An Investigation of Modeling Biologically Active Filter Performance

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Introduction

Water scarcity has become an unavoidable problem in many parts of the US. More than 40% of the US was drought-stricken for much of the time between 2000 and 2020 (USDM 2020). Many utilities and water managers are thus supporting the development of wastewater potable reuse methods, including biologically active filtration (BAFs). BAFs are porous granular media filters with a fixed biofilm to degrade unwanted substrate in the water. They have been used for decades in both wastewater and drinking water treatment and are becoming increasingly important for potable reuse trains. However, little research has been done to improve BAF system treatment efficiency. Modeling presents an important tool in reaching this goal by helping to determine parameters for optimization. However, BAFs are complex systems that prohibit the development are purely mechanistic models, forcing scientists to balance accuracy and ease-of-use with empirical and semi-empirical models (Mendoza-Espinosa 1999). This research aims to compile the ways in which researchers have developed models to understand the current state of BAF modeling and how it can be used to optimize BAF systems for potable reuse.

Methodology

All used data are from Mines' BAF system, which is a pilot-scale potable reuse system that has been running since 2017. The data come from two filters, one with Calgon F600 granular activated carbon (GAC) and one with Calgon F400 GAC. Calgon F600 is better suited for trace organic removal and potable reuse applications due to its unique porosity (Calgon Carbon 2019).

This research project had two steps. First, a simple preliminary modeling project was executed using Mines F600 BAF data and the advection-dispersion equation (ADE). The F600 BAF had a lapse in data sampling between 2017 and 2019, during which total organic carbon (TOC) removal levels dropped from about 80% to about 35%. We hoped to establish whether this drop was due to the natural life cycle of the GAC using the advection-dispersion equation.

The second part of this research project involved compiling BAF modeling methods in a literature review. Because BAF modeling for potable reuse applications is still a fairly nascent field, and because of its importance to BAF system optimization, it is paramount to have a comprehensive overview of existing BAF modeling literature. This literature review was focused on five considerations: assumptions, contaminants modeled, input parameters, tools (such as specific equations or software), and findings. By comparing these five considerations across research papers, a deeper understanding of BAF modeling was developed.

Data and Results

The results of the initial part of the project including the advection-dispersion equation are shown below in **Fig. 1**. Unfortunately, the results were deemed inconclusive as to whether contaminant removal levels dropped due to GAC lifespan because there were too many unknown parameters. For example, different but viable partitioning coefficients drastically altered the amount of time the BAF system took to achieve steady state. Additionally, the advection-dispersion equation inadequately modeled the data because it assumed complete contaminant removal until maximum adsorption had occurred (which is what causes the drop in removal) and ignored the effects of biodegradation.

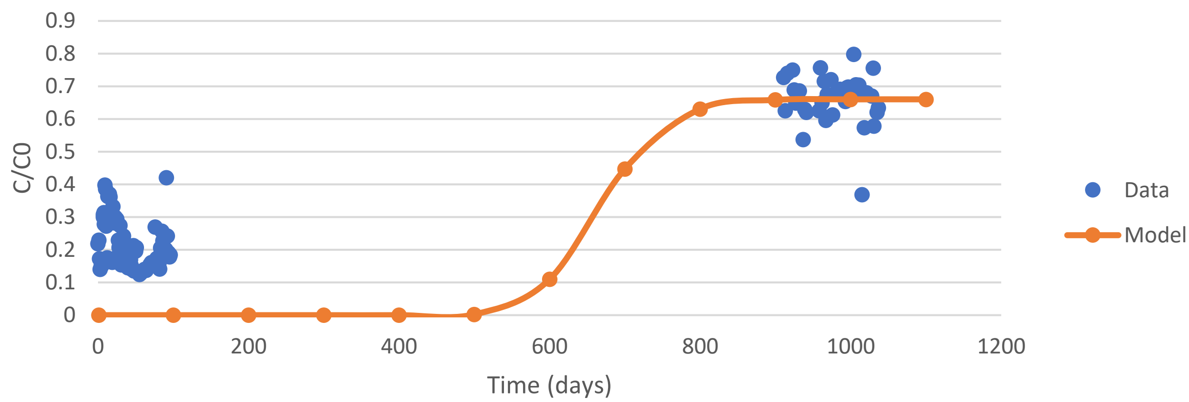

Fig. 1. Comparison of Mines data to the advection-dispersion equation (model). C/C0 is the ratio of the post-BAF to pre-BAF contaminant levels.

The second part of this summer's research, the literature review, was more successful. Ten modeling papers, five of which covered BAF systems, were reviewed and analyzed. Models were split into groups of progressive (for optimization), reflective (for accurately simulating experiments), and educational models (for aiding the development of future models). The majority of BAF models were reflective and relied heavily on models from other disciplines, like anaerobic and sludge systems. Despite their mostly reflective nature, BAF models have gradually become more sophisticated by considering non-steady states, biokinetics, and complicated hydraulics. However, modelers have yet to completely bridge the gap between reflective and progressive models, which will hopefully happen as researchers in the BAF modeling field accumulates more knowledge and resources. The foundation created by a larger pool of BAF modeling resources will allow future modelers to tackle BAF optimization for potable reuse.

Conclusions

The first half of this project involved using the ADE to model a Colorado School of Mines BAF system's drop in efficiency. The results of this study were inconclusive due to a lack of knowledge of system parameters and the ADE's oversimplification of the system. This project was further explored with the literature review, where all reviewed BAF modeling studies suffered from oversimplification which kept BAF models in the reflective, instead of progressive, modeling category. Hopefully as the BAF modeling field expands in expertise and more advanced BAF-specific model frameworks are created, more developers will be able to bridge the gap between reflective and progressive models.

References

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