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Prevention of Sediment Recontamination by Improved BMPs to Remove Organic and Metal Contaminants from Stormwater Runoff

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14. ABSTRACT
This project developed design tools and advanced knowledge on the performance of black carbon (BC)-amended engineered media filters for preventing sediment recontamination while also benefiting water quality and possible beneficial use of stormwater runoff. Column experiments were conducted across various flow rates and flow conditions, e.g., 20-60 cm/hr, to assess tradeoffs in filter performance and design. The experimental results demonstrated that BC-amended engineered media filters successfully removed total suspended solids and a suite of dissolved metals and both hydrophobic and hydrophilic organic contaminants while maintaining adequate hydraulic conductivity. Filter performance tables were developed that account for media- and organic contaminant-specific removal and expected filter performance across a range of site and filter design parameters. Long-term modeling demonstrated that BC-amended engineered media filters may last for years, at which point the filter lifetime is expected to be governed by hydraulic performance and clogging. A technical design manual and TEMPEST filter design tool were created to assist regulators and practitioners in the design, construction, and estimation the life span of BC-amended engineered media filters to improve the treatment of stormwater runoff, reduce risks of sediment recontamination, and facilitate potential stormwater runoff beneficial use.

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List of Acronyms

AC	Activated carbon
AFFF	Aqueous film forming foam
BC	Black carbon
C	Concentration
C_0	Initial concentration
DOC	Dissolved organic carbon
DO	Dissolved oxygen
DI	Deionized
EBCT	Empty bed contact time
EBVs	Empty bed volumes
GC	Gas chromatography
HDPE	High-density polyethylene
HOC	Hydrophobic organic compound
Hyphil	Hydrophilic
LC	Liquid chromatography
LOQ	Limit of quantification
MDL	Method detection limit
MS/MS	Tandem mass spectrometry
NMSE	Normalized mean squared error
NWSSB	Naval Weapons Station Seal Beach, CA
PAHs	Polycyclic aromatic hydrocarbons
PAFB	Peterson Air Force Base, CO *(Now Peterson Space Force Base)*
PCBs	Polychlorinated biphenyls
PES	Polyethersulfone
PFASs	Per- and polyfluorinated substances
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanesulfonic acid
pPAHs	Parent polycyclic aromatic hydrocarbons
PSFB	Peterson Space Force Base
RAC	Regenerated activated carbon
SCM	Stormwater control measure
SUVA	Specific UV absorbance
TEMPEST	Treatment engineered media performance and sizing tool
TN	Total nitrogen
TOC	Total organic carbon
TrOCs	Trace organic compounds
TSS	Total suspended solids

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I. Abstract

Introduction and Objectives: This final report focuses on protecting water quality and preventing sediment recontamination by developing and showing proof-of-concept for engineered media filters for treating stormwater runoff at DoD facilities. While traditional stormwater control measures (SCMs) generally remove suspended particles, traditional SCMs are often limited in their ability to remove dissolved contaminants, posing risks for re-contamination of sediment, transporting constituents of concern (CoCs) offsite, and exceeding receiving water quality standards. In this work, black carbon (BC), i.e., biochar and regenerated activated carbon (RAC), and zeolite amendments are evaluated in engineered stormwater media filters for the removal of dissolved metals and trace organic contaminants (TrOCs) such as polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), per- and polyfluoroalkyl substances (PFASs), and hydrophilic pesticides and corrosion inhibitors. Project objectives and tasks are designed to develop and build knowledge on design and performance tradeoffs for BC-amended engineered media filters for preventing sediment recontamination and benefiting water quality and possible beneficial use of stormwater runoff. Specific objectives include: 1) Assessment of BC- and zeolite-amended engineered media mixtures for removal of dissolved contaminants; 2) Development of performance curves with kinetic and flow rate design parameters; 3) Evaluation of engineered media filters under intermittent wetting/drying periods and saturation levels; 4) Modeling of long-term contaminant removal performance of engineered media filters; and 5) Development of a technical design manual for improved stormwater SCMs and recommended field demonstration testing for future studies.

Technical Approach: Column experiments are conducted across various flow rates and flow conditions to assess tradeoffs in filter performance and design. To increase the relevancy of the laboratory experiments, catch basin material collected from a DoD facility is used to generate a representative synthetic stormwater. Long-term downflow gravity-driven column experiments are conducted to assess both the hydraulic and contaminant-removal performance of various BC- and zeolite- amended engineered media mixtures. Predictive contaminant transport modeling is used to discern the effects of media contaminant removal kinetics, filter design, and site characteristics on contaminant removal performance. Long-term predictive contaminant transport modeling is undertaken to investigate the expected lifetime of filter engineered media at a case study site.

Results: The experimental results demonstrate that BC- and zeolite-amended engineered media filters successfully remove total suspended solids (TSS) and a suite of dissolved metal and organic contaminants while maintaining adequate hydraulic conductivity. Filter design performance tables accounting for media- and contaminant-specific removal summarize expected filter performance across a range of site and filter design parameters. Long-term modeling demonstrates that BC-amended engineered media filters may last decades, at which point the filter lifetime is expected to be governed by hydraulic performance and clogging.

Benefits: The proposed work targets both hydrophilic and hydrophobic contaminants, which are important considerations in runoff at DoD sites, to benefit receiving water quality, prevent the recontamination of surrounding aquatic sediments, and facilitate possible reuse. A technical design manual and TEMPEST filter design tool are created to assist regulators and practitioners design, construct, and estimate the life span of BC-amended engineered media filters at DoD facilities and beyond to improve the treatment of stormwater runoff, reduce risks of sediment recontamination, and facilitate potential stormwater runoff beneficial use.

II. Executive Summary

1 Introduction

This final report for project ER18-1145 focuses on protecting water quality and preventing sediment recontamination by developing and showing proof-of-concept for engineered media filters for treating stormwater runoff at Department of Defense (DoD) facilities. Stormwater runoff is a major pollution source (EPA 2007) that contains a highly variable mixture of particulate-bound and dissolved contaminants, such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), per- and polyfluoroalkyl substances (PFASs), pesticides, corrosion inhibitors, and metals. These stormwater runoff contaminants can be a major source of contamination to surface waters and sediments and is a major concern for DoD facilities (SERDP/ESTCP 2012). In addition, effective management of stormwater trace organic chemicals will facilitate beneficial use of stormwater for water supply. This SERDP project is in response to the SERDP Statement of Need (ERSON-18-C3) to understand the impacts and control of stormwater on sediment recontamination and recovery, as well as the impacts on potential beneficial use of stormwater.

While traditional stormwater control measures (SCMs) generally remove suspended particles, they are often limited in their ability to remove dissolved contaminants, posing risks for re-contamination of sediment, transporting constituents of concern (CoCs) offsite, and exceeding receiving water quality standards. In this project, black carbon (BC), i.e., biochar and regenerated activated carbon (RAC), and zeolite amendments are evaluated in engineered stormwater media filters for the removal of dissolved metals (cadmium II, copper II, nickel II, lead II, zinc II) and trace organic contaminants (TrOCs) such as PCBs, PAHs, PFASs, and commonly-used hydrophilic pesticides (atrazine, diuron, imidacloprid, fipronil, mecoprop) and a corrosion inhibitor (benzotriazole).

2 Objectives

The overall goal of ER18-1145 is to develop and show proof of concept for improved engineered media filters that successfully remove a suite of organic and metal contaminants in stormwater runoff from DoD facilities. Specifically, engineered-media amendments including zeolite, biochar, and RAC are examined. Project objectives and tasks are designed to develop and build knowledge on design and performance tradeoffs for BC-amended engineered media filters for preventing sediment recontamination and benefiting water quality and possible beneficial use of stormwater runoff. Specific objectives include:

2.1 Assessment of engineered media amendments for removal of organic and metal contaminants from stormwater runoff (Task 2).

The first objective is to assess relatively inexpensive and currently commercially available engineered media amendments for removal of organic and metal contaminants from stormwater runoff. Building from recent studies (Ulrich et al., 2015; Xiao et al., 2017; Ashoori et al., 2019), we hypothesize that the performance of biochar, RAC, and zeolite can be an effective alternative to granular activated carbon (GAC) for removal of contaminants in both the aqueous and particulate phases. To closely mimic field conditions and facilitate technology transition to the field, representative synthetic stormwater is developed for laboratory use (*Subtask 2.1*). Second, engineered media amendments are screened (*Subtask 2.2*). Finally, long-term continuous-flow column experiments are conducted with full-length columns using representative media size and flow rates to investigate six engineered media mixtures for hydraulic conductivity as well as the removal of suspended solids and dissolved contaminants (*Subtask 2.3*). The potential for active hydraulic outlet controls to enable superior performance (compared to media flow-through hydraulics of passive systems) are evaluated.

2.2 Development of engineered media filter performance curves with kinetic and design parameters for removal of organic contaminants in stormwater runoff (Task 3).

Based on what is already known about the potential removal of contaminants in BC-amended biofilters (Ulrich et al., 2015) and results from Task 2, the performance of BC-amended engineered media filters likely depends on flow rates through and retention time in the filter bed. To manage a large amount of runoff, SCMs require higher filtration rates, which can result in lower contact time and consequently reduced treatment efficiency (Hatt et al., 2009). Further research on the relationship between flow rates (*Subtask 3.1*), kinetics of contaminant removal (*Subtask 3.2*), and site/filter design is necessary to predict the performance of engineered media systems in the field. Thus, performance curves are developed for different contaminants based on determined removal kinetics, flow rates, and filter/site design parameters (*Subtask 3.3*). Depending on the runoff regime and treatment needed, one can optimize the media contact time and flow rates through these systems for sufficient contaminant removal. We hypothesize that we can predict effective contaminant retention and removal using kinetics and flow rate design parameters.

2.3 Assess efficacy of saturated/unsaturated filters to remove metal and organic contaminants from periodic storm events using black carbon-amended engineered media filters (Modified Task 4).

Further research is necessary to understand how saturation levels and intermittent storm events affect the removal of organic and metal contaminants. This task evaluates the removal of suspended solids and dissolved metal and organic contaminants across recurring storm events in engineered media filters that are either kept saturated or unsaturated. This task has been modified due to the realized need to assess how unsaturated filters perform relative to saturated filters to better understand how continuous saturation flow column experiments conducted in Tasks 2 and Task 3 will transfer to the field where filters are expected to dry out in between intermittent storm events. PFASs are known to preferentially partition to the air-water interface. We evaluate the effect on of intra-filter bed air-water interfaces on PFAS transport under intermittent wet and dry flow conditions (*Subtask 4.1*). The original objective of Task 4 was to assess microbial transformation within the engineered media filters, but due to time and funding limitations and shifting project needs, this is now outside of scope of work.

2.4 Evaluation of the long-term performance modeling of various black carbon-amended engineered media filters for breakthrough based on various design criteria (Task 5).

Long-term performance modeling is necessary to evaluate expected filter lifetimes in the field. This objective validates the contaminant transport model used to develop the performance curves in Task 3 for dynamic flow and varied influent contaminant loading scenarios (*Subtask 5.1*). Additionally, the effect of background dissolved organic carbon (DOC) on filter performance and model predictions is explored (*Subtask 5.1*). The second part of this objective will carry out case study simulations to evaluate breakthrough times for representative contaminants based on site characteristics and filter design parameters (*Subtask 5.2*). We hypothesize that BC-amended filters, when coupled with suspended solid management as a pretreatment, can sufficiently treat runoff for years with high flow rates and reasonable filter design parameters.

2.5 Development of technical design manual for improved stormwater control measures and recommended field demonstration testing for future studies (Modified Task 6).

To validate the proposed engineered media filters to treat stormwater runoff and prevent sediment recontamination at DoD facilities, this work must be effectively scaled up from bench-scale experiments to field testing. A plan for a field demonstration site will be developed after various design parameters are optimized. This plan and the resulting data will aid in the specifications necessary for the development of a technical design manual (*Subtask 6.1*). For the effective dissemination of contaminant transport modeling and proposed technologies at DoD facilities, an excel-based treatment engineered media performance and sizing tool (TEMPEST) will assist users in the design and implementation of BC-amended engineered

media filters (*Subtask 6.2*). This is an efficient way to effectively disseminate the design information and intricate modeling results to DoD site managers to prevent sediment recontamination from stormwater.

3 Technical Approach

The project objectives and tasks were completed through a series of downflow gravity-driven column experiments, batch screening and isotherm tests, and contaminant transport modeling. *Figure 1* shows a diagram of the experimental setup used in Task 2, and similar configurations were used for Tasks 3, 4, and 5. Briefly, synthetic stormwater (*Subtask 2.*1) was created by mixing catch basin material from Naval Weapons Station Seal Beach (NWSSB) and salts, passing the solution through a sedimentation basin, and spiking dissolved organic carbon and contaminant stock solutions. Catch basin material collected from three DoD facilities was assessed based on availability, contaminant content, and DOC leaching, which led to the selection of material from NWSSB for use in the experiments. Contaminants were added to achieve about 40 µg L^{-1} of hydrophilic (hyphil) TrOCs, 100 ng L^{-1} hydrophobic TrOCs, 3 µg L^{-1} of perfluorooctanesulfonic acid (PFOS; derived from AFFF previously used at Peterson Space Force Base, CO and therefore containing other PFASs at lower concentrations), and 30 µg L^{-1} metals. Six engineered media mixtures consisting of sand, zeolite (30 v%), biochar (30 v%, 2.4 wt% when mixed with sand), and RAC (10 v%, 3.3 wt% when mixed with sand) were investigated in triplicate, as shown in *Figure 1*. Columns (4ft x 3in) were packed dry with barrier sand, 60 cm of engineered media mix, and barrier sand on top, flushed with CO_2 to displace the air, and saturated with deionized (DI) water in up-flow. The columns were then flushed in down-flow with DI water, tracer tested using bromide as a mostly conservative tracer, conditioned for 100 empty bed volumes (EBVs) of contaminant-free synthetic stormwater, and then challenge tested with contaminants for 500 EBVs. Synthetic stormwater and contaminant stock solutions were prepared every few days. Hydraulic conductivity was monitored throughout the experiment using manometers attached to sample ports spaced 25% and 75% along the engineered media mixture.

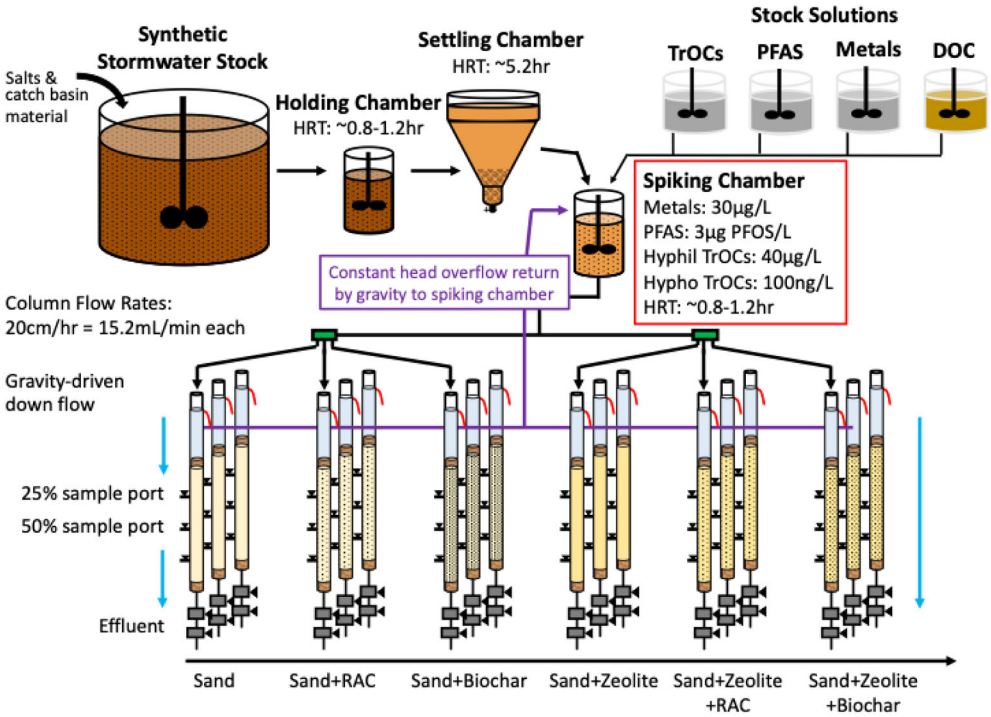

Figure 1 Diagram of experimental setup used in Task 2 showing the stormwater generation, contaminant spiking, and treatment columns. Constant head was maintained in the columns by continuous overflow back to the spiking chamber. System details may be found in the full report. Similar experimental setups were used in

Task 3, 4, and 5 except with different column configurations, flow rates, and levels of contaminant and background DOC loading.

The experimental setup was modified in Task 3 (*Subtask 3.1*) by reducing the number of media mixtures investigated by removing zeolite, increasing the concentration of PFASs and metals to about 10 µg L^{-1} PFOS (and other PFASs) and 300 µg L^{-1} for metal species, and increasing the face velocity flow rate to 40 and 60 cm hr^{-1}. Separately, Task 4 (*Subtask 4.*1) employed shorter columns with only 15 cm of engineered media containing sand, zeolite, and biochar and featured discrete storm events with intermittent dry periods during which three of the columns remained saturated and three of the columns remained unsaturated. Task 5 (*Subtask 5.1*) used a similar experimental setup as Task 3, except only the sand and biochar mixture was assessed, less biochar was used (10 v%), and various scenarios were investigated in which either the flow rate or contaminant loading concentration were varied throughout the experiment (60 cm hr^{-1} to 20 cm hr^{-1} to 120 cm hr^{-1}; 40 µg L^{-1} to 10 µg L^{-1} to 80 µg L^{-1}) and the background DOC was varied from 3 mg C L^{-1} to 7 mg C L^{-1} to 18 mg C L^{-1}.

Batch screening experiments were conducted to select a biochar and RAC to use for the column experiments (*Subtask 2.2*). Additionally, batch isotherms were conducted to determine Freundlich sorption parameters for the hydrophilic TrOCs and PFASs studied to compare with parameters obtained from the contaminant transport modeling (*Subtask 3.2*). Batch experiments were conducted by adding various amounts of sorbent to vessels with synthetic stormwater including the full suites of contaminants and background DOC.

Contaminant transport modeling was conducted using the 1-d advection dispersion equation with retardation due to intraparticle diffusion limited sorption. This transport model was fit to contaminant transport data observed in the column experiments by finding the optimal Freundlich sorption and tortuosity parameters that minimized the normalized mean squared error of the residuals (*Subtask 3.2*). Parameter fitting was conducted using the contaminant transport data from the 20 cm hr^{-1} experiment (Task 2) and the parameters were validated using experiments at higher flow rates (*Subtask 3.2*) and with dynamic flow and contaminant loading (*Subtask 5.1*). Contaminant model fitting was also used to elucidate how DOC affects contaminant sorption (*Subtask 5.1*). The contaminant transport model was also used to create filter performance tables (*Subtask 3.3*) and for long-term modeling of a hypothetical case study at NWSSB (*Subtask 5.2*).

4 Results and Discussion

4.1 Assessment of engineered media filters for removal of contaminants from stormwater runoff (Task 2).

4.1.1 Develop novel and representative lab-based synthetic stormwater using soils and sediments from DoD facilities (Subtask 2.1).

The synthetic stormwater recipe developed by Grebel et al. (2016) was modified by adding the catch basin material (3 g/L) and additional DOC concentrate to provide a representative microbial inoculum and source of DOC. Catch basin material from parking lot storm drains near the wash rack and dock at NWSSB and from a stormwater water detention pond draining a known PFAS-contaminated area at Peterson Space Force Base, CO (PSFB) was collected and screened for background contaminants (PAHs, PFASs, metals) and DOC. Material from NWSSB was chosen based on material availability, contaminant content, and background DOC contribution from leaching studies. DOC is an important parameter due to its interference with TrOCs sorption to black carbon and known presence in stormwater runoff. Straw was used to generate a DOC concentrate to further increase the synthetic stormwater DOC to representative levels. Straw was chosen due to its presence in the collected catch basin material and reproducibility. The synthetic stormwater generated in the laboratory was similar to stormwater collected at NWSSB and reported by the National BMP Database for California.

4.1.2 Select filter engineered media (Subtask 2.2).

Engineered media screening batch tests results indicated that Biochar Supreme (high temperature gasification product) generally outperformed Biochar Now (medium temperature pyrolysis product), Cabot RAC outperformed Calgon RAC, and zeolite outperformed sand with respect to metal removal. Additional screening studies showed that Biochar Supreme performed better than Biochar Now and Calgon RAC outperformed Cabot RAC with respect to PFOS removal while Zeolite did not show any PFOS removal within the 5 days that the solution equilibrated.

4.1.3 Evaluate various engineered media mixtures using downflow column experiment (Subtask 2.3).

All treatments provided substantial water quality improvement with respect to TSS and turbidity. TSS was removed to 0.0-1.3 mg L^{-1} and turbidity was reduced to 0.48-2.22 FNU in the column effluent. Columns amended with BC consistently removed more TSS and turbidity while zeolite did not provide any significant benefit. Although DOC was added to attain approximately 10 mg C L^{-1}, only 3.7±1.1 mg C L^{-1} was present in the stormwater entering the columns, likely due to sorption to TSS and microbial degradation in the spiking chamber and tubing. While RAC and biochar amendment both reduced DOC similarly in the beginning, after ~200 EBVs, the DOC removal in the biochar decreased to levels similar to the sand and zeolite columns while DOC removal in the RAC columns remained at similar levels. Zeolite did not significantly impact DOC removal. Observed SUVA values of 2.59 L mg^{-1} m^{-1} are typical of stormwater runoff. Dissolved oxygen (DO), pH, conductivity, and total dissolved solids trends were consistent throughout the experiment. The DO was depleted in all the columns during the conditioning period and the columns remained anoxic throughout the experiment. Hydraulic conductivity decreased slightly over the course of the experiments for all the media mixtures. Biochar-amendment reduced column hydraulic conductivity from 0.35±0.04 cm s^{-1} to 0.21±0.08 cm s^{-1} after 62 days (32% reduction), while RAC's impact, though not as great, was still measurable, 0.35±0.04 cm s^{-1} to 0.31±0.03 cm s^{-1} (26% reduction).

Dissolved metal removal occurred in all the columns to various degrees (*Figure 2*). Zeolite contributed some benefit for metal removal but less than that reported by others. BC-amendment reduced dissolved metal concentrations most and in the order of Pb>Cu>Cd>Ni>Zn. RAC amendment provided slightly better removal than biochar for nearly all metal species, though the difference is not substantial. Combining zeolite and BC amendment improved metal removal more than zeolite or BC alone. Hydrophobic organic compounds (HOCs) removal was measured in the highest flow rate column experiment conducted at 60 cm hr^{-1} (Task 3). Upon spiking, 81.4%-99.0% of the HOCs became particulate associated and were removed from the dissolved phase before reaching the columns. The sand columns did not provide any benefit to dissolved HOC removal, while BC-amendment greatly reduced dissolved HOCs in the effluent (*Figure 2*). The presence of dissolved HOCs in the BC-amended column effluent may be due to colloidal transport, which is known to be greater at higher flow rates. Even with the influence of colloidal transport, the concentration of dissolved HOCs remained below the level of quantification (0.5 ng L^{-1}) for most of the HOCs studied at the highest flow rate studied.

BC-amended columns removed nearly all of the hyphil-TrOCs over the course of the experiment (*Figure 2*), while the sand columns and zeolite alone saw no appreciable reduction in hyphil-TrOCs. When combined with BC, zeolite gave a slight improvement in performance, likely due to the slight increase in contact time resulting from the increased porosity of the zeolite relative to sand. Measurements at the sample ports showed migration within the column. Biochar reduced hyphil-TrOCs transport more than RAC, likely due to differences in sorption kinetics and contact time. The rapid initial breakthrough observed in the sample ports indicate that sorption is kinetically limited, and that the kinetics favor contaminant removal in the biochar-amended columns. The six PFASs measured and reported (PFHxA, PFOA, PFHxS, PFOS, Cl-PFOS, FHxSA) were best removed with BC-amendment and negligibly removed in the sand and sand+zeolite columns (*Figure 2*). While biochar appeared to have better or equivalent performance initially, RAC performed better over the course of the experiment. As observed for the hyphil-TrOCs, zeolite

addition to the BC-amended mixtures improved PFAS removal. PFOS, the best removed of the studied PFASs, exhibited similar performance to mecoprop, the most mobile of the studied hyphil-TrOCs.

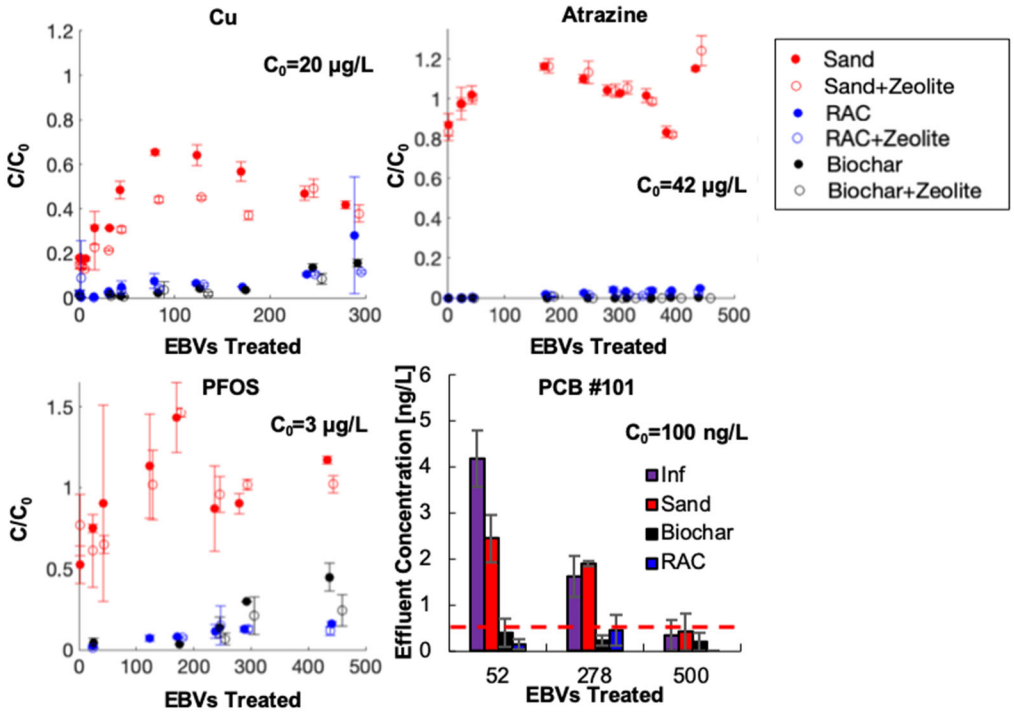

Figure 2 Mean contaminant removal in column effluent in Task 2 experiments. Error bars indicate one standard deviation above and below the mean (n=3). The red dashed line indicates the quantitation limit (0.5 ng L^{-1}).

4.2 Development of filter performance curves with kinetic and flow rate design parameters (Task 3).

4.2.1 Evaluate engineered media filters at higher flow rates (Subtask 3.1).

The influent water quality of the synthetic stormwater remained consistent throughout the 40 cm hr^{-1} and 60 cm hr^{-1} experiments and was similar to Task 2. TSS and turbidity were reduced more for the 40cm hr^{-1} than the 60 cm hr^{-1} experiment and slightly more for BC-amended columns than sand columns. DOC in the synthetic stormwater influent was consistent between the 40 cm hr^{-1} (4.2±1.0 mg C L^{-1}) and 60 cm hr^{-1} experiments (6.3±1.4 mg C L^{-1}). Similar to observations from Task 2, the DOC removal was greater in the BC amended columns than the sand columns. Metals were removed initially in all columns, however rapid breakthrough was observed for Ni, Zn, and Cd in all treatment columns. BC provided significant benefit for metal removal for Cu and Pb. Metals removal performance was worse than observed in Task 2. Metal removal performance was not sensitive to an increase in the flow rate from 40 to 60 cm hr^{-1}. The sand columns provided no substantial benefit to hyphil-TrOCs removal in the 40 cm hr^{-1} or 60 cm hr^{-1} experiments while biochar and RAC provided significant benefit. Biochar provided superior treatment initially, but experienced higher contaminant concentrations in the effluent later, suggesting that contaminant removal kinetics are faster for biochar than RAC. The observed hyphil-TrOC concentrations in the 60 cm hr^{-1} experiment are consistently and significantly higher than those in the 40 cm hr^{-1} experiment, indicating that increasing the flow rate reduces filter performance, and confirming the kinetic-limitation of contaminant removal in BC amended engineered media filters.

4.2.2 *Develop, fit, and validate model to predict contaminant transport in engineered media filters (Subtask 3.2)*

Transport data from the Task 2 column studies was used to fit the model parameters. Bromide breakthrough curves were fit to the tracer test results for the sand, RAC, and biochar columns to find the dispersivity parameter. The contaminant transport model was fit to observed contaminant breakthrough at various locations in the column by finding the optimal Freundlich sorption parameters (K_{fr}, n_{fr}) and tortuosity factor (τ) for each replicate column for each BC mixture. Each replicate column was fitted individually and treated as a separate model. The breakthrough curves resulting from the three models were averaged and plotted with the standard deviation (*Figure 3*). As was observed for the tracer tests, the fitted tortuosity parameters exceed the typical range of the material tortuosity's and likely include other factors contributing to pore-diffusion hindrance. The fitting process was conducted for contaminant transport data observed for each replicate at the 25% sample port, 50% sample port, and entire column (25% sample port, 50% sample port, effluent) together. Validation of the model and model-derived sorption parameters occurred by using the sorption parameters (fit to the 25% sample port) to predict contaminant transport further down the column (at the 50% sample port and column effluent) and indicates that the model may be able to be used to predict contaminant transport at various depths. Batch isotherm experiments show that the Freundlich sorption parameters obtained from the isotherms are similar to those found from fitting the model to the observed breakthrough curves. The model and sorption parameters from fitting the 20 cm hr^{-1} contaminant transport data predict contaminant transport well in the 40 and 60 cm hr^{-1} experiments, providing further validation of the modeling approach (*Figure 3*).

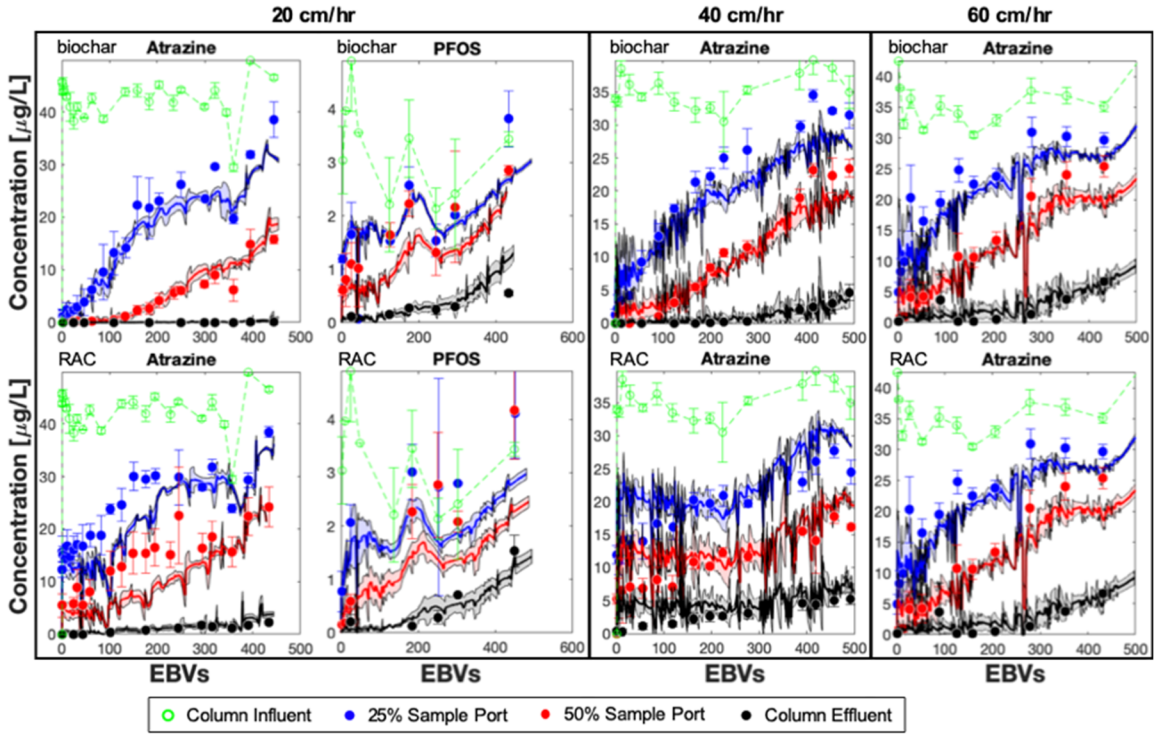

Figure 3 Mean observed (points) and predicted contaminant concentrations (lines) in Tasks 2 and 3. Contaminant transport is predicted using parameters fit from the 20 cm hr^{-1} experiment and validated at higher flow rates. Error bars and shaded regions indicate one standard deviation above/below the mean (n=3).

4.2.3 *Develop filter performance curves to estimate filter longevity under specific site and filter conditions (Subtask 3.3)*

The complex relationship between filter performance and design parameters may be better understood through the development of filter performance curves (*Figure 4*). The filter performance for a given BC

material is expressed as a function of three parameters: empty bed contact time (EBCT), BC content, and influent concentration. Performance tables were created for atrazine, imidacloprid, fipronil, PFOS, and PFOA and show the volume treated until breakthrough ± standard deviation for specific C/C_0 removal levels as a function of EBCT and BC content for distinct influent concentrations. These tables show that certain thresholds of BC content and EBCT are necessary to achieve desired C/C_0 performance and that above the threshold, incremental changes in EBCT and BC content result in decreasing improvements of filter performance. The filter performance tables can be used to estimate the lifetime, performance, and associate cost of contaminant removal for filters of various design and treatment specifications.

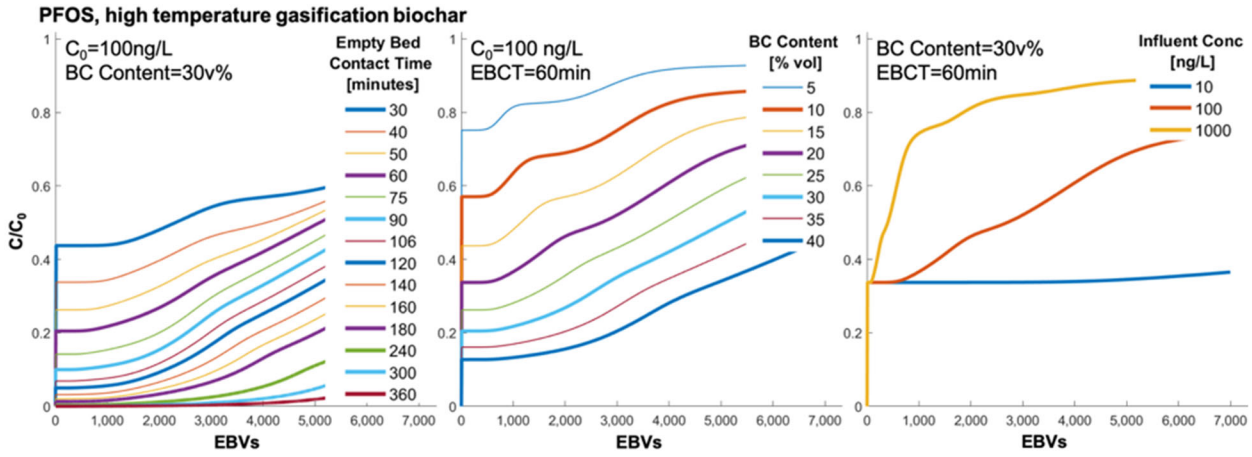

Figure 4 Biochar filter performance curves for PFOS removal performance for various design parameters.

4.3 Assess efficacy of saturated/unsaturated filters to remove metal and organic contaminants from periodic storm events using black carbon-amended engineered media filters (Modified Task 4).

4.3.1 Periodic wetting/drying impact on engineered media filter performance (Subtask 4.1)

Both saturated and unsaturated column configurations provided substantial water quality improvement with respect to PFASs, TrOCs, and metals for the duration of the experiment. Across all PFASs analyzed, unsaturated conditions outperformed saturated conditions, likely due to their preferential sorption to the air-water interface in unsaturated conditions. Saturated conditions performed better for nickel removal, while unsaturated conditions performed better for copper removal. System failure (i.e. unsaturated columns becoming saturated with water during an unplanned flushing event) would remobilize an equivalent amount of PFASs in the unsaturated columns as compared to the saturated conditions. As a percentage of the total mass retained on the column, less total mass was eluted from the unsaturated column during the flush, indicating that the removal of the air-water interface does not threaten filter efficiency. More importantly, less than 0.5% of total loaded PFOS and PFOA mass eluted in the simulated flushing event.

4.4 Long-term performance modeling of BC-amended biofilters for breakthrough based on different design criteria (Task 5).

4.4.1 Assess impacts of dynamic flow, contaminant loading, DOC on engineered media filter performance (Subtask 5.1)

The dynamic flow experiment consisted of conditioning the columns for 100 EBVs at 60 cm hr^{-1} and challenge testing the columns for 5 days at 60 cm hr^{-1}, 5 days at 20 cm hr^{-1}, and 3 days at 120 cm hr^{-1} with constant contaminant loading and background DOC (8.5±0.9 mg C L^{-1}). Each change in flow rate yielded significant and immediate responses of dissolved TrOCs at each location within the column filter. The concentration of contaminant breakthrough sharply fell with the reduction of flow rate and sharply

increased with the increase in flow rate. The contaminant transport model predicted the column performance well, capturing immediate changes in contaminant concentration at each change in flow rate. The dynamic concentration experiment consisted of conditioning the columns for 100 EBVs at 60 cm hr^{-1} and challenge testing the columns for 5 days with normal contaminant loading, 5 days with low (one-fourth-of-normal) contaminant loading, and 2 days of high (twice-normal) contaminant loading at 60 cm hr^{-1} with constant background DOC (6.9±0.8 mg C L^{-1}). Each change in contaminant loading concentration yielded significant responses of contaminant transport at each location within the column filter, with the relative transport lowering as the concentration decreased and increasing as the concentration increased. The contaminant transport model predicts the contaminant transport for the dynamic concentration experiment better than for the dynamic flow experiment. The model-predicted impact of the influent contaminant concentration changes mirrors the observed contaminant breakthrough.

The variable DOC experiment consisted of two additional column studies conducted at a flow rate of 60 cm hr^{-1} and normal contaminant loading with high (18.4±4.5 mg C L^{-1}) and low (2.0±0.2 mg C L^{-1}) background DOC levels. The DO was lower in the influent and effluent during the high DOC experiment than in the low DOC experiment. Increasing background DOC dramatically increases the rate of contaminant breakthrough for the observed contaminants. Reducing the background DOC concentration after five days of high background DOC had variable benefit to contaminant removal. Batch isotherms conducted with background DOC concentrations of 10.5±1.8 mg C L^{-1} and 16.2±2.1 mg C L^{-1} confirm the DOC impact on sorbent sorption capacity.

4.4.2 Conduct case study simulations for engineered media filters at a representative field site (NWSSB) (Subtask 5.2).

Long-term predictive modeling was used to estimate filter lifetime in a hypothetical case study in Seal Beach, CA. Recent reviews of hyphil-TrOC and PFAS occurrence in stormwater were used to select acute (high levels) and chronic (mean levels) for modeling. Relevant acute and chronic water quality standards were used for treatment benchmarks. Fipronil is the limiting contaminant due to its mobility and need for high removal threshold as determined by its very low aquatic health benchmarks. For filters amended with biochar (30 v%) operated at 20 cm hr^{-1} in the chronic scenario, a depth of 0.2m is necessary to adequately remove fipronil for 70±30 years, while a depth of 0.3 m is expected to remove fipronil for >100 years at NWSSB. RAC requires a deeper filter (0.5 m) to achieve the desired performance, and is expected to last >100 years. Increased filter depth is required for the acute scenario: biochar filters 60 cm deep are expected last 10±4 years while increasing the depth is expected to add about 5 years per 0.1 m increment. RAC filters are unable to meet the treatment threshold with an 80 cm filter and require either a longer filter or higher carbon content. PFOS and PFOA are adequately remove in both situations with filter depths of 0.3 m. However, the filter performance and lifetime estimates are very sensitive to the concentration of the influent, and higher concentrations would result in shorter lifetimes and possibly inadequate treatment. Increasing the filter depth disproportionately increases the filter lifetime, demonstrating the impact of contaminant removal kinetics on filter performance. RAC appears to be more impacted by depth than biochar. The influent concentration and target removal also impact filter lifetime, as the filter performance is superior in the chronic scenario than the acute scenario for each BC material and filter depth.

4.5 Development of a technical design manual for improved stormwater control measures and recommended field demonstration testing for future studies (Task 6).

4.5.1 Development of technical design manual.

Geosyntec Consultants developed a guidance manual for evaluation and implementation of BC-amended engineered media filtration for passive treatment of stormwater runoff. The guidance manual assists DoD site managers and Remedial Project Managers (RPMs) in making decisions about whether BC-amended engineered media filters should be considered for their site, whether BC-amended engineered media filters

can meet their regulatory and/or treatment objectives, and how to design, construct, and operate/maintain BC-amended engineered media filters. A draft of the guidance manual is included in the Appendix C.1. The guidance manual also details how to use the TEMPEST stormwater filter design spreadsheet tool.

4.5.2 Development of treatment engineered media performance and sizing tool (TEMPEST).

The TEMPEST stormwater filter design tool was developed in partnership with Geosyntec Consultants and is attached in the Appendix C.3. This Microsoft excel spreadsheet tool allows the integration of contaminant transport modeling into traditional stormwater filter design to estimate the contaminant removal performance and filter lifetime for user-inputted design specifications, allowing the user to optimize the stormwater control design to address hydrological constraints as well as contaminant removal objectives.

4.5.3 Recommendation for future studies.

This project report demonstrates the potential for BC-amended engineered media filters to remove a wide suite of contaminants from stormwater runoff, including TSS, metals, HOCs, hyphil-TrOCs, and PFASs. However, field testing and validation is essential to facilitate transfer of the filter technology and TEMPEST modeling tool from the laboratory to real-world practice. The experimental design of the laboratory experiments emphasized conducting experiments that were as representative as possible of field conditions to facilitate translation to the field.

5 Implications for Future Research and Benefits

Engineered filters with BC amendment are a promising technology for the treatment of stormwater runoff. This is demonstrated for filters operated in a gravity-driven down-flow mode with consistent TSS and DOC loading. Filter clogging was managed by periodic maintenance during which the top layer of barrier sand was cleaned and replaced. Filters amended with high-temperature gasification biochar or regenerated activated carbon removed a suite of metals, TrOCs, and PFASs while removing nearly all TSS and reducing turbidity. Zeolite did not appear to substantially benefit the contaminant removal. Contaminant transport in the columns indicate that the TrOCs removal is kinetically limited at face velocity flow rates of 20 cm/hr. This report offers proof-of-concept for BC-amended engineered media filters as effective stormwater control measures. While this study used relatively high concentrations of contaminants and low BC contents to observe contaminant transport, performance in the field is likely to be significantly better with higher BC-content filters and lower ambient stormwater contaminant concentrations. Additionally, contaminant transport modeling, based on and validated with observed contaminant transport in laboratory experiments, e.g., flow rates of 40 and 60 cm hr^{-1}, is used to estimate field performance and understand the design implications of kinetically limited contaminant removal performance. Filter performance tables, incorporating design parameters to provide filter lifetime estimates, are incorporated into a design manual and filter design tool (TEMPEST). Field testing is required to demonstrate the efficacy of BC-amended filters and to validate the contaminant transport modeling and TEMPEST design tool for real world conditions. Such testing would move the technology towards widescale implementation at DoD facilities and beyond.

Both the guidance manual and TEMEPST design tool disseminate key results from this project in a practical form that may be used by practitioners, DoD site managers, and RPMs to implement better stormwater management practices. Improved stormwater management practices should help to reduce sediment recontamination and improve the quality of stormwater runoff, thereby also facilitating beneficial use of stormwater. Beneficial use of stormwater runoff is likely to become a necessity in drought-prone regions such as the American west. Examples of beneficial use include capture of stormwater runoff for managed aquifer recharge to supplement drinking water sources and protect against salt water intrusion, release to protect environmental base flows to support aquatic environments and recreation activities, and or urban/industrial uses.

III. Objectives

This SERDP project is in response to the SERDP Statement of Need (ERSON-18-C3) to understand the impacts and control of stormwater on sediment recontamination and recovery. Stormwater runoff is a major pollution source (EPA 2007) that contains a highly variable mixture of particulate-bound and dissolved contaminants, such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), per- and polyfluoroalkyl substances (PFASs), pesticides, corrosion inhibitors, and metals. These stormwater runoff contaminants can be a major source of recontamination of surface waters and sediments and is a major concern for Department of Defense (DoD) facilities (SERDP/ESTCP 2012). Additionally, changes in runoff patterns due to expected increases in the frequency and intensity of storms create increased unreliability in controlling sediment recontamination. Novel systems are needed that integrate stormwater capture and treatment that enhance water resources and prevent sediment recontamination.

