This dissertation research assessed the engineered biological filtration (biofiltration) of a nutrient-enriched, low-alkalinity, organic-laden surface water supply downstream of conventional pretreatment and ahead of a ultrafiltration (UF) membrane process. The impacts of biofiltration pretreatment on the performance of UF membranes were evaluated by investigating watershed feed chemistry and assessing subsequent impacts on productivity and distribution. Additionally, biofiltration performance was compared to two alternative pretreatment technologies, including magnetic ion exchange (MIEX®) and granular activated carbon (GAC) adsorption.

The MIEX®, GAC adsorption, and biologically active carbon (BAC) pretreatments were integrated with conventional pretreatment then compared at the pilot-scale. Comparisons were based on collecting data regarding operational requirements, dissolved organic carbon (DOC) reduction, regulated disinfection byproduct (DBP) formation potential, and improvement on the downstream UF membrane operating performance. UF performance, as measured by the temperature corrected specific flux or mass transfer coefficient (MTC), was determined by calculating the percent MTC improvement relative to the existing conventional-UF process that served as the control. The pretreatment alternatives were further evaluated based on cost and non-cost considerations.

Compared to the MIEX® and GAC pretreatment alternatives, which achieved effective DOC removal (40 percent) and MTC improvement (14 and 30 percent respectively), the BAC pretreatment achieved the lowest overall DOC removal (5 percent) and MTC improvement (4.5 percent). While MIEX® and GAC rely on respective anion exchange and adsorption mechanisms to target the removal of DOC, biofiltration uses microorganisms attached on the filter media to remove the biodegradable DOC.

An empirical model that predicted the performance of biofiltration pretreatment relative to UF membrane processes was developed. The modeling approach was based on the empirical relationship between the MTC improvement and the dimensionless ratio of alkalinity to substrate (ALK/DOC). By combining the biofiltration results from this study with previous studies, the empirical relationship between the MTC improvement versus the ALK/DOC ratio was modeled using non-linear regression in Minitab®. For surface water sources, the MTC improvement can be modeled as a function of the gram C/gram C dimensionless ALK/DOC ratio according to a normal distribution, as defined by:

\[
\text{MTC Improvement} = \alpha \cdot 36.4611 + (57.264 + 36.4611) \cdot e^{[\alpha \cdot 0.0060822 \cdot (\text{ALK/DOC} - 12.0296)^2]}
\]

The results of the research documented for the first time that biofiltration performance is optimized when the alkalinity to substrate ratio is approximately twelve. The empirical model provides the water community a practical tool that can be used to evaluate biofiltration performance when integrated ahead of UF membrane processes.

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