An Investigation into Biologically Active Filter Modeling

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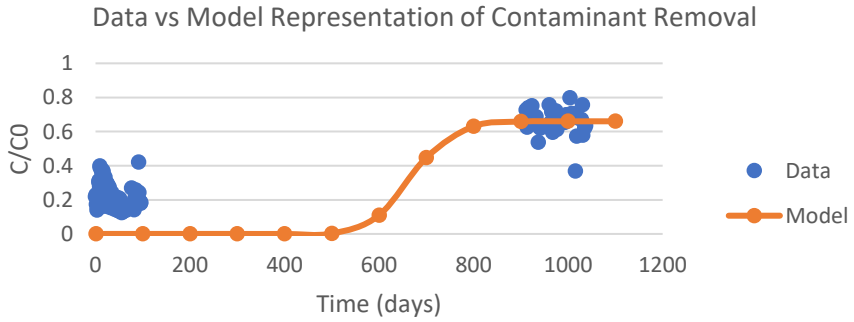
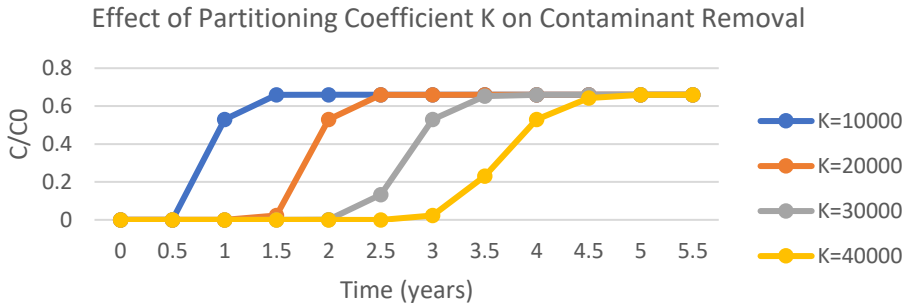
Summary: This research explored biologically active filters (BAFs) that use porous media covered in biofilm to passively remove contaminants from water. BAFs have been used for decades in wastewater and drinking water treatment and have recently gained importance in the potable reuse sphere. Modeling BAF systems can expedite experimental processes by helping to find parameters that can be used for contaminant removal optimization. This research has focused on understanding and compiling BAF models to track model development for future BAF modelers.

Phase 1: Modeling the BAF system at Colorado School of Mines (CO Mines) using the advection-dispersion equation (ADE)

The BAF system at CO Mines was started in 2017 and has been functioning to the present day. However, data were not taken for about 1.5 years, during which the contaminant removal efficiency of the system dropped from about 70% to 35%. The ADE was used to model the system to ascertain if the drop in efficiency was due to biofilm naturally saturating the medium or a system malfunction.



The above graph shows the original system data in blue dots and the model representation in orange. C/C_0 is current contaminant level over original contaminant level and is a measure of removal efficiency. The ADE equation successfully modeled increased contaminant levels in post-BAF treated water, but was too simplistic to adequately measure initial contaminant levels.



The above graph shows numerous viable partitioning coefficients (K) and how they drastically affected how long biomass took to saturate the BAF media. These data show there were too many unknown parameters to adequately model the BAF system with the ADE.

Phase 2: Writing a literature review on the development of BAF modeling

As a continuation of this research, a literature review focusing on the development and characteristics of existing BAF models was written. Ten models, five of which covered BAF systems, were reviewed. Common contaminants, assumptions, modeling tools, input parameters, and findings were compiled and analyzed, and modeling frameworks were suggested for future modeling projects.

Creating the ADE model to simulate the CO Mines BAF system was an introduction to many problems that published BAF modelers face.

During the research process, I split the models reviewed into three groups based on purpose, outlined in the table below.

Table 1. A comparison of modeling approaches.

Objective	Model Examples	Characteristics
Progressive Modeling	Sun et al. 2019 de Kreuk et al. 2006	Uses modeling results as evidence to change the experimental system.
Reflective Modeling	Liang et al. 2006 Ying and Weber 1979 Chang et al. 1987	Simulates the actual system as accurately as possible to better understand system mechanics.
Educational Modeling	Henze et al. 2000 Batstone et al. 2002	Creates general models that are easily modifiable, usually to encourage adaptations by other researchers.

All but the most recent BAF model were reflective models. Since progressive models (which focus on optimization) require a high level of accuracy, it can be concluded that BAF modelers still struggle to balance the feasibility of the model with required levels of precision for optimization. The gradual development of intricacy in BAF modeling can be seen in Table 2.

Table 2. A timeline of BAF model development.

Date	Development
1970s	Steady state modeling that neglected metabolic byproducts and biomass traits (Ying et al. 1979)
1980s	Modeling the BAF biomass with a focus on biokinetics (Chang and Rittmann 1987)
1990 – 2000s	Investigating adsorption and biodegradation (non-steady state) (Walker and Weatherly 1997, Liang et al. 2006)
2010s	Beginning to model for optimization (Sun et al. 2019)

We can see that BAF models have been able to address key assumptions as time has gone on. This accumulation of knowledge bodes well for future progressive models.

Conclusions

Modeling the CO Mines BAF system using the ADE was inconclusive because the equation was too simplistic and there were too many unknown parameters. These problems were noticed repeatedly while writing a literature review on the development of BAF modeling, in which common modeling characteristics were compiled and modeling frameworks were suggested to future modelers. It was observed in the literature review that most BAF models were reflective (as opposed to progressive or educational) because knowledge on modeling BAF system performance is still not extensive enough to obtain the accuracy required for progressive models. However, simple progressive models have been published and more complicated ones are likely to follow as the BAF modeling field continues to grow.

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