The overall goal of ER18-1145 is to develop and show proof of concept for improved engineered media filters that successfully remove a suite of organic and metal contaminants in stormwater runoff from United States Department of Defense (DoD) facilities. Specifically, engineered media amendments including zeolite and black carbon materials such as biochar and regenerated activated carbon (RAC) are examined. Contaminant transport modeling is conducted to understand the expected long-term performance and better understand the tradeoff in filter design characteristics including flow rate and depth, site characteristics including influent contaminant loading, and resulting filter performance. Information from bench-scale studies and predictive computer modeling will increase understanding of chemical fate and transport in these amended filters, demonstrate the long-term effectiveness of black carbon- and zeolite-amended filters as a cost-effective treatment strategy, and support development of a technical design manual and design tool and recommended future field testing of these filters. Specific objectives have been modified from the initial proposal over the course of the project based on findings. The updated objectives include:

1 Assessment of engineered media amendments for removal of organic and metal contaminants from stormwater runoff (Task 2).

The first objective (Task 2) is to assess relatively inexpensive and currently-commercially available engineered media amendments for removal of organic and metal contaminants from stormwater runoff. Activated carbon and biochar are effective for the removal of organic contaminants in runoff (Ulrich et al., 2015), and zeolite is effective for the removal of metals in runoff (Kim et al., 2010). However, stormwater filters need to be effective for the removal of contaminants that are in the particulate phase (such as polychlorinated biphenyls [PCBs] and polycyclic aromatic hydrocarbons [PAHs]), as well as those that can be in both the particulate-bound and dissolved phases in stormwater runoff (hydrophilic pesticides and corrosion inhibitors, per- and polyfluorinated substances [PFASs], and metals) at flow rates and contact times representative of those in the field. With the cost of granulated activated carbon (GAC) typically six times the cost of biochar (Ahmad et al., 2014), large-scale DoD facilities can benefit from the use of cheaper but effective commercially available materials such as biochar, regenerated activated carbon (RAC), and zeolite. Biochar is a renewable resource that also sequesters carbon (Lehmann and Joseph 2009) and RAC is well-suited for reuse in industrial applications. Implementation of engineered media filters will be analyzed to evaluate their overall performance

in removing a broad suite of organic and metal contaminants. We evaluate the potential for active hydraulic outlet controls to enable superior performance (compared to media flow-through hydraulics of passive systems). We hypothesize from recent studies (Ulrich et al., 2015; Xiao et al., 2017; Ashoori et al., 2019) that the performance of biochar, regenerated activated carbon, and zeolite can be an effective alternative to GAC for removal of contaminants in both the aqueous and particulate phases.

2 Development of performance curves with kinetic and flow rate design parameters for engineered media filters treatment of organic contaminants in stormwater runoff (Task 3).

Based on what is already known about the potential removal of contaminants in black carbon (BC)-amended biofilters (Ulrich et al., 2015) and results from Task 1, the performance of BC-amended engineered media filters likely depends on flow rates through and retention time in the filter bed. To manage a large amount of runoff, stormwater control measures (SCMs) require higher filtration rates, which can result in lower contact time and consequently reduced treatment efficiency (Hatt et al., 2009). Further research on the relationship between flow rates, kinetics of contaminant removal, and site/filter design is necessary to predict the performance of engineered media systems in the field. Thus, performance curves are developed for different contaminants based on determined removal kinetics, flow rates, and filter/site design parameters. For sufficiently large watersheds, detention may be required to collect the runoff and provide storage before filtration through the engineered media filters. This will lead to efforts focused on evaluating watershed properties and flow rates necessary to adequately treat the contaminated stormwater runoff to prevent potential recontamination. Depending on the runoff regime and treatment needed, one can optimize the media contact time and flow rates through these systems for sufficient contaminant removal. We hypothesize that we can predict effective contaminant retention and removal using kinetics and flow rate design parameters.

3 Assess efficacy of saturated/unsaturated filters to remove metal and organic contaminants from periodic storm events using black carbon-amended engineered media filters (Modified Task 4).

Further research is necessary to understand how saturation levels and intermittent storm events affect the transport and removal of total suspended solids and organic and metal contaminants. This objective is to evaluate the removal of suspended solids and dissolved metal and organic contaminants across recurring storm events in engineered media filters that are either kept saturated or unsaturated. This task has been modified due to the realized need to assess how unsaturated filters perform relative to saturated filters in order to better understand how continuous-saturation and flow column experiments conducted in Tasks 2 and 3 will transfer to the field where filters are expected to dry out in between intermittent storm events. PFAS is known to preferably partition to the air-water interface. We evaluate the impact of the presence of intra-filter bed air-water interfaces on PFAS transport and removal (*Subtask 4.1*). Specifically, engineered media filter performance is assessed under intermittent wet and dry flow conditions based on historical rainfall data and watershed information for a hypothetical site. The original objective of Task 4 was to assess microbial transformation within the engineered media filters, but due to limitations of time and funding and evolving needs, the scope of work has been modified to assess engineered media performance under unsaturated and intermittent flow conditions.

4 Evaluation of the long-term performance modeling of various black carbon- and zeolite-amended biofilters for breakthrough based on different design criteria (Task 5).

Long-term performance modeling is necessary to evaluate expected filter lifetimes in the field. This objective validates the contaminant transport model used to develop the performance curves in Task 3 for dynamic flow and varied influent contaminant loading scenarios. Additionally, the effect of background dissolved organic carbon (DOC) on filter performance and model predictions is explored. The second part of this objective will carry out case study simulations to evaluate breakthrough times for representative contaminants based on site characteristics and filter design parameters. Design criteria will be varied to demonstrate the effect that design parameters have on filter lifetime. We hypothesize that black carbon- and zeolite-amended filters, when coupled with suspended solid management as a pretreatment, can sufficiently treat runoff for years with high flow conditions and reasonable filter design parameters.

5 Development of a technical design manual for improved stormwater control measures and recommended field demonstration testing for future studies (Modified Task 6).

To validate the proposed engineered media filters to treat stormwater runoff and prevent sediment recontamination at DoD facilities, this work must be effectively scaled up from bench-scale experiments to field testing. A plan for a field demonstration site will be developed after various design parameters are optimized. This plan and the data results will aid in the specifications necessary for the development of a technical design manual. For the effective dissemination of the proposed technologies and other improved SCMs at DoD facilities, a technical manual and excel-based treatment engineered media performance and sizing tool (TEMPEST) will assist users in design and implementation of black carbon-amended engineered media filters. Technical design manuals are widely used in the water treatment industry by consultants, municipalities, and other users for guidance in proper design, installation, and management of SCMs. The goal of the technical manual is to provide examples, design parameters, specifications, criteria, and considerations for DoD site managers to develop site-specific stormwater strategies. The TEMPEST design tool assists regulators and practitioners to design engineered media filters while ensuring the designed filters achieve desired performance and lifetime goals. This is an efficient way to effectively disseminate the design information and intricate modeling results to DoD site managers to prevent sediment recontamination from stormwater.

This final report details all of the project findings. Below are the corresponding subtasks for each project objective. Note that subtasks have also been modified to better reflect the full nature of the tasks.

Task 2. Assessment of engineered media filters for removal of contaminants from stormwater runoff.

Subtask 2.1 Develop novel and representative lab-based synthetic stormwater using soils and sediments from DoD facilities.
Subtask 2.2 Select BC engineered material.
Subtask 2.3 Evaluate various engineered media mixtures using downflow column experiments.

Task 3. Development of performance curves with kinetic and flow rate design parameters.

Subtask 3.1 Evaluate engineered media filters at higher flow rates
Subtask 3.2 Develop, fit, and validate a model to predict contaminant transport in engineered media filters.
Subtask 3.3 Develop filter performance curves to estimate filter longevity under specific site and filter conditions.

Task 4. Evaluation of black carbon- and zeolite-amended engineered media filters for breakthrough under realistic intermittent wetting/drying periods.

Subtask 4.1 Periodic wetting/drying impact on engineered media filter performance.

Task 5. Long-term performance modeling of balck carbon-amended biofilters for breakthrough based on different design criteria.

Subtask 5.1 Assess impacts of dynamic flow, contaminant loading, and DOC on engineered media filter performance.
Subtask 5.2 Conduct case study simulations for engineered media filters at a representative field site (NWSSB).

Task 6. Development of a technical design manual for improved stormwater control measures and recommended field demonstration.

Subtask 6.1 Develop technical design guidance manual.
Subtask 6.2 Develop a treatment engineered media performance and sizing tool (TEMPEST).

IV. Background

1 Stormwater runoff conveys contaminants and causes sediment recontamination.

Contamination of sediment from runoff is a common problem at DoD facilities. At the July 2016 workshop on reducing the impact of stormwater discharge on sediment recontamination, the working group noted that runoff is typically regulated under National Pollutant Discharge Elimination System (NPDES) permits, and frequently have total maximum daily loads (TMDLs) for specific contaminants (e.g., metals and persistent organics). Yet, at several DoD remedial sites, sediment cleanup is being required prior to stormwater source control having been achieved. In some cases, the permitted concentrations of contaminants of concern in stormwater particulates exceed sediment cleanup levels. This places the burden on DoD to deal with unregulated discharges and watershed-wide diffuse surface runoffs. Illustrative examples are:

- Stormwater loads that contribute directly to known sediment contamination, e.g., the Lower Duwamish Waterway in Seattle (PCBs), Puget Sound Naval Shipyard (PCBs, PAHs, metals), and Paleta Creek at the Naval Shipyard San Diego, CA (copper).
- Diffuse flow that is implicated to on-going contamination, e.g., surface flow through Yosemite Creek to bay sediments at Hunters Point Naval Shipyard, CA (PCBs), and Naval Air Station Joint Reserve Base Willow Grove, PA (PFASs) input to streams.
- Sites where permitted contaminant discharge limits in stormwater are higher than the cleanup levels (Joint Base Pearl Harbor-Hickam, Oahu, HI).

The July 2016 workgroup consensus was that existing regulatory programs do not effectively manage for sediment recontamination, with uncertainties related to the effect of stormwater-associated contaminants on remediation and recovery goals. TMDLs in permits most often focus on bulk parameters (total load), and regulatory tools such as TMDLs focus on water quality impairments (e.g., eutrophication), not on sediment-bed contaminants. What remains uncertain is the defining and quantifying of connections between stormwater-associated sediment load, dissolved-phase concentrations, and benthic impairment.

A challenging problem to provide state-of-the-art treatment is that stormwater control processes are typically based on standard specifications and designs. Termed “best management practices (BMPs)” or “stormwater control measures (SCMs),” these designs are not validated in terms of hydraulic performance, sediment capture, or with respect to dissolved metal and organic contaminants removal. Further, SCMs are intended primarily to be protective of general water quality rather than prevent sediment contamination specifically. Thus, the ***SERDP relevance*** is that designs do not exist to assess improvements in stormwater control processes that are needed to be protective of receiving water quality and sediment cleanup.

2 Contaminants of concern in stormwater runoff.

While legacy contaminants such as PAHs and PCBs have been the target of environmental remedial efforts for decades, emerging contaminants of concern, including PFASs, are of significant interest. PAHs and PCBs are hydrophobic and tend to associate with the particulate phase; however, PFASs and many other hydrophilic organics including pesticides and corrosion inhibitors tend to remain in the dissolved phase. These dissolved organic compounds are of

particular interested due to their regulatory relevance (PFASs), known aquatic toxicity (pesticides), and difficulty to remove in traditional stormwater control measures (SCMs).

Trace organic contaminants (TrOCs) have many sources and when analyzed for, have been observed extensively in stormwater (Spahr et al., 2020). For example, pesticides were detected in 97% of urban stream water samples across the United States and exceeded human health and aquatic life benchmarks 6.7% and 83% of the time, respectively (Gilliom, 2006). TrOCs may be generally partitioned into two groups, hydrophobic and hydrophilic TrOCs based on their octanol-water coefficients (K_{ow}). Hydrophilic TrOCs are thought to exist mostly in the dissolved phase while hydrophobic TrOCs are thought to exist primarily in the particulate phase, though evidence suggests that this may not always be so (Wolfand et al., 2019; Zgheib et al., 2011). TrOCs in the particulate phase are easier to remove because their removal may be achieved by particulate settling or filtering, while TrOCs in the dissolved phase need to be removed by other processes. Moreover, little is known about dissolved TrOCs transport and removal in SCMs and the environment (Skutlarek et al., 2006). Thus, TrOCs in the dissolved phase are of particular concern because they are thought to be transported more readily to surface water bodies and groundwater aquifers (Spahr et al., 2020). Dissolved TrOCs are also able to contribute to sediment recontamination for those having larger k_d values.

Common hydrophilic TrOCs include herbicides, pesticides, flame retardants, corrosion inhibitors, and plasticizers. These substances are frequently used in urban settings and have become ubiquitous in stormwater runoff in the urban environment. These compounds have been observed in the ng L^{-1} – µg L^{-1} range in stormwater ponds, creeks, and surface water in Europe and the US (Spahr et al., 2020). Many are known to be toxic to aquatic life, such as fipronil (Lethal Concentration values of 0.14 µg L^{-1} and 0.32 µg L^{-1} for Mysid Shrimp and Grass Shrimp) (Spahr et al., 2020). Understanding the removal of dissolved TrOCs in SCMs is crucial to preventing their transport into the environment.

3 Previous studies indicate black carbon potential for stormwater runoff treatment.

Traditional stormwater management strategies focus on reducing flooding by stream channeling and creating stormwater retention basins to reduce peak runoff flow (Luthy et al., 2020). The state of practice to improve stormwater quality employs SCMs including dry ponds, sand beds, infiltration trenches, grass swales, and bioretention basins to achieve sedimentation, filtration, biodegradation, and infiltration (Center for Watershed Protection. and Maryland. Water Management Division., 2000; Erickson et al.). While these techniques may improve stormwater quality, with bioretention basins showing the most promise, conventional SCMs are largely ineffective at removing dissolved concentrations of metals, organic contaminants, nutrients, and other constituencies in stormwater (Okaikue-Woodi et al., 2020; Spahr et al., 2020). Thus, new approaches at runoff treatment increasingly use engineered media amendments such as carbonaceous and/or reactive media to improve stormwater runoff quality. However, large gaps exist regarding the efficacy of engineered media amendment in SCMs.

Many carbonaceous materials have been researched for SCM amendment including: compost (Faucette et al., 2013; Pritchard et al., 2018; Ulrich et al., 2017), wood chips (Ashoori et al., 2019), straw (Ashoori et al., 2019), biochar (Mohanty and Boehm, 2014; Ulrich et al., 2015; Ulrich et al., 2017), and activated carbon (AC) (Ulrich et al., 2015). Of these materials, only biochar and AC

show promise for continued use in SCMs (Genc-Fuhrman et al., 2007; Ulrich et al., 2015). While compost provides benefit by means of increased microbial degradation of contaminants and some sorption of TrOCs and complexation of metals, compost has been observed to leach nutrients and DOC, potentially compromising stormwater quality (Hurley et al., 2017; Mohanty and Boehm, 2014; Pritchard et al., 2018; Seelsaen et al., 2006). Woodchips are effective for denitrification; however, woodchips do not appear to be effective for removing TrOCs and metals (Ashoori et al., 2019; Okaikue-Woodi et al., 2020; Spahr et al., 2020). Similar to woodchips, straw does not appear to significantly benefit contaminant removal (Ashoori et al., 2019).

Activated carbon (AC), commonly used in drinking water treatment processes due to its high surface area and favorable sorptive properties, has been observed to effectively remove metals and TrOCs from stormwater (Crittenden et al., 2012; Spahr et al., 2020; Ulrich et al., 2015). AC is produced from coal, coconut husks, and peat by pyrolytic carbonization and subsequent activation by steam at 850-1,000°C (Crittenden et al., 2012). Regenerated activated carbon (RAC) is produced by thermal regeneration and reactivation of spent AC. While less expensive than AC, RAC is not nearly as effective at removing contaminants as virgin AC (Crittenden et al., 2012). Biochar is viewed as a favorable SCM amendment due to its similarities to AC, yet lower price (350-1,200 $/metric ton) relative to AC (1,100-1,700 $/metric ton) (Mohanty et al., 2018). Biochar consists of organic material that has undergone pyrolysis or gasification by the thermal decomposition of the volatile compounds of an organic substance when organic material is heated (350-600°C for pyrolysis or 800-1,200°C for gasification) in the absence of oxygen (Roos, 2010). Biochar is desirable because of its high surface area (~300-600 m^2 g^{-1}), though less than that of AC (~900-1,000 m^2 g^{-1}) (Crittenden et al., 2012). Biochar successfully removes TrOCs, metals, and bacteria among other constituents in stormwater, though performance varies significantly by production temperature and feed stock (Angin et al., 2013). Higher-temperature biochars produced from pine wood feed stock exhibit the most favorable TrOCs removal while lower-temperature biochars appear more favorable for metals removal (Ulrich et al., 2015). Biochars remove contaminants by surface complexation and sorption, consisting of charge-assisted hydrogen bonding, π-π interactions, and van der Waals forces (Tong et al., 2019).

While AC and biochar have been shown to be effective amendments for metal and TrOCs removal from stormwater runoff, past studies have been limited in scope. Past studies considered relatively small particle sizes (210-595 μm) and low flow rates (1-6 cm hr^{-1}) similar to natural infiltration rates (Ashoori et al., 2019; Lu and Chen, 2018; Sun et al., 2020; Ulrich et al., 2015; Ulrich et al., 2017). Slow treatment flow rates would result in larger SCM foot prints to hold and treat all of the stormwater runoff. Increased treatment flow rates may reduce the footprint required for SCMs, a significant benefit for sites with low land availability. However, study is required to understand how faster flow rates will affect the kinetics of contaminant removal. A tradeoff between flow rate and removal efficacy is expected: increasing the flow rate will decrease contaminant contact time and necessitate larger media particle size in order to guarantee sufficient hydraulic conductivity, both of which will decrease contaminant removal, leading to faster contaminant breakthrough. Thus, by better understanding the tradeoffs between contaminant removal and flow rate, site managers may be able optimize SCM flowrates to better balance SCM footprint and life span, according to specific site constraints.

While numerous reactive media, including iron-enhanced sand filters, manganese oxide coated sand, and zeolite, have been shown to be effective for contaminant removal within SCMs, their efficacy is limited. Iron-enhanced sand filters successfully remove phosphorus and metals from stormwater; however removal of TrOCs is less effective as removal relies on polar and electrostatic interactions with functional groups on the surfaces of iron oxide (Reddy et al., 2014; Spahr et al., 2020). As a result, iron-enhanced sand filters experience uneven removal of TrOCs, effectively removing some while negligibly removing others (Fairbairn et al., 2018). Manganese oxide coated sands successfully remove metals and some TrOCs from stormwater runoff through adsorption, surface catalysis, and direct oxidation (Charbonnet et al., 2020; Grebel et al., 2016; Remucal and Ginder-Vogel, 2014). While manganese oxides may be regenerated in situ by hypochlorous acid, resulting in similar performance as virgin manganese oxide, their efficacy is greatly reduced in the presence of DOC (Charbonnet et al., 2020). Zeolites, crystalline hydrated aluminosilicates with high surface area, are a naturally occurring mineral formed in basaltic lava (Reddy et al., 2014; Smith, 2011). Zeolites are shown to be effective at removing nutrients, metals, and even some TrOCs (Okaikue-Woodi et al., 2020; Smith, 2011). Zeolite removes contaminants by adsorption, ion exchange, complexation, and electrostatic attraction (Okaikue-Woodi et al., 2020). The Si^{4+} and Al^{3+} in zeolite's structure create a net negative surface charge, resulting in strong attraction of cations and cationic metals while anionic compounds are repelled, leading to poor removal of anionic species (Okaikue-Woodi et al., 2020). Opportunities may exist for increased contaminant removal by pairing reactive media with carbonaceous material amendment to better target different groups of contaminants such as metals and TrOCs. Research is needed to understand these opportunities in the context of stormwater runoff treatment.

Certain black carbons (BCs), such as granular activated carbon (GAC) and biochar, have been shown to remove organic and metal contaminants from stormwater runoff due to high sorption affinities and the potential for enhancing biodegradation of organic contaminants (Chen and Yuan, 2011; Ulrich *et al.,* 2015). BCs such as GAC are also particularly effective for reducing porewater concentrations of PCBs and PAHs in contaminated sediment systems (Choi *et al.,* 2013, Choi *et al.,* 2014, Choi *et al.,* 2016a, Choi *et al.,* 2016b). However, sorption is limited by kinetics in the filters, as these systems are often designed for high infiltration rates to reduce flooding, and thus BC-amended engineered media filters will not generally be at equilibrium (Ulrich *et al.,* 2015).

4 Modeling organic contaminant transport in treatment columns.

Modeling contaminant removal in SCMs is essential for predicting biofilter performance and lifetime. In black-carbon (BC) amended biofilters, sorption is an important mechanism for contaminant removal. Sorption describes the interaction between the sorbate (contaminant) and the sorbent material. Chemisorption describes the chemical bonding of a sorbate to the sorbent by ionic or covalent bonding at the sorbent surface and is typically an irreversible process. Physical sorption describes the casual bonding of a sorbate to the sorbent, typically by van der Waal forces and is a reversible process, and is the predominate mechanism for TrOCs sorption to black-carbon (BC) sorbents.

Sorption models are used to predict contaminant sorption to sorbents in batch and flow-through systems (Ashoori et al., 2019; Trinh et al., 2017; Ulrich et al., 2015; Werner et al., 2012). Sorption is described using isotherms, in which the amount of sorbate that is sorbed to a sorbent is quantified at constant temperature (equation 1) (Crittenden et al., 2012). Common isotherm models used to

describe sorption are linear (equation 2), Langmuir, and Freundlich. The Langmuir isotherm is derived using the assumption that the sorbate only sorbs as a single layer (Crittenden et al., 2012). The Langmuir isotherm equation (equation 3a) and its linear form (equation 3b) are shown below. The Freundlich isotherm was initially developed empirically to describe sorption to heterogenous sorbents, but it is consistent with the thermodynamics of heterogenous sorption and can be derived from the Langmuir equation assuming that the sorbate can form multiple layers around the sorbent (Crittenden et al., 2012). The Freundlich isotherm equation (equation 4a) and its linear form (equation 4b) are shown below:

$$q_e = \frac{V}{M}(C_0 - C_e) \quad (1)$$

$$C_e = K_d q_e \quad (2)$$

$$q_e = \frac{K_L Q_M C_e}{1 + K_L C_e} \quad (3a)$$

$$\frac{C_e}{q_e} = \frac{1}{K_L Q_M} + \frac{C_e}{Q_M} \quad (3b)$$

$$q_e = K_f {C_e}^N \quad (4a)$$

$$N = \frac{1}{n} \quad (4b)$$

$$\log(q_e) = \log(K_f) + \frac{1}{N}\log(C_e) \quad (4c)$$

where q_e is the equilibrium sorbent-phase concentration [mg sorbate g^{-1} sorbent], V is the volume of aqueous phase [L], M is the mass of sorbent [g], C_0 is the initial aqueous-phase sorbate concentration [mg L^{-1}], and C_e is the equilibrium aqueous-phase sorbate concentration [mg L^{-1}], K_d is the equilibrium distribution coefficient[(mg g^{-1})(L mg^{-1})], K_L is the Langmuir sorption coefficient [L mg^{-1}], Q_M is maximum sorbent-phase sorbate concentration [mg g^{-1}], K_f is the Freundlich sorption capacity coefficient [(mg g^{-1})(L mg^{-1})$^{1/n}$], and $1/n$ is the Freundlich sorption intensity parameter.

While Langmuir isotherms are generally used to describe metal sorption to sorbents, as metals generally only sorb to the outer most surfaces of the sorbent typically through complexation and ion exchange, either Freundlich or Langmuir isotherms may be used to describe TrOCs sorption to back carbon. In the case of TrOCs, the sorbate may diffuse through intraparticle pore space the sorbent particle from the exterior to the interior. Thus, TrOCs are often modeled using shell-theory, in which the sorbent particle is divided into shells, to describe the intra-sorbent transport of the sorbate into the sorbent (Werner et al., 2006).

Contaminant transport in a flow-through column may be modeled using the 1-d dispersion-advection equation (equation 5). In the case of TrOCs transport through a column amended with BC, the shell theory may be incorporated by modifying the dispersion-advection equation to incorporate intraparticle diffusion of TrOCs into the interior of the sorbent particle (equation 6a). When discretizing equation 6a, the integral is evaluated from 0 (the outermost shell, i.e. sorbent surface) to the number of shells chosen (to reach the sorbent particle center). Equation 6b shows the partial differential equations for change in contaminant concentration within the column in each shell of the sorbent particle. The apparent diffusivity in pores may be represented by sorption-retarded diffusion and tortuosity, or by sorption and surface spreading (Werner et al., 2006). The following does not consider surface spreading. Equation 6c provides an estimate of the aqueous diffusivity of organic compounds:

$$\frac{\partial C_{aq}}{\partial t} = -u_x \frac{\partial C_{aq}}{\partial x} + E_{disp} \frac{\partial^2 C_{aq}}{\partial x^2} \quad (5)$$

$$\frac{\partial C_{aq}}{\partial t} = -u_x \frac{\partial C_{aq}}{\partial x} + E_{disp} \frac{\partial^2 C_{aq}}{\partial x^2} - \frac{\theta_{bc}}{\theta_{aq}} \frac{d}{dt}\left[3 \int_0^1 y^2 S dy\right] \quad (6a)(\text{Werner et al., 2012})$$

$$\frac{\partial S(r)}{\partial t} = \frac{D_{app}}{R^2} \frac{\partial}{\partial r}\left(r^2, \frac{\partial S(r)}{\partial r}\right) \quad (6b)(\text{Werner et al., 2012})$$

$$D_w = \frac{2.7 \times 10^{-4}}{MW^{0.71}} \quad (6c)(\text{Hayduk and Laudie, 1974})$$

The S and D_{app} take several forms depending on assumptions about the sorption isotherm. Equations 7-10 provide equations to calculate the volumetric sorbate concentration in the sorbent (equation 7) and apparent intraparticle diffusion coefficients assuming a linear isotherm (equation 8), Langmuir isotherm (equation 9), and Freundlich isotherm (equation 10):

$$S(r) = (1 - p_{bc}) d_{bc} S'(r) + p_{bc} C_{aq,bc} \quad (7a)(\text{Wu and Gschwend, 1988})$$

$$D_{app} = \frac{p_{aq}^2}{(1 - p_{aq}) d_s K_d + p_{aq}} D_w \quad (8)(\text{Werner et al., 2006})$$

$$D_{app} = \frac{D_w p_{aq}}{\left((1 - p_{aq}) d_s K_L Q_M \left(\frac{1}{(1 + K_L C_{aq,bc})^2}\right) + p_{aq}\right) \tau} \quad (9)(\text{Ulrich et al., 2015})$$

$$D_{app} = \frac{D_w p_{aq}}{(d_s K_f N C_{aq}^{N-1} + p_{aq}) \tau} \quad (10)(\text{Werner et al., 2012})$$

where C_{aq} is the aqueous sorbate concentration [mg L^{-1}], t is time [s], u_x is the porewater velocity [cm], x is the distance from the column inlet in the flow direction [cm], E_{disp} is the dispersion coefficient [$cm^2 s^{-1}$], θ_{bc} is the volume fraction of the BC grains [-], θ_{aq} is the volumetric water content of the column external to the grains directly measured during a column experiment [-], $y = r * R^{-1}$ where r is the radial distance from the center of the BC grain [cm] and R is the BC grain radius [cm], S is the volumetric concentration of the sorbate in the sorbent [mg L^{-1}] and is comprised of the aqueous sorbate and sorbate sorbed to the sorbent, D_w is the aqueous phase sorbate diffusion coefficient [$cm^2 s^{-1}$], $S'(r)$ is the sorbed concentration of sorbate as a function of r [mg sorbate g^{-1} sorbent], $C_{aq,bc}$ is the intraparticle aqueous sorbate concentration [mg L^{-1}], D_{app} is the apparent intraparticle diffusion coefficient [$cm^2 s^{-1}$], p_{aq} is the volumetric water content inside the grains equal to the intraparticle porosity, K_d is the equilibrium distribution coefficient[(mg g^{-1})(L $mg)^{-1}$], d_s is the solid density of the BC grain [g cm^{-3}], K_f is the Freundlich sorption capacity coefficient [(mg g^{-1})(L $mg^{-1})^{1/n}$], $1/n$ is the Freundlich sorption intensity parameter, and τ is the intraparticle tortuosity [-].

V. Materials and Methods

Summary of analytical methods.

All compounds are analyzed following EPA Methods or other peer-reviewed analytical methods. Gas chromatography (GC) compounds, including PCBs, PAHs, munition compounds, and pyrethroids, are extracted (EPA Method 3550B) and samples are cleaned (EPA Method 3630C) before analysis. PAHs are analyzed using gas chromatography with mass spectrometry (GC-MS) (Choi et al., 2013) and the remaining GC compounds are analyzed using gas chromatography with electron capture detection (GC-ECD) (EPA Method 8082). Liquid chromatography (LC) compounds are analyzed using liquid chromatography tandem-mass spectrometry (LC-MS/MS) with electrospray ionization in both positive and negative modes (Ashoori et al., 2019). Metals are analyzed using ICP-MS (EPA Method 3015).

PFASs are measured on a SCIEX X500R quadrupole time-of-flight mass spectrometer (QTOF-MS) system using electrospray ionization in both positive and negative modes with SWATH® Data-Independent Acquisition for both TOFMS and MS/MS mode. Water sample preparation is consistent with that used in Murray et al. (2019), and soil sample extraction methods are detailed in Nickerson et al. (2020).

Nutrients are measured with WestCo SmartChem 200 discrete analyzer and colorimetrically using Hach TNTPlus™ Chemistries and a Hach spectrophotometer. Chemistries used are TNT830 for ammonia (EPA Methods 350.1, 351.1, 351.2 equivalent), TNT830 for nitrate (40 CFR 141/136 approved), and TNT843 for total and reactive phosphorus (EPA methods 365.1, 365.3 equivalent). Dissolved oxygen (DO), pH, total dissolved solids (TDS), and temperature are measured with a portable Ultrameter II 6P (Myron L Company, Carlsbad, USA) and YSI ProODO probes (YSI Inc., Yellow Springs, Ohio). DOC is analyzed after filtration (0.45 µm PES) using Shimadzu TOC-VCSH.

Summary of analytical quality assurance/quality control.

Analysis of all of the contaminants of interest contain quality control measures and samples. Quality assurance and quality control (QA/QC) for sample analysis consist of at least one reagent water (i.e., MilliQ deionized water) blank, one duplicate sample, and one matrix recovery sample spiked at an environmentally relevant concentration (typically 1-100 ng/L) with a mixture of all target analytes per 10-15 test samples. Deionized (DI) water blanks, which will be used to assess potential sample contamination, must indicate that no sample contamination has occurred above the limit of quantitation. Duplicate samples, which are used to assess method reproducibility, must always agree within 15%. Recovery in matrix-spiked samples must indicate that the method is reproducible and robust in all environmental matrices, and analyte recoveries must range from 75-125%. Samples that fail QA/QC protocols will initiate a thorough review of analytical procedures to determine the specific methods and techniques that need alteration or improvement. After attempts are made to restore method performance to meet QA/QC criteria, field samples that failed QA/QC will be reanalyzed if possible. If reanalysis is not possible, the data will be flagged and reported as “Failed QA/QC”.

PFAS QA/QC is detailed in the Colorado School of Mines Standard Operating Procedures for Poly- and Perfluoroalkyl Substance (PFAS) Analysis Version 3.0. Quality assurance samples are included during sample preparation. For each sample batch a method blank, matrix spike, laboratory control sample (LCS), and laboratory control sample duplicate (LCS Duplicate) are included. A sample batch is defined as a group of 20 samples or less that are processed at the same time. Method blanks (internal standard added) consist of HPLC-grade Optima® Water. The LCS and LCS Duplicate are also prepared by spiking the water with a known concentration of standards. The sample should be spiked so that the final concentration of PFASs is greater than the limit of quantification of all PFASs, but also falls below the midpoint of the calibration curve. A matrix spike is prepared by adding PFASs to a sample included in the batch. The method blank, matrix spike, LCS, and LCS Duplicate are then treated as samples and undergo the entire extraction procedure, including cleanup steps.

The method blank allows researchers to check for contamination that occurred during the sample preparation process. The LCS will be used as a check that analytes were not lost during the preparation process (recoveries 70-130%). The LCS Duplicate will be used to check batch precision (within 30%). The matrix spike acceptable recoveries are 70-130%.

For ESI- PFAS analysis, all samples, including all QC, are spiked with internal standards and M2PFOA is used as an injection standard in all samples to check for instrumental consistency. All concentrations in all field samples and QC samples are corrected for internal standard recoveries. Analytes with internal standard or injection standard recoveries outside of 50-150% are flagged. For each sample run on the LC-MS analysis, a series of quality assurance samples are prepared and run in addition to the samples and calibration points. Blanks are included in the analysis to check for instrumental contamination. The instrument blanks and double blanks (all reagents without IS) are prepared directly in autosampler vials at the same percent composition water, methanol, basic water, isopropanol, and 2,2,2-trifluoroethanol as samples. At a minimum, a trio of one continuing calibration verification (CCV) sample, one double blank, and one instrument blank are prepared and analyzed after every 10 aqueous samples in the aforementioned order. Each run is preceded with a double blank and an instrument blank is analyzed after the highest calibration point (e.g., 10,000 ng L^{-1}) to ensure that concentrations are <½ lowest LOQ). If significant contamination is evident (> prior LOQs), corrective actions will be taken to reduce blank signal.

CCV samples ensure all compounds remain within ±30% of known concentrations to monitor for instrumental drift. A CCV is run after the calibration curve and prior to sample analysis. CCV samples are also prepared directly in autosampler vials. These consist of all target analytes at a concentration in the mid-range of the calibration curve and all internal standards at the same concentration as in the calibration curve, with the same percent composition as samples and blanks. All prepared blanks, double blanks, and CCV samples are kept refrigerated until analysis. A CCV sample is analyzed, at a minimum, after every 10 samples to ensure all compounds remain within 70-130% of known concentrations. If the CCV sample does not meet the required parameters in injections, the bracket of samples analyzed before CCV failure and after the failed CCV up until the next passing CCV are rerun. Concentrations detected in instrument blanks raise the reporting limit (RL) for that run if they are greater than <½ LOQ. If the blanks are all <½ LOQ, the RL will be set as the LOQ. Otherwise, the RL will be set to 3 times the highest blank concentration.

1 Assessment of engineered media filters for removal of contaminants from stormwater runoff (Task 2).

1.1 Develop novel and representative lab-based synthetic stormwater using soils and sediments from DoD facilities (Subtask 2.1).

The goal of subtask 2.1 was to create synthetic stormwater runoff in the lab that is representative of stormwater in the field, consistent, and reproducible between experiments. This project improves upon past procedures (Grebel et al., 2013) for creating synthetic stormwater by using catch basin material from a DoD facility to provide a background matrix of ions, dissolved organic carbon (DOC), and microbial community. Material from Naval Weapons Station Seal Beach, CA (NWSSB) and Peterson Space Force Base, CO (PSFB, Figure 5) were evaluated and catch basin material from NWSSB was selected for use in the long-term tests based on material availability, contaminant content, and DOC leaching. Materials were screened for PFAS, parent polycyclic aromatic hydrocarbons (pPAHs), and metals (Cu, Cd, Ni, Pb, Zn) content. In addition, leaching tests found the amount of metals, DOC, and nutrients released by the material into deionized (DI) water.

Figure 5 Maps of collection sites for test sediment: Peterson Space Force Base, CO (left); Naval Weapons Station Seal Beach, CA; and Breitburn Oil Field, CA (right).

Initial testing of the DoD site materials was conducted by extracting contaminants from dried material. Material was first screened to remove particles larger than 3 mm, and then subsequently sieved to form coarse (>0.420 mm) and fine (<0.420 mm) fractions. Material was dried at 80°C for 48 hours. Samples were analyzed in triplicate and averages and standard deviations are reported for all cases except for PFAS samples, for which only the averages have been reported. Also, catch-basin material was added to deionized water and the aqueous equilibrium concentrations of metals, DOC, total nitrogen (TN), and nutrients were analyzed. Testing of the aqueous concentrations of contaminants leaching from catch-basin material added to DI water was achieved by adding 40 g dry sieved-material into 2 L synthetic stormwater and allowed to mix for 48 hours. Aqueous samples were then filtered with 0.45 µm PES syringe filters.

After selecting NWSSB catch-basin material for the development of the synthetic stormwater, stormwater samples were collected from NWSSB on March 12, 2020 to compare to the synthetic stormwater generated in the laboratory.

Catch basin material was collected from stormwater drains from parking lots near a wash station and wharf area and screened with 3 mm mesh to remove debris and trash (Figure 1). Catch basin material and salts were mixed into deionized (DI) water to create a base synthetic stormwater. Suspended solids were removed from the synthetic stormwater using a sedimentation tank with a hydraulic residence time of 5.1 hours, as is typical of pre-treatment systems used in many SCMs. Additional DOC concentrate derived from straw was added to the synthetic stormwater to reach an environmentally relevant DOC concentration. The DOC concentrate was created by soaking straw (construction site straw wattle, Home Depot, CA) in DI water for 3 days, filtering with a 400 mesh sieve (38 μm), autoclaving, and freezing at -20°C until use. Straw was chosen because it is known to release high amounts of DOC and was found in the catch basin material received from NWSSB.

1.2 Select filter engineered media (Subtask 2.2).

Biochars were initially screened according to TrOC sorption performance from Ulrich *et al.*, (2015) and large-scale commercial availability of the biochar. Batch tests were then conducted for final material selection based on metal and PFAS sorption to the two most promising biochars, two regenerated activated carbons, zeolite, and sand. Samples from Biochar Supreme (WA) and Biochar Now (CO) were obtained and tested. Biochar Supreme offers two environmental biochar products, Environmental Ultra and a proprietary Stormwater Mix. Environmental Ultra is the plain biochar and is available either pre-wetted or dry: we chose the dry biochar to better control the dry mass added. Two regenerated activated carbons—one from Calgon Carbon (DSR A 8x40) and one from Cabot Corporation (Norit GAC 830R M-2384)—were also obtained. Zeolite provided by BioGreen Technologies was recommended by our partner environmental consultant at Geosyntec Inc. Sand (#2/12 Lapis Lustre) was obtained from Cemex. All materials were obtained dry and sieved to a size range mesh size 12-18 (grain size diameter 1.68-1.00 mm) for the filter amendment screening batch tests.

Metal sorption batch tests were conducted by adding sorbent (75 mg of zeolite, Biochar Now, Biochar Supreme, Calgon RAC, Cabot RAC; 300 mg sand) to 45 mL of modified synthetic stormwater with metals at an initial concentration of 100 μg/L in 50 mL polypropylene centrifuge tubes. The modified synthetic stormwater comprised a pH of 7.0-7.2 and background ionic matrix but did not contain any catch-basin material or DOC. Sorbents were soaked for 48 hours prior to metal addition. Batch reactors were placed on shaking racks and sampled periodically over the course of six days.

PFAS batch sorption tests were conducted in 50 mL polypropylene centrifuge tubes. After purging with CO_2 to minimize bubbles, each sorbent was added in quantities ranging from 2 mg to 100 mg sorbent and allowed to equilibrate with the CO_2 for at least 15 minutes. 45 mL of modified synthetic stormwater was added to each, and sorbent was allowed to soak in synthetic stormwater for 48 hours before spiking with dilute AFFF in methyl tert-butyl ether. After two days of shaking and three days of settling, the samples were subsampled for analysis.

1.3 Evaluate various engineered media mixtures using downflow column experiment (Subtask 2.3).

The object of the column experiments is to determine the impact of different engineered media configurations and flow rates on contaminant removal. Therefore, six different configurations in triplicate were selected: sand, sand + zeolite, sand + RAC, sand + biochar, sand + zeolite + RAC, and sand + zeolite + biochar. Figure 6 is a diagram of the experimental setup. Sand with biochar or RAC was tested in triplicate and employed low weight percent sorbents, 2.4 wt% biochar and 3.3 wt% RAC, in order to observe transport of TrOCs during the experiment (Table 2). Engineered media mixtures consisting of sand amended with zeolite (30 v%), biochar (30 v%), and regenerated activated carbon (10 v%) were tested in triplicate. Columns (1.22 m length, 7.6 cm inner diameter) were constructed of clear PVC with a sufficient size ratio (column diameter to maximum grain diameter) to ensure proper fluid hydraulics 32. Pre-measured masses of engineered media were mixed dry by hand. The columns were filled with 10 cm of barrier sand followed by 60 cm of engineered media followed by 6 cm of barrier sand on top. A mechanical massager was used to ensure adequate packing of the material and column, and ~4 cm lifts of material were massed to ensure proper distribution of engineered media amendments vertically in the column. The columns were then saturated in an up-flow configuration with carbon dioxide gas for 1 hour at a flow rate of 2 L min^{-1} and then with DI water at a flow rate of 3.4 mL min^{-1}. Carbon dioxide gas was used to displace the air inside the column and grains because it dissolves readily in water. The columns were then flushed with DI water in the downflow configuration and outlet controls were used to control the flow rate of 20 cm hr^{-1} (15.2 mL min^{-1}). Tracer tests were conducted using bromide as a conservative tracer (Figure 52); the porosity was determined gravimetrically. During the tracer test, the water level in the columns was reduced to the top of the barrier sand to prevent initial dilution of the tracer. The columns were then conditioned with synthetic stormwater for 100 empty bed volumes (EBVs). Finally, the columns were challenge-tested with synthetic stormwater spiked with contaminants for about 480 EBVs. Constant head (~39 cm) was maintained in the columns by continuous overflow of water back to the spike tank, as shown in Figure 6.

During the conditioning and challenge tests, synthetic stormwater and contaminant stock solutions were prepared every 2-3 days. Synthetic stormwater was made periodically and DOC, total nitrogen, and other water quality parameters were measured periodically to ensure consistent quality over the course of the experiment. Contaminants were spiked at various concentrations, as shown in Figure 1, to ensure adequate detection within 2 orders of magnitude change in concentration. Following the challenge tests, the columns were flushed with ~40 EBVs of synthetic stormwater. The flow rate of each column was checked daily and adjusted to maintain the target flow rate. Every 6-8 days, tubing, tanks, and the barrier sand on top of the columns were cleaned to remove biological growth. The hydraulic conductivity was monitored throughout the experiment using manometers attached to the 25% and 75% sample ports (Figure 54). Detailed system information is shown in the supplemental information.

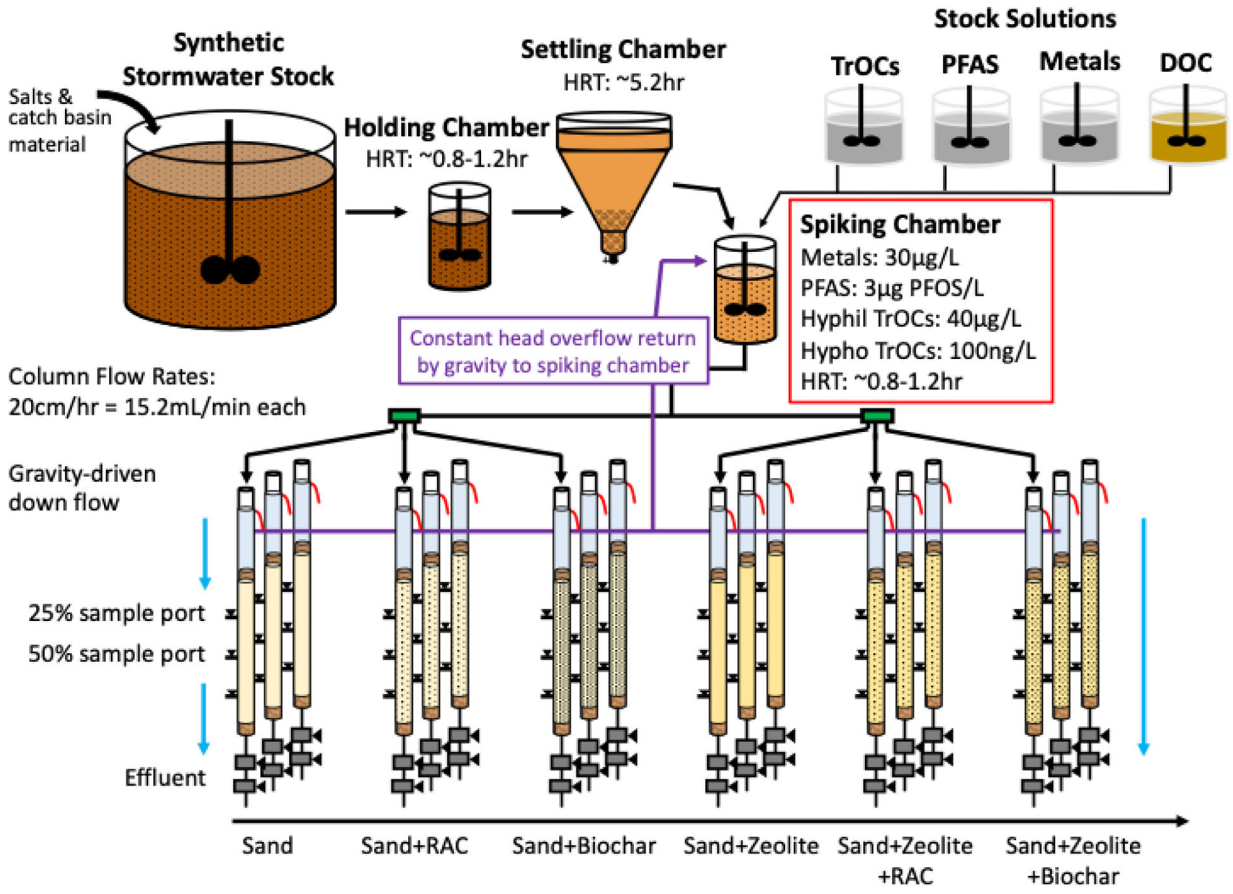

Figure 6 Diagram of experimental setup showing the stormwater generation, contaminant spiking, and treatment columns. Constant head was maintained in the columns by continuous overflow back to the spiking chamber. System details may be found in Table 30 and Figure 51.

