella occurrence and exposure for more informed management decisions.