2 Development of filter performance curves with kinetic and flow rate design parameters (Task 3).

2.1 Evaluate engineered media filters at higher flow rates (Subtask 3.1).

2.1.1 Column Experiments

The column experimental setup was based on the previous column experiment as described in detail in Task 2. Briefly, 1.22 m by 7.6 cm clear PVC columns were used to ensure a sufficient ratio of column radius-to-filter media grain radius to ensure proper fluid hydrodynamics (Gibert et al., 2014). Columns were dry packed by adding 10 cm of barrier sand at the bottom, then adding 60 cm of engineered media, and 10 cm of barrier sand at the top. The engineered media was placed in 200 mL lifts that were massed to ensure a consisted distribution of material along the length of the column. The media comprised mixtures of sand, biochar (30 v%, 2.4 wt%), and RAC (10 v%, 3.3 wt%). During the packing, the column was periodically vibrated to ensure sufficient material settling and packing. Columns were saturated in up-flow configuration first with carbon dioxide for 1 hour at a flow rate of 2 L min^{-1} and then with deionized water for 8 hours at a flow rate of 3.4 mL min^{-1}. Columns were then flushed with deionized water in downflow configuration for 36

hours, and the downflow configuration was used for the remainder of the tests. Constant head (~39 cm) was maintained in the columns by continuously overflowing untreated-synthetic storm water from the columns back to the spike chamber and flow rates were adjusted using outlet controls consisting of a globe valve and needle valve. Tracer tests with a 15 second (40 cm hr^{-1}) or 10 second (60 cm hr^{-1}) pulse of bromide as a conservative tracer were conducted to calculate dispersivity and ensure proper flow patterns. Column porosity was determined gravimetrically. During the tracer test, the water level in the columns was reduced to the top of the barrier sand to prevent initial dilution of the tracer. Columns were then conditioned with 100 empty bed volumes (EBVs) of synthetic stormwater. Columns were then challenge tested for 500 EBVs with synthetic stormwater with additional contaminants spiked to assess contaminant removal and transport. Experiments were conducted initially at a flow rate of 40 cm hr^{-1} (30.4 mL min^{-1}) and then repeated at a flow rate of 60 cm hr^{-1} (45.6 mL min^{-1}) with columns repacked with fresh material.

During the conditioning and challenge tests, synthetic stormwater was prepared every day and contaminant and DOC concentrate stock solutions were prepared every 1-3 days. Contaminants were spiked at various concentrations, as shown in Figure 7, to ensure adequate detection within two orders of magnitude. The flow rate for each column was checked gravimetrically and adjusted periodically using needle valves to finely tune the flow rate.

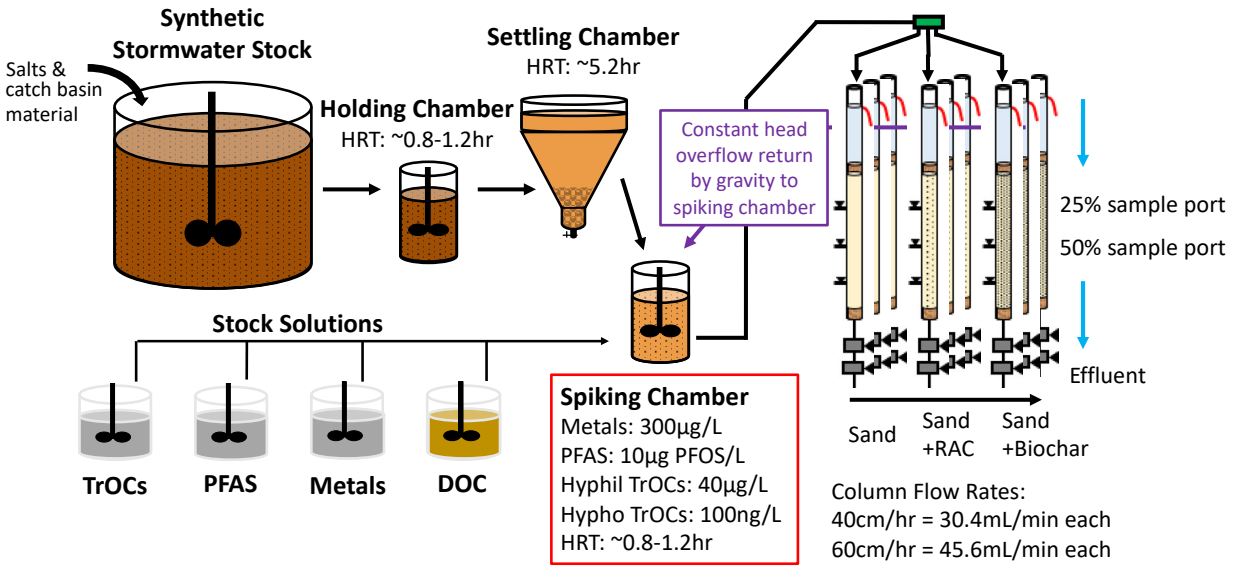

Figure 7 Diagram of column setup showing the synthetic stormwater generation, contaminant and DOC spiking, and treatment columns configured in downflow with constant head maintained by continuous overflow back to the spike tank.

2.1.2 Batch Isotherm Experiments

Batch isotherms were conducted to elucidate Freundlich sorption parameters of the hydrophilic TrOCs for the biochar and RAC. Experiments were conducted by adding increasing amounts of biochar (10 mg L^{-1} to 250 mg L^{-1}), RAC (10 mg L^{-1} to 380 mg L^{-1}), and sodium azide (200 mg L^{-1}) to 1L amber jars. Sodium azide was used to inhibit biological growth, as commonly been used in the past (Ulrich et al., 2015). Synthetic stormwater with 9.5±0.7 mg C L^{-1} DOC was then added and the jars were spiked with all the contaminants together. The samples were placed onto a

horizontal shaker for 90 days. Initial contaminant concentrations were increased by a factor of 2.5 from levels used in the column experiment to 100 µg L^{-1} hyphil-TrOCs, 250 ng L^{-1} hypho-TrOCs, 900 µg L^{-1} metals, 24 µg PFOS L^{-1} PFAS to increase the range of detection, as was necessary due to the large range in contaminant sorption properties. Synthetic stormwater was generated with the same recipe as used in the column experiments, with a background level of DOC as was used in the column experiment.

2.2 Develop, fit, and validate model to predict contaminant transport in engineered media filters (Subtask 3.2).

Hyphil-TrOCs and PFAS contaminant transport were modeled using a 1-dimensional advection-dispersion model with retardation due to intraparticle pore diffusion-limited sorption (equation 1). The contaminant transport model is based on models used in previous studies to describe organic contaminant transport in carbon-amended columns (Ashoori et al., 2019; Ulrich et al., 2015; Werner et al., 2006) and is briefly described here. The change in aqueous contaminant concentration, C_{aq} [mol L^{-1}] with respect to time t [s], is a function of advective transport, dispersion, and retardation due to intraparticle pore diffusion-limited sorption:

$$\frac{\partial C_{aq}}{\partial t} = -u_x \frac{\partial C_{aq}}{\partial x} + E_{disp} \frac{\partial^2 C_{aq}}{\partial x^2} - \frac{\theta_{bc}}{\theta_{aq}} \frac{d}{dt}\left[3 \int_0^1 y^2 S dy\right] \qquad (1)\ \text{(Werner et al., 2012)}$$

where u_x is the porewater velocity [cm s^{-1}], x is the distance from the column inlet in the flow direction [cm], E_{disp} is the dispersion coefficient [cm^2 s^{-1}], θ_{bc} is the volume fraction of the BC grains [-], θ_{aq} is the volumetric water content of the column external to the grains directly measured during a column experiment [-], $y = r * R^{-1}$ where r is the radial distance from the center of the BC grain [cm] and R is the BC grain radius [cm], and S is the volumetric concentration of the sorbate in the sorbent [mg L^{-1}] and is comprised of the aqueous sorbate and sorbate sorbed to the sorbent:

$$S(r) = (1 - p_{bc}) d_{bc} S'(r) + p_{bc} C_{aq,bc} \qquad (2)\ \text{(Wu and Gschwend, 1988)}$$

where p_{aq} is the volumetric water content inside the grains (equal to the intraparticle porosity) [-], d_{bc} is the solid density of the BC grain [g cm^{-3}], $S'(r)$ is the sorbed concentration of sorbate as a function of r [mg sorbate g^{-1} sorbent], and $C_{aq,bc}$ is the intraparticle aqueous sorbate concentration [mg L^{-1}]. The change in S with respect to time is described as:

$$\frac{\partial S(r)}{\partial t} = \frac{D_{app}}{R^2} \frac{\partial}{\partial r}\left(r^2, \frac{\partial S(r)}{\partial r}\right) \qquad (3)\ \text{(Werner et al., 2012)}$$

where D_{app} is the apparent intraparticle pore diffusion coefficient [cm^2 s^{-1}]. D_{app} may be expressed in different forms depending on how sorption is described. The Freundlich isotherm model is used here to describe sorption as it is commonly used to describe sorption of organic compounds onto black carbon and assumes the sorbate can form multiple layers around a heterogenous sorbent:

$$q_e = K_f {C_e}^N; \quad N = \frac{1}{n} \qquad (4)\ \text{(Crittenden et al., 2012)}$$

$$D_{app} = \frac{D_w p_{aq}}{(d_s K_f N C_{aq}^{N-1} + p_{aq})\tau} \quad (5)$$ (Werner et al., 2012)

where q_e is the equilibrium sorbent-phase concentration [mg sorbate/g sorbent], C_e is the equilibrium aqueous-phase sorbate concentration [mg L^{-1}], K_f is the Freundlich sorption capacity coefficient [(mg g^{-1})(L mg^{-1})$^{1/n}$], $1/n$ is the Freundlich sorption intensity parameter [-], and τ is the tortuosity factor [-], which is a factor of the material tortuosity and intraparticle diffusion hindrance. Additional equations and information about the model are shown in the SI.
The transport model was enhanced to incorporate real-time influent concentration and flow rate data rather than assuming constant flow rate and influent concentration. This accounted for experimental variations in influent concentration and flow rate resulting from the presence of suspended catch basin material in the gravity-driven downflow column configuration and use of outlet controls to manage the flow rate over the three-month duration of the column experiment. This modification allows for the modeling of non-continuous time-dependent flow and influent contaminant concentration conditions.

The model was fit to the observed transport data by finding optimal solute Freundlich sorption parameters (K_f, $^1/_n$) and tortuosity factors (τ) that minimized the normalized mean squared error of the difference between model prediction and observed values greater than the limit of quantification. The normalized mean squared error is calculated as:

$$NMSE = \frac{1}{j}\sum_{i=1}^{j} \frac{(y_{i,pred} - y_{i,obs})^2}{y_{i,pred} * y_{i,obs}} \quad (6)$$

where j is the total number of observations, $y_{i,pred}$ is the predicted concentration, and $y_{i,obs}$ is the observed concentration. NMSE is used to avoid bias in the fitting that favors larger absolute residuals relative to smaller absolute residuals that may have similar relative difference. This particular form of NMSE is normalized by multiplying the $y_{i,pred}$ and $y_{i,obs}$ to avoid bias towards underpredicting breakthrough, as normalizing the difference of $y_{i,pred}$ and $y_{i,obs}$ by $y_{i,obs}$ inflates error resulting from the case in which the $y_{i,obs} > y_{i,pred}$ relative to cases when $y_{i,obs} < y_{i,pred}$. The MatLab (MathWorks, Natick, MA, USA) fminsearch solver was used to perform the multi-parameter optimizations and the fminbnd solver was used to perform the single-parameter optimizations. Fminsearch is a nonlinear programming solver that finds the local minimum of a multi-variable function using the Nelder-Mead simplex algorithm (Lagarias et al., 1998). Fminbnd is a single variable minimizer that find the minimum output for a function for which the input variable is bounded by a minimum and maximum value.

2.3 Develop filter performance curves to estimate filter longevity under specific site and filter conditions (Subtask 3.3).

BC amended engineered media filter performance tables are constructed using the contaminant transport model to elucidate the practical implications of the effect off flow rate and other site and design parameters on TrOCs removal. Specifically, the filter parameters that may affect contaminant removal are identified. Next, realistic ranges of values are specified to create a defined universe of modeling input parameters. The contaminant transport model is then used to estimate performance for each combination of parameters, and these outputs are then organized into tables and are featured in the Microsoft Excel-based SCM Treatment Engineered Media Performance

and Sizing Tool (TEMPEST). This tool is being developed with Geosyntec Consultants Inc. and will be publicly available for download and use.

3 Assess efficacy of saturated/unsaturated filters to remove metal and organic contaminants from periodic storm events using black carbon-amended engineered media filters (Modified Task 4).

3.1 Periodic wetting/drying impact on engineered media filter performance (Subtask 4.1).

The column experimental setup is shown below in Figure 8 and was based partially on the previous column experiments described in Task 2. A mixture of zeolite (30% by volume), high-temperature gasification biochar (30% by volume), and silica concrete sand (40% by volume) was mixed by a local sand supplier and delivered to a site at Colorado School of Mines for use in a full-scale bioretention system, where it was field-aged for six months before a representative sample was taken for use in column experiments. Clear PVC columns (90 cm length, 7.2 cm diameter) of a sufficient size ratio to ensure proper fluid hydraulics were capped at the bottom with PVC endcaps and PVC reducing adapters connected to PTFE tubing, then filled with 5 cm coarse silica barrier sand, followed by 15 cm of engineered media mixture, followed by 5 cm silica barrier sand. During the challenge phase, barrier sand was removed and cleaned as needed to maintain sufficient flow. The effects of constantly saturated or constantly unsaturated treatment conditions were evaluated using hydraulic controls on three replicate columns for each condition. Constantly saturated conditions were maintained through the use of outlet controls by fixing the outflow tubing 10 cm above the top of the barrier sand, creating a 35 cm head. The three constantly unsaturated columns were allowed to drain freely by gravity, and inlet controls were employed to maintain unsaturated conditions. The empty bed volume in each column (calculated as total volume of engineered media, not including barrier sand) was 0.68 L.

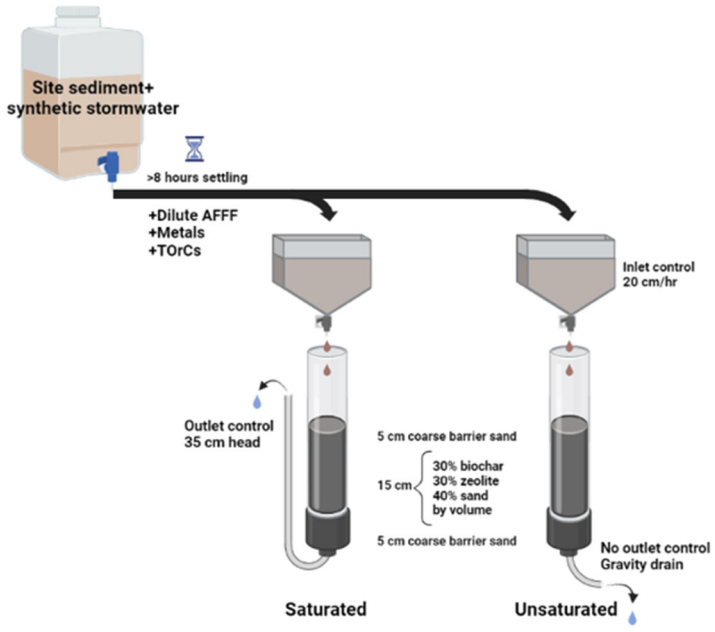

Figure 8 Diagram of the experimental setup showing the synthetic stormwater generation and treatment configuration columns. Note that the mixtures were tested in triplicate and that U-shaped tubing ensured saturation of the "saturated" columns.

Synthetic stormwater was generated in 20 L HDPE carboys by mixing catch-basin site sediment from NWSSB at 3 g L^{-1} with straw-derived DOC concentrate and salts (as in Task 2), shaken vigorously, then allowed to settle at least 8 hours. The settled stormwater was then decanted into two more 20 L HDPE carboys for fortification with various contaminants (ECF-derived PFASs in dilute AFFF, at 4 µg as PFOS L^{-1}; hyphil-TrOCs at 40 µg L^{-1} and HOCs at 100 ng L^{-1}; and metals at 300 µg L^{-1}) and then introduced into individual high-density polyethylene cone bottom tanks (2.5 gallons) fit with a ¼ inch inner-diameter on/off ball valve and a ¼ inch inner-diameter precision flow-adjustment valve, connected to PTFE tubing. Flow into the columns was maintained at approximately 20 cm hr^{-1}, though flow into the unsaturated columns was adjusted to ensure maintenance of the unsaturated conditions.

Columns were conditioned with clean synthetic stormwater (stormwater prepared with DOC and site sediment, but without additional contaminants) for 100 EBV (17 instances of 4 L $column^{-1}$ over six weeks), with one to two antecedent dry days between events. Saturated-condition columns were kept saturated during these events, while unsaturated columns drained freely during this conditioning. The challenge phase consisted of 24 individual 4 L "storm events" per column sized to a 95th percentile design storm at NWSSB (https://dpw.lacounty.gov/wrd/hydrologygis/), or 0.7 inches; the filter area was assumed as 2% of a hypothetical catchment area. Each storm event was dosed into the columns three times a week for eight weeks, with one to two antecedent dry days between each simulated storm.

One composite sample was taken per storm event at 1 hour intervals, with 6 mL sample taken for PFASs in a pre-weighed 15 mL polypropylene centrifuge tube, 10 mL sample for metals in a 15 mL polypropylene centrifuge tube, 5-15 mL sample for TrOCs in a 20 mL glass scintillation vial. After the challenge phase was complete, a bromide tracer test was conducted with 2L clean synthetic stormwater per column. Each column was then cored with a 1.25 inch vinyl core to preserve soil contaminant content while a flush event was conducted to determine the effect of inadvertent column saturation in field applications (i.e., a simulated failure of the inlet controls). During the flush event, the head in the unsaturated columns was raised to 35 cm to saturate the media equivalently to the saturated columns, and columns were dosed with a double storm event volume (8 L). Three composite samples were taken throughout the event.

4 Long-term performance modeling of BC-amended biofilters for breakthrough based on different design criteria (Task 5).

4.1 Assess impacts of dynamic flow, contaminant loading, DOC on engineered media filter performance (Subtask 5.1).

4.1.1 Column Experiments

The column experimental setup was based on previous experiments as described in detail in Task 2 and Task 3. Briefly, 1.22 m x 7.6 cm clear PVC columns were used to ensure a sufficient ratio of column radius-to-filter media grain radius to obtain proper fluid hydrodynamics. Columns were dry packed by first adding 10 cm of barrier sand at the bottom, then adding 60 cm of engineered media, and 10 cm of barrier sand at the top. Engineered media, delivered in 200 mL lifts that were massed to achieve a consistent distribution of material along the length of the column, comprised a mixture of sand and biochar (15 v%, 1 wt%). The relatively low fraction of biochar was chosen

in order to observe responses to contaminant loading and flow rates. Columns were saturated in up-flow configuration first with carbon dioxide for 1 hour at a flow rate of 2 L min^{-1} and then with deionized water for 8 hours at a flow rate of 3.4 mL min^{-1}. Columns were then flushed with deionized water in downflow configuration for 36 hours, and the downflow configuration was used for the remainder of the tests. Constant head (~39 cm) was maintained in the columns by continuously overflowing untreated-synthetic water from the columns back to the spike chamber and flow rates were adjusted using outlet controls consisting of a globe valve and needle valve. Tracer tests, conducted at a flow rate of 60 cm hr^{-1} and using a 10 s pulse of bromide as a conservative tracer, were conducted to calculate dispersivity and ensure proper flow patterns. Column porosity was determined gravimetrically. During the tracer test, the water level in the columns was reduced to the top of the barrier sand to prevent initial dilution of the tracer. Columns were then conditioned with 100 empty bed volumes (EBVs) of synthetic stormwater.

Columns were then challenge tested using synthetic stormwater spiked with additional contaminants to assess contaminant removal and transport. Experiments were conducted also to assess dynamic flow conditions, dynamic influent contaminant loading conditions, and various DOC loading conditions. For the dynamic flow experiment, columns were operated at a flow rate of 60 cm hr^{-1} for five days, 20 cm hr^{-1} for five days, and 120 cm hr^{-1} for three days with normal influent contaminant loading. For the dynamic influent contaminant loading experiment, columns were operated at 60 cm hr^{-1} with normal influent contaminant loading for five days, one-fourth the influent contaminant loading for five days, and two times the influent contaminant loading for two days. For the DOC experiment, two sets of triplicate columns were operated at a flow rate of 60 cm hr^{-1} with normal influent contaminant loading conditions for five days and low DOC conditions and high DOC conditions. Columns operated at high DOC conditions were operated for an additional two days at low DOC conditions immediately after the period of high DOC.

During the conditioning and challenge tests, synthetic stormwater was prepared every day and other contaminant and DOC concentrate stock solutions were prepared every 1-3 days. Contaminants were spiked at various concentrations, as shown in Figure 9, to ensure adequate detection within 2 orders of magnitude. The flow rate for each column was checked gravimetrically and adjusted periodically using needle valves to finely tune the flow rate.

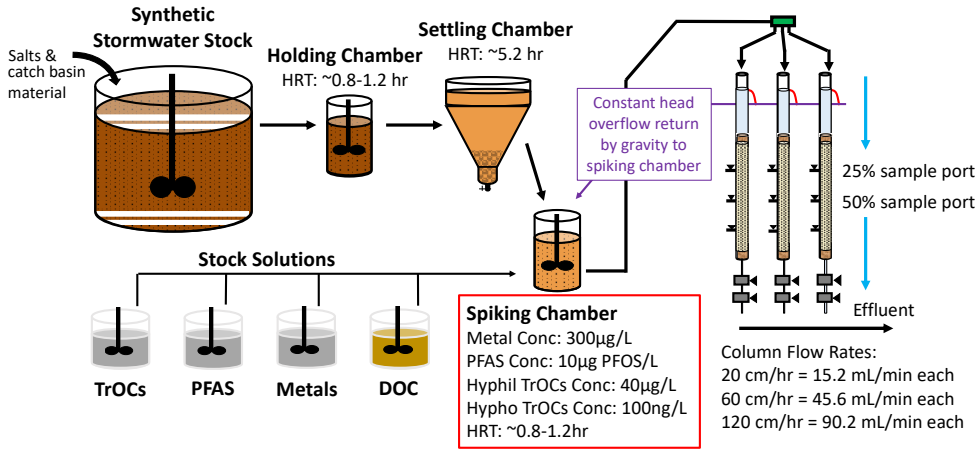

Figure 9 Schematic of the experimental setup showing the synthetic stormwater mixing and settling, contaminant spiking, and downflow column configuration with constant head overflow back to the spiking chamber.

4.1.2 Batch Isotherm Experiments

Batch isotherms were conducted at low DOC (10.5±1.8 mg C L^{-1}) and high DOC (16.2±2.1 mg C L^{-1}) levels using similar methods as described previously in Task 3. Briefly, 1 L glass amber jars were filled with 800 mL synthetic stormwater and autoclaved. Sodium azide (200 mg L^{-1}) and varying masses of BC (10 mg – 550 mg) were added and allowed to soak overnight. Finally, the full suite of contaminants was added and the jars were placed on a shaker table for 88 days after which the jars were removed and sampled. The DOC in the synthetic stormwater used for the batch tests was manipulated through the volume of straw tea-derived DOC concentrate addition. Additional details may be found in the appendix.

4.2 Conduct case study simulations for engineered media filters at a representative field site (NWSSB) (Subtask 5.2).

The intraparticle pore diffusion model and fitting parameters were used to estimate long-term performance for a hypothetical unit filter located in Seal Beach, CA, from where the catch basin material used in the synthetic stormwater was obtained. Long-term performance modeling was conducted using the contaminant transport model trained to the observed contaminant transport at the 25% sample port and validated using the observed transport at the column 50% sample port and effluent. The leading breakthrough contaminant of the six hyphil-TrOCs studied (atrazine, benzotriazole, diuron, fipronil, imidacloprid, mecoprop) and two PFASs (PFOS and PFOA) is identified based on typical site and stormwater parameters and available aquatic health benchmarks set by the US EPA (US EPA) and California Drinking Water Standards. Conservative design assumptions were made to size the filter. Specifically, the filter was assumed to treat 100% of the precipitation that fell in a unit catchment with the surface area of the filter set to 1% of the catchment area. The flow rate was set to 20 cm hr^{-1} with the filter BC content similar to what was tested in the column experiments, and the average annual precipitation (11.52 inches) over the last 124 years (1895-2019) was assumed. Tables were constructed to show the estimated filter lifetime in years using both biochar and RAC for filters of various depths.

5 Development of a technical design manual for improved stormwater control measures and recommended field demonstration testing for future studies (Task 6).

5.1 Development of technical design manual (Subtask 6.1).

Geosyntec Consultants are developing a technical guidance manual to disseminate key experimental results and findings from this study. This guidance document support DoD site managers and Remedial Project Managers (RPMs) for evaluating, designing, and implementing BC-amended engineered media filters to address contaminants included in this study. This document is intended to provide guidance for how the findings of this project can be included in BC-amended engineered media filters planning, design, and implementation as a singular stormwater control measure or as part of a treatment train. The document is not intended to be a comprehensive stormwater design manual. There are numerous existing guidance documents available for DoD site managers and their contractors related to stormwater management and SCM design. This guidance document is intended to be used as a companion to these with guidance specifically focused on BC-amended engineered media treatment systems. The manual will also describe key findings from a separate project completed for the same Statement of Need.

5.2 Development of treatment engineered media performance and sizing tool (TEMPEST) (Subtask 6.2).

Modeling results of TrOCs transport will be incorporated into the Treatment Engineered Media Performance and Sizing Tool (TEMPSEST). This Microsoft excel spreadsheet based tool will assist practitioners to size and design black carbon amended stormwater water filters to ensure the filter is able to remove target TrOCs to the desired level. The user will input rain fall, land use, physical site stormwater characteristics, filter design, and TrOCs treatment target parameters. The tool will then compute the filter dimensions or proportion of target rain fall event captured and the estimated lifetime of the filter for removing the target TrOCs to its desired level of removal. This tool therefore easily disseminates the intricate contaminant transport modeling and results from Tasks 3 and 5 into a practical form that may be applied to specific sites and individual and unique cases. The tool's purpose is to translate the newly learned knowledge of TrOCs transport in BC-amended filters into a useable form that stormwater practitioners may use and apply. This tool is being developed in partnership with Geosyntec Consultants.

VI. Results and Discussion

1 Assessment of engineered media filters for removal of contaminants from stormwater runoff (Task 2).

1.1 Develop novel and representative lab-based synthetic stormwater using soils and sediments from DoD facilities (Subtask 1.1).

We conducted analysis of catch-basin material from several potentially impacted locations to select a catch-basin material source to use for making realistic synthetic stormwater in the laboratory. We obtained catch-basin material from PFAB from a stormwater retention pond shown in Figure 5. Here, the material was particularly coarse and few fines were present to analyze. We also collected material from the wash rack drain and wharf drain of NWSSB and a stormwater retention pond at BOF (Figure 5).

Among the five metals analyzed (Cd, Cu, Ni, Pb, Zn), Zn was found at the highest concentration in the catch-basin material collected from each of the three sites (Figure 10). Catch-basin material from NWSSB had the highest concentration of Zn (510.3 µg/g), Pb (44.1 µg/g), Ni (28.5 µg/g), and Cd (5.1 µg/g) and second highest concentration of Cu (58.5 µg/g). The concentrations of the metals in the fine fraction were consistently greater than in the coarse fraction in catch-basin material from NWSSB and BOF, with a singular exception for Pb in NWSSB material (Figure 11).

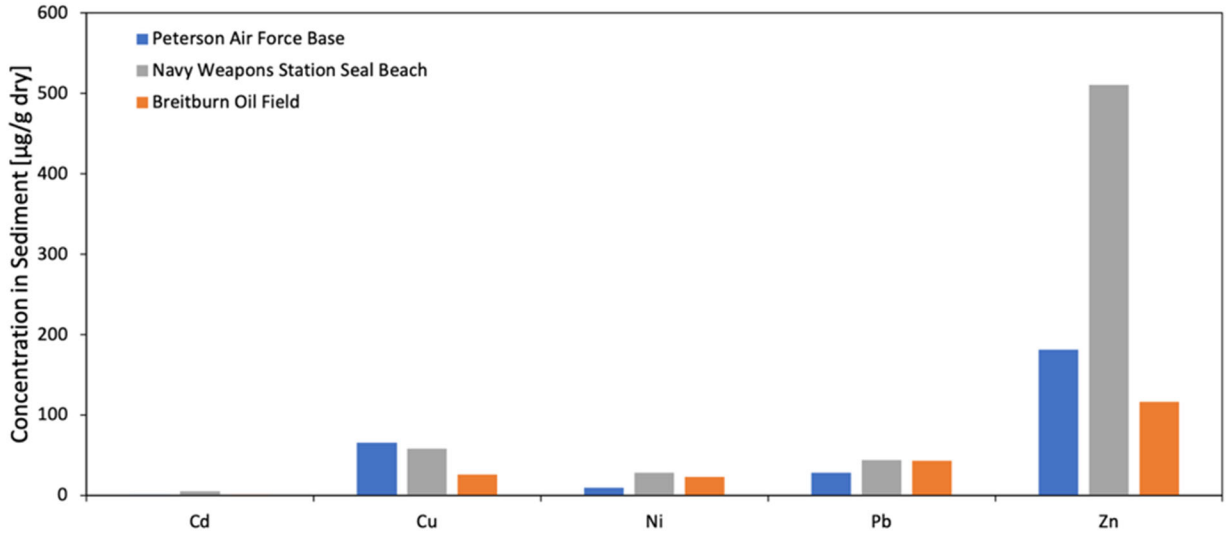

Figure 10 Concentration of cadmium, copper, nickel, lead, and zinc in catch-basin material (µg g^{-1} dry) collected at PFAB, NWSSB, and BOF. Catch-basin material was been screened to remove particles >3 mm.

While metal concentrations were highest in NWSSB catch-basin material, total pPAH concentration was slightly larger in catch-basin material from PFAB (12±2 µg/g) than material from NWSSB (7±2 µg/g) and significantly larger than material from BOF (4±1 µg/g). The distribution of pPAHs were similar in catch-basin material from PFAB and NWSSB where 3- and 4-ring pPAHs were dominant, while catch-basin material from BOF had a somewhat different

distribution, as seen below in Figure 12. The concentration of pPAHs in the coarse fraction was substantially greater than the concentration in the fine fraction in the catch-basin material from NWSSB and BOF, as seen below in Figure 13 and Figure 14.

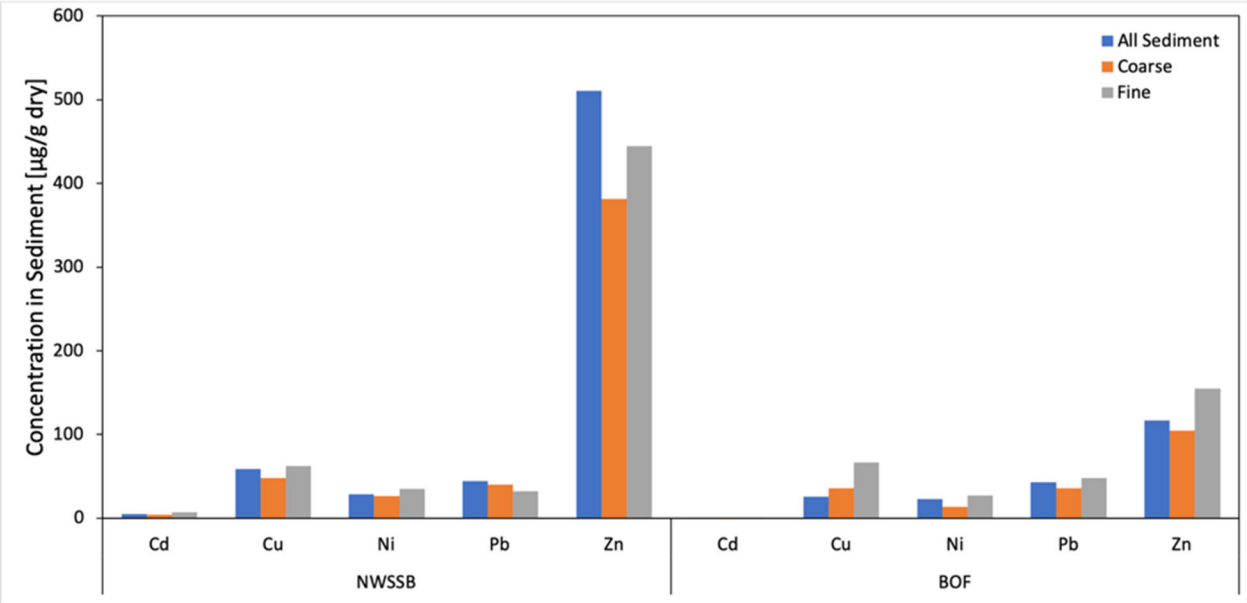

Figure 11 Concentration of cadmium, copper, nickel, lead, and zinc in catch-basin material (µg g^{-1} dry) collected from NWSSB and BOF. Catch-basin material was sieved into the coarse (diameter > 0.420mm) and fine fraction (diameter < 0.420 mm).

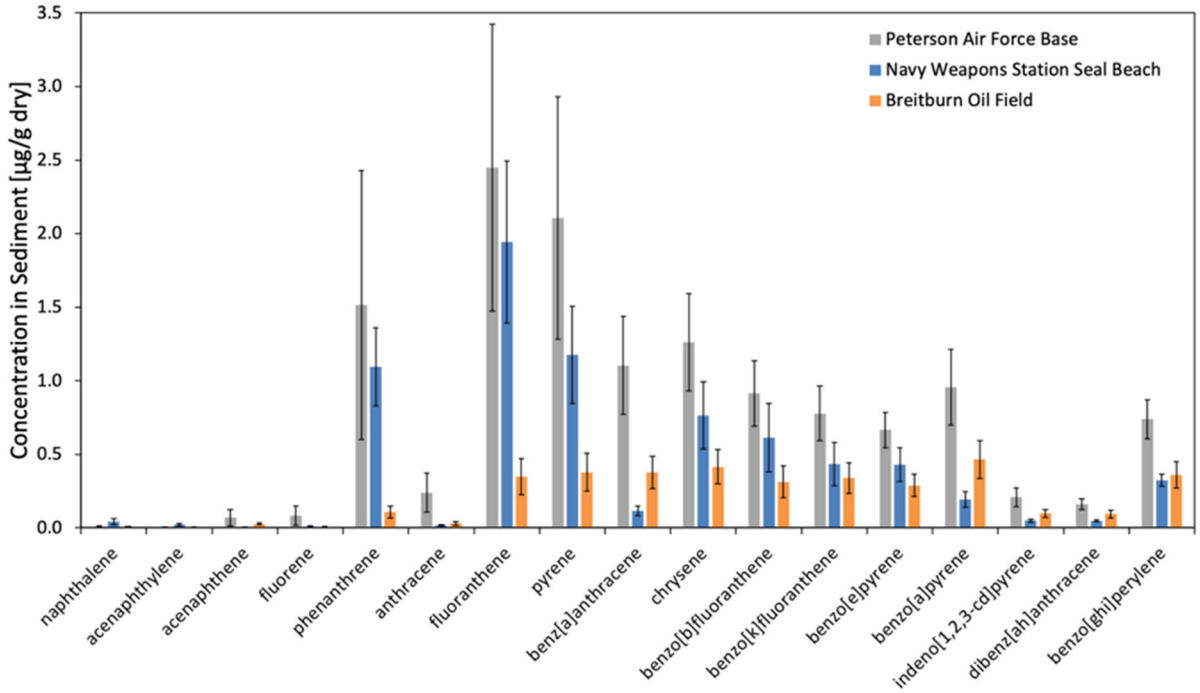

Figure 12 pPAH concentration (µg g^{-1} dry) in sediment from NWSSB, BOF, and PFAB.

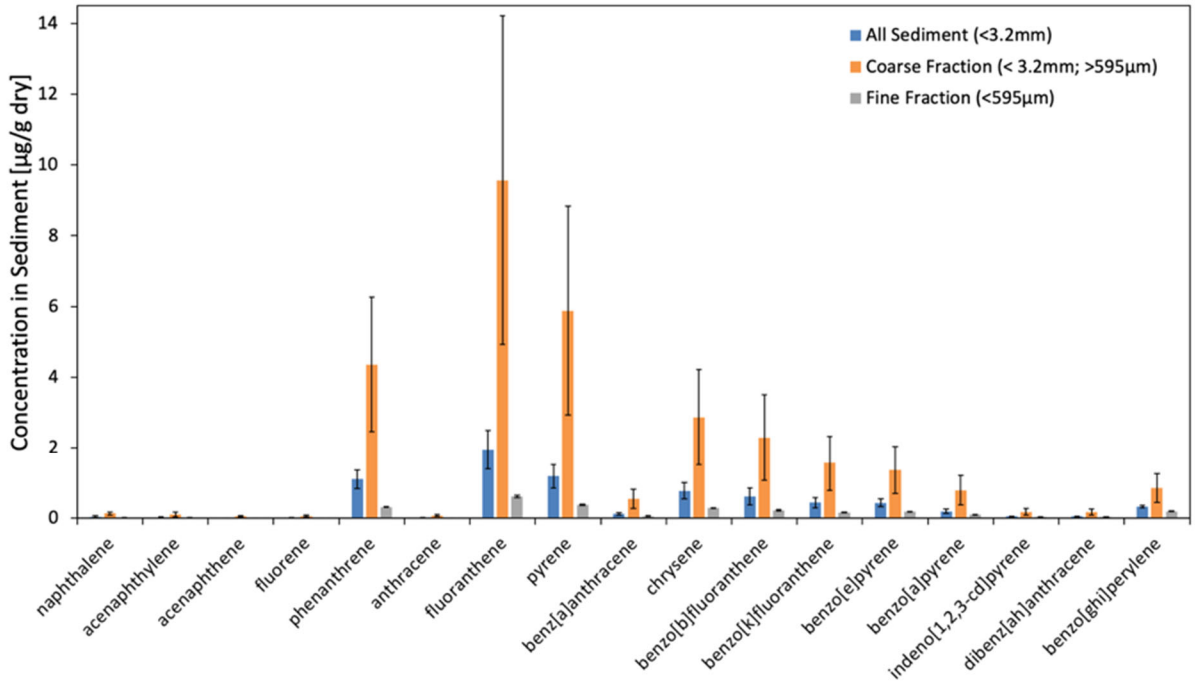

Figure 13 pPAH (µg g^{-1} dry) in catch-basin material from NWSSB. Catch-basin material was sieved into a coarse fraction (diameter > 0.420 mm) and fine fraction (diameter < 0.420 mm).

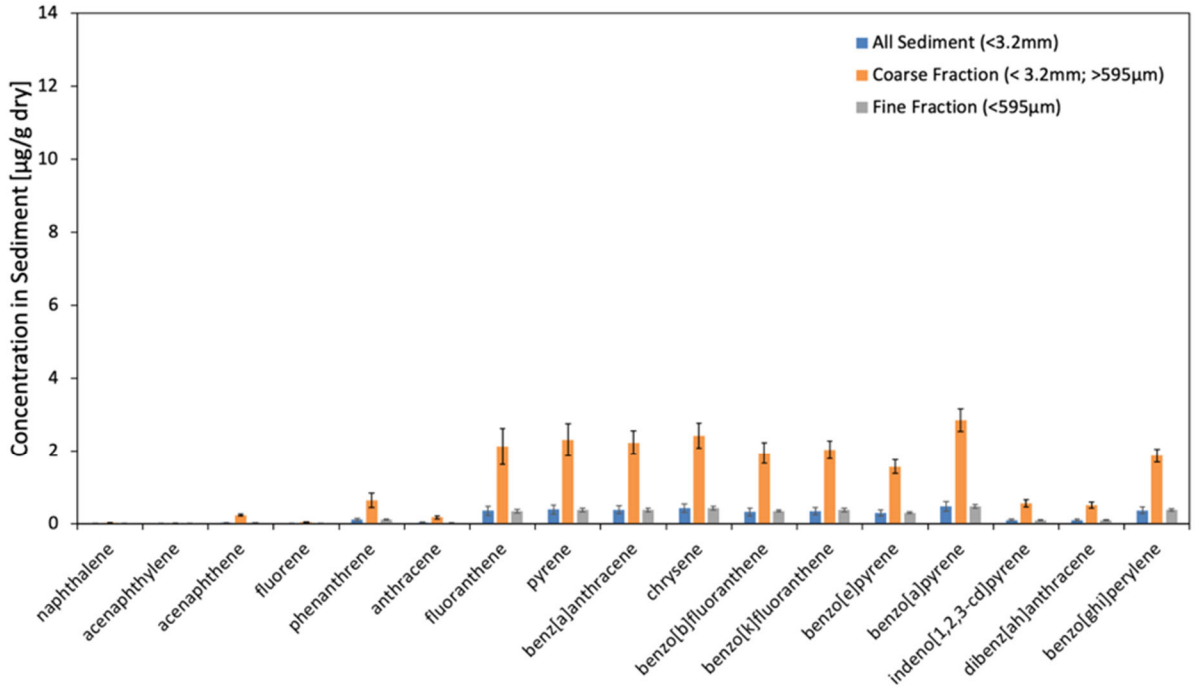

Figure 14 pPAH in (µg g^{-1} dry) catch-basin material from BOF. Catch-basin material was sieved into a coarse fraction (diameter > 0.420 mm) and fine fraction (diameter < 0.420 mm).

Catch-basin material from NWSSB had the highest concentration of perfluorooctanesulfonic acid (PFOS) (28.1 µg/kg) (Figure 15) and many target PFASs (Figure 16). PFAB's catch-basin material

was particularly concentrated in longer-chain fluoroalkanoic acids such as perfluorododecanoic acid and perfluorotetradecanoic acid.

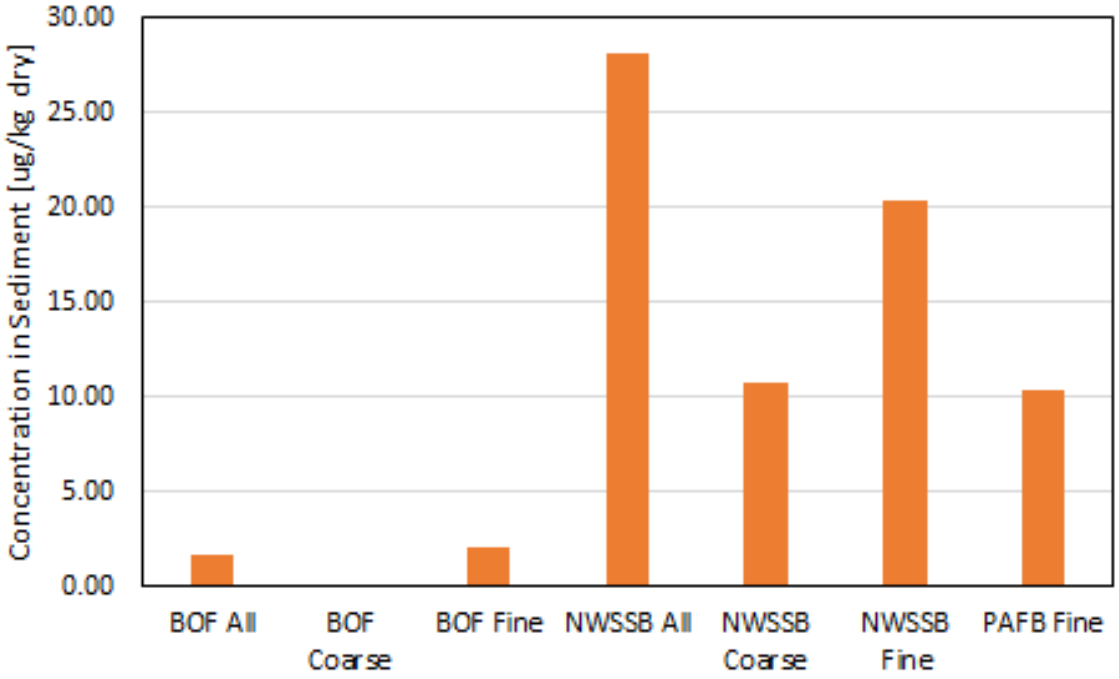

Figure 15 Concentration of PFOS (µg kg^{-1} dry) in catch-basin material from NWSSB, BOF, and PFAB. Catch-basin material was sieved into a coarse fraction (diameter > 0.420 mm) and fine fraction (diameter < 0.420 mm).

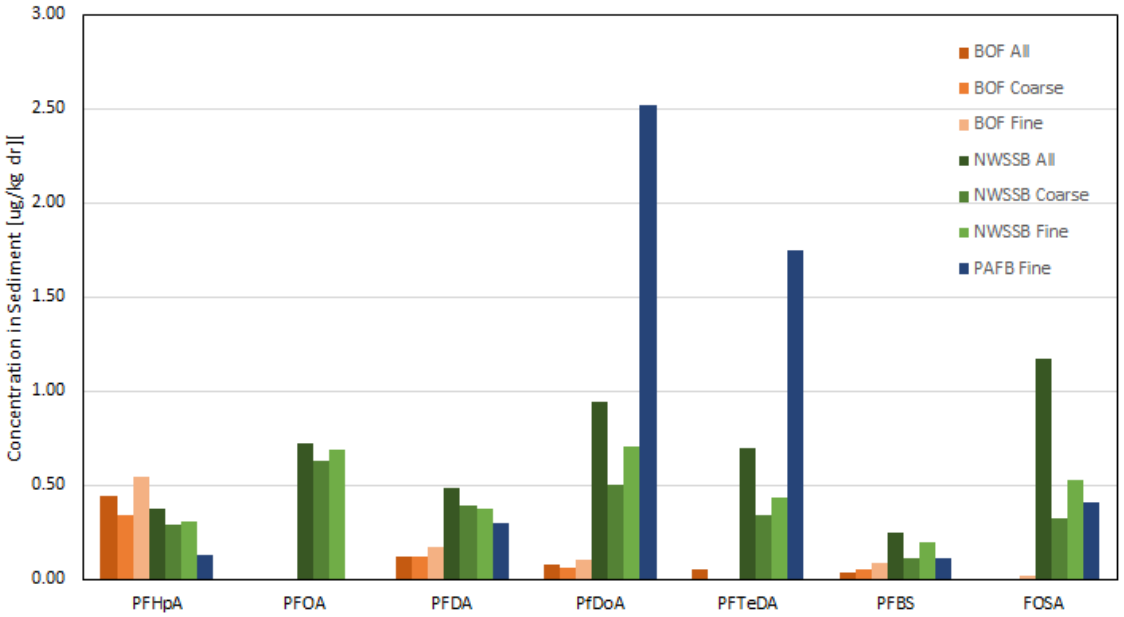

Figure 16 Concentration of selected PFAS (µg kg^{-1} dry) in catch-basin material from NWSSB, BOF, and PFAB. Catch-basin material was sieved into a coarse fraction (diameter > 0.420 mm) and fine fraction (diameter < 0.420 mm).

Aqueous leaching experiments in which catch-basin material was added to DI water revealed that catch-basin material from NWSSB leached higher concentrations of metals, nutrients, and DOC than material from BOF and PFAB (Figure 17 and Figure 18). Aqueous concentrations of metals were consistently higher in samples with catch-basin material from NWSSB except for Pb, which was highest in samples with material from BOF. Metal concentrations in samples with fine catch-basin material from NWSSB were generally higher than in samples with coarse material from NWSSB. Likewise, concentrations of DOC and TN leached from catch-basin material were highest in samples with material from NWSSB and fine NWSSB material leached higher concentrations than coarse NWSSB material. Aqueous concentrations of nutrients varied in samples with different site material. While NWSSB material leached significantly higher concentration of NH3-N, BOF material leached higher concentrations of PO4-P and all materials leached similar concentrations of NO3-N (Figure 19).

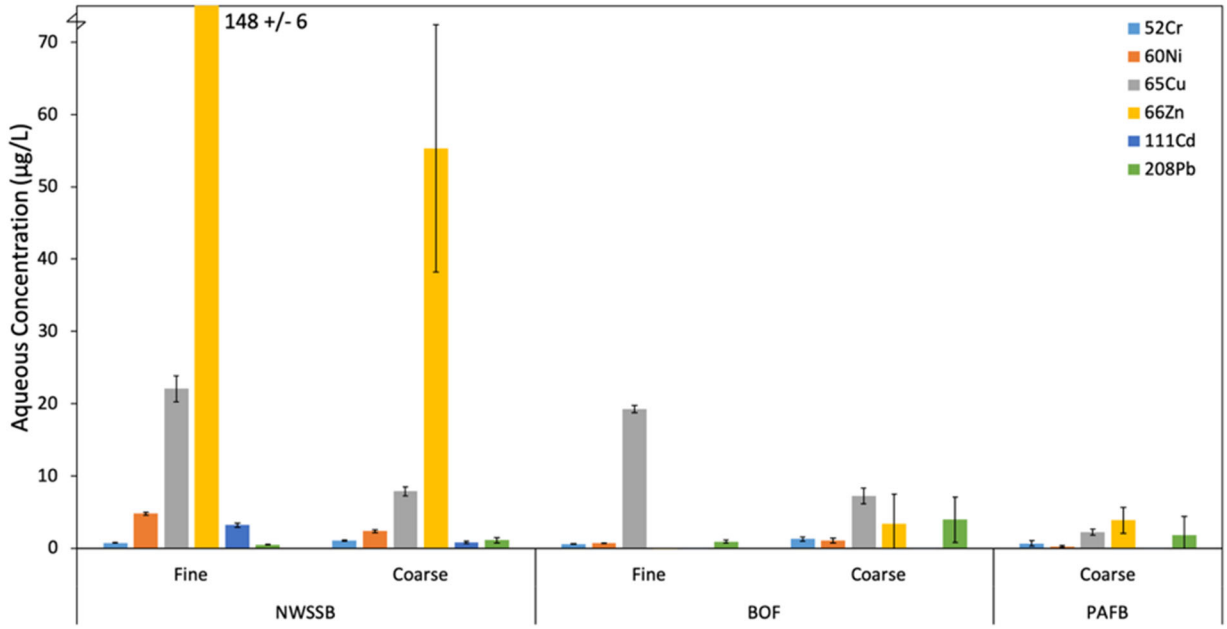

Figure 17 Aqueous concentrations (µg L^{-1}) of chromium, nickel, copper, zinc, cadmium, and lead in water samples containing catch-basin material from NWSSB, BOF, and PFAB sieved into a coarse (diameter > 0.420 mm) and fine (diameter < 0.420 mm) fraction at a dose of 20 g dry material L^{-1}.

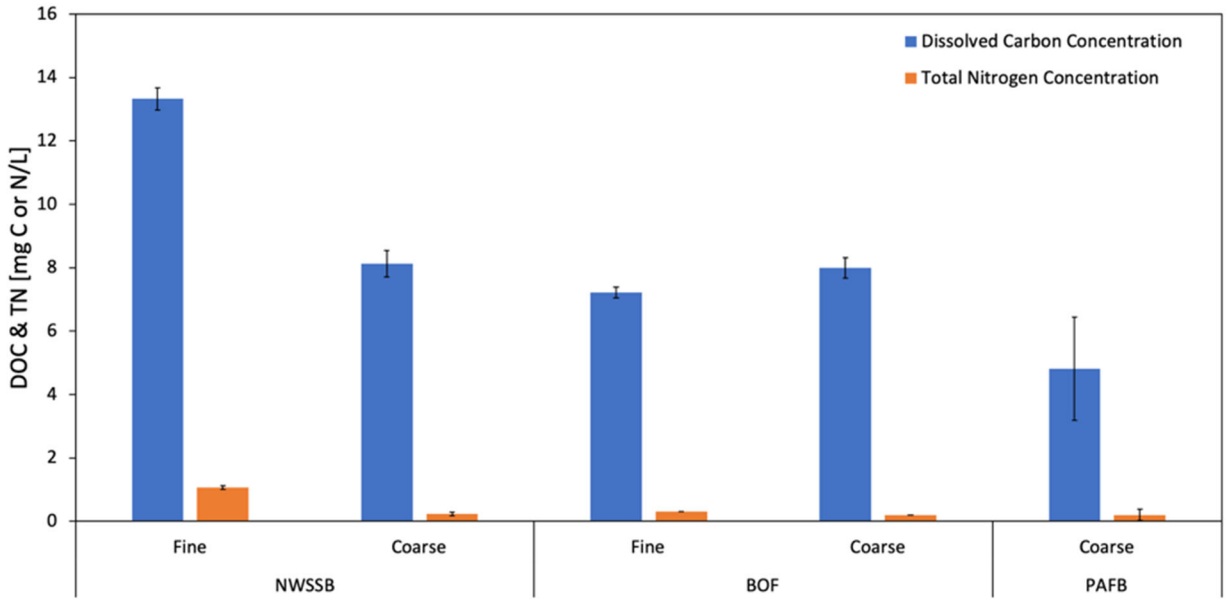

Figure 18 Aqueous concentration (mg/L) of DOC (as C) and total nitrogen (as N) in DI Water with 20 g dry catch-basin material/L.

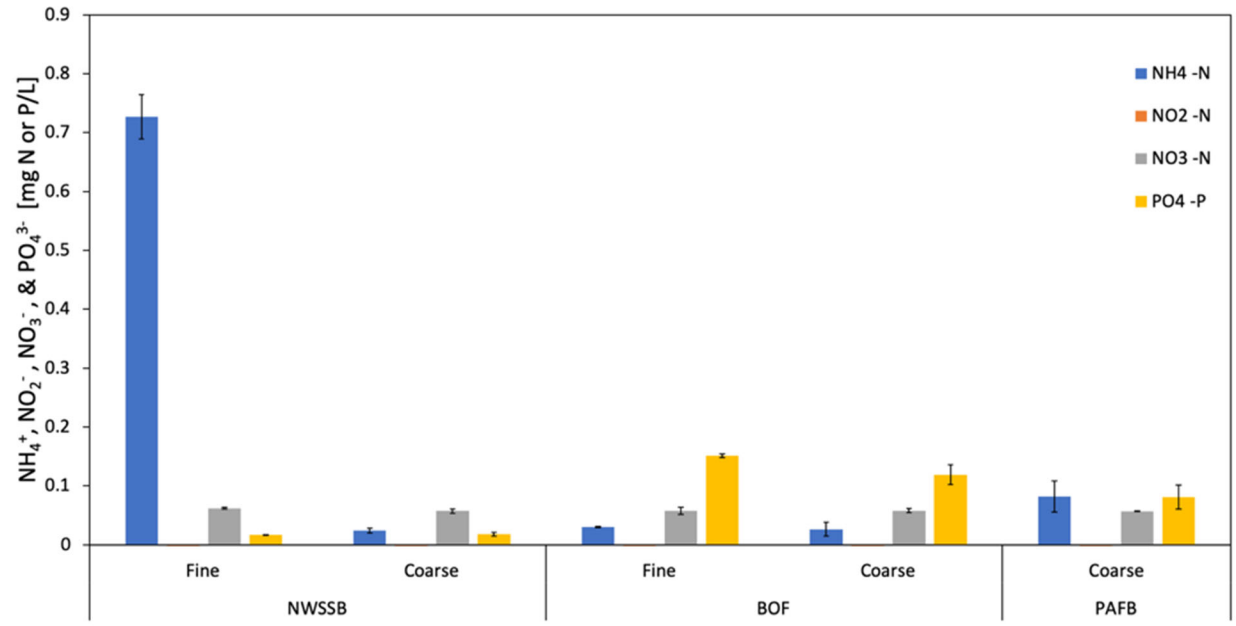

Figure 19 Aqueous concentrations (mg L^{-1}) of ammonium, nitrate, nitrate (as N), and phosphate (as P)in water samples containing catch-basin material from NWSSB, BOF, and PSFB sieved into a coarse (diameter > 0.420 mm) and fine (diameter < 0.420 mm) fraction at a dose of 20 g dry material L^{-1}.

Experiments revealed that NWSSB catch-basin material generally contains greater concentrations of contaminants and leaches higher concentrations of metals, DOC, and nutrients than material from BOF and PFAB. These results indicate that NWSSB catch-basin material is most advantageous for developing representative synthetic stormwater containing elevated levels of contaminants and DOC. We therefore selected catch-basin material from NWSSB for use to create synthetic stormwater for our experiments. On November 20, 2019, we received 522 lbs of dry catch-basin material from NWSSB, which had been vacuumed from stormwater drains near the wash rack and docks as seen above in Figure 5. We received another shipment of NWSSB catch-basin material later for use in our long-term periodic

Results of the NWSSB catch-basin material leaching study and follow-up experiments with various doses of NWSSB material indicated that the catch-basin material alone could not deliver sufficient DOC and a background ionic matrix, necessitating salt and DOC concentrate additions. The DOC and ionic contributions from the catch-basin material and salt/DOC additions, final values in the synthetic stormwater, as well as values in actual stormwater from NWSSB may be found below in Table 1. Note that the synthetic stormwater ion composition is based on that developed by Grebel et al. (2016). Actual stormwater from the wash rack at NWSSB was collected on March 12, 2020 and shipped on ice to Colorado School of Mines, where it was analyzed for metals, nutrients. Due to the weekend delivery and subsequent time required, some parameters, such as DO, were not measured. Due to the inherently variable nature of stormwater, this single sample cannot be considered wholly representative of NWSSB stormwater.

Table 1. Synthetic stormwater composition.

	Contribution from NWSSB Catch Basin Material	Contribution from Salt & DOC Addition	Final Synthetic Stormwater Values	NWSSB Stormwater
Ca^{2+}	3.88	26.18	30.1	7.19
Mg^{2+}	0.51	1.31	1.82	2.37
Na^{+}	4.13	39.2	43.3	9.93
NH_4^{+}as N	<0.1	1.3	1.3	0.8
SO_4^{2-}	2.06	29.6	31.7	-
HCO_3^{-}	<0.1	61	61	-
Cl^{-}	3.83	52.7	56.5	-
NO_3^{-} as N	<0.1	4.46	4.46	9.21
$H_2PO_4^{-}$ as P	<0.1	1.55	1.55	0.5
DOC*	2.08	7.92*	10*	-

Units: mg L^{-1}; mg C L^{-1} for DOC; - indicates no value measured; *indicates target concentration.

The final synthetic stormwater recipe may be found below in Table 2. The DOC concentrate is made by soaking ~50 g straw per liter in DI water for three days, after which the straw is removed, and the DOC concentrate is filtered through a 400 mesh (38 μm) sieve. The DOC concentrate is then frozen until use, at which point the DOC concentrate is thawed, autoclaved, and diluted to the appropriate concentration. Straw is taken from wattles (Home Depot), commonly used for stormwater management and erosion prevention, and cut into small 1-3 inch pieces to maximize

the resulting DOC concentration. Final DOC concentrations in the DOC concentrate ranged from 1030-1575 mg C/L.

Table 2. Synthetic stormwater recipe.

Ingredient	Quantity Added	
NWSSB Catch-Basin Material	3	g dry L^{-1}
$CaCl_2*2H_2O$	96	mg L^{-1}
$MgCl_2*6H_2O$	11	mg L^{-1}
$NaHCO_3$	84	mg L^{-1}
NaH_2PO_4*H2O	2.21	mg L^{-1}
$NaNO_3$	6.12	mg L^{-1}
Na_2SO_4	43.8	mg L^{-1}
NH_4Cl	3.85	mg L^{-1}
DOC Concentrate	7.92	mg C L^{-1} [a]

[a] Target total DOC concentration is 10mg C L^{-1}, as contributed from the catch-basin material and DOC concentrate. Observed DOC concentration was observed to be lower.

The synthetic stormwater generated in the laboratory compares favorably with a sample of stormwater collected at NWSSB with respect to major ions and also with stormwater reported from California in the International Stormwater BMP Database (http://www.bmpdatabase.org/). Table 3 shows water quality parameters for the synthetic stormwater before and after sedimentation, actual NWSSB stormwater from one storm, and average stormwater recorded in California from the International BMP Database.

Table 3. Synthetic, actual NWSSB from one event, and California stormwater parameters.

	Lab Generated Synthetic Stormwater		Actual NWSSB Stormwater (3/12/20 Storm)	Average California Stormwater[b]
	Pre-Sedimentation[a]	Post-Sedimentation[a]		
Conductivity ($\mu S\ cm^{-1}$)	344	326.3	---	---
DO ($mg\ L^{-1}$)	8.21	7.39	---	8.19-8.97 (8.66)
DOC ($mg\ C\ L^{-1}$)	2.08[c]	10[d]	---	4.6-18.0 (9.5)
pH	7.45-7.57 (7.52)	7.06-7.48 (7.28)	7.12	6.60-7.60 (7.1)
TDS ($mg\ L^{-1}$)	163.3	172	---	36-110 (64)
Turbidity (NTU)	131.0-170.0 (158.5)	24.4-44.5 (32.2)	112	7.0-34.7 (15)
TSS ($mg\ L^{-1}$)	214.8	25.9	54	30-110 (60)

[a] Range indicates maximum and minimum measured values, average value in parenthesis
[b] Range indicates 25-75% range, median value in parenthesis; data from International BMP Database
[c] DOC stock solution is added post-sedimentation
[d] Target DOC concentration is 10 mg C L^{-1} however the observed value was lower

1.2 Select filter engineered media (Subtask 1.2).

Engineered media amendment batch tests results indicate that Biochar Supreme outperforms Biochar Now, and that Cabot RAC outperforms Calgon RAC, and that zeolite outperforms sand with respect to metal removal. Samples with Biochar Supreme (dashed lines in Figure 20, top) had consistently lower concentrations for each metal than samples with Biochar Now (solid lines in Figure 20, top). Concentrations of metals rapidly decreased within the first six hours of contact time before stabilizing although Cu, Pb, and Cr continued to decrease at a slower rate. Samples with Cabot RAC (dashed lines in Figure 20, middle) likewise had consistently lower concentrations of each metal than samples with Calgon RAC (solid lines in Figure 20, middle), with metal concentrations decreasing rapidly and generally plateauing after 24 hours of contact time. Samples with zeolite exhibited similar performance with metal concentrations sharply decreasing before stabilizing after six hours. Samples with sand showed a small decrease in Pb, Cu, and to a lesser extent, Zn, concentration over the course of the six days (Figure 20, bottom).

For PFOS removal in batch tests, Biochar Supreme performed better than Biochar Now and Calgon RAC outperformed Cabot RAC (Figure 21). Zeolite was not effective for PFAS sorption within the 5 days the solution equilibrated.

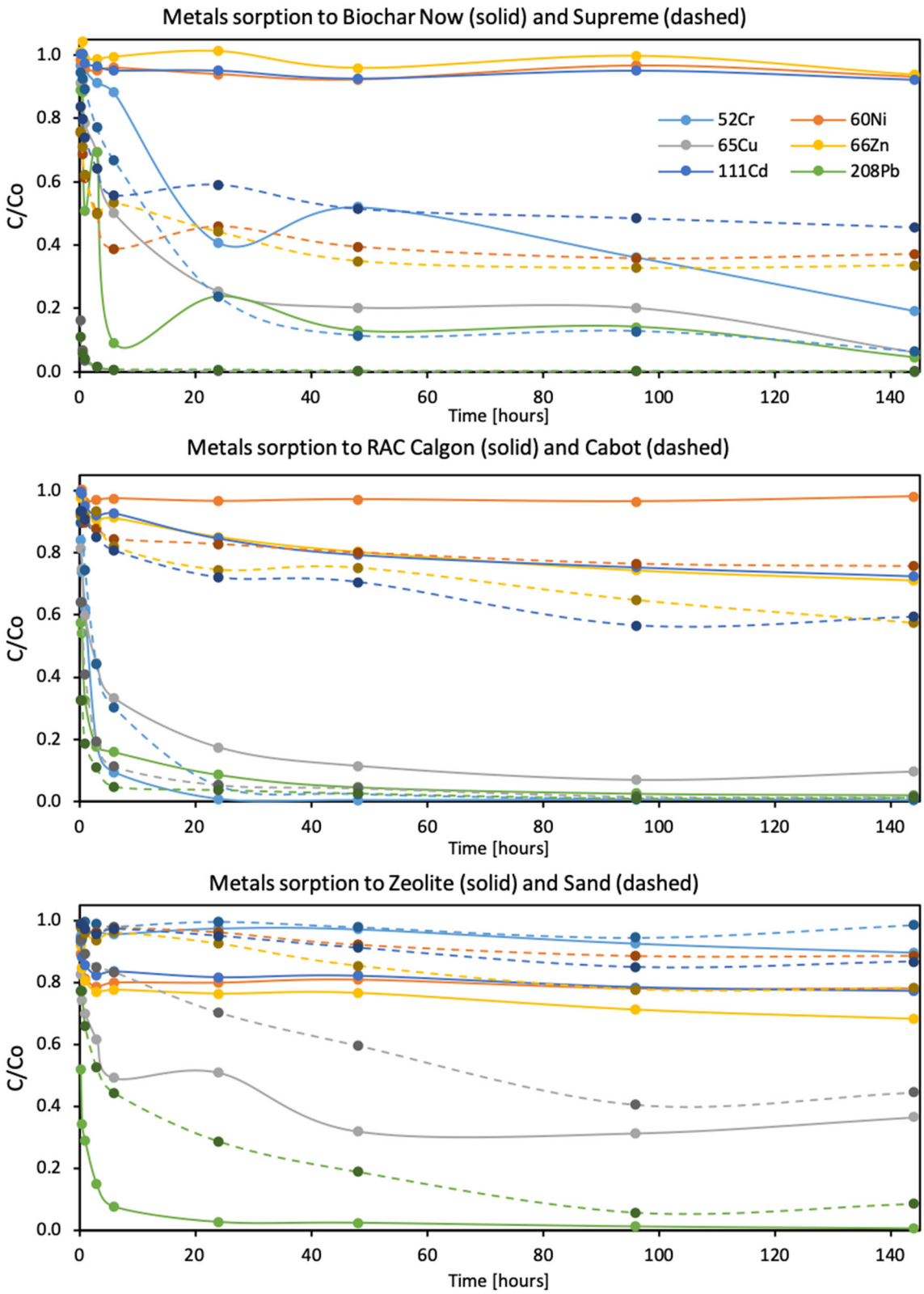

Figure 20 Metal removal (C_0 = 100 µg L^{-1}) in 45 mL modified synthetic stormwater samples with added sorbents: 75mg of Biochar Now (top), Biochar Supreme (top), Cabot RAC (middle), Calgon RAC (middle), and zeolite (bottom) and 300 mg of sand (bottom).

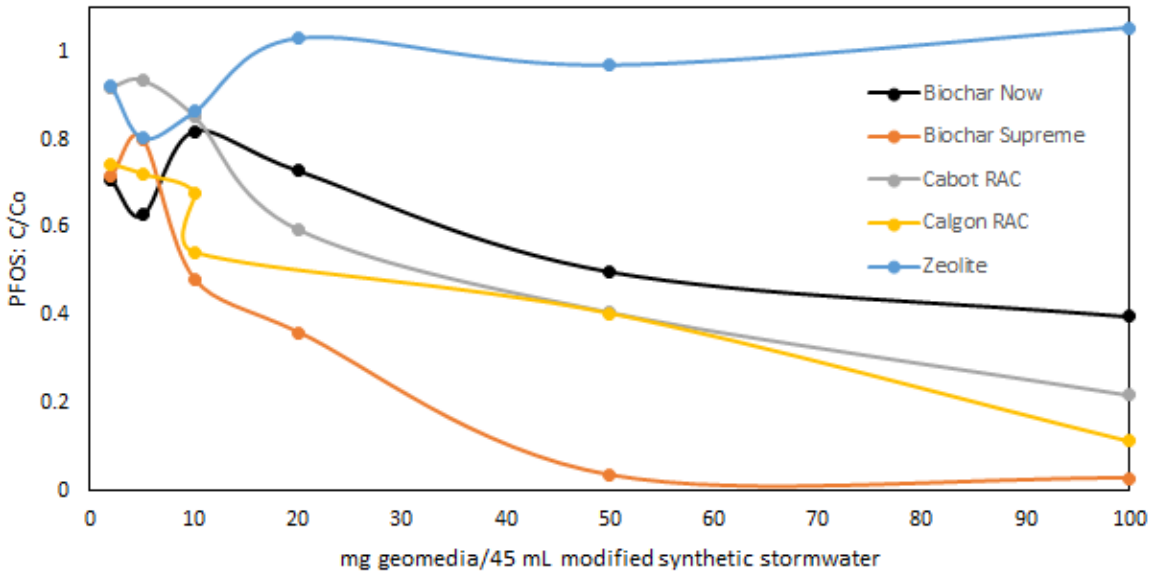

Figure 21. PFOS removal (C_0 = 86 ng L^{-1}) in 45 mL modified synthetic stormwater samples with added sorbents.

1.3 Evaluate various engineered media mixtures using downflow column experiment (Subtask 2.3).

1.3.1 Basic Water Quality Parameters and Hydraulic Conductivity

The columns were conditioned and challenge-tested with synthetic stormwater prepared as described above. TSS ranged from 13.5-40.2 mg L^{-1} in the column influent and turbidity ranged from 40-414 FNU (181±109 FNU) pre-sedimentation and 21-33 FNU (26.9±3.9 FNU) in the column influent.

All treatments provided substantial water quality improvement with respect to TSS and turbidity (Figure 55, Figure 59). TSS was removed to 0.0-1.3 mg L^{-1} at effluent (97-99%), although the columns amended with BC consistently removed more TSS. Additionally, zeolite amendment did not significantly improve TSS removal. Similar trends were observed for turbidity, which ranged from 0.48-2.22 FNU in the column effluent. Biochar amendment reduced the turbidity most (0.76±0.16 FNU, 97%) followed by RAC amendment (1.33 ±0.41 FNU, 95%). Zeolite amendment did not add any benefit to turbidity removal.

Although DOC was added to attain approximately 10 mg C L^{-1}, only 3.7±1.1 mg C L^{-1} was present in the stormwater entering the columns, likely due to sorption to TSS and microbial degradation in the spiking chamber and tubing (Figure 56). DOC was partially removed by all of the columns throughout the experiment in the order of sand~zeolite<biochar<RAC. While RAC and biochar amendment both reduced DOC similarly in the beginning (~80% at 120 EBVs), after ~200 EBVs, the DOC removal in the biochar decreased to become similar to the sand and zeolite columns (~55% at 208 EBVs) while DOC in the RAC columns remained at 70% at 208 EBVs. Zeolite did not significantly impact DOC removal. The sand columns reduced the DOC by ~20% initially but steadily increased the removal to ~40% by the conclusion of the experiment. DOC removal in the

sand columns is likely due to initial DOC removal by sorption to suspended solids that were removed by interception and gradual increased biological degradation of the DOC until steady state. The DOC breakthrough profile in the biochar and RAC columns suggest that the primary mechanism for DOC removal is likely adsorption to the black carbon as DOC was reduced completely at the beginning of the experiment before leveling off at ~70% removal, likely due to fouling and saturation of surface DOC sorption sites on the BC. TN remained fairly consistent in the column influent and was removed in the BC amended columns by ~30%. Zeolite did not benefit total nitrogen removal. Observed SUVA values of 2.59 L mg^{-1} m^{-1} are typical of stormwater runoff (Fellman et al., 2009; Mermillod-Blondin et al., 2015).

Dissolved oxygen (DO), pH, conductivity, and total dissolved solids trends were consistent throughout the experiment. The DO was depleted in all the columns during the conditioning period and the columns remained anoxic throughout the experiment (Figure 58). The DO was depleted within the top 15 cm media + barrier sand. The columns lowered the pH of the column influent (7.43 ±0.13) to 6.80-6.95 while not affecting the conductivity (influent=343±23 µS cm^{-1}) or total dissolved solids (influent =346±34 mg L^{-1}). Further, the sedimentation process also did not affect pH, conductivity, or total dissolved solids (Table 40 – Table 45).

Hydraulic conductivity decreased some over the course of the experiments for all the media mixtures (Table 4). Biochar-amendment reduced column hydraulic conductivity from 0.35±0.04 cm s^{-1} to 0.21±0.08 cm s^{-1} after 62 days (32% reduction), while RAC's impact, though not as great, was still measurable, 0.35±0.04 cm s^{-1} to 0.31±0.03 cm s^{-1} (26% reduction). The column's contact time ranged from 54 minutes to 108 minutes, with the zeolite and black carbon amendment increasing the engineered media porosity. The volumetric black carbon and zeolite content was kept constant, and the weight content measured for each mixture is reported in Table 4.

Table 4 Measured column porosity, contact time, and hydraulic conductivity.

Eng. Media Mixture	BC Content		Porosity [a]		Nominal Contact Time [b] [min]	Hydraulic Conductivity [cm s^{-1}] [c]			
	v%	wt%				Initial		t=62 days	
Sand	-	-	0.30	±0.03	54	0.69	±0.22	0.35	±0.04
+Zeolite	-	-	0.42	±0.01	76	0.50	±0.07	0.37	±0.01
+RAC	10	3.3	0.37	±0.01	67	0.42	±0.02	0.31	±0.03
+Biochar	30	2.4	0.51	±0.05	92	0.31	±0.01	0.21	±0.08
+Zeolite+Biochar	30	3.0	0.60	±0.01	108	0.47	±0.08	0.28	±0.08
+Zeolite+RAC	10	4.0	0.44	±0.00	79	0.44	±0.00	0.33	±0.04

[a] Measured gravimetrically using dry and saturated weights. Average ± standard deviation (n=3).
[b] Computed based on measured porosity and flow rate. Note, empty bed contact time (EBCT) = 3 hours.
[c] Initial hydraulic conductivity tested after flushing with DI water but before conditioning. Average ± standard deviation (n=3).

1.3.2 Metals Removal

Preliminary leaching tests showed the catch basin material used to create the synthetic stormwater released metals when added to water (Figure 17). Zn (16.1±4.75 µg L^{-1}) was observed in the synthetic stormwater prior to contaminant addition, indicating that dissolved Zn was loaded onto the columns during the 100 EBV conditioning period. Dissolved metal concentrations in the

influent fluctuated from the target spike concentration (30 µg L^{-1}) over the course of the experiment (Table 5, Figure 60), likely due to sorption/desorption and complexation with suspended catch basin material and heterogeneity in the catch basin material. Aqueous concentrations of Pb, in particular, were very low, likely due to Pb interaction with suspended catch basin material. Visual Minteq equilibrium software confirmed that in the absence of suspended solids, the metals are expected to be in dissolved forms at their target concentration in the synthetic stormwater based on the major ions present. Therefore, Pb removal can be attributed to suspended particle removal through physical filtration by the engineered media.

Dissolved metal removal occurred in all the columns to various degrees based on the engineered media mixture and metal species (Table 5, Figure 22). The sand columns experienced initial metal removal for all the metals analyzed, which may be attributed to surface chemisorption on the surface of sand grains (Grebel et al., 2013). Dissolved metals removal in the sand columns (C/C_0) were in the order Pb>Cd>Cu>Ni>Zn, though note that the dissolved metal influent concentrations varied among the group of metals included (Table 5). While Pb was largely particle associated and thereby removed by physical filtration, low dissolved Pb concentrations were observed in the sand column effluent, indicating that small amounts of Pb can still pass through un-amended sand columns.

Zeolite contributed some benefit for metal removal but less than that reported by others (Grebel et al., 2013; Okaikue-Woodi et al., 2020). Reddy et al. (2014) found zeolite to remove significantly more Cd, Cu, Pb, Ni, and Zn than sand in batch tests with initial concentrations ranging as high as 300 mg L^{-1} [34]. Charters et al. (2021) found zeolite to effectively remove Zn and Cu from roof water runoff. The poor performance of zeolite in this study may be attributed to the experimental conditions including relatively low dissolved metal concentrations, relatively low contact time, the presence of DOC, and pre-loading of Zn during the conditioning phase. Zeolite removal of metals is sensitive to ionic strength (particularly Na^+, Ca^{2+}, Mg^{2+}) and dissolved metal concentration (Payne and Abdel-Fattah, 2004) and inhibited by dissolved components in stormwater (Pitcher et al., 2004). Nguyen et al. (2015) found zeolite in column experiments to have a lower adsorption capacity than the same material in batch experiments, possibly due to lower metal-zeolite contact time in the column experiment (Nguyen et al., 2015). Dissolved metals may complex with DOC and become unavailable for cation exchange on the surface of zeolite (Christensen et al., 1996), and DOC is generally adsorbed to the outer surface of zeolite, thereby preventing metal species from accessing the interior of the zeolite (Islam et al., 2020). Finally, dissolved Zn may have already occupied many of the cation exchange and adsorption sites on the zeolite during the conditioning phase, reducing the efficacy of the zeolite during the challenge tests.

Overall, BC amendment reduced dissolved metal concentrations more than zeolite. Greater removal efficacy of BC amendment relative to zeolite aligns well with observations in previous studies (Genc-Fuhrman et al., 2007). BC amendment removed metals in the order of Pb>Cu>Cd>Ni>Zn as shown in Table 5 where breakthrough is defined as 40% of influent concentration as a consistent benchmark to assess transport for each studied contaminant. RAC amendment provided slightly better removal than biochar for nearly all metal species, though the difference is not substantial. Combining zeolite and BC amendment improved metal removal more than zeolite or BC alone. This is significant because the combined zeolite+BC mixture had equal or less zeolite and BC while improving performance. One explanation for this is that the BC

amendment reduced the DOC in the column, thereby reducing the DOC interference with the zeolite and the potential for DOC to complex with metals.

Table 5 Comparison of empty bed volumes treated for dissolved metals as indicated by C/C_0=0.4 at the column effluent.

	EBV Treated Until C/C_0=0.4 at Column Effluent [b]											
Eng. Media Mix	Al		Ni		Cu		Zn		Cd		Pb	
Sand	26	±1	35	±13	25	±2	26	±1	74	±5	>450	-
+Zeolite	60	±3	72	±1	59	±28	60	±3	164	±2	>450	-
+RAC	122	±35	275	-	44	±42	122	±35	237	±41	>450	-
+Biochar	76	±2	>450	-	38	±30	76	±2	129	±35	>450	-
+Zeolite+Biochar	124	±39	>450	-	39	±43	124	±39	201	±4	>450	-
+Zeolite+RAC	172	±18	>450	-	105	±94	172	±18	213	±16	>450	-
Inf. Conc. [ug/L]	17.6	±2.2	16.8	±1.9	20.2	±7.9	17.6	±2.2	8.8	±2.7	1.1	±0.6

[a] Time weighted average ± standard deviation (n=3).
[b] Mean ± standard deviation (n=3) [EBVs].
- Indicates no calculated value due to lack of observed contaminants in sample.

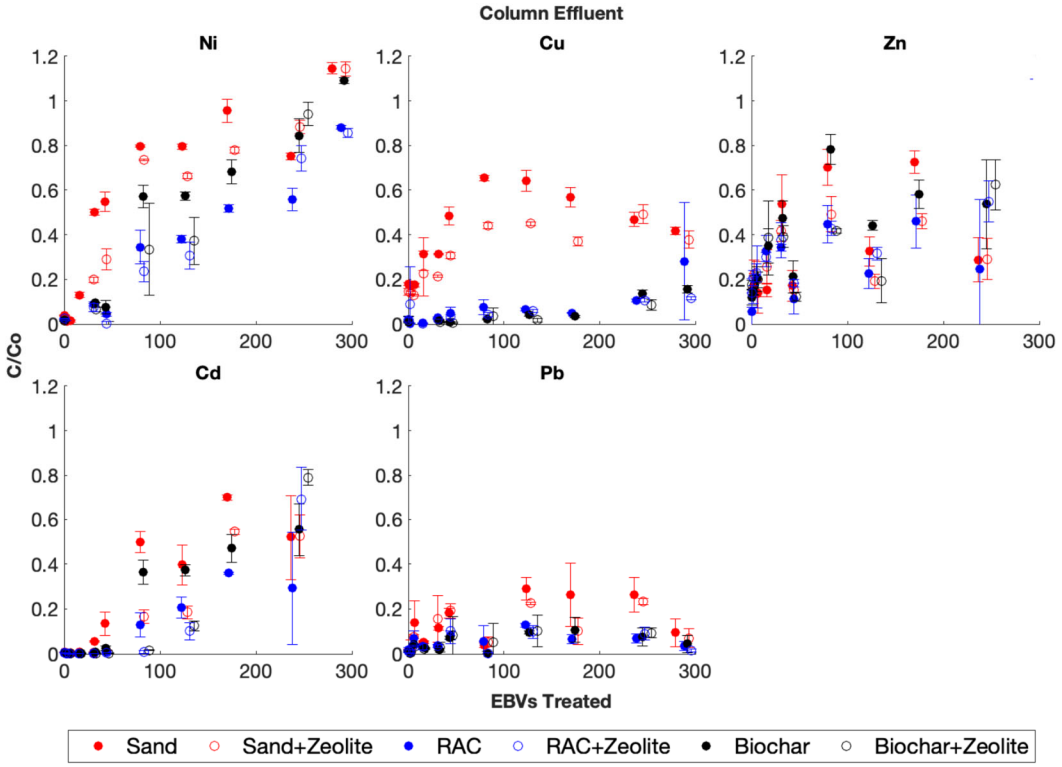

Figure 22 Dissolved metal transport and breakthrough over the first 300 empty bed volumes treated (n=3).

1.3.3 Hydrophobic TrOCs Removal

Hydrophobic organic compounds (HOCs) transport and removal results were measured in the highest flow rate column experiment conducted at 60 cm hr^{-1} (Task 3) but are reported here to demonstrate their removal with carbon-amended engineered media filters. HOCs were spiked to

deliver an aqueous concentration of 100 ng L^{-1}, however most (81.4%-99.0%) of the compounds became particulate associated and were removed from the dissolved phase before reaching the columns. The sand columns did not provide any benefit to removal of dissolved HOCs, as shown below in Figure 23. Dissolved HOCs in the biochar- and RAC-amended column effluent is greatly reduced compared to the sand columns. The presence of dissolved HOCs in the carbon-amended columns may be due to colloidal transport, which is known to facilitate the transport of PCBs and other HOCs. DNAN, the most hydrophilic (log K_{ow} = 1.6) of the compounds measured with gas chromatography that were studied, was not detected in the carbon-amended column effluent while bifenthrin, one of the most hydrophobic (log K_{ow} = 6.4), was detected at the highest concentrations in the carbon-amended column effluent (biochar=2.9±0.9 ng L^{-1}, RAC=2.7±1.1 ng L^{-1}). As colloidal transport and removal is affected by flow rate, this project only reports the dissolved HOCs transport at the highest flow rate, representing the "worst case scenario." Even with the influence of colloidal transport, the concentration of dissolved HOCs remained below the level of quantification (0.5 ng L^{-1}) for most of the HOCs studied.

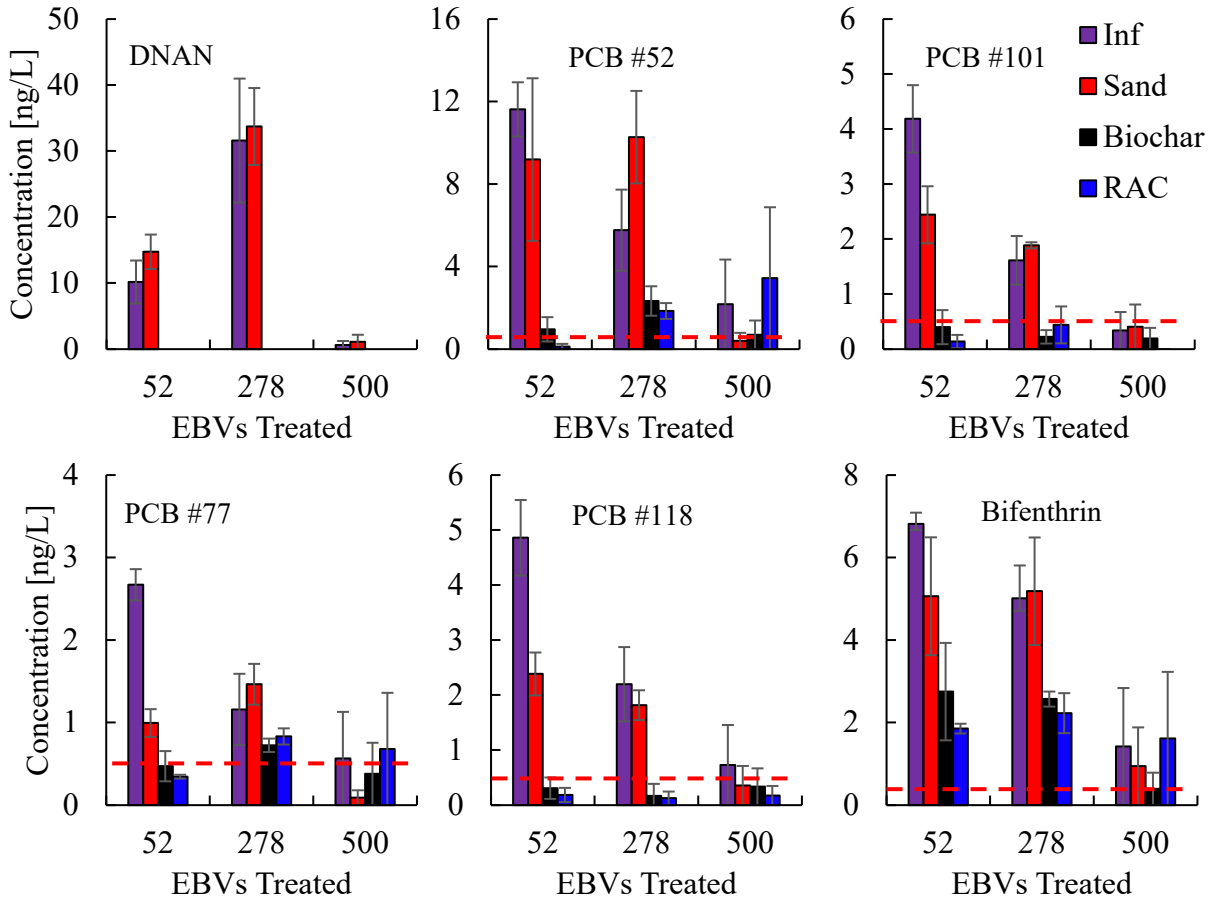

Figure 23 Dissolved hydrophobic organic contaminant in the column influent and column effluent of the sand, biochar, and regenerated activated carbon columns in the column experiment conducted at 60 cm hr^{-1}. Note that the dashed red line indicates the level of quantification (0.5 ng L^{-1}). Error bars indicate one standard deviation above and below the mean (n=3). The spiked level of HOCs was 100 ng L^{-1} and most of the HOC was removed by being particle associated and settling or filtration.

1.3.4 Hydrophilic TrOCs Removal

Dissolved influent concentrations of hyphil-TrOCs in the column test were 29-54 μg L^{-1} and remained in this range throughout the experiment (Table 6, Figure 65). Variation between targeted spike concentration (40 μg L^{-1}) and observed concentration (Table 6) is likely due to interaction with suspended catch basin material, which appeared to reduce the dissolved concentration of benzotriazole and fipronil most significantly. Data in Figure 24 show that BC-amended columns removed nearly all of the hyphil-TrOCs over the course of the experiment, while the sand columns and zeolite alone saw no appreciable reduction in hyphil-TrOCs. When combined with BC, zeolite gave a slight improvement in performance, even though the zeolite+BC columns have equal or less mass of BC. This is likely due to the slight increase in contact time resulting from the increased porosity of the zeolite relative to sand (Table 4). Hyphil-TrOCs were removed to a much greater extent than metals.

Measurements at the 25% and 50% sample ports (Figure 24, Figure 66) provide a view of hyphil-TrOCs migration within the column. For example, samples from the 25% sample port show that biochar reduced hyphil-TrOCs transport more than RAC. This improved benefit of biochar amendment relative to RAC is notable since there is greater mass of RAC in the column (153 g) than biochar (90 g, Table 4). However, the observed performance difference between RAC and biochar may be due to RAC's sorption kinetics and differences in porosities resulting in shorter contact time (67 minutes for RAC, 92 minutes for biochar; Table 4) and the influence of background DOC. The rapid initial breakthrough observed at the 25% and 50% sample ports in the RAC columns indicates that sorption is kinetically-limited, and the kinetics favor contaminant removal in the biochar-amended columns. Biochar has a substantially lower density (0.103 g mL^{-1}) than RAC (0.559 g mL^{-1}), so although the mass of biochar is less than RAC, the volume of biochar is substantially greater (30 v%) than RAC (10 v%).

This difference in density and volume may be a function of the pore size distribution and plays an important role in biochar's faster kinetics. Biochar's larger pores may facilitate faster contaminant transport into the interior of the carbon grains than RAC (Figure 48 – Figure 49), especially in the presence of DOC. DOC is known to generally inhibit the sorption of TrOCs on BC by reducing the effective surface area and competing for sorption sites, and reducing effective pore volume by pore-blocking (Wang et al., 2017).

The column experiments with biochar or RAC employed low weight percent sorbents (Table 4) in order to observe transport of TrOCs. The relative transport of the hyphil-TrOCs is in the order: mecoprop > fipronil > atrazine > imidacloprid > benzotriazole > diuron. Interestingly, this order does not correlate with solute K_{ow} or solubility, but instead agrees with the measured equilibrium isotherm sorption capacity. Relative transport may be impacted by background DOC and compound-specific properties such as molar volume, polar surface area, and charge. The order of compound mobility appears to be consistent between biochar and RAC, though the difference in performance between biochar and RAC appears to decrease as the compound mobility increases, with mecoprop having the smallest difference in performance. At a pH of 6.80-6.95, mecoprop exists as an anionic species, and therefore experiences electrostatic repulsion from the negatively-charged BC surfaces and inhibits its ability to diffuse into BC's pores due to their negatively-charged-surface (Spahr et al., 2022). Dechene et al. observed that biochar amendment of soil did

not show any benefit for three anionic polar herbicides, perhaps due to electrostatic repulsion, while there was significant benefit for a neutrally-charged polar herbicide (Dechene et al., 2014).

Table 6 Comparison of empty bed volumes (EBV) treated for hyphil-TrOCs as indicated by C/C_0=0.4 at the 25% sample port.

	EBV Treated Until C/C_0=0.4 at 25% Sample Port [b]											
Eng. Media Mix	Benzotriazole		Atrazine		Diuron		Fipronil		Imidacloprid		Mecoprop	
Sand	<1	±0	<1	±0	<1	±0	<1	±0	<1	±0	<1	±0
+Zeolite	<1	±0	<1	±0	<1	±0	<1	±0	<1	±0	<1	±0
+RAC	164	±14	39	±60	260	±43	1	±1	98	±45	6	±1
+Biochar	>450	-	154	±14	>450	-	100	±44	>450	-	39	±24
+Zeolite+Biochar	>450	-	150	±16	>450	-	134	±86	>450	-	46	±10
+Zeolite+RAC	359	±56	82	±34	>450	-	17	±3	162	±8	5	±1
Inf. Conc. [ug/L]	29.1	±3.1	42.3	±4.2	54.1	±4.5	33.0	±2.7	51.6	±4.2	50.6	±6.1

[a] Time weighted average ± standard deviation (n=3).

[b] Mean ± standard deviation (n=3) [EBVs].

- Indicates no calculated value due to lack of observed contaminants in sample.

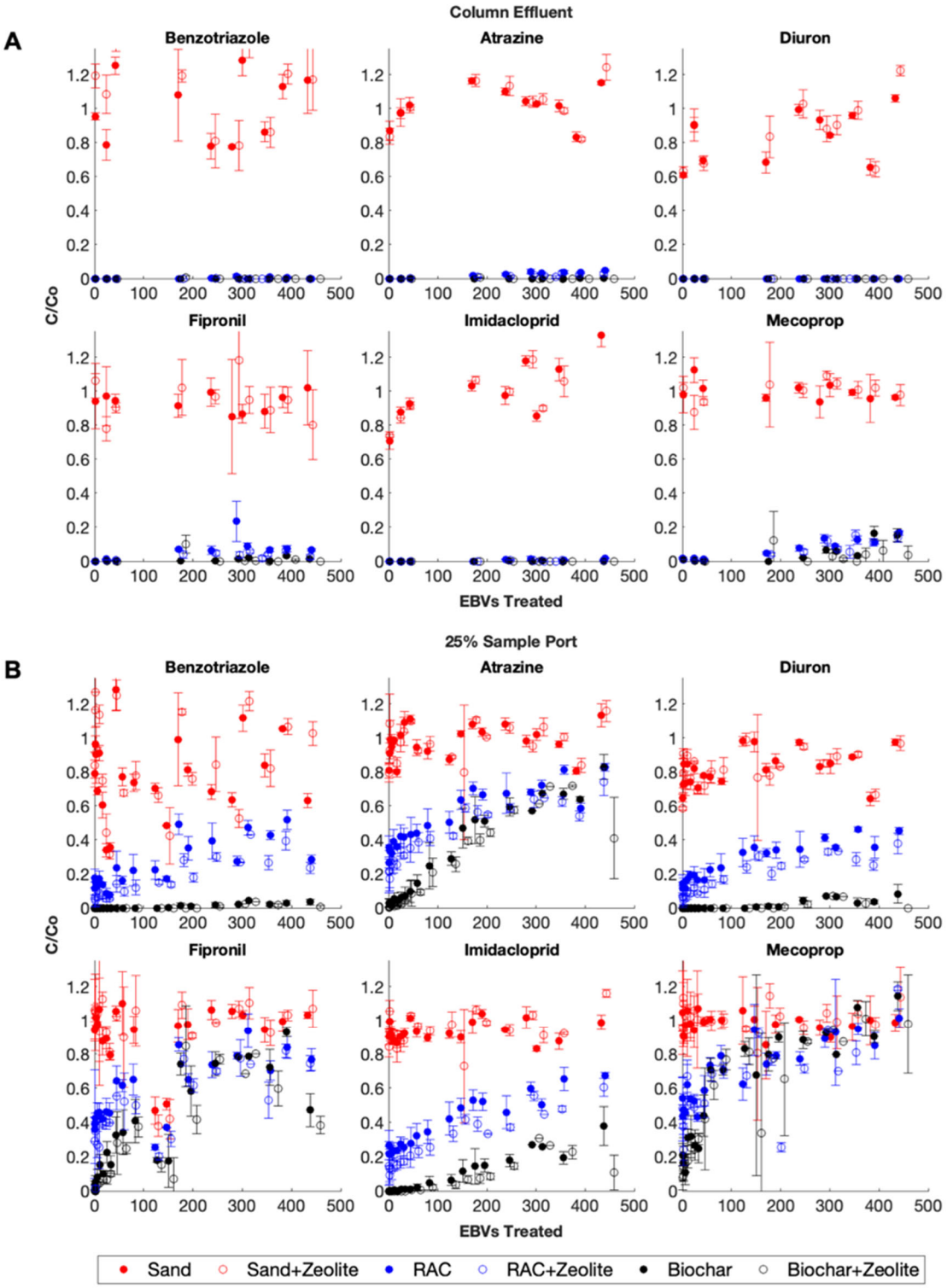

Figure 24 Dissolved hydrophilic TrOCs transport and breakthrough in the column effluent (A) and 25% sample port (B) (depth=15 cm media). Error bars indicate one standard deviation above and below the mean (n=3).

1.3.5 PFAS Removal

Dissolved influent concentrations of PFOS were 2,900±600 ng L^{-1} throughout the experiment (Table 7, Figure 70). Influent and sand column concentration variability may have been impacted by variable accumulation at air-water interfaces within the experimental design (i.e., the constant head overflow return; Figure 6). The six PFASs measured and reported here (PFHxA, PFOA, PFHxS, PFOS, Cl-PFOS, FHxSA) were best removed with BC amendment and negligibly removed in the sand and sand+zeolite columns (Figure 25 and Table 7). While biochar appeared to have better or equivalent removal performance initially, RAC performed better over the course of the experiment. Similar to the hyphil-TrOCs, zeolite addition to the BC-amended mixtures improved PFAS removal, likely due to the increased contact time resulting from zeolite's increased porosity relative to sand.

Of the PFASs with six perfluoroalkyl carbons (i.e., C6), PFAS species mobility is ranked PFHxA > FHxSA > PFHxS, as observed in Table 7. PFASs with eight perfluoroalkyl carbons (i.e., C8) ranked similarly with respect to species mobility: PFOA > PFOS > Cl-PFOS; steric effects and electronegativity differences between hydrophilic functional groups likely contribute to the differences in mobility across both carbon lengths. Long-chain C8 PFASs were better removed than shorter-chain C6 PFASs, as shown in Table 7 for both the RAC and biochar columns. This is fully expected due to steric effects on hydrophobic interactions and surface aggregation and has been widely observed in the literature (Du et al., 2014; Inyang and Dickenson, 2017). Furthermore, stormwater is a complex medium for PFAS sorption, as sorption may be hindered by the presence of DOC in stormwater (Appleman et al., 2014) but increased via electrostatic interactions by the presence of divalent cations such as calcium that are commonly found in stormwater (Du et al., 2015; Higgins and Luthy, 2006).

Effluent concentrations were observed to exceed influent values in some cases. An increase in semi-stable intermediates such as FHxSA can be expected due to transformation of precursors present in the AFFF spike solution such as AmPr-FHxSA, as illustrated by recent experimental evidence in soil columns (Maizel et al., 2021; Nickerson et al., 2020) although investigation of such transformation is beyond this study's scope. Some observed effluent concentrations relative to influent concentrations are likely high as a result of variability in influent concentration variation. PFOS, the best removed of the studied PFASs, has similar performance to mecoprop, the least removed of the studied hyphil-TrOCs.

Table 7 Comparison of empty bed volumes (EBV) treated for PFAS as indicated by C/C_0=0.4 at the 50% sample port.

	EBV Treated Until C/C_0=0.4 at 50% Sample Port [b]											
Eng. Media Mix	PFHxA		PFOA		PFHxS		PFOS		Cl-PFOS		FHxSA	
Sand	<1	±0	<1	±0	<1	±0	<1	±0	<1	±0	<1	±0
+Zeolite	<1	±0	<1	±0	<1	±0	<1	±0	<1	±0	<1	±0
+RAC	3	±2	45	±49	53	±61	75	±36	92	±52	1	±0
+Biochar	13	±1	76	±38	79	±27	93	±43	114	±25	69	±15
+Zeolite+Biochar	38	±35	115	±27	122	±4	157	±26	202	±16	102	±20
+Zeolite+RAC	8	±10	157	±109	80	±55	199	±63	111	±74	16	±24
Inf. Conc. [ug/L]	74.3	±14.9	98.1	±17.9	440	±68	2900	±600	47.3	±17.6	69.4	±30.1

[a] Time weighted average ± standard deviation (n=3).
[b] Mean ± standard deviation (n=3) [EBVs].
PFHxA is perfluorohexanoic acid; PFOA is perfluorooctanoic acid; PFHxS is perfluorohexane sulfonate; PFOS is perfluorooctane sulfonate; Cl-PFOS is chloro-perfluorooctane sulfonate; FHxSA is perfluorohexane sulfonamide.

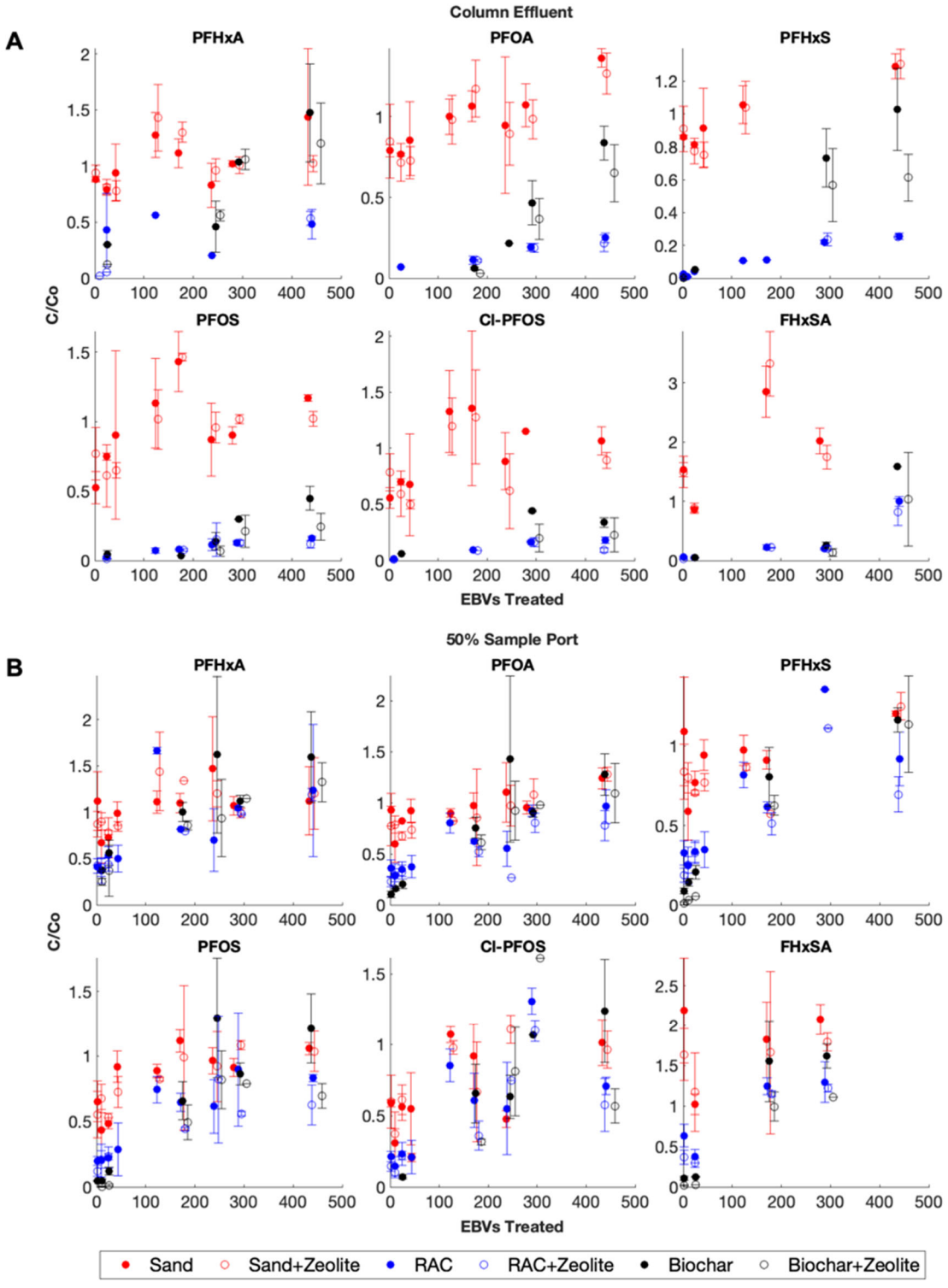

Figure 25 Dissolved PFAS transport and breakthrough in the column effluent (A) and 50% sample port (B). Error bars indicate one standard deviation above and below the mean (n=3).

2 Development of filter performance curves with kinetic and flow rate design parameters (Task 3).

2.1 Evaluate engineered media filters at higher flow rates (Subtask 3.1).

The measured porosity and calculated empty bed contact time and contact time are shown below in Table 8.

Table 8 Column Filter BC Content, Measured Porosity, EBCT, and Contact Time

40 cm hr^{-1} Engineered Media Mixture	BC v%	BC wt%	Porosity [-]	EBCT[a] [min]	Contact Time[b] [min]
Sand	-	-	0.34	90	30.6
+RAC	10	3.3	0.35	90	31.5
+Biochar	30	2.4	0.52	90	46.8
60 cm hr^{-1} Engineered Media Mixture	BC v%	BC wt%	Porosity [-]	EBCT[a] [min]	Contact Time[b] [min]
Sand	-	-	0.36	60	21.6
+RAC	10	3.3	0.36	60	21.6
+Biochar	30	2.4	0.55	60	33

[a] Empty bed contact time
[b] In-bed contact time

2.1.1 Water quality parameters.

The influent water quality of the synthetic stormwater remained consistent throughout the conditioning and challenge tests for both the 40 cm hr^{-1} and 60 cm hr^{-1} experiments, and was similar to experiments conducted in the previous tests at 20 cm hr^{-1}. The TSS and turbidity in the influent were 25.0±18.7 mg L^{-1} and 22.9±9.9 FNU during the 40 cm hr^{-1} experiment and 30.7±21.2 mg L^{-1} and 16.8±6.6 FNU during the 60 cm hr^{-1} experiment. All columns saw improvement in effluent TSS and turbidity, with TSS and turbidity reduced slightly more for the 40cm hr^{-1} (sand=85% reduction of TSS, 96% reduction of turbidity; RAC=87% TSS, 96% turbidity, biochar=87% TSS, 97% turbidity) than the 60 cm hr^{-1} experiment (sand=83% TSS, 95% turbidity; RAC=85% TSS, 95% turbidity, biochar=86% TSS, 97% turbidity), as shown in Table 55 – Table 66. The TSS and turbidity in the column effluent were higher than previously found for similar experiments conducted in Task 2 at 20 cm hr^{-1}. This is not surprising as interception is influenced by velocity. The turbidity dropped significantly (77%) after the sedimentation basin.

The pH, conductivity, and TDS of the synthetic stormwater remained consistent between the 40 cm hr^{-1} and 60 cm hr^{-1} experiments. For the 40 cm hr^{-1} experiment, the pH, conductivity and TDS were 7.4±0.2, 295±49 µS cm^{-1}, and 147±24 mg L^{-1} while these values were 7.0±0.6, 327±69 µS cm^{-1}, and 163±35 mg L^{-1} in the 60 cm hr^{-1} experiment. While the pH dropped slightly in the column effluent (~7.1 for each mixture in the 40 cm hr^{-1} experiment, ~6.8 for each mixture in the 60 cm hr^{-1} experiment), the conductivity and TDS remained constant.

DO and DOC in the synthetic stormwater influent were consistent between the 40 cm hr^{-1} (6.68±0.95mg L^{-1}, 4.2±1.0 mg C L^{-1}) and 60 cm hr^{-1} experiments (7.86±0.61mg L^{-1}, 6.3±1.4 mg C L^{-1}). The DO in all the columns decreased most for the RAC and biochar columns with the effluent DO<0.3 mg L^{-1} during the 40 cm hr^{-1} experiment and <0.4 mg L^{-1} during the 60 cm hr^{-1} experiment. The DO in the sand also decreased substantially to <0.4 mg L^{-1} during both the 40 cm hr^{-1} and 60 cm hr^{-1} experiments, though DO in the sand was consistently higher than in the BC amended columns. The DOC removal was greater in the BC amended columns than the sand columns. While the sand columns experienced ~20% and ~40% removal in the effluent during the 40 cm hr^{-1} and 60 cm hr^{-1} experiments, the RAC and biochar columns showed ~50% and >60% removal in the effluent during the 40 cm hr^{-1} and 60 cm hr^{-1} experiments, suggesting that the BC amendment provides a benefit to DOC removal. Notably, the DOC in the biochar effluent mirrored that of the RAC until about 200 EBVs during the 40 cm hr^{-1} experiment before the DOC increased in the biochar columns relative to the RAC. In the 60 cm hr^{-1} experiment, the DOC was consistently higher in the biochar columns relative to the RAC. The reduction in DO and removal of DOC, especially in the sand columns where sorption is not expected to significantly occur, suggests that biofilms are growing and consuming both the DO and DOC. While the decrease in DOC is immediate in the BC columns, the decrease in DOC is more gradual in the sand columns. The increased DOC removal in the BC amended columns may be due to a combination of sorption and increased microbial activity.

2.1.2 Metals Removal

Metal concentrations in the influent were consistent throughout the 40 cm hr^{-1} and 60 cm hr^{-1} experiments, as seen in Table 9. Although the same mass of each metal was spiked into the stormwater to achieve a concentration of 300 µg L^{-1} in clean water, the dissolved metal concentrations were less due to interactions with the TSS. Analysis with Minteq confirmed that the expected concentration of each metal was 300 µg L^{-1} based on the major ions present.

Metals were removed initially in all columns as seen in Figure 26, however rapid breakthrough was observed for Ni, Zn, and Cd in all treatment columns. In the BC amended columns the removal order was Pb>Cu>Cd~Ni~Zn. BC provided significant benefit for metal removal for Cu and Pb. As BC amendment was shown to provide significant benefit for all metal removal at lower concentration in Task 2, it appears the benefit of BC addition may not be able to overcome high concentrations of some metals in the influent. Biochar and RAC provided similar benefit, though biochar consistently provided slightly higher removal, as seen Task 2.

Metal removal performance was not sensitive to an increase in the flow rate from 40 to 60 cm hr^{-1}. The volume treated until C/C_0 breakthrough for each metal and engineered media mixture at each flow rate was within 10 EBVs, except for zinc in the biochar and RAC columns. This observation is not surprising, given that metal removal mechanisms are purported to be relatively fast.

Interestingly, observed metal removal differed when compared to Task 2, in which the same material mixtures using an identical experimental setup except for flow rate (20 cm hr^{-1}) and metal influent concentration (~10x less). Previously, experiments in Task 2 showed higher volume treated until C/C_0=0.4 breakthrough for nickel (RAC = 122±35 EBVs; biochar = 72±2 EBVs) and cadmium (RAC = 237±47 EBVs; biochar = 129±35 EBVs) at the lower metal concentration conditions while copper, zinc, and lead appear to have similar breakthrough profiles.

Table 9 Volume (EBVs) Treated Until Dissolved Metal Breakthrough

Flow Rate	Eng. Media Mix	Volume Treated Until Breakthrough C/C_0=0.4 [b] Ni		Cu		Zn	
40 cm hr^{-1}	Sand	4.9	±0.2	5.2	±0.2	27.0	±4.5
	+RAC	30.4	±3.8	>500	-	104.8	±121.1
	+Biochar	37.1	±0.6	>500	-	45.9	±11.1
	Influent Conc. [a]	187.8	±31.7	117.0	±20.5	64.9	±52.7
60 cm hr^{-1}	Sand	10.6	±1.8	15.3	±1.8	22.9	±2.5
	+RAC	31.3	±4.2	>500	-	30.0	±11.8
	+Biochar	35.9	±0.6	>500	-	32.7	±4.5
	Influent Conc. [a]	189.8	±30.4	118.2	±20.5	67.1	±53.1

Flow Rate	Eng. Media Mix	Volume Treated Until Breakthrough C/C_0=0.4 [b] Cd		Pb	
40 cm hr^{-1}	Sand	26.4	±1.3	>500	-
	+RAC	34.6	±2.8	>500	-
	+Biochar	34.2	±4.7	>500	-
	Influent Conc. [a]	93.4	±28. 4	20.8	±6.8
60 cm hr^{-1}	Sand	26.1	±1.9	>500	-
	+RAC	30.1	±9.0	>500	-
	+Biochar	35.3	±2.5	>500	-
	Influent Conc. [a]	92.3	±29.1	21.8	±6.6

[a] Time weighted average/standard deviation (n=3) [µg L^{-1}];
[b] Mean ± standard deviation (n=3) [EBVs];
- indicates no value

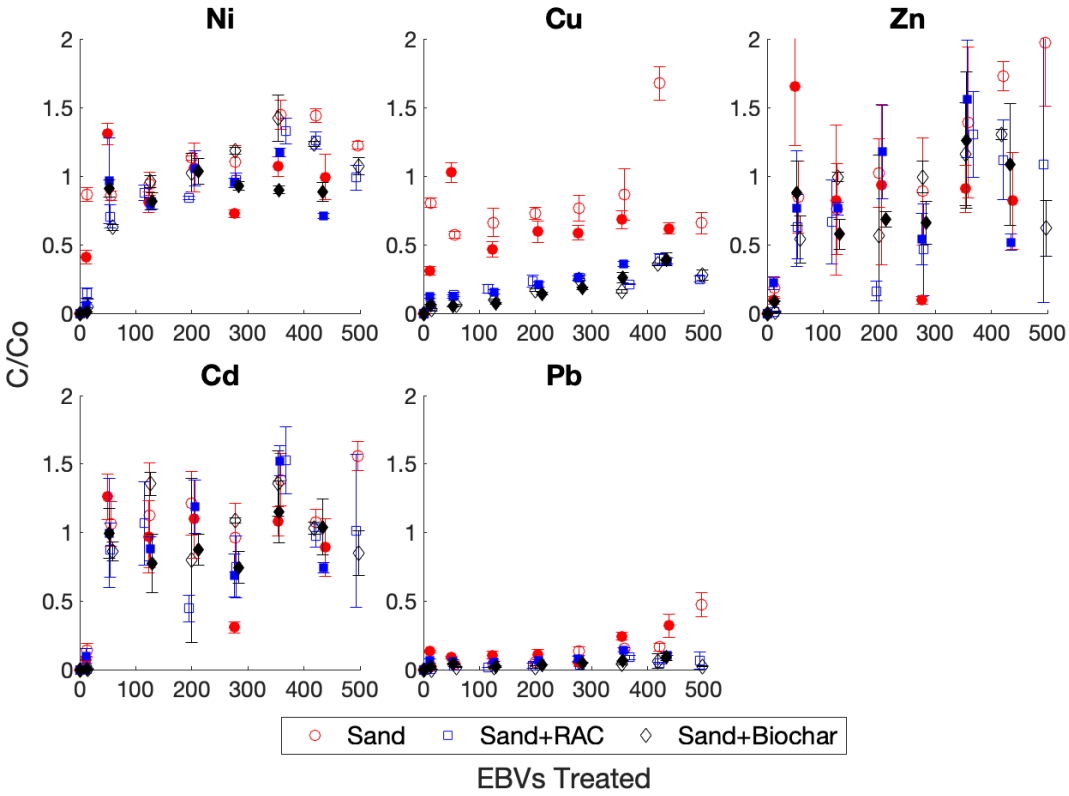

Figure 26 Dissolved metal breakthrough in column effluent for each engineered media mixture at 40 cm hr^{-1} (unfilled) and 60 cm hr^{-1} (filled) flow rates. Error bars indication one standard deviation above and below the mean (n=3).

2.1.3 Hydrophilic TrOCs Removal

Hyphil-TrOCs concentration in the spiked synthetic stormwater was consistent throughout the 40 cm hr^{-1} and 60 cm hr^{-1} experiments, as shown below in Table 10. The same mass of each hyphil-TrOC was added to achieve a concentration of ~40 µg L^{-1}. Similar to the metals, the observed concentration in the influent was less, in the range of 20-35 µg L^{-1}, indicating that the hyphil-TrOCs were removed in part with the suspended solids. Mecoprop concentration appeared higher, likely due to matrix affects. The observed influent concentrations were benzotriazole < imidacloprid < fipronil < atrazine < diuron < mecoprop, similar to the order observed in Task 2.

The sand columns provided no substantial benefit to hyphil-TrOCs removal in either the 40 cm hr^{-1} or 60 cm hr^{-1} experiments. Both biochar and RAC provided significant benefit for removal. Mecoprop and fipronil were the most mobile hyphil-TrOCs, and saw breakthrough of 35% and 24% in the RAC and 57% and 36% in the biochar columns after ~500 EBVs at a flow rates of 60 cm hr^{-1} and 40 cm hr^{-1} (Figure 27). While this is higher than previously observed at 20 cm hr^{-1}, the filters still provide significant contaminant removal. Interestingly, biochar provided superior treatment initially, but experienced higher concentrations of breakthrough later in the run.

This trend is particularly observable for mecoprop, fipronil, and atrazine at the 50% sample port and in the column effluent (Figure 27), in both the 40 cm hr^{-1} and 60 cm hr^{-1} experiments. This difference in breakthrough curve shape may be indicative of different sorption kinetics and reflect

the different sorption capacity of the columns. Better initial removal in the biochar columns followed by greater breakthrough towards the end of the experiment suggests that contaminant removal kinetics are faster for biochar but that over time, the biochar sorption capacity is exhausted leading to greater breakthrough. The faster removal kinetics for biochar may be explained by greater contact time and the higher distribution of mesopores, which facilitate faster diffusion of solutes into the biochar grain as the pores are less likely to be blocked by DOC or solute diffusion into the intraparticle pores is less likely to be impacted by steric hindrance. The faster exhaustion of sorption capacity is not surprising as there is less mass of biochar in the columns (2.4 wt% biochar; 3.3 wt% RAC) and biochar has a smaller surface area than RAC.

The breakthrough curves for each compound in the 40 cm hr^{-1} and 60 cm hr^{-1} experiments are very similar, as shown in Figure 27. However, the observed concentrations in the breakthrough curves for the 60 cm hr^{-1} experiment are consistently and significantly higher than those of the 40 cm hr^{-1} experiment, indicating that increasing the flow rate will reduce the filter performance. This is particularly evident at the beginning of the experiment, where breakthrough at the 60 cm hr^{-1} occurs much earlier than during the 40 cm hr^{-1} experiment. Due to the complex shape of the breakthrough curves, the 50% increase in flow rate does not appear to correlate to an equal decrease in performance for each contaminant over time and at each sampling location. Instead, the increased flow affect seems to be most noticeable initially for the more mobile contaminants and later for the better removed compounds. Moreover, small changes in the appearance of the breakthrough curves may translate to large changes in the volume of stormwater treated before achieving a certain level of breakthrough, as shown below in Table 10. The effect of flow rate is significant, but requires modeling to fully elucidate the implications on filter performance. Additionally, the significant effect of flow rate on filter performance further confirms the kinetic-limitations of contaminant removal in BC amended engineered media filters.

Table 10 EBVs Treated until Hyphil-TrOCs Breakthrough (C/C_0=0.4) at 25% Sample Port

Flow Rate	Eng. Media Mix	Approximate Volume Treated Until Breakthrough C/C_0=0.4 [b]					
		Benzotriazole		Atrazine		Diuron	
40 cm hr^{-1}	Sand	0	±0	0	±0	0	±0
	+RAC	64.7	±11.3	33.7	±43.4	224.8	±117.2
	+Biochar	>500	-	95.5	±13.9	>500	-
	Influent Conc. [a]	15.2	±1.7	35.4	±2.5	37.7	±2.7
60 cm hr^{-1}	Sand	0	±0	0	±0	0	±0
	+RAC	0	±0	0	±0	24.3	±15.8
	+Biochar	>500	-	18.7	±5.1	331.0	±63.6
	Influent Conc. [a]	19.0	±2.5	35.3	±2.5	36.8	±1.6
Flow Rate	Eng. Media Mix	Approximate Volume Treated Until Breakthrough C/C_0=0.4 [b]					
		Fipronil		Imidacloprid		Mecoprop	
40 cm hr^{-1}	Sand	0	±0	0	±0	0	±0
	+RAC	0	±0	132.3	±12.5	0	±0
	+Biochar	70.3	±24.0	240.8	±79.5	19.4	±16.1
	Influent Conc. [a]	36.7	±9.0	35.8	±1.9	50.4	±2.9
60 cm hr^{-1}	Sand	0	±0	0	±0	0	±0
	+RAC	0	±0	11.3	±6.1	0	±0
	+Biochar	14.7	±2.1	109.9	±7.5	1.7	0.0
	Influent Conc. [a]	33.5	±3.4	32.4	±2.7	48.4	±3.6

[a] Time weighted average/standard deviation (n=3) [µg L^{-1}];
[b] Mean ± standard deviation (n=3) [EBVs];
- indicates no value

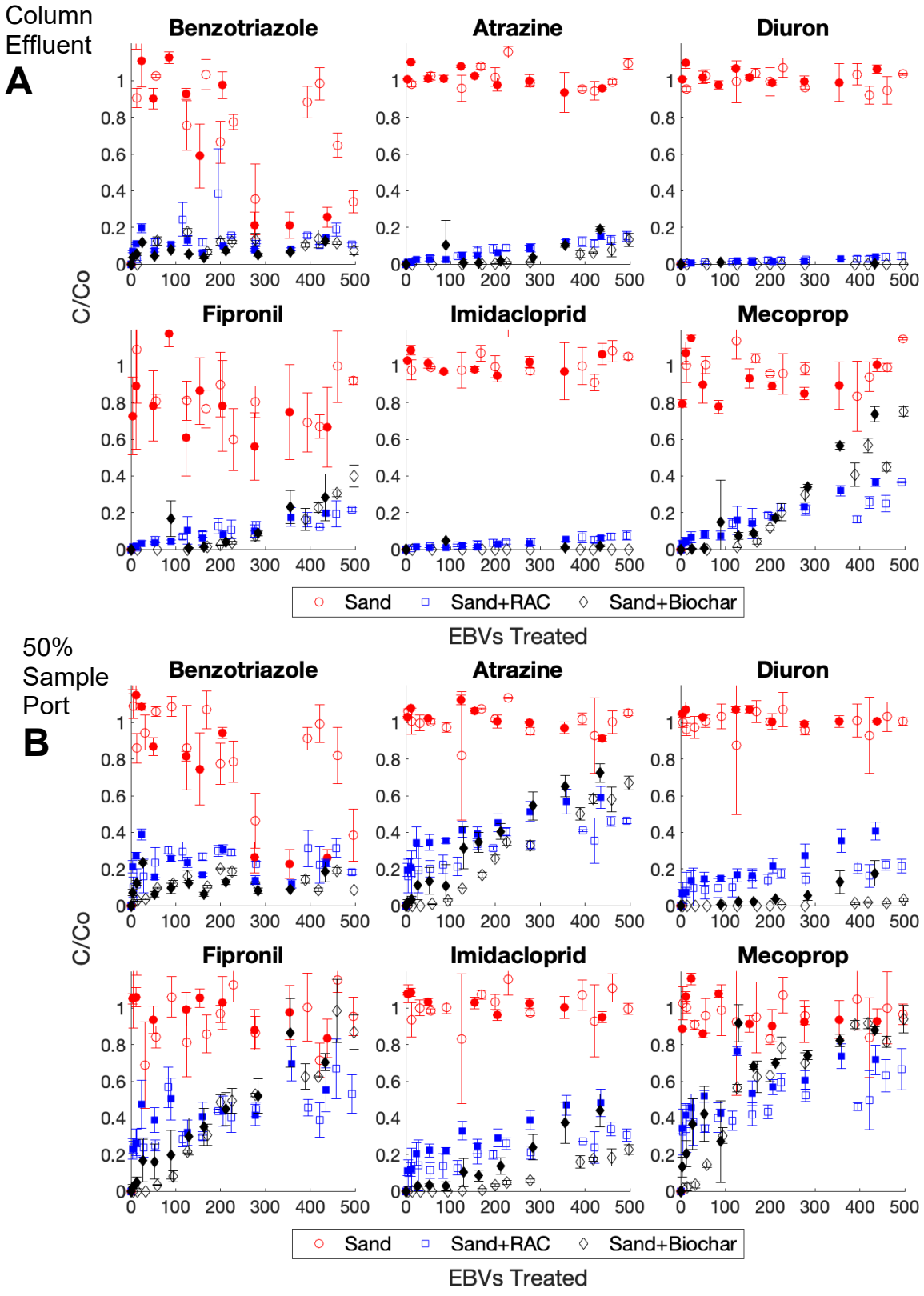

Figure 27 Observed hyphil-TrOCs breakthrough in the column effluent (A) and 50% sample port (B) at 40 cm hr^{-1} (unfilled) and 60 cm hr^{-1} (filled) flow rates. Error bars indicate one standard deviation above and below the mean (n=3).

2.2 Develop, fit, and validate model to predict contaminant transport in engineered media filters (Subtask 3.2)

2.2.1 Model fitting

Transport data from the column studies from Task 2 were used to fit the model parameters. Tracer tests from Task 2 were conducted with a pulse of bromide to determine column dispersivity by fitting the transport model to the tracer breakthrough observed in the sand columns (Figure 95). For sand, this is effectively a 1-d advection dispersion transport model, as there was no intraparticle diffusion because the sand grains were assumed to be solid. Tracer curves were then fit for the RAC and biochar columns to confirm the dispersivity parameter found in the sand columns by introducing a tortuosity and apparent linear-sorption coefficient parameter. Including the tortuosity factor and apparent bromide linear-sorption coefficient were necessary to reproduce the observed tracer breakthrough using the average dispersivity found in the sand columns (Figure 95). The use of the dispersivity from the sand columns was necessary to reduce the number of parameters optimized for the tracer fitting for the biochar and RAC columns.

The tracer tests suggest that bromide is weakly interactive when used in BC amended media. Further, tortuosity factor values outside the accepted tortuosity range for black carbon of 1-6 (Leyvaramos and Geankoplis, 1994; Ocampo-Perez et al., 2012) suggest an additional pore-diffusion hindrance factor, as postulated by Portmann et al. (2022). In the case of the tracer tests, the additional pore-diffusion hindrance may be due to electrostatic repulsion between the negatively charged bromide and the negatively charged surfaces of the BC. The larger tortuosity factor values observed in the RAC relative to the biochar may be due to the smaller pore size distribution of the RAC, where the smaller pores may elevate pore diffusion hindrance. Additional material and column properties were gathered for the sand, biochar, and RAC. Model input parameters are shown below in Table 11.

The contaminant transport model was fit to observed contaminant breakthrough at various locations in the column by finding the optimal Freundlich sorption parameters (K_{fr}, n_{fr}) and tortuosity factor (τ) for each replicate column for each BC mixture. The fminsearch solver first makes a simplex computation around the initial guess by adding 5% increments of each component and modifies the simplex until the local minimum of the error function is reached, thus, the starting sorption and tortuosity parameters directly influence the resulting fit parameters. Therefore, the fitting procedure was iterated several times using different start parameters in order to find the start parameters that resulted in the lowest error. Details regarding the start parameters may be found in the Appendix.

Table 11 Model, Material, and Column Input Parameters for Modeling

n_{sv}	# column sub-volumes	160	-
n_{bc}	# shells in black carbon	100	-
n_{ts}	# time steps	3,000	-
L_c	column length	0.6	m
R_c	column radius	0.0381	m
α_L	longitudinal dispersivity	0.00368	m
d_S	solid density of sand	2,650	kg m^{-3}
d_{bc}	BC skeletal density[c]	1,998[a]	kg m^{-3}
		2,055[b]	kg m^{-3}
p_{bc}	BC intraparticle porosity[d]	0.465[a]	-
		0.838[b]	-
R_S	radius of sand[e]	0.00100	m
R_{bc}	BC radius[e]	0.00080[a]	m
		0.00088[b]	m

[a] Value for RAC
[b] Value for biochar
[c] Measured by helium pycnometry (Particle Technology Labs, Downers Grove, IL, USA)
[d] Measured by mercury intrusion porosimetry (Particle Technology Labs, Downers Grove, IL, USA)
[e] Measured by dry sieving particle size analysis

As the flow rate, material mass, and engineered media length were column-specific, each column was fitted individually. Since the optimized sorption and tortuosity parameters resulting from each column fit are dependent combinations, where the value of one parameter influences the values of the other two, the parameters themselves may not be averaged between column replicates. Instead, each combination of sorption and tortuosity parameters was treated as a separate model and the breakthrough curves resulting from the three models were averaged and plotted with the standard deviation. The sorption and tortuosity parameters are shown in Table 12. As was observed for the tracer tests, the fitted tortuosity parameters exceed the typical range of material tortuosity and therefore likely also includes other pore-diffusion hindrance factors, such as solute steric hindrance, solute electrostatic repulsion and interaction with the BC surface, and BC pore-blocking from background DOC (Wang et al., 2017), among others. Mecoprop, the only contaminant studied that exists as an anion under the experimental conditions, has the highest tortuosity value. Similar to the tracer tests, the tortuosity values are greater for the RAC than they are for the biochar, perhaps indicating that the pore structure affects the rate of hyphil-TrOC diffusion into the BC grains. The PFASs carboxylic acids generally have higher tortuosity parameters than the sulfonates. The Freundlich sorption coefficient is significantly lower for the PFASs than the hydrophilic TrOCs.

Table 12 Modeled Sorption and Tortuosity Parameters Fit Using All Available Data

Biochar	τ[a]			K_{fr}[b]			$1/n$[c]		
	B1	B2	B3	B1	B2	B3	B1	B2	B3
Atrazine	15.7	30.7	39.1	0.41	0.26	0.18	0.30	0.18	0.12
Benzotriazole	21.0	30.4	41.7	1.13	1.17	2.43	0.09	0.14	0.13
Diuron	17.5	36.8	30.3	1.06	1.87	2.81	0.11	0.06	0.05
Fipronil	22.3	28.0	42.9	0.12	0.097	0.090	0.22	0.16	0.09
Imidacloprid	22.3	19.8	29.5	0.48	0.52	0.46	0.14	0.22	0.13
Mecoprop	66.7	68.8	74.1	0.15	0.16	0.18	0.10	0.13	0.11
RAC	τ[a]			K_{fr}[b]			$1/n$[c]		
	R1	R2	R3	R1	R2	R3	R1	R2	R3
Atrazine	30.0	25.9	23.1	0.18	0.16	0.15	0.11	0.10	0.10
Benzotriazole	34.6	30.9	24.4	0.32	0.29	0.19	0.16	0.16	0.08
Diuron	21.6	17.9	15.8	0.56	1.44	0.67	0.25	0.36	0.25
Fipronil	18.0	19.3	16.0	0.08	0.04	0.03	0.23	0.09	0.11
Imidacloprid	21.6	19.8	17.2	0.18	0.2	0.28	0.05	0.11	0.16
Mecoprop	37.3	30.7	31.9	0.13	0.14	0.19	0.11	0.14	0.17
Biochar	τ[a]			K_{fr}[b]			$1/n$[c]		
	B1	B2	B3	B1	B2	B3	B1	B2	B3
PFHxA	59.3	153.5	20.5	0.0022	0.0031	0.1482	0.48	0.39	0.78
PFOA	56.8	67.0	81.2	0.0010	0.0012	0.0011	0.79	0.26	0.17
PFPeS	61.4	77.2	89.4	0.0004	0.0002	0.0003	0.27	0.08	0.08
PFHxS	57.0	38.1	30.6	0.0018	0.0177	0.0309	0.23	0.46	0.65
PFOS	32.2	61.6	61.7	0.0053	0.0115	0.0107	0.16	0.15	0.15
CL-PFOS	31.1	66.7	49.6	0.0017	0.0055	0.0007	0.31	0.33	0.23
FHxSA	97.8	76.1	74.5	0.0052	0.0073	0.0092	0.67	0.67	0.73
RAC	τ[a]			K_{fr}[b]			$1/n$[c]		
	B1	B2	B3	B1	B2	B3	B1	B2	B3
PFHxA	45.3	50.1	44.2	0.0107	0.0289	0.0288	0.38	0.59	0.63
PFOA	35.4	33.8	35.5	0.0099	0.0079	0.0063	0.34	0.31	0.30
PFPeS	35.9	27.6	32.4	0.0005	0.0004	0.0003	0.15	0.14	0.10
PFHxS	26.4	21.5	22.2	0.0081	0.0104	0.0050	0.27	0.27	0.22
PFOS	23.0	19.3	21.0	0.0037	0.0058	0.0047	0.07	0.12	0.03
CL-PFOS	18.9	19.1	20.1	0.0100	0.0044	0.0112	0.39	0.32	0.36
FHxSA	42.7	33.2	35.7	0.0092	0.0104	0.0130	0.74	0.69	0.77

[a] Tortuosity [-]
[b] Freundlich sorption capacity coefficient [$(mol\ L^{-1})(L\ mol^{-1})^{1/n}$]
[c] Freundlich sorption intensity parameter [-]

The fitting process was conducted for contaminant transport data observed for each replicate test at the 25% sample port, 50% sample port, and all three sample locations (25% sample port, 50% sample port, effluent) together. PFASs fitting was conducted at only the 50% sample port. The full column fit weighed the three sample locations equally. Since observations below the minimum

quantification limit were not used in the fitting, the full column fit consisted of only the 25% and 50% sample port locations for the biochar for most of the contaminants. Tables of the sorption and tortuosity parameters fit at the 25% sample port may be found in Table 67, 50% sample port in Table 68, and using the whole column in Table 12. Plots of the predicted breakthrough and observed breakthrough at each sample port are shown below (for the parameters fit using all available data at all sample locations) in Figure 28 and Figure 29, and in Figure 96 –Figure 99 (for the 25% and 50% sample ports respectively). The fluctuations in the prediction are due to variability in both the flow rate and influent concentration during the tests. The short-term fluctuations are due to the highly variable nature of the column flow rate and show the great impact flow rate has on contaminant removal kinetics. The greater fluctuations in the RAC predictions suggest that RAC may be more sensitive to flow rate than biochar, which may be indicative of greater sensitivity of RAC's contaminant removal kinetics compared to biochar.

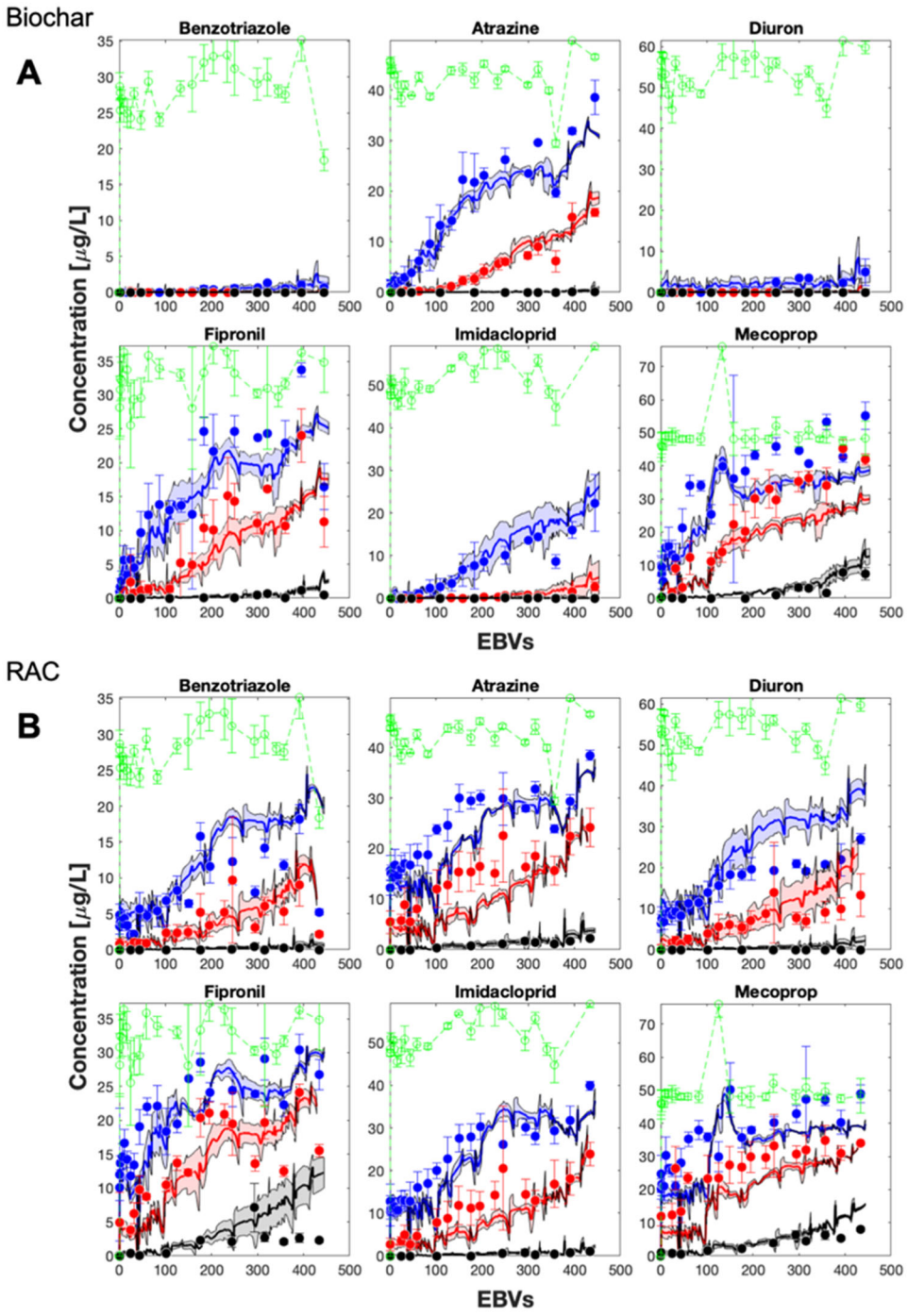

Figure 28 Mean observed (points) and predicted (line) and breakthrough curves for biochar (A) and RAC (B) at 20 cm hr^{-1} as found by fitting all observed data together. Column breakthrough is shown for the 25% sample port (blue), 50% sample port (red), and effluent (black). Shaded area shows the standard deviation of the predicted breakthrough curves. Mean observed influent is shown in green and error bars indicate one standard deviation above and below the mean.

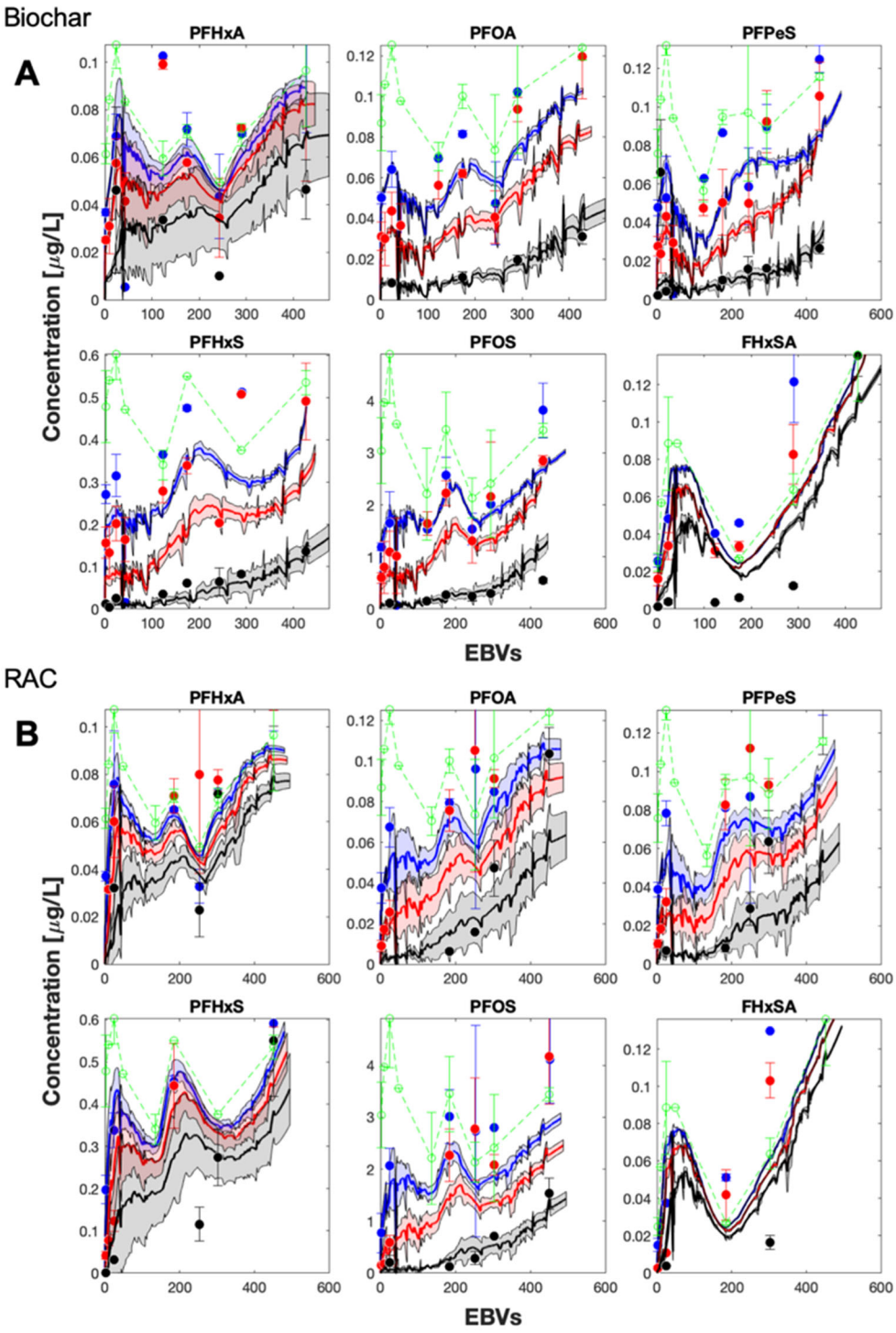

Figure 29 Mean observed (points) and predicted (line) PFASs breakthrough curves for biochar (A) and RAC (B) at 20 cm hr^{-1} as found by fitting all observed data together. Column breakthrough is shown for the 25% sample port (blue), 50% sample port (red), and effluent (black). Shaded area shows the standard deviation of the predicted breakthrough curves. Mean observed influent is shown in green and error bars indicate one standard deviation above and below the mean.

The NMSE of each modeled prediction using the three sets of fitting parameters was computed, and is shown below in Table 13. The sum of NMSE (equally weighted among the three sample locations) was highest for the parameters fit at the 25% port, indicating that sorption and tortuosity parameters fit further down the column better predicted breakthrough than parameters fit to the contaminant transport data at the 25% sample port. Indeed, standard deviations are largest for the predictions made by parameters fit from the 25% sample port. While the parameters fit from all available data best predicted contaminant breakthrough in the RAC columns, the parameters fit from the 50% sample port and all available data appeared to predict breakthrough similarly for the biochar columns. Since most of the contaminants in the biochar column effluent were either not visible or only at very low concentrations, the contaminant transport data in the biochar column effluent likely did not greatly influence the fit parameters as much as the 25% and 50% sample port data. Therefore, the full column fit for the biochar was more heavily influenced by the observed contaminant transport at the 25% sample port than was the case for the RAC columns. The greater accuracy of the sorption parameters fit from further down the column may be due to less and/or delayed fouling from microbial activity and DOC that was present within the top 25% of the column. The tortuosity and sorption parameters fit using the transport data further down the column appear to be more accurate and are likely better estimates of the sorption and tortuosity values.

While the parameters found from the 25% sample port are likely not as good an estimate of the true compound sorption and tortuosity parameters, they are still able to predict contaminant transport at each location in the column and may serve as validated parameters to predict contaminant transport. While the model with these parameters closely predicts breakthrough at the 50% sample port, the model and these parameters overestimate breakthrough in the column effluent. Thus, the model and sorption parameters fit to the 25% sample port is validated for predicting contaminant transport in similar BC filters, with the understanding that the prediction is a more conservative estimate of the longer term the treatment.

Table 13 NMSE of Model Predictions Fit from Various Locations

Biochar	25% Sample Port[a]				50% Sample Port[a]				Full Column[a]			
	25%	50%	Eff	**Sum[b]**	25%	50%	Eff	**Sum[b]**	25%	50%	Eff	**Sum[b]**
Atrazine	0.68	0.71	16.3	**17.7**	0.69	0.19	0.97	**1.85**	0.67	0.19	1.10	**1.96**
Benzotriazole	0.42	58.0	-	**58.4**	0.42	58.0	-	**58.4**	0.37	48.2	-	**48.6**
Diuron	0.23	-	-	**0.23**	0.23	-	-	**0.23**	0.24	-	-	**0.24**
Fipronil	0.31	1.56	27.5	**29.4**	0.58	0.46	2.94	**3.97**	0.53	0.51	1.12	**2.16**
Imidacloprid	0.34	2.82	376.8	**380.0**	0.93	0.25	58.7	**59.9**	0.60	0.68	112.1	**113.4**
Mecoprop	0.19	0.51	4.39	**5.09**	0.22	0.34	4.90	**5.46**	0.27	0.45	0.58	**1.30**
PFHxA					0.23	0.16	0.45	**0.83**	0.22	0.24	0.53	**0.99**
PFOA					0.11	0.14	1.32	**1.57**	0.13	0.25	0.47	**0.84**
PFPeS					0.14	0.11	0.82	**1.07**	0.16	0.23	0.55	**0.94**
PFHxS					0.08	0.08	3.79	**3.94**	0.08	0.33	1.23	**1.64**
PFOS					0.23	0.18	2.20	**2.62**	0.18	0.43	0.53	**1.15**
FHxSA					0.58	0.54	0.64	**1.75**	0.37	1.37	1.44	**3.18**
RAC	25% Sample Port				50% Sample Port				Full Column			
	25%	50%	Eff	**Sum**	25%	50%	Eff	**Sum**	25%	50%	Eff	**Sum**
Atrazine	0.03	0.11	3.94	**4.07**	0.02	0.10	3.67	**3.80**	0.06	0.30	0.25	**0.61**
Benzotriazole	0.21	0.59	1.64	**2.43**	0.28	0.43	0.24	**0.94**	0.31	0.50	0.21	**1.01**
Diuron	0.09	0.41	-	**0.50**	0.14	0.51	-	**0.66**	0.18	0.27	-	**0.46**
Fipronil	0.27	0.11	4.90	**5.27**	0.28	0.08	4.05	**4.41**	0.27	0.16	1.33	**1.76**
Imidacloprid	0.06	0.22	2.10	**2.37**	0.06	0.20	3.78	**4.05**	0.07	0.31	0.43	**0.81**
Mecoprop	0.05	0.07	3.59	**3.72**	0.05	0.07	3.62	**3.74**	0.13	0.33	0.30	**0.76**
PFHxA					0.67	0.16	0.74	**1.57**	0.65	0.16	0.78	**1.59**
PFOA					0.08	0.08	0.97	**1.12**	0.09	0.18	0.05	**0.32**
PFPeS					3.87	0.10	1.68	**5.66**	3.15	0.24	1.36	**4.75**
PFHxS					4.70	0.10	2.82	**7.62**	2.96	0.49	0.33	**3.78**
PFOS					5.98	0.13	1.18	**7.29**	4.48	0.22	0.16	**4.87**
FHxSA					0.24	0.14	3.71	**4.09**	0.26	0.14	2.09	**2.49**

[a] Location of observed data used to fit sorption and tortuosity parameters
[b] Sum of NMSE from each sample location (equally weighted)
- Indicates no NMSE calculated due to no observations above the minimum quantification level

2.2.2 Batch isotherm fit parameter comparison to modeled parameters

Batch isotherms conducted over 90 days with similar stormwater matrix conditions as in the column experiment are shown below in Figure 30. The log-transformed isotherms were linear and the coefficient of correlation (r^2) value for the isotherm fits was high (>0.9; Table 70), suggesting confidence in the observed values. The order of compound affinity to BC observed in the isotherms generally matched the obscrved transport in the column experiments, with fipronil and mecoprop the most mobile contaminants in the column experiments also sorbing least to the BC in the batch isotherm experiments. Biochar appears to sorb more contaminants than RAC on a per-mass basis, which is consistent with the superior initial performance of biochar in the column experiments.

The same amount of DOC was added to the batch test jars, however due to the inhibition of biological growth for the isotherm measurements, the background DOC (9.7 mg C L^{-1}) was greater than observed in the column influent. Biochar appears to sorb more contaminants than RAC on a

per-mass basis, which is consistent with the superior initial performance of biochar in the column experiments.

While RAC surface area (~800 – 1100 m^2 g^{-1}) is greater than biochar used in this study (499 m^2 g^{-1}) and would suggest that RAC has a greater sorption capacity than biochar, the biochar appeared to sorb more contaminants than RAC on a mass basis, as shown below in Figure 30. The reduction in sorption capacity in the BC may be due to competition and interference from the background DOC, and may be more significant for RAC than biochar, as the sorption capacity of RAC is larger than biochar in the absence of DOC (Pignatello et al., 2006). Koelmans et al. found that increasing humic acid loadings decreased the isotherm slopes while increasing the nonlinearity of isotherms describing PCB sorption to charcoal, indicating more competition at the surface (Koelmans et al., 2009). Pignatello et al. found that humic acid and fulvic acid suppressed organic compound adsorption in proportion to increasing DOC molecular size, and thus contribute to pore blocking or act as competitive adsorbates (Pignatello et al., 2006). Quinlivan et al. reported that the ratio of the size of pores to the kinetic diameter of the adsorbate was crucial to preventing pore blockage or constriction due to DOC adsorption, and that micropollutant adsorption capacity decreased more dramatically in adsorbents with smaller pores (Quinlivan et al., 2005). Thus, the larger pore sizes in biochar used in this work compared to RAC **(**Figure 48 **–** Figure 49) may contribute to the reduced inhibition of contaminant removal capacity caused by DOC.

The Freundlich sorption parameters observed in the batch tests and those derived from the column-fit data are similar. However, the column test-derived linearized isotherms generally show greater sorption capacity than the isotherm-derived linearized isotherm in Figure 100. The slope factors derived from the column data are generally less than the batch isotherms, while the intercept is considerably higher for the column-fit isotherms. The slope factor (1/n) is generally considered to be the intensity parameter while the intercept (K_f) is considered to be the capacity parameter. Thus, it appears that the capacity of the carbon in the batch tests were consistently lower than in the column experiments. The difference in performance may be indicative of the difference in conditions of a continuous flow system compared to a static batch test. Since a period of 90 days is considered adequate for assuming equilibrium (Portmann et al., 2022), the difference in estimated isotherm parameters is more likely due to systematic difference between a batch and column system, particularly with respect to DOC.

The DOC loading is different for the batch and column systems. In the batch test, all of the carbon is subjected to the same initial concentration of DOC (9.5±0.7 mg C L^{-1}) while in the column experiment, the DOC concentration profile in the influent (3.7±1.1 mg C L^{-1}) is reduced as the stormwater travels down the column. Since DOC largely is believed to interact only with the surface of the carbon due to steric limitations and therefore not accumulate inside the carbon, the steady state concentration of DOC is likely to impact TrOCs sorption more than the total mass of DOC loading over the course of the experiment. While the DOC was partially removed by the carbon in the batch test, the minimum observed concentration of DOC was 9.5 mg C L^{-1} while the steady state DOC concentration was 1.6 mg C L^{-1} and 1.1 mg C L^{-1} in the biochar and RAC column effluent by the end of the column experiment. Therefore, the carbon at the bottom of the column sees a lower DOC concentration than the carbon in the batch test. As DOC is known to impact TrOCs kinetics through slowing pore diffusion by pore-blocking and compete with TrOCs for

surface sorption sites (Wang et al., 2017), the reduced steady state concentration of DOC in the columns likely explains the better sorption than observed in the batch tests.

The isotherm-derived parameters were used to fit the observed breakthrough curves from the full column by conducting a single parameter fit of the tortuosity factor. The single-parameter-fit tortuosity values are less than those found from the from fitting the sorption and tortuosity parameters together, though the relative order of values is similar, with mecoprop having the highest tortuosity values (Table 14). The NMSE of the predicted breakthrough using the isotherm sorption parameters and fit-tortuosity are higher than for the observed breakthrough-fit sorption and tortuosity parameter predictions. The model predictions using the isotherm parameters over-predicts breakthrough at each sample port, with the over-prediction greater the further down the column.

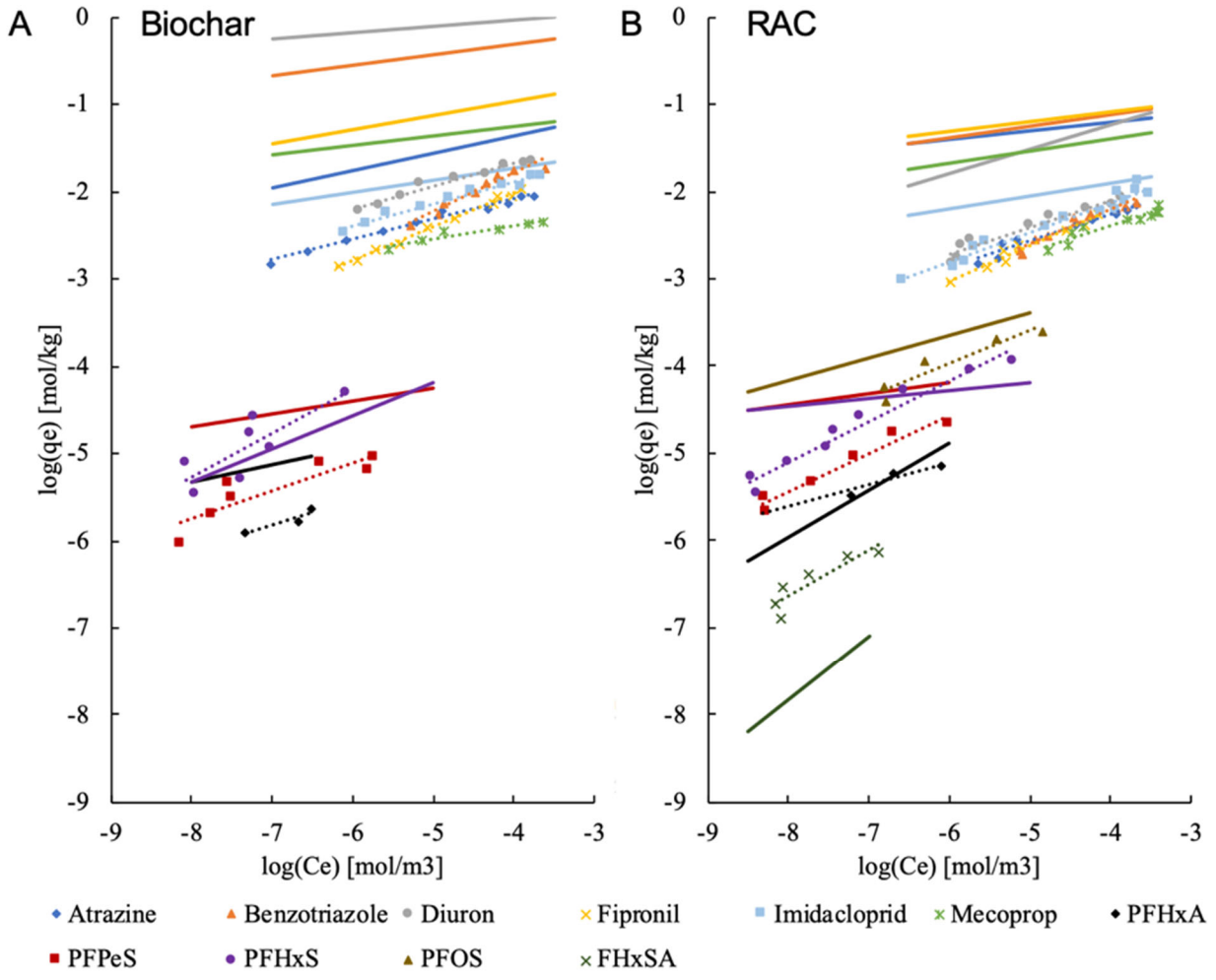

Figure 30 Batch isotherms conducted with biochar (left) and RAC (right) with same suite of contaminants, background DOC, and water quality conditions as used in the column experiments. Contaminant concentrations in the batch tests (hyphil TrOCs: 100 µg L^{-1}, PFASs: 8µg PFOS L^{-1}) were increased from levels used in the column experiments (hyphil TrOCs: 40 µg L-1, PFASs: 3µg PFOS L^{-1}) to facilitate analysis.

Table 14 Isotherm Sorption Parameters, Fit Tortuosity, and Prediction NMSE

Biochar	K_{fr}[a]	$1/n$[b]	r^2	τ[c]			NMSE[d]			
				B1	B2	B3	25%	50%	Effluent	Sum
Atrazine	0.071	0.23	0.99	10.2	16.8	19.4	1.65	7.37	127.89	136.91
Benzotriazole	0.92	0.44	0.97	1.0	2.4	43.5	4.99	-	-	4.99
Diuron	0.22	0.26	0.98	1.3	1.9	3.1	2.57	-	-	2.57
Fipronil	0.34	0.39	1.00	11.7	13.0	18.1	0.23	1.07	17.09	18.40
Imidacloprid	0.13	0.25	0.99	5.7	6.2	15.8	3.34	26.16	1.90	31.40
Mecoprop	0.017	0.15	0.96	53.8	53.7	55.6	0.40	1.94	10.88	13.23
PFHxA	0.00015	0.28	0.92	58.0	39.3	47.8	0.24	0.17	0.39	0.80
PFPeS	0.00061	0.31	0.87	55.2	42.2	56.5	0.19	0.22	1.24	1.65
PFHxS	0.055	0.50	0.81	11.7	17.6	19.0	4.49	29.55	108.24	142.28
RAC	K_{fr}[a]	$1/n$[b]	r^2	τ[c]			NMSE[d]			
				R1	R2	R3	25%	50%	Effluent	Sum
Atrazine	0.093	0.31	0.98	12.7	9.7	10.2	0.13	0.68	21.76	22.58
Benzotriazole	0.24	0.40	0.97	17.2	15.9	14.9	1.29	4.36	41.63	47.28
Diuron	0.14	0.31	0.97	12.6	10.5	9.7	0.81	3.26	-	4.07
Fipronil	0.26	0.41	0.98	11.9	10.9	10.9	0.26	0.15	6.72	7.14
Imidacloprid	0.17	0.34	0.98	8.8	7.1	7.3	0.33	1.58	45.27	47.18
Mecoprop	0.063	0.30	0.95	22.8	17.0	20.5	0.10	0.29	10.92	11.30
PFHxA	0.00023	0.24	0.97	36.1	87.4	147.9	0.75	0.18	0.80	1.73
PFPeS	0.012	0.44	0.98	36.8	29.4	32.5	4.70	0.14	2.22	7.06
PFHxS	0.044	0.47	0.98	22.6	17.9	19.1	4.94	0.34	0.85	6.14
PFOS	0.019	0.37	0.94	14.2	11.2	13.2	7.54	0.54	2.59	10.66
FHxSA	0.0035	0.52	0.90	27.3	18.9	19.5	0.39	0.43	3.15	3.97

[a] Freundlich sorption capacity coefficient [(mol L^{-1})(L mol^{-1})$^{1/n}$]
[b] Freundlich sorption intensity parameter [-]
[c] Tortuosity [-] found by single parameter fitting of full column observed transport data
[d] NMSE found for averaged contaminant breakthrough prediction at each column location
[e] Sum of NMSE from each sample location (equally weighted)
- Indicates no NMSE calculated due to no observations above the minimum quantification level

2.2.3 Model validation at higher flow rates

Observed hyphil-TrOCs data are plotted below in Figure 31 and Figure 32 with the contaminant transport model-predicted breakthrough for the 40 cm hr^{-1} and 60 cm hr^{-1} experiments. The model predicts contaminant transport well, as calculated NMSE values are low relative to NMSE values found for the initial model fitting of the different sample locations in the 20 cm hr^{-1} experiment (Table 15). The model seems to predict contaminant transport in the RAC columns better than for the biochar columns, as the NMSE is larger for the biochar columns. The close agreement between the observed data and the predicted breakthrough curve validates that the 1-d intraparticle pore diffusion-sorption model for predicting hyphil-TrOCs transport in BC amended engineered media filters for flow rates up to 60 cm hr^{-1}. Generally, the model predicts breakthrough best for the 25% sample port and worsens further down the column. NMSE values for the contaminant transport at the column effluent are likely inflated due to normalizing small observed and/or predicted values.

The jagged nature of the contaminant transport predictions results from the highly variable nature of the observed flow rate (Figure 77) and highlights the kinetic limitations of TrOCs removal. The more jagged contaminant transport predictions for the RAC columns are indicative of greater sensitivity to flow rate due to greater kinetic limitations of contaminant sorption to RAC relative to biochar. Additionally, the greater initial breakthrough in the RAC columns, particularly at the 25% sample port, demonstrate insufficient contact time for contaminant removal due to the slower kinetics. This is consistent with earlier observations of higher initial breakthrough in the RAC columns compared to biochar, and has significant implications for filter design in the field, for which filters must have sufficient depth to allow for full removal contaminants.

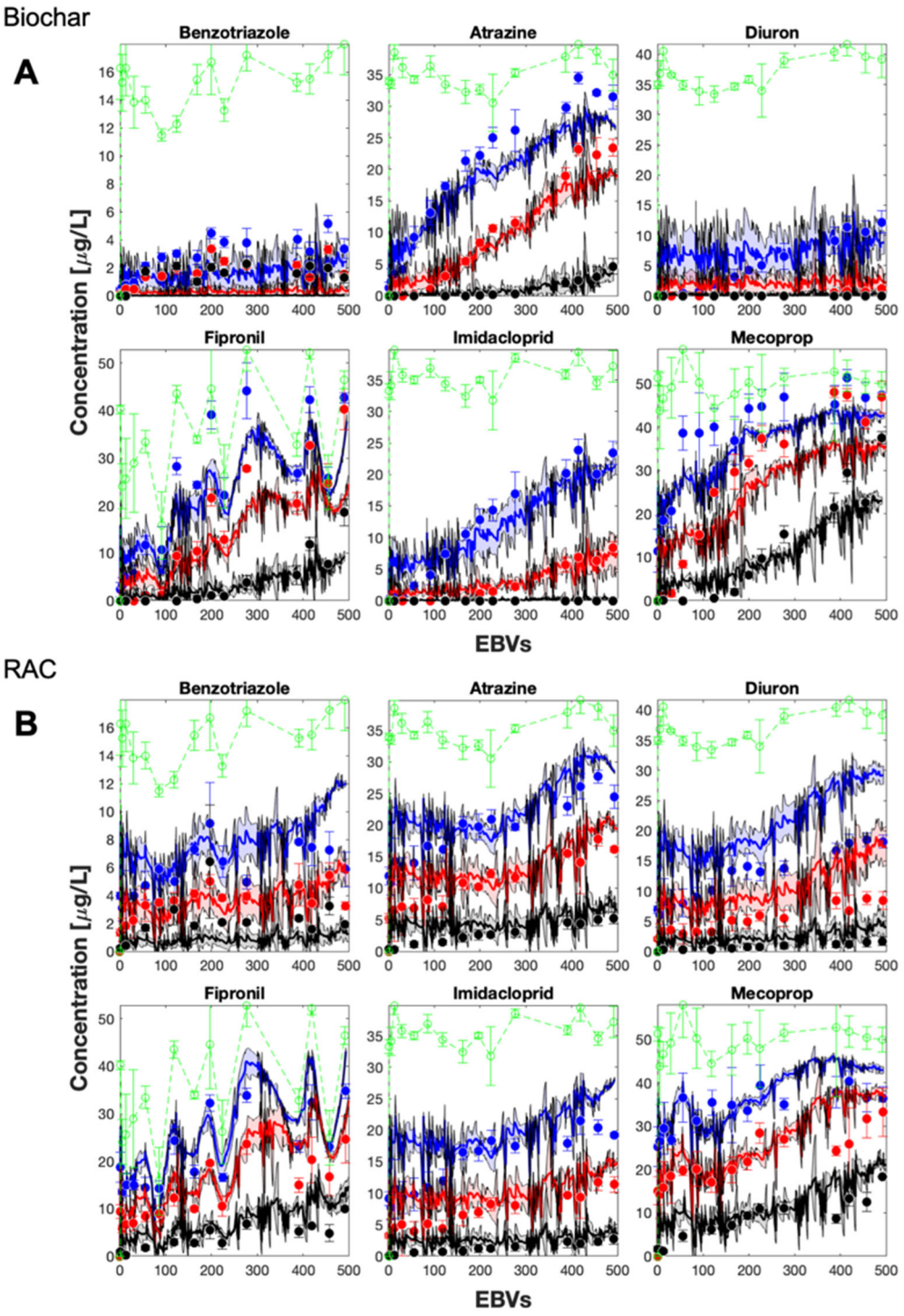

Figure 31 Mean observed (points) and predicted (line) and breakthrough curves for biochar (A) and RAC (B) at 40 cm hr^{-1} as found using the sorption and tortuosity parameters fit from the contaminant transport data from the 20 cm hr^{-1} column experiment. Column breakthrough is shown for the 25% sample port (blue), 50% sample port (red), and effluent (black). Shaded area shows the standard deviation of the predicted breakthrough curves. Mean observed influent is shown in green and error bars indicate one standard deviation above and below the mean.

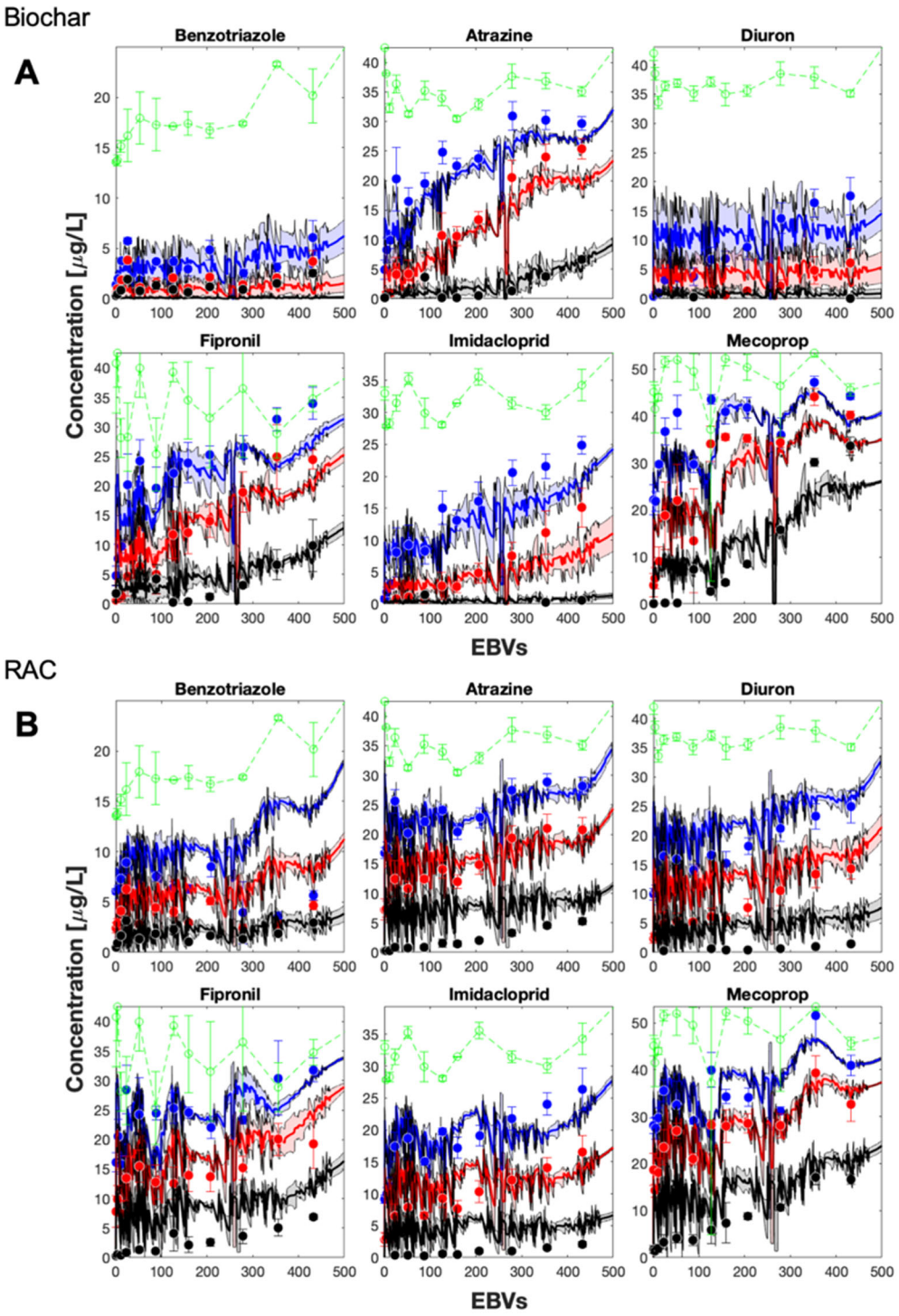

Figure 32 Mean observed (points) and predicted (line) and breakthrough curves for biochar (A) and RAC (B) at 60 cm hr^{-1} as found using the sorption and tortuosity parameters fit from the contaminant transport data from the 20 cm hr^{-1} column experiment. Column breakthrough is shown for the 25% sample port (blue), 50% sample port (red), and effluent (black). Shaded area shows the standard deviation of the predicted breakthrough curves. Mean observed influent is shown in green and error bars indicate one standard deviation above and below the mean.

Table 15 NMSE of Model Predicted Contaminant Breakthrough and Observed Contaminant Breakthrough at 40 cm hr^{-1} and 60 cm hr^{-1}

Biochar							
	Location[a]	Atrazine	Benzotriazole	Diuron	Fipronil	Imidacloprid	Mecoprop
40 cm hr^{-1}	25%	0.62	0.76	3.80	0.67	2.51	0.14
	50%	4.08	0.75	2.75	0.44	0.50	5.77
	Effluent	131.20	0.68	-	0.43	-	2.04
60 cm hr^{-1}	25%	0.17	0.19	4.39	0.38	1.47	0.04
	50%	3.82	0.87	2.29	4.74	1.00	1.18
	Effluent	2.18	16.56	1.48	6.74	0.29	9.34
RAC							
	Location[a]	Atrazine	Benzotriazole	Diuron	Fipronil	Imidacloprid	Mecoprop
40 cm hr^{-1}	25%	0.29	0.13	0.51	0.06	0.29	0.03
	50%	0.43	0.40	1.55	0.17	0.84	0.10
	Effluent	1.25	2.66	1.81	1.04	1.44	0.97
60 cm hr^{-1}	25%	0.06	0.72	0.22	0.08	0.13	0.04
	50%	0.30	0.55	1.36	0.27	0.75	0.06
	Effluent	11.08	0.33	6.34	8.20	5.00	2.41

[a] Sample location: 25% sample port, 50% sample port, or column effluent

2.3 Develop filter performance curves to estimate filter longevity under specific site and filter conditions (Subtask 3.3).

The complex relationship between filter performance and flow rate may be better understood through creation and use of filter performance curves. BC amended engineered media filter performance was determined to be a function of flow rate, filter depth, BC content, and influent concentration for a given BC material. Flow rate and filter depth may be expressed together as empty bed contact time (EBCT), as the performance is nearly identical for operating conditions with the same EBCT, regardless of the flow rate (20-120 cm hr^{-1}) or filter depth (0.2 m – 1.2 m) as shown in Figure 88. Therefore, the filter performance for a given BC material may be expressed a function of three parameters: EBCT, BC content, and influent concentration. Filter performance tables, shown in XI. Appendix C.2., show the volume treated until breakthrough ± standard deviation for specific C/C_0 breakthrough levels as a function of EBCT and BC content, for distinct influent concentrations, and for specific contaminants.

Performance tables were developed for atrazine, imidacloprid, fipronil, PFOA, and PFOS for both biochar and RAC for a wide range of parameters, as shown below in Table 16. Performance tables were created by finding the EBVs treated until breakthrough for various levels of breakthrough at various depths along a 3.6 m filter at a flow rate of 60 cm hr^{-1}. Specific filter depths were used to find the performance for various EBCTs. The EBVs until breakthrough for each column replicate-derived model were then averaged to find the mean and standard deviation, as shown in Figure 33. The performance table construction model used similar parameters as shown in Table 11 except for column length, flow rate, number of subvolumes (n_{sv} = 900), and number of time steps (n_{ts}=6000).

Table 16 Filter Design Parameters Used to Construct Filter Performance Tables

Parameter	Units	Values
EBCT	[minutes]	30, 40, 50, 60, 75, 90, 106, 120, 140, 160, 180, 240, 300, 360
BC Content	[volume %]	5, 10, 15, 20, 25, 30, 35, 40
Influent Concentration	[ng L^{-1}]	10, 100, 1000 (PFOA, PFOS) 100, 400, 1000, 4000 (atrazine, imidacloprid, fipronil)
C/Co	[-]	1, 0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1, 0.05, 0.01

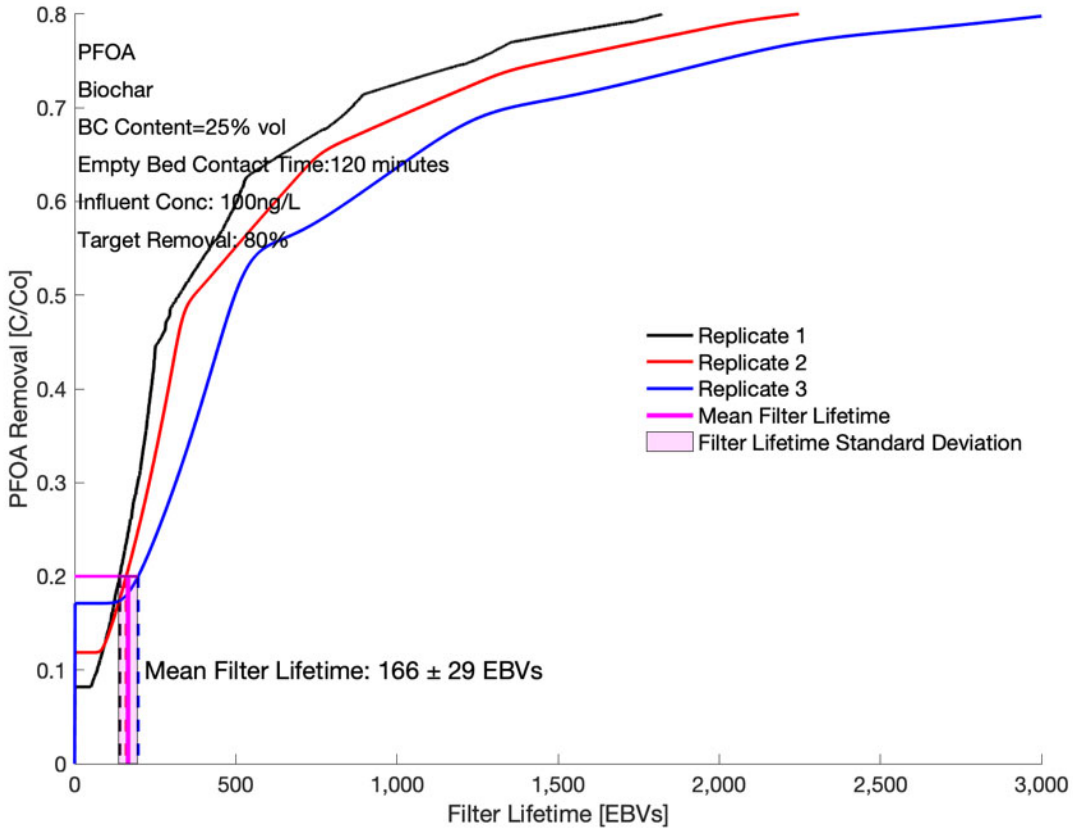

Figure 33 Mean filter lifetime (vertical magenta line) is computed from the calculated filter lifetimes of each of the three column replicate-derived models (black, red, blue curves).

These tables show that certain thresholds of BC content and EBCT are necessary to achieve desired C/C_0 performance. Above the threshold, incremental changes in EBCT and BC content result in decreasing improvements of filter performance, defined as the volume treated while achieving a target C/C_0. Generally, to achieve 90% removal of fipronil for ~600 EBVs, an EBCT greater than 60 minutes and biochar content of 40 v% (3.7 wt%) or RAC content of 20 v% (7.2 wt%) is required. To achieve similar removal for an EBCT of 180 minutes, 20 v% (1.4 wt%) biochar and 10 v% (3.3 wt%) RAC are required. Based on cost estimates reported in Table 24 in section VII, for a unit filter of 1 m depth, this corresponds to a cost of \$104.80 m^{-3} (60 min EBCT) and \$52.40 m^{-3} (180 min EBCT) for biochar and \$152.60 m^{-3} (60 min EBCT) and \$76.30 m^{-3} (180 min EBCT)

for RAC. Thus, on a treatment lifetime basis, biochar is cheaper than RAC. Interestingly, increasing the empty bed contact time by a factor of three brings the cost down by half.

These performance tables include numerous design and operation assumptions. Constant flow rate and influent concentrations, as well as consistent saturated filter operations are assumed. Stormwater runoff DOC is assumed to be 3-7 mg C L^{-1}. Additionally, the performance tables are only relevant for biochars and RACs that have similar properties to those studied here. While RACs from other batches and supplies are likely to be somewhat similar, there may be a wide range in biochars from different suppliers, and special care should be taken to ensure that the biochar is of similar quality to that used in this study. These tables are featured in a Microsoft Excel-based SCM design and sizing tool, Treatment Engineered Media Performance and Sizing Tool (TEMPEST) being developed in collaboration with Geosyntec. The TEMPEST tool will disseminate the results of modeling contaminant transport in SCM engineered media filters in this study to stormwater practitioners and regulators and is a significant product of this project.

3 Assess efficacy of saturated/unsaturated filters to remove metal and organic contaminants from periodic storm events using black carbon-amended engineered media filters (Modified Task 4).

3.1 Periodic wetting/drying impact on engineered media filter performance (Subtask 4.1).

3.1.1 PFAS Removal

Dissolved influent concentrations of AFFF-derived PFOS were 3996±1400 ng L^{-1} throughout the experiment (Table 73). Retention of PFASs in the columns was somewhat chain-length dependent as shorter chain PFASs were generally less retained than longer-chain PFASs (Figure 34). Figure 36 depicts the number of storm events that occurred before 10% breakthrough (C/C_0) was observed for each PFAS. With the exception of PFHpS and PFOS (for which 10% breakthrough was observed for both at the 22nd simulated storm event), chain-length dependent breakthrough was consistently observed. However, in contrast to what has been observed in previous experiments, the C6-based PFAS removal varied in the unsaturated columns: PFHxA < PFHxS < FHxSA (Figure 34 and Figure 36), as compared to PFHxA < FHxSA < PFHxS as noted previously. This may be a result of precursor biotransformation occurring more readily in one experiment versus another, as FHxSA is a commonly observed semi-stable intermediate (Choi et al., 2022). In all PFAS cases, unsaturated columns outperformed saturated columns, likely due to enhanced retention at the air-water interface due to the maintenance of unsaturated conditions via inlet controls.

Data from the simulated inlet control failure (i.e., flushing event with clean synthetic stormwater) suggest that system failure for the unsaturated conditions would remobilize an equivalent amount of PFASs as the fully saturated conditions, despite retention of greater PFAS masses in the columns (Figure 35). For most PFASs, no significant differences were apparent between the mass of PFAS released from the unsaturated and saturated conditions. More importantly, as a percentage of the total mass retained on the column, less total mass was eluted from the unsaturated column during the flush, suggesting that if retention at the air-water interface was responsible for greater contaminant removal, the collapse of these interfaces would not threaten filter resiliency. Less than 0.5% of the total loaded PFOS and PFOA mass eluted in the flush event.

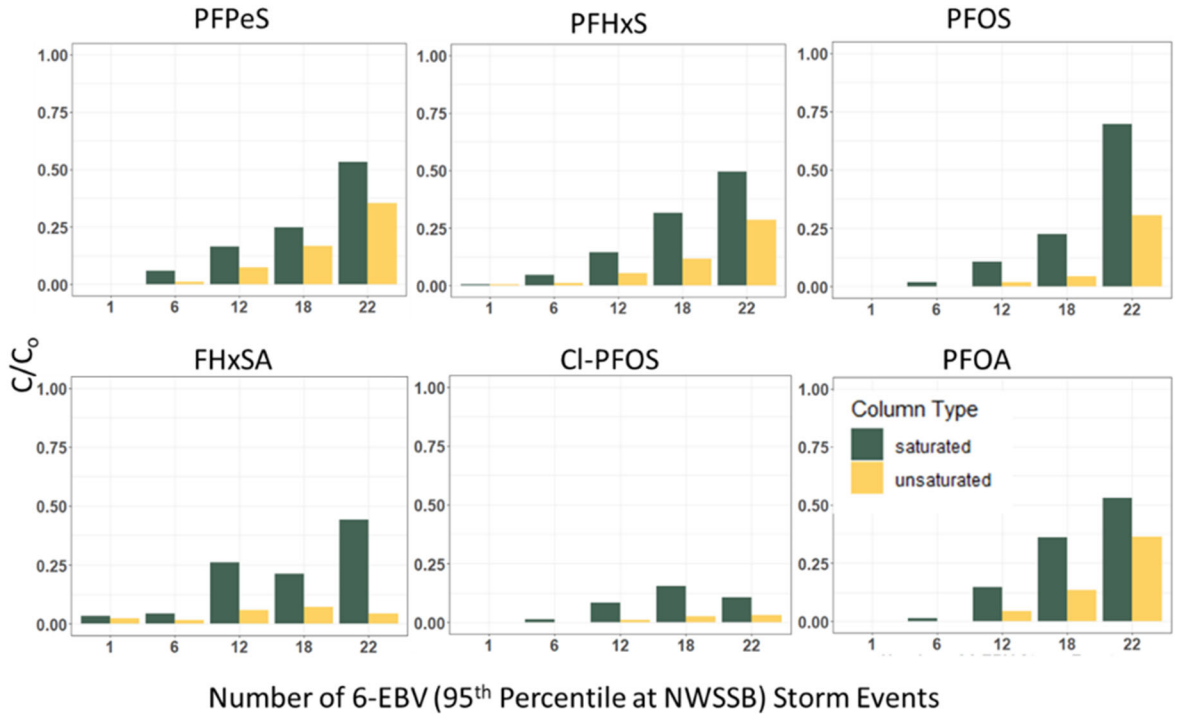

Figure 34 Mean removal of various PFASs during simulated storm events (n=3).

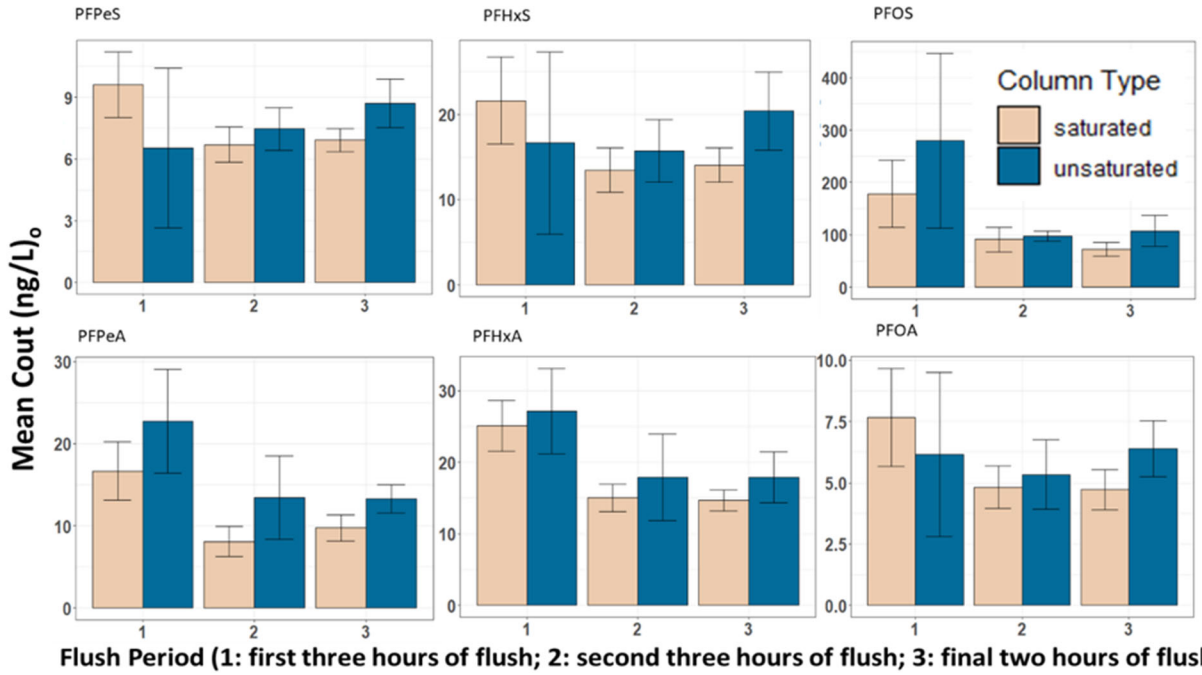

Figure 35 Mean concentrations in column effluent resulting from the flush test, indicating concentrations of composite samples taken during the flush. Error bars indicate one standard deviation above and below the mean (n=3).

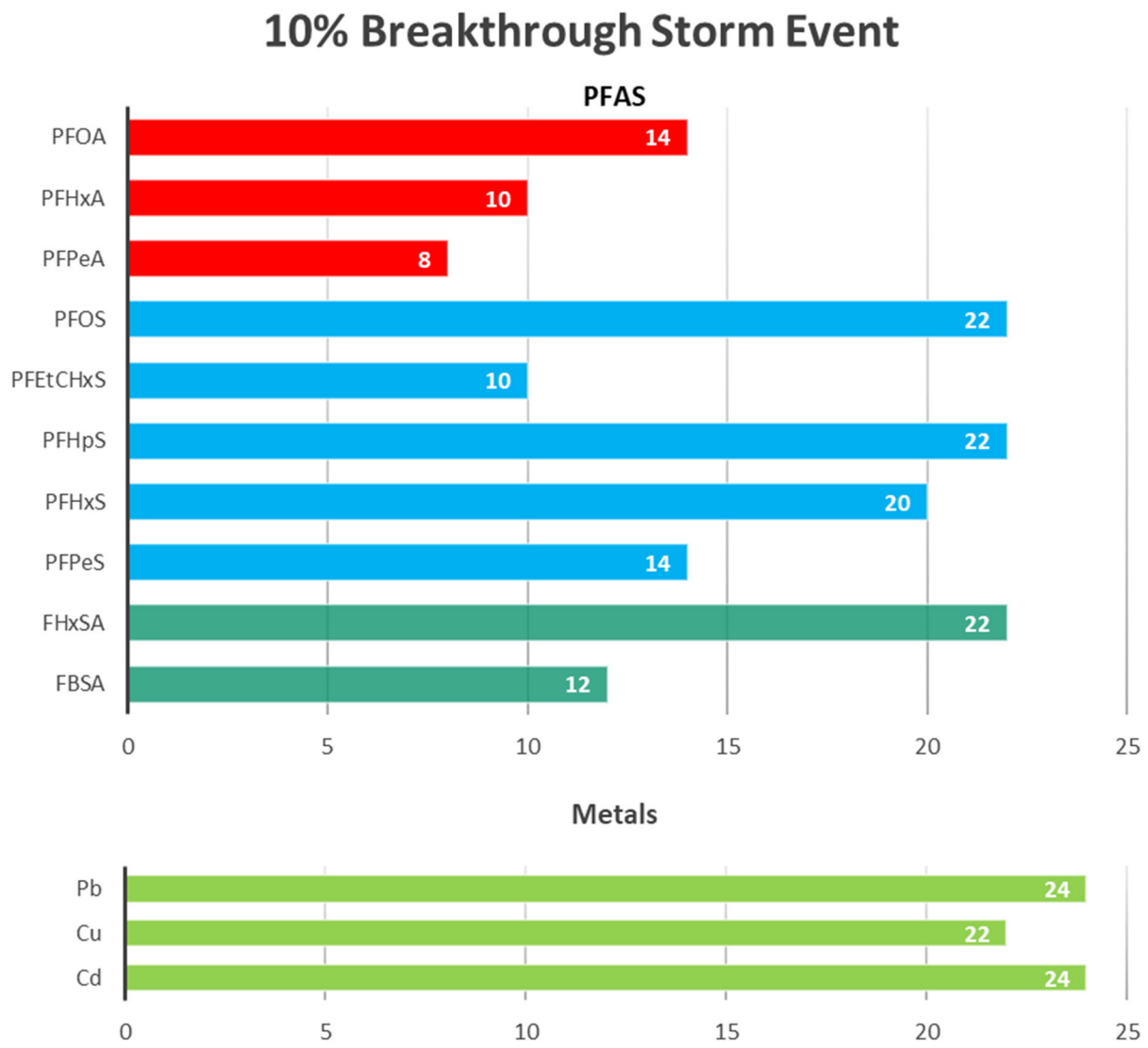

Figure 36 Storm event at which various PFASs and metals species reached 10% breakthrough in unsaturated columns.

3.1.2 Metals Removal

Dissolved metals removal were in the order Cd>Zn>Pb>Cu>Ni (Figure 37). Similar to observed in Tasks 2 and 3, Pb was likely particle-associated, though DOC complexation was also possible. Furthermore, the Zn-containing catch-basin material potentially preloaded the columns during the conditioning phase. Nevertheless, Zn removal was constant throughout the experiment, indicating that Zn removal capacity had not (yet) been exceeded. Interestingly, Ni removal improved in the saturated columns, in contrast to almost every other contaminant species observed during this study.

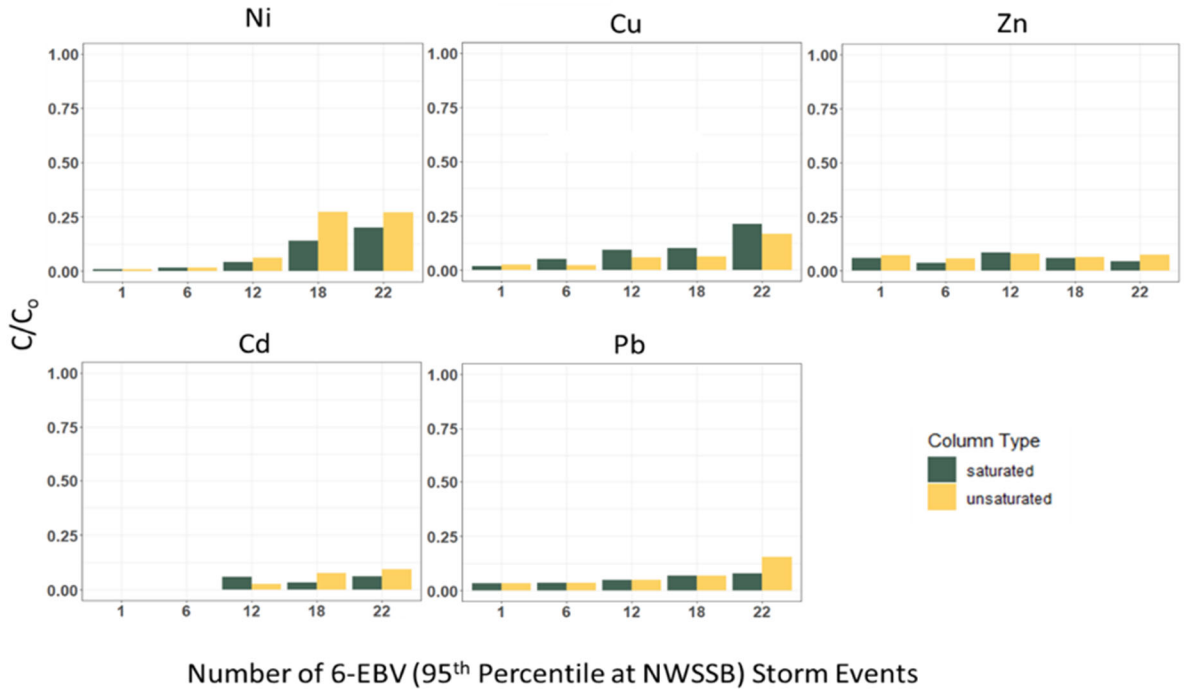

Figure 37 Mean removal of various metals in unsaturated vs. saturated column conditions (n=3).

4 Long-term performance modeling of BC-amended biofilters for breakthrough based on different design criteria (Task 5).

4.1 Assess impacts of dynamic flow, contaminant loading, DOC on engineered media filter performance (Subtask 5.1)

Measured column porosity and calculated empty bed contact time and contact time are shown below in Table 17.

Table 17 Column biochar content, measured porosity, and calculated contact time

Experiment	BC v%	BC wt%	Porosity	EBCT [min]	Contact Time [min]
Dynamic Flow	15.1%	1.0%	0.41	60.0	24.5
Dynamic Concentration	15.1%	1.0%	0.38	60.0	23.1
Low DOC	15.1%	1.0%	0.42	60.0	25.1
High DOC	15.1%	1.0%	0.42	60.0	24.9

Mean values (n=3)

4.1.1 Dynamic Flow Experiments

The dynamic flow experiment consisted of conditioning the columns for 100 EBVs at 60 cm hr^{-1} and challenge testing the columns for 5 days at 60 cm hr^{-1} (empty bed contact time, EBCT ~60 min), 5 days at 20 cm hr^{-1} (EBCT ~180 min), and 3 days at 120 cm hr^{-1} (EBCT ~30 min) with constant contaminant loading and with background DOC (8.5±0.9 mg C L^{-1}). The dissolved oxygen, pH, conductivity and total dissolved solids (TDS) were consistent in both the influent and effluent throughout the entire dynamic flow experiment. The dissolved oxygen and pH decreased

through the columns (DO from 7.36 mg O L^{-1} to 0.56 mg O L^{-1}; and pH from 6.99 to 6.58), and conductivity and TDS remained constant (conductivity 502 µS cm^{-1}, 517 µS cm^{-1}; TDS 251 mg L^{-1}, 258 mg L^{-1}). The turbidity in the column influent and effluent decreased some during the test (influent, effluent=15.6, 3.2 FNU to 14.5 FNU, 2.6 FNU) and increased (influent, effluent=43.3, 5.0 FNU) with the flow rate. The change of turbidity in the influent is likely due to the change in hydraulic residence time in the settling chamber corresponding to each flow rate (5.2 hr at 60 cm hr^{-1}; 15.6 hr at 20 cm hr^{-1}; 2.6 hr at 120 cm hr^{-1}). The change in turbidity of the column effluent is likely a result of changing suspended particle and colloid loading, flow rate-dependent suspended particle and colloid removal, and potential intra-bed colloidal mobilization due to increased shear stress.

Each change in flow rate yielded significant and immediate responses of dissolved TrOCs at each location within the column filter, as demonstrated in Figure 113. The concentration of contaminant breakthrough sharply fell with the reduction of flow rate and sharply increased with the increase in flow rate. After each change in flow conditions, the resulting change in contaminant concentration was immediate and the period of change appeared to be of short duration (~10.0±1.3 hours; Table 82). The significant effect on performance from flow rate is not surprising, as the flow rate directly impacts the contact time of the contaminants with the biochar or RAC in the filter and the removal of contaminants is dependent on the kinetics of their removal.

Initial contaminant breakthrough in the 25% and 50% sample ports demonstrate the kinetic limitations of removal for more mobile contaminants under the experimental conditions. Interestingly, the change in contaminant concentration resulting from each flow rate change appeared to be more significant when initial breakthrough was lower while the change in contaminant concentration was less when the initial breakthrough of contaminants was high. The breakthrough curve had greater continuity when the initial breakthrough was high, as was the case for mecoprop and fipronil at the 25% sample port. The low change in breakthrough concentration when contaminant breakthrough is already high indicates that as columns approached exhaustion, the column performance becomes less sensitive to changes in flow rate. Thus, the flow rate appears to have the greatest effect on performance when the media sorption capacity is not yet saturated.

The contaminant transport model simulated the column performance well, as the prediction matches with the observed breakthrough during the initial 5-day period before the flow rate was changed and the two preceding two periods of altered flow rate. The transport model captures the immediate changes in contaminant concentration at each change in flow rate. The transport model predicted transport in the top sample port best, as NMSE is smallest for the 25% sample port and largest for the column effluent (Table 18). The large NMSE value for atrazine at the effluent is likely an artifact of normalizing very small concentrations, as the effluent prediction seems to match up closely with the observed data visually in the plot. The fact that the prediction mirrors the observed contaminant transport validates the model for predicting unsteady flow conditions, and strengthens the hypothesis that contaminant removal kinetics may be described by the rate of diffusion into BC grains, as approximated by the aqueous diffusion coefficient, tortuosity and contaminant-specific diffusion hindrance factor, and concentration gradient, and limited by the adsorption onto the BC surface area within the grains.

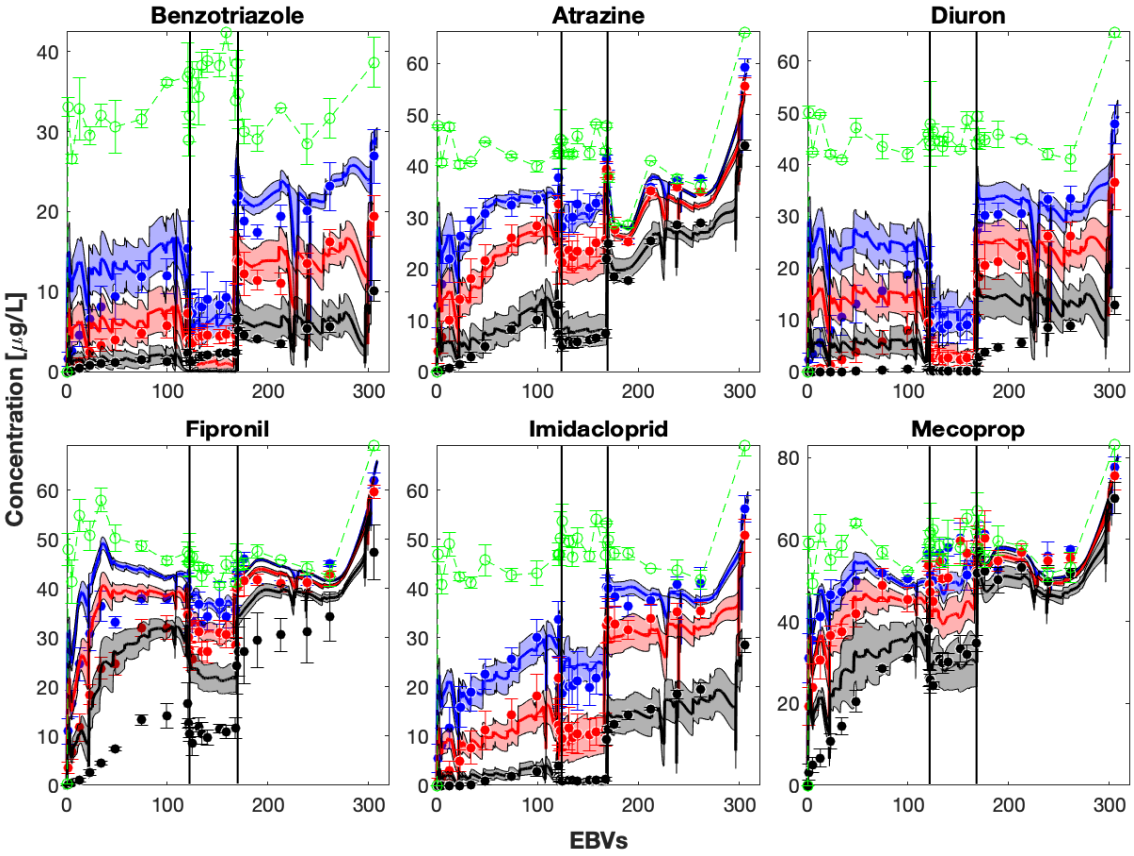

Figure 38 TrOCs observed and predicted breakthrough in dynamic flow experiment with 1 wt % biochar during which the column filters were operated at 60 cm hr^{-1} for 5 days, 20 cm hr^{-1} for 5 days, and 120 cm hr^{-1} for 3 days. Column influent is shown in green. Column breakthrough is shown at each the 25% sample port (blue), 50% sample port (red), and effluent (black). Shaded areas indicate the standard deviation on the predicted breakthrough (n=3). Error bars on the observed TrOCs concentrations represent one standard deviation above and below the mean (n=3).

Table 18 Calculated NMSE for Modeled Predictions versus Observed Contaminant Transport for Dynamic Flow Rate Experiment

Location[a]	Atrazine	Benzotriazole	Diuron	Fipronil	Imidacloprid	Mecoprop
25%	0.78	0.04	1.31	0.08	0.22	0.02
50%	1.84	0.24	4.78	0.27	0.50	0.05
Effluent	25.24	1.90	5.57	2.29	0.99	0.50

[a] Location of observed transport data: column effluent, 50% sample port, 25% sample port

4.1.2 Dynamic Contaminant Loading Experiments

The dynamic concentration experiment consisted of conditioning the columns for 100 EBVs at 60 cm hr^{-1} and challenge testing the columns for 5 days with normal contaminant loading, 5 days with low (one-fourth-of-normal) contaminant loading, and 2 days of high (twice-normal) contaminant loading at 60 cm hr^{-1} (EBCT ~60 min) with constant background DOC (6.9±0.8 mg C L^{-1}). Each change in contaminant loading concentration yielded significant responses of contaminant breakthrough at each location within the column filter, as demonstrated in Figure 39. The column

filters took about five times longer to reach their new steady state (~51.1±18.1 hours; Table 83) than was observed in the previous flow rate experiment. Contaminant concentrations took longer to stabilize further down the columns. This is likely due to the delay in contaminant propagation due to interaction with the carbon, as the carbon leached contaminants after the influent concentration was reduced and provided superior treatment for a short while after the influent concentration was increased. Contaminants that were better removed took longer to stabilize than more mobile contaminants (Table 83).

The change in concentration does not appear to alter the influent-normalized contaminant breakthrough curve as much as the change in flow rates, as seen in Figure 38. After the observed concentration reaches the new steady state, the breakthrough curve appears to continue from where it previously left off before the change in influent concentration, with only a slight shift in the x-direction. Interestingly, once the new steady-state concentration is reached, the change in contaminant loading does not impact the level of breakthrough as much as the change in flow rate, for which the entire breakthrough curve was dramatically shifted and slope altered. Thus, the degree of contaminant removal appears to be more sensitive to changes in flow rate than changes in contaminant loading, though the level of contaminant loading significantly impacts the effluent concentration.

The contaminant transport model predicted the breakthrough for the dynamic concentration experiment better than the dynamic flow experiment, as the NMSE is lower for each compound and sample location (Table 19). The transport model captures the impact of the influent contaminant concentration change as the model mirrors the observed contaminant breakthrough very well, as seen in Figure 39. The fact that the model predicts the observed results indicates that this model, by calculating the mass of contaminant in each shell of carbon, in each section of the column, at each time step, is adequate for use in situations with dramatically changing contaminant loading, as may be expected in the field.

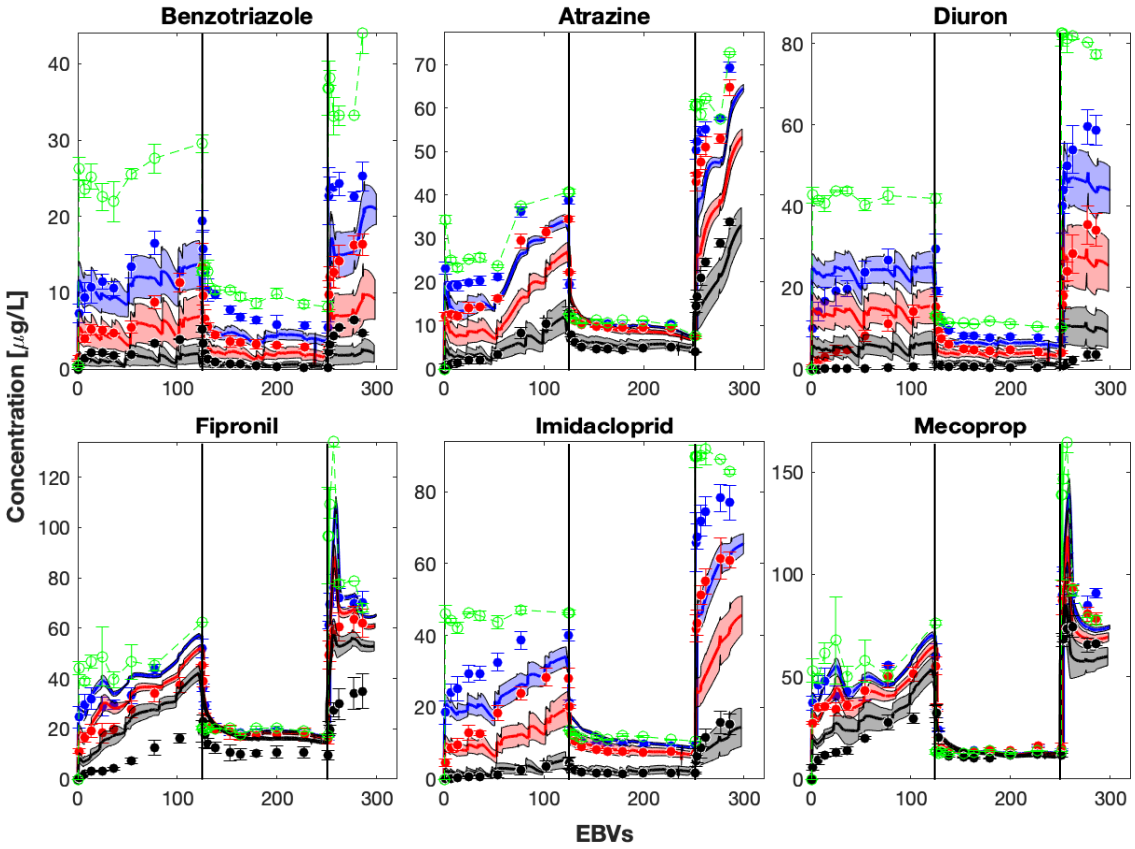

Figure 39 TrOCs observed and predicted breakthrough in dynamic flow experiment during which the column filters were loaded with normal concentration of contaminants for 5 days, low concentrations (1/4 normal) for 5 days, and high concentrations (2x normal) for 2 days. Column influent is shown in green. Column breakthrough is shown at each the 25% sample port (blue), 50% sample port (red), and effluent (black). Shaded areas indicate the standard deviation on the predicted breakthrough (n=3). Error bars on the observed TrOCs concentrations represent one standard deviation above and below the mean (n=3).

Table 19 Calculated NMSE for Modeled Predictions versus Observed Contaminant Transport for Dynamic Concentration Experiment

Location[a]	Atrazine	Benzotriazole	Diuron	Fipronil	Imidacloprid	Mecoprop
25%	0.21	0.05	0.16	0.02	0.08	0.04
50%	0.42	0.13	1.26	0.05	0.18	0.03
Effluent	0.72	0.46	6.59	1.11	0.66	0.17

[a] Sample location: 25% sample port (15 cm), 50% sample port (30 cm), or column effluent (60 cm)

4.1.3 Variable DOC Experiments

The variable DOC experiment consisted of two additional column studies conducted at a flow rate of 60 cm hr^{-1} and normal contaminant loading with high (18.4±4.5 mg C L^{-1}) and low (2.0±0.2 mg C L^{-1}) background DOC levels. At the end of the high-DOC experiment, the DOC level was reduced from 18.4±4.5 mg C L^{-1} to 2.0±0.2 mg C L^{-1} and the column experiment was extended for

an additional 2.5 days to investigate if contaminant removal rebounds with a reduction in background DOC.

The DO was lower in the influent and effluent during the high DOC experiment than in the low DOC experiment (high DOC 5.8±1.1 mg L^{-1}, 0.4±0.0 mg L^{-1}; low DOC 8.6±0.1 mg L^{-1}, 8.0±0.0 mg L^{-1}). The DO rapidly increased in the column effluent upon reducing the DOC loading at the conclusion of the high DOC experiment (0.35±0.02 mg L^{-1} to 2.26±0.85 mg L^{-1} after 1 hour, 7.19±0.18 mg L^{-1} within 18.9 hours). The depletion of DO is indicative of greater microbial activity and increased DOC biodegradation in the presence of higher background DOC levels. Similarly, the SUVA increased from 2.3±0.3 L mg^{-1} m^{-1} to 3.3±0.2 L mg^{-1} m^{-1} with the reduction in background DOC, suggesting that the quality of the low-level DOC was more aromatic and less biodegradable than the high-level DOC (Weishaar et al., 2003). This may be due to the majority of the high DOC coming from the straw DOC concentrate while the low-level DOC originated from the catch basin material that was more weathered. Another relevant implication of the increased DOC levels was increased biofouling of the top barrier sand layers of the engineered media filters. Maintenance was required at a higher frequency during the high DOC experiment in order to maintain the target flow rate.

The observed dissolved TrOCs breakthrough is plotted in Figure 40 with the initial phase (t=0–5 days) of the dynamic flow and dynamic concentration experiments, which had similar experimental conditions except for background DOC. Increasing background DOC dramatically increases the rate of contaminant breakthrough for the observed contaminants. Interestingly, benzotriazole was the only TrOCs to not display this trend. DOC is known to interfere with TrOC sorption to black carbon materials by competing to sorption sites and contributing to pore-blocking by which DOC blocks TrOCs diffusion into intraparticle pore space (Wang et al., 2017).

Reducing the background DOC concentration after five days of high background DOC had variable benefit to contaminant removal, as seen in Figure 117. Nearly all contaminants experienced an immediate reduction in concentration that was most evident in the column effluent. While benzotriazole experienced a brief benefit before breakthrough surpassed pre-DOC reduction levels, atrazine, fipronil, imidacloprid, and diuron experienced sustained benefit for the remaining 2.5 days. Mecoprop experienced no benefit, as mecoprop breakthrough remained at ~90% in the effluent and ~100% at the sample ports. The benefit from DOC reduction seemed greatest at the column effluent for contaminants that had not yet fully broken through and faded with higher levels of contaminant breakthrough, as seen at the 50% and 25% sample ports (Figure 117). This result suggests that reductions in DOC influent loading may allow contaminant removal to improve, however the improvement of contaminant removal may only be short-lived and diminishes as contaminant breakthrough increases. Further study is necessary to determine the impacts from high-DOC conditions on long-term filter performance, as these affects are not likely to be captured by the current intraparticle pore diffusion-sorption modeling approach.

Freundlich sorption and tortuosity parameters were calculated by fitting the transport model to the observed high and low DOC contaminant breakthrough curves. The increase in DOC increased the fit for tortuosity parameters and Freundlich intensity parameters (1/n) (Table 20) and appeared to reduce the sorption capacity (q_e) of the biochar as described by the Freundlich sorption parameters plotted in Figure 40. The increased tortuosity parameter suggests that the pore diffusion

hindrance is increased by background DOC. This observation is supported by literature that identifies pore-blocking to be a significant impact of DOC (Quinlivan et al., 2005). The slightly reduced capacity is also in line with past studies that have found background DOC to compete with BC outer-grain sorption sites (Pignatello et al., 2006). Notably, the tortuosity increased most acutely for mecoprop (17.4–18.2 to 98.2–117.5), which is an anionic species at studied conditions.

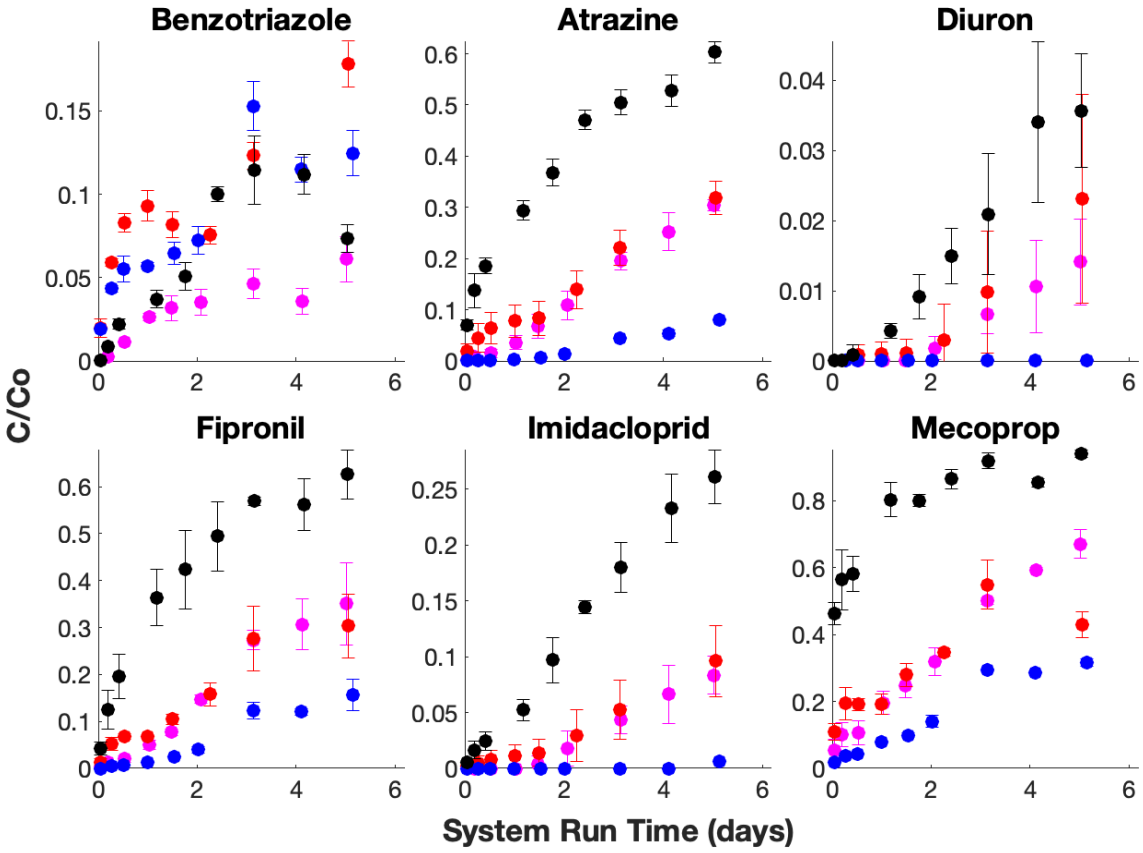

Figure 40 Observed contaminant breakthrough in the column effluent as a function of background DOC for column filters operated at 60 cm hr^{-1} and normal contaminant loading as depicted in Figure 9. DOC levels plotted include 18.4±4.5 mg C L^{-1} (black), 8.5±0.9 mg C L^{-1} (red), 6.9±0.8 mg C L^{-1} (pink), and 3.1±0.4 mg C L^{-1} (blue). Error bars indicate one standard deviation above and below the mean (n=3). Note change in y-axis scale to highlight differences.

Table 20 Freundlich sorption and tortuosity parameters fit to the observed contaminant transport

Experiment	Parameter	Atrazine			Benzotriazole			Diuron		
Low DOC	τ[a]	10.2	9.6	9.7	18.0	13.5	18.5	5.5	2.8	5.6
	K_{fr}[b]	0.35	0.34	0.30	0.50	0.55	0.42	0.65	0.64	0.76
	$1/n$[c]	0.27	0.26	0.25	0.16	0.15	0.17	0.37	0.23	0.27
	NMSE	0.11	0.11	0.17	0.06	0.09	0.04	0.07	0.15	0.06
High DOC	τ[a]	25.7	28.2	26.5	11.1	13.1	10.6	8.4	11.1	8.9
	K_{fr}[b]	0.48	0.44	0.37	0.77	0.34	0.69	1.00	0.94	0.85
	n[c]	0.46	0.43	0.41	0.29	0.20	0.30	0.39	0.38	0.39
	NMSE	0.07	0.03	0.05	0.09	0.04	0.04	0.13	0.06	0.09
Experiment	Parameter	Fipronil			Imidacloprid			Mecoprop		
Low DOC	τ[a]	7.2	7.3	7.2	5.3	4.8	6.2	18.2	17.4	18.1
	K_{fr}[b]	0.09	0.08	0.10	0.67	0.43	0.66	0.12	0.12	0.12
	$1/n$[c]	0.21	0.20	0.24	0.29	0.17	0.32	0.18	0.18	0.18
	NMSE	0.05	0.09	0.08	0.07	0.04	0.08	0.10	0.06	0.04
High DOC	τ[a]	11.5	14.3	14.7	11.8	12.5	11.5	98.2	117.5	107.3
	K_{fr}[b]	0.09	0.10	0.11	0.31	0.39	0.40	0.11	0.08	0.06
	$1/n$[c]	0.62	0.62	0.61	0.34	0.35	0.35	0.31	0.32	0.28
	NMSE	0.08	0.04	0.04	0.22	0.12	0.12	<0.01	<0.01	<0.01

[a] Tortuosity [-]
[b] Freundlich sorption capacity coefficient [(mol L^{-1})(L mol^{-1})$^{1/n}$]
[c] Freundlich sorption intensity parameter [-]

4.1.4 DOC effect on hydrophilic TrOCs sorption

Batch isotherms were conducted with background DOC concentrations of 10.5±1.8 mg C L^{-1} and 16.2±2.1 mg C L^{-1} plotted below in Figure 41 and these demonstrate the impact of DOC on TrOCs sorption. The Freundlich isotherms conducted with higher DOC are shifted down the y axis, indicating that for a given equilibrium contaminant concentration, the equilibrium mass of contaminant sorbed is reduced at higher DOC. This may be due to DOC competition for sorption sites on the biochar outer surface (Koelmans et al., 2009). This finding is consistent with the observed impact of DOC on fit sorption parameters derived from fitting the observed column breakthrough curves using the intraparticle pore diffusion-sorption contaminant transport model, which are plotted below with the batch isotherms. The batch isotherms are similar to the sorption parameters derived from fitting the higher DOC breakthrough curves and are consistently lower than the isotherms derived from fitting the low DOC breakthrough curves. As observed with the model-derived sorption parameters, the Freundlich intensity parameter (1/n) generally increases for the higher DOC condition. These batch tests serve to confirm the impact of background DOC on sorption capacity and intensity, and support the sorption parameters fit from observed contaminant breakthrough curves.

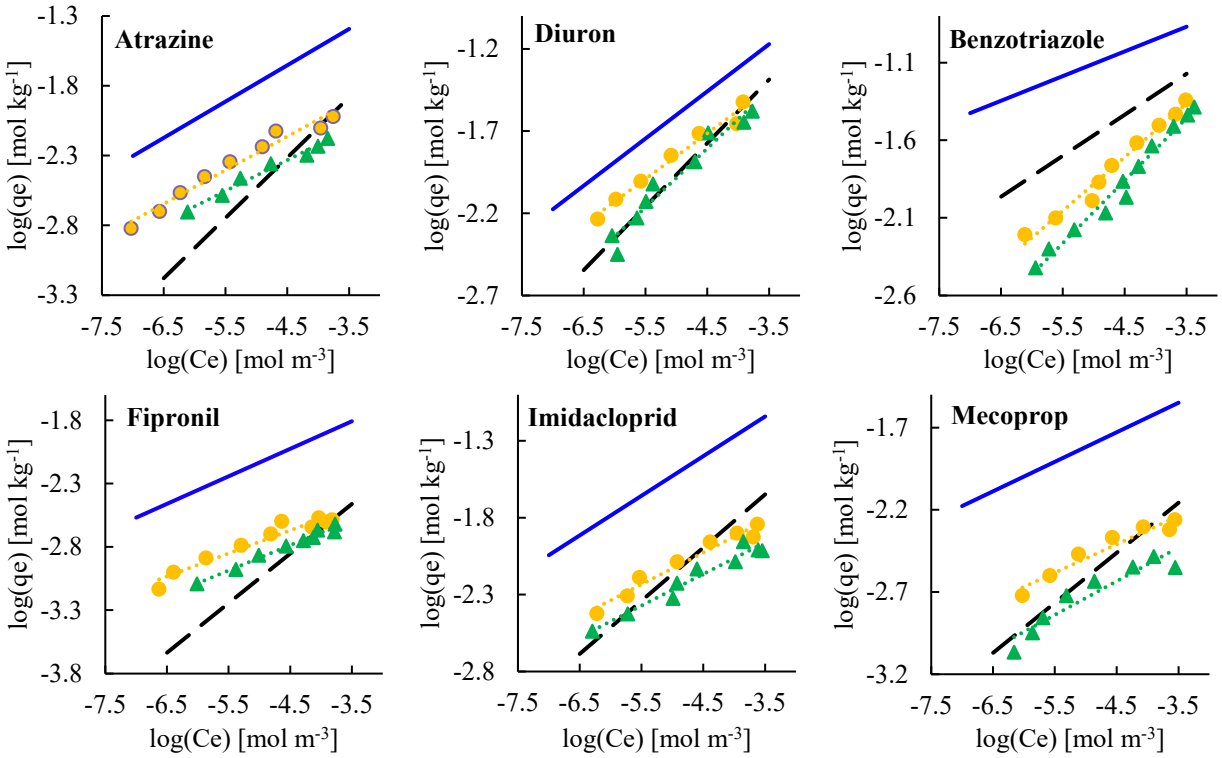

Figure 41 Batch isotherms of hyphil-TrOCs on biochar at 10.5±1.8 mg C L^{-1} (yellow circles) and 16.2±2.1 mg C L^{-1} (green triangle) plotted with isotherms derived from fitting observed breakthrough curves from the high-DOC (16.5±4.4 mg C L^{-1}; black dashed) and low-DOC (3.2±2.2 mg C L^{-1}; blue solid) experiments with the intraparticle pore diffusion-sorption transport model.

Table 21 Batch isotherm sorption parameters at 10.5 mg C L^{-1} and 16.2 mg C L^{-1} of DOC

	10.5±1.8 mg C L^{-1}			16.2±2.1 mg C L^{-1}		
	K_{fr} [a]	$1/n$ [b]	r^2	K_{fr} [a]	$1/n$ [b]	r^2
Diuron	0.34	0.28	0.99	0.64	0.36	0.97
Fipronil	0.01	0.18	0.97	0.01	0.20	0.99
Benzotriazole	0.70	0.35	0.99	0.90	0.40	0.99
Atrazine	0.07	0.22	0.97	0.03	0.19	0.96
Imidacloprid	0.08	0.21	0.98	0.06	0.20	0.97
Mecoprop	0.02	0.17	0.97	0.02	0.21	0.94

[a] Freundlich sorption capacity coefficient [(mol kg^{-1})(m^3 mol^{-1})$^{1/n}$]
[b] Freundlich sorption intensity parameter [-]

4.2 Conduct case study simulations for engineered media filters at a representative field site (NWSSB) (Subtask 5.2).

Long-term predictive modeling using the fit sorption and tortuosity parameters from the 25% sample port were used to estimate filter lifetime in a hypothetical case study in Seal Beach, CA. Stormwater influent contaminant concentrations were obtained from the review by Spahr et al.

(2020). Two situations were modeled; a "worst case" situation in which the stormwater influent was assumed to contain the highest observed levels of contaminants, and a "mean" situation in which the stormwater influent was assumed to contain the mean observed contaminant levels. For the "worst case" scenario, acute environmental health benchmarks were used to assess filter breakthrough, while the chronic environmental health benchmarks were used to assess filter breakthrough for the "mean" case, as shown in Table 22. Some of the contaminants have higher aquatic health benchmarks than have been observed in stormwater samples, including mecoprop and atrazine. Benzotriazole does not have an aquatic health benchmark.

Table 22 Observed Contaminant Concentrations [µg L^{-1}] in Stormwater Runoff and Relevant Regulatory Limits [µg L^{-1}] for Long-Term Filter Performance Modeling

	Acute Scenario			Chronic Scenario		
	Highest Conc[a]	Bench-mark[b]	Target C/C_0	Median Conc[c]	Bench-mark[b]	Target C/C_0
Atrazine	0.79[1]	1.0[1]	>1	0.62[2]	1.0[1]	>1
Benzotriazole	1.91[3]	-	-	0.36	-	-
Diuron	10.8[4]	0.13[2]	0.012	1.34	0.13[2]	0.097
Fipronil	10.0[4]	0.11[3]	0.011	0.13	0.011[3]	0.084
Imidacloprid	0.67[4]	0.39[3]	0.58	0.050	0.010[3]	0.20
Mecoprop	1.06[3]	14.0[1]	>1	0.15	14.0[1]	>1
PFOS	0.16[1]	0.01[5]	0.064	0.02	0.0065[4]	0.43
PFOA	0.03[1]	0.02[5]	0.65	0.01	0.0051[4]	0.55

[a] Highest reported observed concentration in stormwater samples in [1]MN, USA, [2]Australia, [3]WI, USA, and [4]southern CA, USA (Spahr et al., 2020)

[b] Aquatic health benchmark (acute or chronic) value for [1]nonvascular plants, [2]vascular plants, or [3]invertibrates (US EPA) or California Drinking Water [4]Notification Level or [5]Action Level

[c] Mean reported observed concentration (Spahr et al., 2020)

- No aquatic health benchmark exists (US EPA)

Table 23 shows the estimated filter lifetime for biochar (30 v%) and RAC (10 v%) for various depth filters when operated at a flow rate of 20 cm hr^{-1}. Fipronil is the limiting contaminant due to its mobility and high removal threshold as determined by its very low aquatic health benchmark. For filters operated at 20 cm hr^{-1} in the chronic scenario, a depth of 0.2m is necessary to adequately remove fipronil for 70±30 years, while a depth of 0.3 m is expected to remove fipronil for >100 years at NWSSB. RAC requires a deeper filter (0.5 m) in order to achieve the desired performance, and is expected to last >100 years. Increased filter depth are required for the acute scenario, where breakthrough is also expected to be faster. Biochar filters 60 cm deep are expected last 10±4 years while increasing the by depth is expected to add about 5 years per 0.1 m increment. RAC filters are unable to meet the treatment threshold with an 80 cm filter and require either a longer filter or higher carbon content. PFOS and PFOA are adequately remove in both situations with filter depths of 0.3 m. However, the filter performance and lifetime estimate is very sensitive to the concentration of the influent, and higher concentrations would likely result in shorter lifetimes and possibly inadequate treatment.

Increasing the filter depth disproportionately increases the filter lifetime, demonstrating the impact of contaminant removal kinetics on filter performance. RAC appears to be more limited by kinetics than biochar, as the RAC filters exhibit worse contaminant removal than the biochar for each filter

depth even though the RAC filters contain more carbon by mass (3.3 wt% RAC, 2.4 wt% biochar). The influent concentration and target removal also impact the filter lifetime significantly, as the filter performance is far superior for the chronic scenario than the acute scenario for each BC material and filter depth. The standard deviation of the filter lifetime estimate provides a sense of the certainty of the predictions, and stormwater practitioners and regulators should be encouraged to be mindful of the degree of uncertainty when specifying a factor of safety.

Table 23 Long-Term Modeling Filter Lifetimes [years] for Seal Beach, CA Case Study for Fipronil Breakthrough at the Acute or Chronic Aquatic Health Benchmark and Respective Highest or Median Input Levels

Acute Scenario

Depth	Biochar								RAC							
[m]	**Fipronil**		Imidacloprid		PFOS		PFOA		**Fipronil**		Imidacloprid		PFOS		PFOA	
0.2	**0.0**	**±0.0**	10.3	±17.8	>100	-	70.9	±25.2	**0.0**	**±0.0**	0.0	±0.0	0.0	±0.0	0.0	±0.0
0.3	**0.7**	**±1.3**	80.8	±40.4	>100	-	>100	-	**0.0**	**±0.0**	0.0	±0.0	>100	-	>100	-
0.4	**3.3**	**±1.7**	>100	-	>100	-	>100	-	**0.0**	**±0.0**	4.5	±7.9	>100	-	>100	-
0.5	**6.3**	**±2.6**	>100	-	>100	-	>100	-	**0.0**	**±0.0**	23.7	±9.0	>100	-	>100	-
0.6	**10.3**	**±3.7**	>100	-	>100	-	>100	-	**0.0**	**±0.0**	45.0	±14.4	>100	-	>100	-
0.7	**15.0**	**±5.0**	>100	-	>100	-	>100	-	**0.0**	**±0.0**	70.8	±20.9	>100	-	>100	-
0.8	**20.2**	**±6.5**	>100	-	>100	-	>100	-	**0.0**	**±0.0**	99.7	±28.2	>100	-	>100	-

Chronic Scenario

Depth	Biochar								RAC							
[m]	**Fipronil**		Imidacloprid		PFOS		PFOA		**Fipronil**		Imidacloprid		PFOS		PFOA	
0.2	**69.7**	**±29.9**	>100	-	>100	-	>100	-	**0.0**	**±0.0**	11.7	±20.3	>100	-	>100	-
0.3	>100	-	>100	-	>100	-	>100	-	**0.0**	**±0.0**	88.2	±33.2	>100	-	>100	-
0.4	>100	-	>100	-	>100	-	>100	-	**0.0**	**±0.0**	>100	-	>100	-	>100	-
0.5	>100	-	>100	-	>100	-	>100	-	>100	-	>100	-	>100	-	>100	-
0.6	>100	-	>100	-	>100	-	>100	-	>100	-	>100	-	>100	-	>100	-
0.7	>100	-	>100	-	>100	-	>100	-	>100	-	>100	-	>100	-	>100	-
0.8	>100	-	>100	-	>100	-	>100	-	>100	-	>100	-	>100	-	>100	-

Biochar content = 30 v%, 2.4 wt%; RAC content = 10 v%, 3.3 wt%.
Values indicate mean ± standard deviation (n=3).

5 Development of a technical design manual for improved stormwater control measures and recommended field demonstration testing for future studies (Task 6).

5.1 Development of technical design manual (Subtask 6.1).

Geosyntec Consultants are currently developing a guidance manual for evaluation and implementation of BC-amended engineered media filtration for passive treatment of stormwater runoff. A draft of the manual may be found in Appendix C.1. The manual intends to distill the key findings from this project to help DoD site managers and Remedial Project Managers (RPMs) make key practical decisions about using BC-amended engineered media filters as a stormwater treatment alternative, including (1) whether BC-amended engineered media filters should be considered for a site, (2) whether BC-amended engineered media filters can meet their regulatory and/or treatment objectives with acceptable maintenance cycles, and if so, (3) how systems should be designed, constructed, and operated/maintained. The manual consists of five sections:

- Section 1 provides an orientation to the overall project and the intended purpose of this guidance document.
- Section 2 includes an orientation to passive BCSMFs for stormwater treatment, including when they should be considered and what key questions need to be asked and addressed in evaluating potential project designs.
- Section 3 includes guidance for evaluating BCSMF system application and designs and introduces a design and performance estimation tool that can be used to support design variables to successfully construct and treat CoCs.
- Section 4 includes additional guidance, specifications, and considerations related to the design, construction, and O&M of BCSMFs, as a subset of traditional biofiltration BMPs.
- Section 5 summarizes the findings of companion research [ER18-1371: Development of Tools to Inform the Selection of Stormwater Controls at DoD Bases to Limit Potential Sediment Recontamination] that was in progress at the time of publication. This research is related to different pollutants of concern and regulatory conditions than the remainder of this guidance.

The guidance manual is expected to be completed by the end of fall 2022.

5.2 Development of treatment engineered media performance and sizing tool (TEMPEST) (Subtask 6.2).

The Microsoft excel spreadsheet-based TEMPEST design tool is attached in XI. Appendix C. Section 3. This tool consists of multiple tabs including: *Read Me, Instructions*, *1. Rainfall*, *2. Land Use*, *3. TofC*, *4. BMP Design and Results*, *5. Compare Scenarios*, and a series of look up tables.

The *1. Rainfall*, *2. Land Use*, *3. TofC* tabs constitute the hydrologic modeling input parameters. The user inputs the geographic location, rainfall type distribution, and specifies a design storm event size in tab *1. Rainfall*. The default storm event size is the 95th percentile 24 hour event rainfall total as this is what is specified for DoD SCM Design. The mean annual rainfall is determined for the geographic location selected by the user based on the last 30 years of precipitation data reported by NOAA. The user can specify user-defined values for the rainfall event depth and annual rainfall depth. The user then defines the dominant hydrologic soil type for the site, total drainage area, and land use of the drainage area. The weighted curve number is then computed based off the defined land use and proportion of the total drainage area for the defined land use. The tool assumes that the drainage area is a fully developed drainage area. Tab *3. TofC* calculates the peak runoff and runoff depth using the TR55 method based on physical site stormwater runoff characteristics (sheet flow, shallow concentrated flow, or open channel flow). The user must specify the length and slope and either surface type, or Manning's N, cross sectional area, and wetted perimeter depending on the type of flow by which the runoff is conveyed to the BC-amended filter. This tool assumes open and unconfined flow over land or in channels – no sewer flow – and a single hydrologically homogenous subwatershed area.

Tab *4. BMP Design and Results* calculate the filter dimensions or proportion of rainfall event captured for the specific storm event specification and user-inputted filter dimensions, and estimates the filter lifetime for a specific TrOC and target removal level. In order to size the filter, users must specify if the filter surface area is to be calculated to capture the entire designed storm

event or user-defined (user must specify the length and width), the ponding depth, media filter depth, and if the outflow is to be controlled by an orifice (user must specify the diameter and coefficient of discharge) or user-defined. The tool then calculates the media flow through rate and time, number of filter empty bed volumes treated per year, and the number of filter empty bed volumes treated per storm event. In order to calculate the filter lifetime, the user must specify the constitute of concern (CoC), media filter material, black carbon content, influent concentration, and target removal level. The filter lifetime is then found by converting the number of filter empty bed volumes treated until the CoC concentration in the filter effluent exceeds the targeted removal level as read from the filter performance lookup table (developed in Task 3) expressed in years based on the calculated number of filter empty bed volumes treated per year. The standard deviation on the filter lifetime is also reported to provide a degree of confidence to the estimated filter lifetime value. The user can additionally input costs for the filter materials (sand, biochar, RAC) or use default values in order to estimate the cost of the materials. Default values are based on quotes received for biochar and RAC used in this study. Tab *5. Compare Scenarios* allows the user to compare two BC-amended filter designs or TrOC removal scenarios.

The TEMPEST spreadsheet tool can be used to optimize BC-amended engineered media filter design to ensure removal of PFOA, PFOS, fipronil, imidacloprid, or atrazine. The tool indicates that biochar is cheaper to use then RAC even though biochar's performance is not as good per volume of media required. Estimated filter lifetimes of 0 indicate that the targeted CoC removal level is never met for the specified filter. Large standard deviations relative to the mean indicate low confidence in the estimated lifetime. This occurs due to disagreement among the column replicate-derived models as shown in Figure 42, and is more common with high levels of targeted CoC removal (low C/C_0), for which removal may not be possible in all of the column replicate-derived models. To increase the estimated filter lifetime and reduce the relative standard deviation, thus increasing confidence in the estimated filter lifetime, the user can either increase contact time of stormwater in the filter by decreasing the outflow (decrease the orifice control), or increase the black carbon content. The filter lifetime is more sensitive to increasing BC content than decreasing flow rate. The TEMPEST tool is useful because it has flexibility to be adaptable to various sites and treatment goals, and can offer insights into the contaminant removal performance expected from various filter designs.

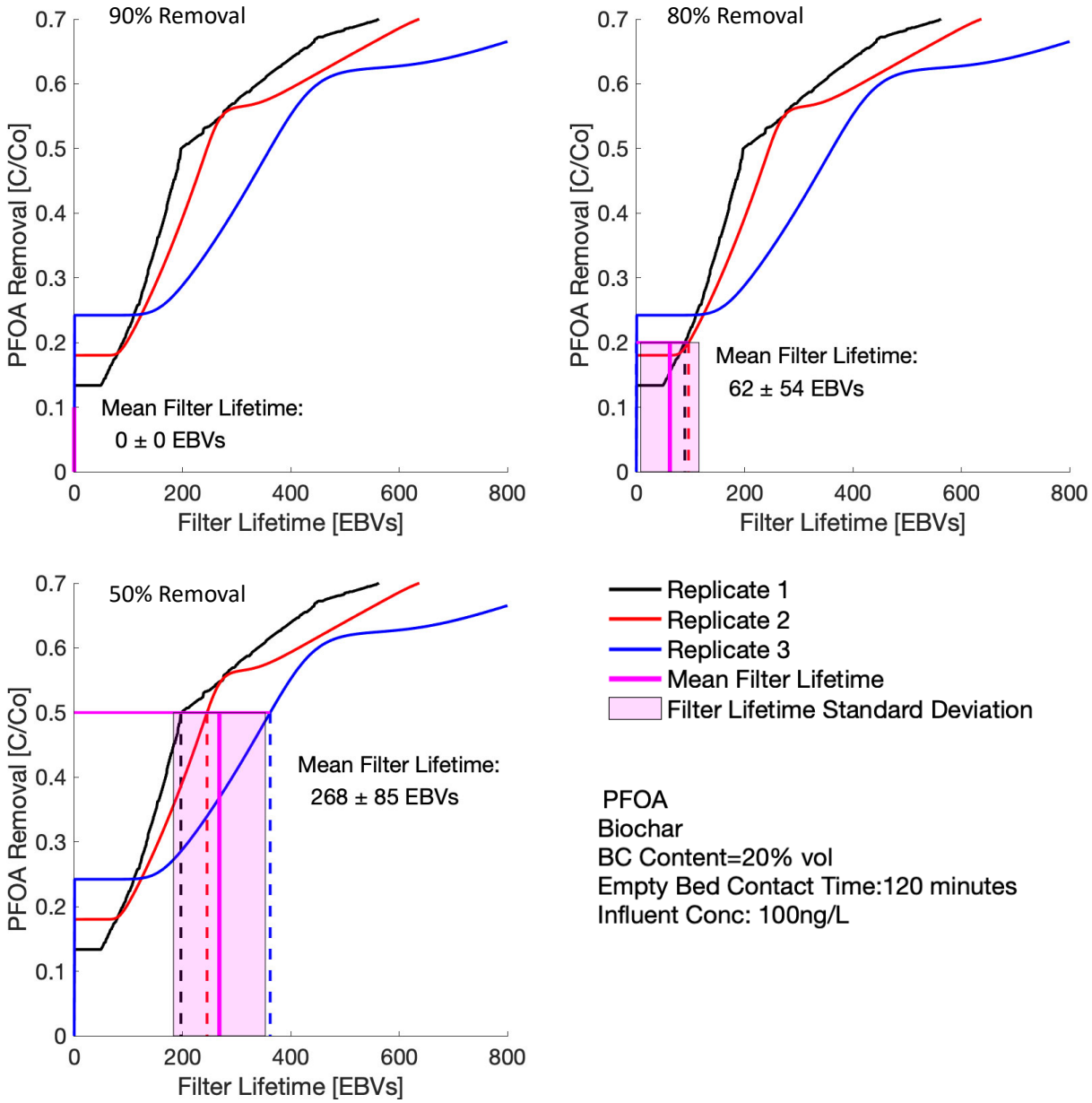

Figure 42 Expected filter lifetime (years) for various target PFOA removal for the specific filter design parameters.

5.3 Recommendation of field testing and future studies.

This project report demonstrates the potential for BC-amended engineered media filters to remove a wide suite of contaminants from stormwater runoff, including TSS, metals, HOC, hyphil-TrOCs, and PFAS. The realistic nature of the column experiments conducted in the laboratory will facilitate transfer to the field. Specifically, the column experiments were designed to operate in down flow with gravity driven flow using synthetic stormwater that was developed with DOC, microbial inoculum, and suspended sediment sourced from catch basin material from a DoD facility. Moreover, a full-scale BC-amended engineered media filter was constructed outside

McNeil Parking Garage at Colorado School of Mines (Figure 43) to demonstrate the commercial availability of the media, process for mixing the media amendment, and construction of the filter foundation and conveyances.

The column experimental design demonstrated the importance of using a top layer of barrier sand that can be maintained and replaced from time to time to prevent filter clogging. Additionally, the unsaturated experiments (Task 4) demonstrate that the BC-amended engineered media filters remove contaminants as well as if not better in unsaturated conditions than in fully saturated conditions. In fact, improvement in PFAS removal in the unsaturated conditions (Task 4) suggest that performance in the field may be similar to or better than observed in the continuous flow saturated lab experiments (Task 2, 3, and 5). Long-term contaminant transport modeling (Task 5) demonstrates how filters are expected to perform under various conditions and for longer periods of time. Field testing would be an opportunity to validate both BC-amended engineered media filter performance and the TEMPEST filter design tool. Field testing is necessary to validate project results to allow for wide-spread use of results and the TEMPEST modeling tool to guide improved stormwater treatment, and facilitate potential stormwater runoff beneficial use at DoD facilities and beyond.

The laboratory experiments and TEMPEST filter design tool can be used to guide future field tests, such as proposed in ER23-B3-7840. Field testing is necessary to ensure that the BC-amended engineered media filters can adequately operate for many years under environmental conditions (with various saturation conditions, storm event durations, and time between storm events), across different seasons, and in various climates. Field testing could consist of using relatively small modular systems, such as shown below in Figure 43, to capture and treat stormwater runoff at DoD facilities and monitor contaminants in the influent and filter effluent. Modular BC-amended engineered media filters could be designed for specific sites using the TEMPEST tool to treat target CoCs based on the observed contaminants in stormwater runoff at individual sites. The modular design could be used to artificially “stress test” the filter by under-designing the filter so that it must treat more filter empty bed volumes per storm event than a full-scale filter, thereby reducing the needed time period to complete the field test. Implementation will occur at sites where concentrations can be reasonably managed through passive treatment. The use of modular systems will support consistency in design, implementation, and monitoring across sites; allow in or near channel placement; and prevent infiltration within the subgrade to avoid unwanted interactions with or transference to groundwater. Additional monitoring of the full-scale BC-amended engineered media filter outside of the McNeil parking garage at the Colorado School of Mines could assess the filter’s long-term physical integrity and durability.

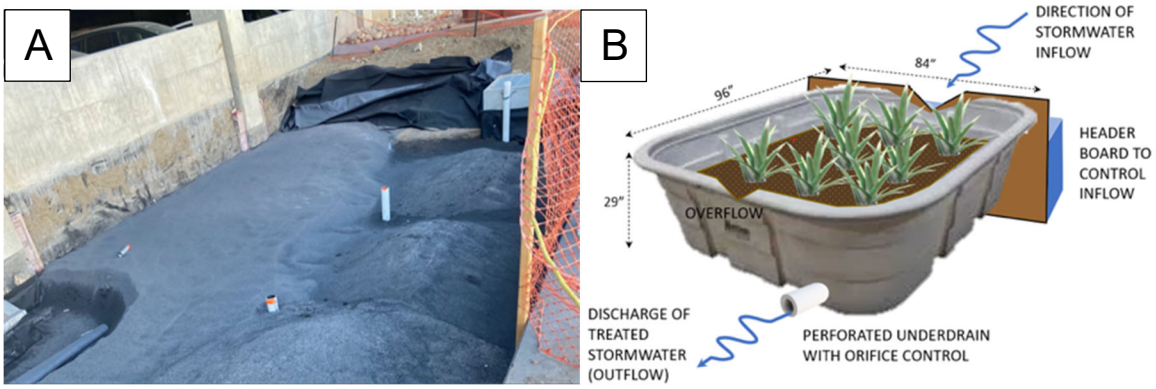

Figure 43 Full-scale constructed BC-amended engineered media filter outside McNeil Parking Garage at Colorado School of Mines (A), and proposed modular BC-amended engineered media for field testing (B).

Future laboratory studies would be useful to investigate the influence of DOC on BC-amended filter lifetime predictions, incorporate metals into the TEMPEST filter design tool, and assess the variability in biochar across various supplies and various batches. Results from Task 5 show that DOC impacts contaminant removal in BC-amended engineered media filters. However, it is unclear how DOC impacts the filter lifetime, as the specific impact on contaminant removal kinetics has not been fully understood. The contaminant transport model used in Tasks 3 and 5 must be modified to include the background DOC in order to predict filter performance at various DOC concentrations. Similarly, a metals transport model must be developed to predict the metals removal in the filters under various conditions, so that performance tables for metals removal may be developed and included in TEMPEST. Finally, unlike GAC and RAC, biochar is not standardized and it is unknown how much its quality may vary batch to batch or supplier to supplier. It is crucial that standard feedstock material and production specifications are created for biochar so that that different suppliers are able to produce similar product so that biochar from different suppliers can be used interchangeably and confidently without risking contaminant removal or hydraulic performance.

VII. Conclusions and Implications for Future Research/Implementation

The research has been successfully completed in regards to the project milestones as summarized below. All of the project's objectives were met. Additionally, future research including both field tests and laboratory-based tests are suggested and discussed.

1 Assessment of engineered media filters for removal of contaminants from stormwater runoff (Task 2).

This project shows that the studied BC amendment—whether high temperature gasification biochar or RAC—effectively removes a suite of metals, hydrophilic TrOCs, and PFASs from stormwater runoff while maintaining sufficient hydraulic conductivity. While zeolite provided slight benefits for metals, hyphil-TrOCs, and PFAS removal under the studied conditions, the benefit was not substantial, and likely due to the increased porosity and detention time of the zeolite relative to the sand. RAC amendment provided greater benefit for PFAS removal than biochar. Cost data for biochar, RAC and AC were obtained from manufacturers but do not include shipping. Biochar amendment appeared to be more effective for hyphil-TrOCs removal even though there was more RAC present on a wt% basis. While biochar ($262 m^{-3}) costs less than RAC ($763 m^{-3}) and virgin AC ($1,630 m^{-3}) on a volume-basis, biochar costs more ($2.53 kg^{-1}) than RAC ($1.5 kg^{-1}) on a mass-basis because of the significant difference in material density (Table 24). This raises questions about which material may be more beneficial for widescale use in SCMs where cost is an important consideration and SCMs are built to specific material-standards rather than based on individual site conditions.

For example, constructing a filter with RAC will likely be less expensive than biochar if designs call for a certain wt% BC content, while the opposite is likely true if designs call for a specific v% BC content. In terms of performance, using a set volumetric content will likely yield better performance for a RAC system while using a set mass content will yield better performance for a biochar system. Further, because of the clogging concerns due to increased friability and reduction in hydraulic conductivity associated with biochar relative to RAC, constructed systems may not be able to contain as much biochar (on either a wt% or v% basis) as RAC, likely limiting their maximum potential treatment life. These experiments with biochar and RAC employed low weight percent to observe transport of TrOCs and a design consideration is an optimal weight percent for longer performance and sustained hydraulic conductivity. A full life cycle assessment including handling, maintenance, and material sustainability considerations is needed to determine individual selections of biochar or RAC for general SCM guidance. Due to the nonuniformity of biochar material, production methods, cost, and performance (especially relative to RAC), individual life cycle assessments must include specific biochars. This work found that the studied biochar and RAC are both capable of effectively removing a broad suite of dissolved co-contaminants under relatively high-flow conditions with representative grain sizes and synthetic stormwater and are worthy of further study.

Table 24 Cost estimates for BC amendment used in this study based on manufacturer data not including shipping.

Parameter		Biochar[a]	RAC[b]	AC[c]
Cost by Mass	$ kg^{-1}	2.54	1.50	3.19
Density	$kg\ m^{-3}$	103	510	510
Cost by Volume	$ m^{-3}	262	763	1,630

[a] Biochar Supreme Environmental Ultra, WA; [b] Norit GAC 830R; [c] Calgon AC

This study identified an important tradeoff between contaminant removal performance and flow rate. Previous studies have shown successful contaminant removal at slower flow rates and with smaller-sized media particles for which filter lifetime is a function primarily of sorption capacity (Ashoori et al., 2019). This study shows that successful contaminant removal is possible at higher flow rates in which filters must be designed with larger sized media and for which sorption kinetics become an important factor. Increasing the treatment flow rate of stormwater control measures reduces the amount of stormwater that must be detained for a controlled flow and therefore reduces the total footprint of the system. Reducing the footprint is especially important in urban areas and at industrial facilities where space is often limiting. More work is needed to fully understand the impact of flow rates on design and validate a contaminant transport model at higher flow rates. Still, this study shows that adequate contaminant removal is possible at flow rates of 20 cm hr^{-1}.

Maintenance is an important performance consideration for BC-amended stormwater control measures. Too often, maintenance is overlooked and stormwater control measures clog or are overgrown. In this study, the downflow configuration with continued TSS loading was chosen to better replicate field-operation conditions in which clogging would be a concern. The barrier sand at the top of the filter in this study was designed to trap particles and was vacuumed and replaced every 6-8 days to remove biologic growth and trapped suspended particles. Maintaining the top layer of barrier sand helped ensure that the filters operated at their design flow. While plants have been shown to provide a benefit to maintaining adequate hydraulic conductivity (Hatt et al., 2009), some locations may not be able to be planted due to space or wildlife concerns. In these instances, maintaining a layer of barrier sand at the top of the filter may provide an easy method for maintaining the hydraulic conductivity of the filter and preventing the filter from clogging. And, in order to facilitate media maintenance, plants would not be included in the design.

Engineered filters with BC amendment are a promising technology for the treatment of stormwater runoff. Filters operated in a gravity-driven down-flow mode were conditioned for 100 EBVs and then challenge tested for 480 EBVs with a wide suite of co-contaminants at elevated concentrations including metals, hydrophilic and hydrophobic TrOCs, and PFASs. Filters were operated with consistent TSS and DOC loading without clogging with periodic maintenance during which the top layer of barrier sand was cleaned and replaced. Filters amended with high-temperature gasification biochar or regenerated activated carbon removed a suite of metals, TrOCs, and PFASs while removing nearly all TSS and reducing turbidity. Zeolite did not appear to substantially benefit the contaminant removal in this study. Contaminant transport in the columns indicate that the TrOCs removal is kinetically-limited at face velocity flow rates of 20 cm/hr. This study offers proof-of-concept for BC-amended engineered media filters as effective stormwater control measures. While this study used relatively high concentrations of contaminants and low BC contents in order to observe contaminant transport, performance in the field is likely to be

significantly better with higher BC-content filters and lower ambient stormwater contaminant concentrations. Additional modeling, using the contaminant transport observed in this study, may be used to estimate field performance and understand the design implications of kinetically-limited contaminant removal performance.

2 Development of filter performance curves with kinetic and flow rate design parameters (Task 3).

Increasing filter flow rates from 40 cm hr^{-1} to 60 cm hr^{-1} appears to affect the removal of turbidity, TSS, and dissolved TrOCs. These findings are consistent when comparing filter performance in this study on the basis of EBVs treated with performance compared to findings in Task 2 using a similar experimental set up operated at 20 cm hr^{-1}. While a decrease in removal was slight relative to the large increase in flow rate from 20 cm hr^{-1} to 40 cm hr^{-1} to 60 cm hr^{-1}, the decrease in removal is indicative of flow impacts on suspended sediment interception affecting TSS and turbidity removal and kinetic limitations of TrOCs removal. The slight decrease in TrOCs in performance at higher flow rates shows that while the TrOCs removal is kinetically limited, it is possible to still obtain good performance at higher flow rates, permitting the use of higher-flow SCMs in the field. Higher-flow SCMs are advantageous because they can treat greater volumes of water in less time and with a smaller footprint. This allows space-limited sites to better treat a greater proportion of their stormwater runoff and minimize the volume of stormwater runoff bypassing treatment. However, high-throughput SCMs are likely to require a deeper filter bed to increase the flow contact time to allow for desired TrOCs removal.

The validation of the TrOCs transport model and sorption and tortuosity parameters used to predict TrOCs transport in BC amended engineered media filters at 20 cm hr^{-1} for use at higher flow rates helps to elucidate the tradeoff between flow rate and filter performance. Filter performance tables demonstrate how long differently designed BC amended engineered media filters may perform for specific levels of C/C_0 breakthrough. These curves are designed to be used by stormwater practitioners and regulators to design improved SCMs that better remove dissolved TrOCs. The finding that filter performance is a function of EBCT has interesting implications, as two sites, for example one constrained by available land area and one constrained by a high-water table, with the same volume of filter material, can arrange their filters in ways to minimize surface area (by increasing filter depth) or minimize filter depth (by increasing filter surface area) and still treat the same volume of water with the same performance. The performance tables also reveal minimal specifications for filter EBCT and BC content to achieve specific levels of C/C_0 removal for various influent contaminant concentrations. Too short EBCTs or low BC content lead to incomplete removal and initial breakthrough.

While the performance tables are only applicable for predicting performance of BC-amended engineered media filters that use the specific materials used in this study, they may offer estimates of how other BC materials might perform. For instance, other BC materials that have a smaller grain size, increase surface area, or increased mesopore distribution ratio are likely to perform better than the tables predict, as the kinetics of TrOCs removal increase with smaller BC grains, increased surface area, and greater mesopore distribution. Likewise, the performance is expected to be worse for BC materials of larger grain size, smaller surface area, and smaller mesopore distribution.

In summary, this study found that increasing the flow rate in BC amended engineered media filters to 40 and 60 cm hr^{-1}, as is representative of field conditions, slightly decreased the removal of TSS, turbidity, and dissolved TrOCs. Removal of dissolved metals were negligently affected by the increase in flow rate, though the removal was affected by increased influent concentrations relative to that found in Task 2 with an identical column set up but lower flow rate and reduced metal influent concentrations. The contaminant transport model and fit sorption and tortuosity parameters used to predict TrOCs transport in similar BC amended engineered media filters at 20cm hr^{-1} adequately predicted breakthrough in this study for similar columns operated at 40 cm hr^{-1} and 60 cm hr^{-1}. This finding validated the transport model and previously fit parameters for use in constructing BC amended engineered media filter performance tables. These performance tables define filter performance by the volume treated before specific levels of C/C_0 breakthrough, as a function of BC content, EBCT, and influent concentration. These performance tables have been incorporated into a design manual and are meant for use by stormwater practitioners to design improved SCMs to better remove dissolved TrOCs.

3 Assess efficacy of saturated/unsaturated filters to remove metal and organic contaminants from periodic storm events using black carbon-amended engineered media filters (Modified Task 4).

The goal of this task was to assess the effect of saturation on removal of the suite of metal and organic contaminants. Columns maintained a state of constant saturation using hydraulic controls or drained freely by gravity. Appropriately sized storm events were simulated using synthetic stormwater created as described in previous tasks. After the dosing was complete, all columns were saturated to assess the effect of a flooding event.

Both saturated and unsaturated column configurations provided substantial water quality improvement with respect to PFASs, TrOCs, and metals for the duration of the experiment. Across all PFASs analyzed, unsaturated conditions outperformed saturated conditions, likely due to their preferential sorption to the air-water interface in unsaturated conditions. While there were insufficient data to observe and compare the removal of TrOCs in this experiment due to exceedingly efficacious sorption by the BC amendment, data for metals indicated saturated conditions performed better for nickel removal, while unsaturated conditions performed better for copper removal.

Data from the simulated flushing event suggest that system failure (i.e. unsaturated columns becoming saturated with water) would remobilize an equivalent amount of PFAS as compared to the saturated conditions: for most PFASs, no significant differences were observed with respect to PFAS release between unsaturated and saturated conditions. As a percentage of the total mass retained on the column, less total mass was eluted from the unsaturated column during the flush, indicating that the removal of the air-water interface does not threaten filter efficiency. More importantly, less than 0.5% of total loaded PFOS and PFOA mass eluted in the simulated flushing event.

4 Evaluation of the long-term performance modeling of various black carbon- and zeolite-amended biofilters for breakthrough based on different design criteria (Task 5).

Contaminant removal benefited from reducing the flow rate, influent concentration, and background DOC content, while the removal suffered from increasing these values. Increasing the flow rate reduced the contact time available for the dissolved TrOCs to be removed by the black carbon, which in turn reduced the amount of contaminant removed in the kinetically-limited system. Increasing the influent concentration resulted in the increased loading of contaminant onto the carbon, which resulted in the increased rate of depletion of the carbon sorption capacity. Interestingly, DOC appears to affect both the kinetics and the carbon sorption capacity of dissolved TrOCs removal, through reduction in the isotherm and increase in the tortuosity factor. It is observed that the contaminant removal performance only noticeably increased in the effluent upon reducing the background DOC. While DOC was still being removed in the column filter effluent immediately before the DOC level was reduced, the column filters appeared to leach DOC briefly and then reach a steady state of 100% DOC breakthrough. It is possible that the top half of the filter was fouled with DOC to an extent that reducing the DOC had negligible immediate effect on increasing contaminant removal whereas the bottom of the column was not as fouled to the same degree and saw some immediate benefit of reduced contaminant competition with DOC for surface sorption sites and reduced pore-blocking.

The accurate prediction of filter performance under dynamic flow and influent concentration conditions using sorption parameters previously fit in Task 2 further validates the intraparticle pore diffusion-sorption transport model for use in predicting filter performance under dynamic flow and influent loading conditions. The flow rate impact on turbidity suggests that colloidal transport increases with increasing flow rate, which is consistent with past studies. However, the close match of the model-predicted contaminant transport with the observed contaminant transport suggests that colloidal transport, which is not included in the transport model, may not be a significant mechanism of hydrophilic TrOCs transport. Additionally, this study validates the model and sorption parameters for predicting filter performance at different carbon contents. For example, this study investigated filters packed with 1 wt% biochar (15 v%) using parameters derived from breakthrough curves fit to filters containing 2.4 wt% biochar (30 v%). Error associated with the model underpredicting breakthrough in this study is likely attributed to the slightly higher DOC in this study. DOC increases contaminant breakthrough due to both reduced BC sorption kinetics and sorption capacity.

The ability to model dynamic flow and influent contaminant concentration loading conditions allows for investigation of how engineered media filters are likely to perform in the field under natural conditions in which the flow rate and influent loading are likely to be highly variable. Using actual time-dependent flow rate and influent pollutant concentrations rather than event mean concentration will allow for more accurate predictions of filter performance since the time-dependent influent concentration may differ substantially from the event mean concentration. Event mean concentrations, which are reported by collecting grab samples over the course of a storm and finding the flow rate-weighted mean pollutant concentration, are not representative of the maximum concentration observed and may be further diluted by long-duration storm events (Bertrand-Krajewski et al., 1998). Further investigation is needed to ensure that event mean concentration-sized filters are not at risk of premature breakthrough from sudden increases in contaminant loading, as might be expected during first flush events. Additionally, the model may

be used to inform real-time operation of engineered media filters by which the filter infiltration velocity is manipulated to optimize stormwater runoff volume treated while ensuring adequate contaminant removal.

The implications of high-DOC induced contaminant breakthrough due to reduced BC removal kinetics and sorption capacity are significant and require additional study. A logical next step would be to incorporate background DOC into the model, perhaps by modifying the tortuosity term or adding an additional term to the apparent diffusion equation to capture expected kinetic effects of background DOC. Additionally, scalar factors could be used to empirically adjust Freundlich sorption parameters depending on background DOC content and type. However, further work is necessary to mechanistically assess the specific impacts of various sources and types of DOC on BC sorption capacity and BC diffusion kinetics.

In summary, this study investigated the effect of dynamic flow rate and influent concentration and variable DOC on biochar amended engineered media filters. The filters contained 1 wt% biochar, a relatively low value in order to more readily assess the effects of influent variables. The intraparticle pore diffusion-sorption transport model with previously fit sorption and tortuosity parameters reported in Task 3 was validated for predicting contaminant transport and filter performance under dynamic flow and influent concentration conditions. Background DOC significantly impacts contaminant breakthrough and may limit filter performance and lifetime in the field. Model tortuosity and Freundlich intensity parameters were increased and BC sorption capacity decreased with increased levels of background DOC. More work is necessary to incorporate the impact of variable background DOC on contaminant removal kinetics and BC sorption capacity into the transport model. The validation of the intraparticle pore diffusion-sorption transport model and fit sorption and tortuosity parameters make it possible to model engineered media filter performance over the course of individual storm events in which flow rate and influent concentration are likely to vary. The model was then used to predict long-term filter lifetimes in a hypothetical case study for Seal Beach, CA. The kinetics of contaminant removal were found to have a large impact on contaminant removal in the filter lifetime case study, and are likely to become even more important with faster flow rates, increased contaminant concentration, and increased background DOC.

5 Development of a technical design manual for improved stormwater control measures and recommended field demonstration testing for future studies (Modified Task 6).

Geosyntec Consultants developed a guidance manual for evaluation and implementation of BC-amended engineered media filtration for passive treatment of stormwater runoff. The guidance manual assists DoD site managers and Remedial Project Managers (RPMs) in making decisions about whether BC-amended engineered media filters should be considered for their site, whether BC-amended engineered media filters can meet their regulatory and/or treatment objectives, and how to design, construct, and operate/maintain BC-amended engineered media filters. A draft of the guidance manual is included in the Appendix C.1. The guidance manual also details how to use the TEMPEST stormwater filter design spreadsheet tool to design and size BC-amended engineered media filters to adequately remove target contaminants while meeting hydrologic constraints.

The TEMPEST stormwater filter design tool was developed in partnership with Geosyntec Consultants and is also attached in the Appendix C.3. This design tool is significant because it allows the integration of contaminant removal performance into traditional stormwater control design. The tool estimates the contaminant removal performance and filter lifetime for user-inputted filter specifications, allowing the user to optimize the stormwater control design to address hydrological constraints as well as contaminant removal objectives. Both the guidance manual and TEMEPST design tool disseminate key results from this project in a practical form that may be used by practitioners, DoD site managers, and RPMs to implement better stormwater management practices to reduce sediment recontamination and improve the quality of stormwater runoff to facilitate beneficial use of stormwater runoff. Beneficial use of stormwater runoff is likely to become a necessity in drought-prone regions such as the American west. Examples of beneficial use include capture of stormwater runoff for managed aquifer recharge to supplement drinking water sources and protect against salt water intrusion, release to protect environmental base flows to support aquatic environments and recreation activities, and or urban/industrial uses.

This project report demonstrates the potential for BC-amended engineered media filters to remove a wide suite of contaminants from stormwater runoff, including TSS, metals, HOCs, hyphil-TrOCs, and PFAS. However, field testing and validation is essential to facilitate transfer of the filter technology and the TEMPEST modeling tool from the laboratory to real-world practice. The experimental design of the laboratory experiments emphasized conducting experiments that were as representative as possible of field conditions to facilitate translation to the field. The laboratory tests also provided key insights, such as the importance of using a top layer of barrier sand to prevent filter clogging and the potential for improved PFASs removal in unsaturated conditions (Task 4). This finding suggests that contaminant removal performance in the field with intermittent flow and saturation conditions may yield similar to or better contaminant removal than observed in the continuous flow saturated lab experiments (Task 2, 3, and 5), increasing the confidence of success with respect to field tests. Field testing is necessary to validate project modeling results to allow for wide-spread use of the modeling results and the TEMPEST design tool to guide improved stormwater treatment, and facilitate potential stormwater runoff beneficial use at DoD facilities and beyond. Although the contaminant transport model was validated extensively in the laboratory, field-scale validation is necessary to build confidence in the model approach and laboratory-fit parameters to allow use for real-world applications. The project team has submitted an ESTPC proposal (ER23-B3-7840) to support field tests of the BC-amended engineered media filters and validation of the TEMPEST modeling tool. Additional experiments are necessary to understand the impact of variable background DOC concentrations on the kinetics of contaminant transport and filter lifetime estimates, and incorporate metals transport modeling into the TEMPEST design tool.

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IX. Appendix A. Supporting Data

1 Materials and Chemicals

1.1 Engineered Media Size Analysis

Engineered media grain size analysis was conducted with mechanical sieving using mesh no. 12, 16, 18, 20, 30, 35, ad 40 size sieves. Engineered media was added to the top of the sieve stack and the shaken for 7 minutes after which the mass retained on each sieve was massed and converted to number of grains by the following equation:

$$n_{grains} = \frac{m_{retained}}{d \times v_{grain}}$$

Where n_{grains} is the number of grains retained on the sieve, $m_{retained}$ is the mass of material retained on the sieve, d is the density of the material, and v_{grain} is the volume of a single grain as determined by the size of the mesh on which the grain is retained. The percent of total grains retained on each sieve was then computed, and the percent passing each sieve was plotted. Polynomial curves of best fit were then found and used to find the d_{50}, shown below in Table 25. Plots of the grain size distribution for the sand, RAC, and biochar are shown below in Figure 44 - Figure 47.

Table 25 Engineered media measured d_{50}.

	Particle Size (mm)		
	Sand	RAC	Biochar
d_{50}	1.00	0.80	0.88

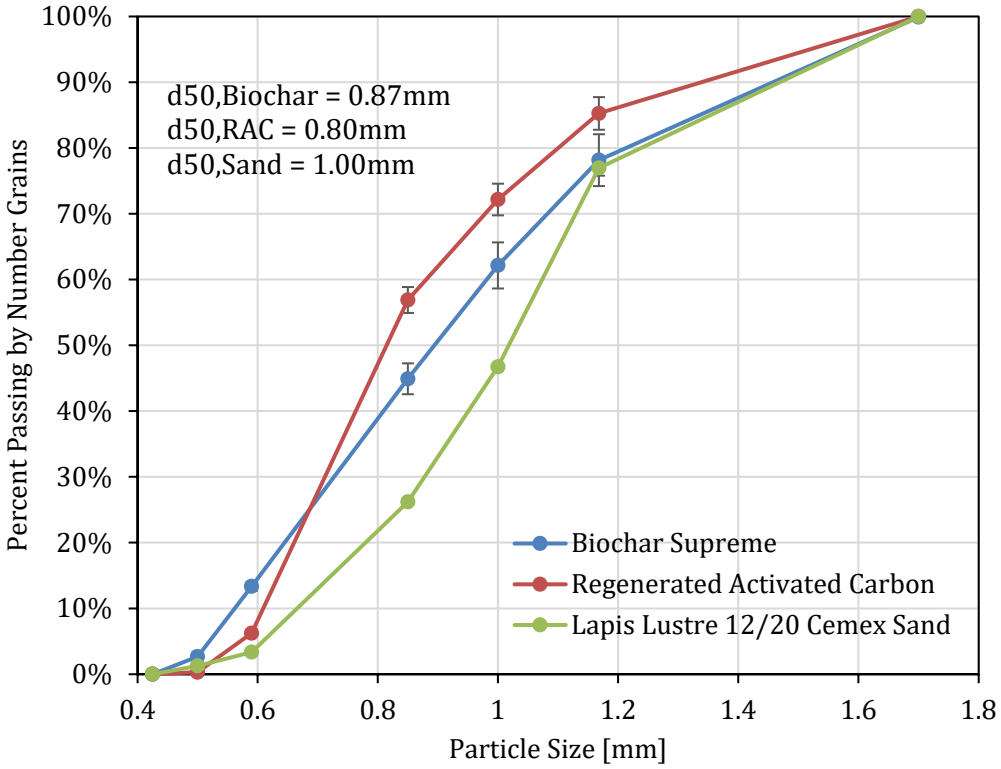

Figure 44 Engineered media grain size distribution measured using mechanical sieve analysis for sand (green), RAC (red), and biochar (blue). Points indicate mean (n=3) and error bars show one standard deviation above and below the mean.

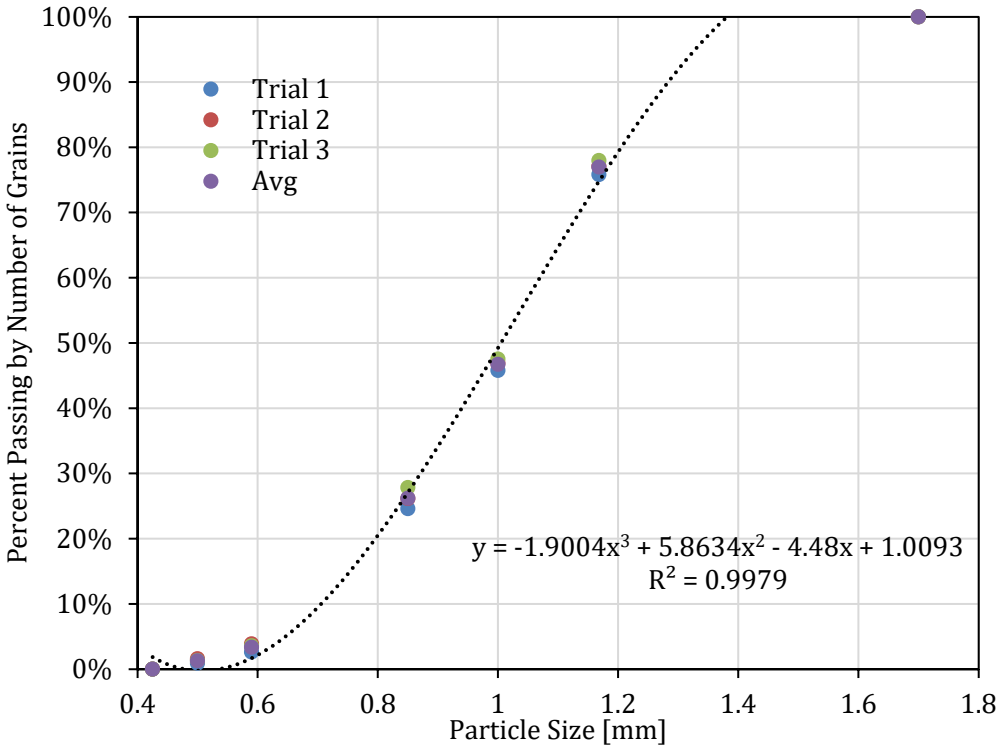

Figure 45 Measured grain size distribution for sand using mechanical sieve analysis. The best fit polynomial curve is shown with the equation used to calculate the d_{50}.

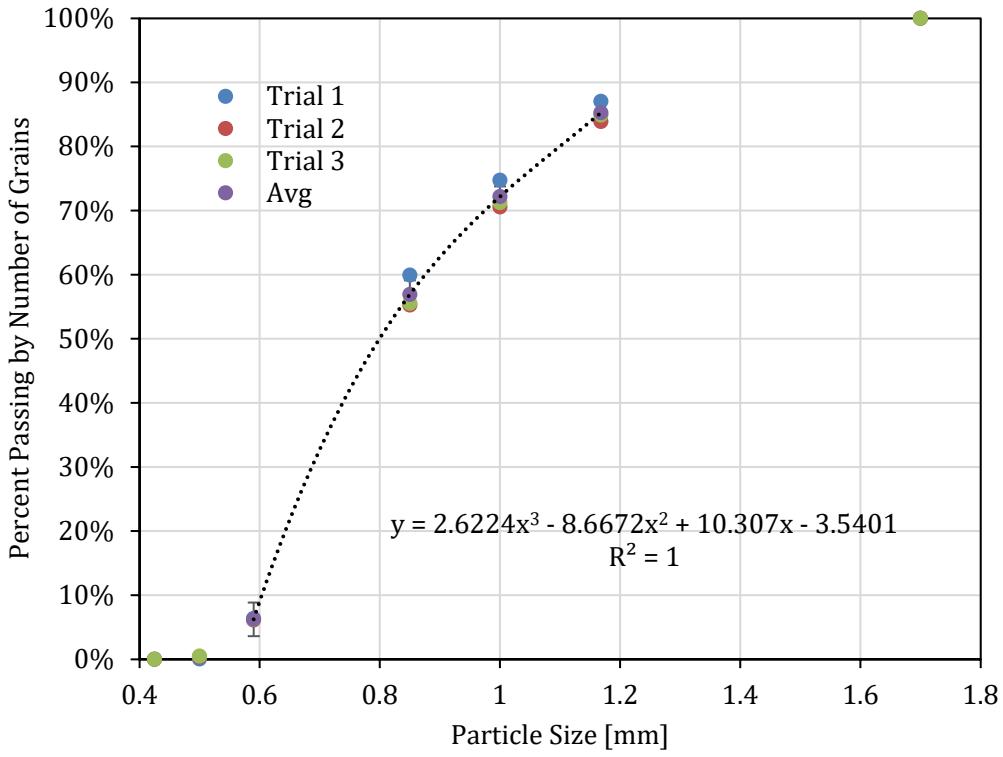

Figure 46 Measured grain size distribution for RAC using mechanical sieve analysis. The best fit polynomial curve is shown with the equation used to calculate the d_{50}.

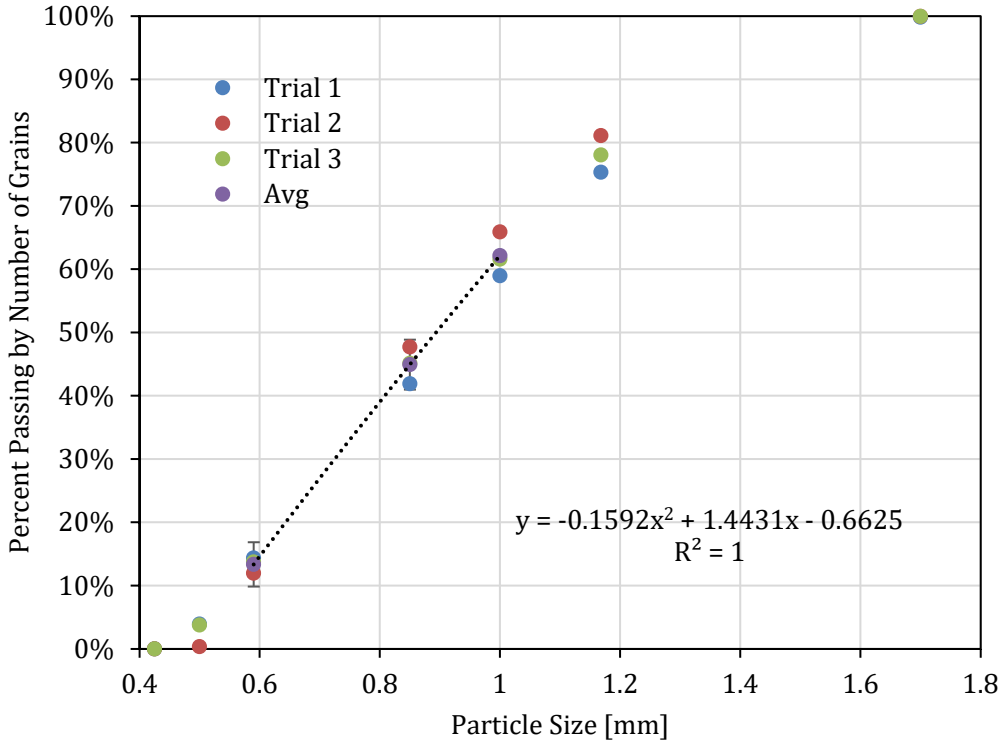

Figure 47 Measured grain size distribution for biochar using mechanical sieve analysis. The best fit polynomial curve is shown with the equation used to calculate the d_{50}.

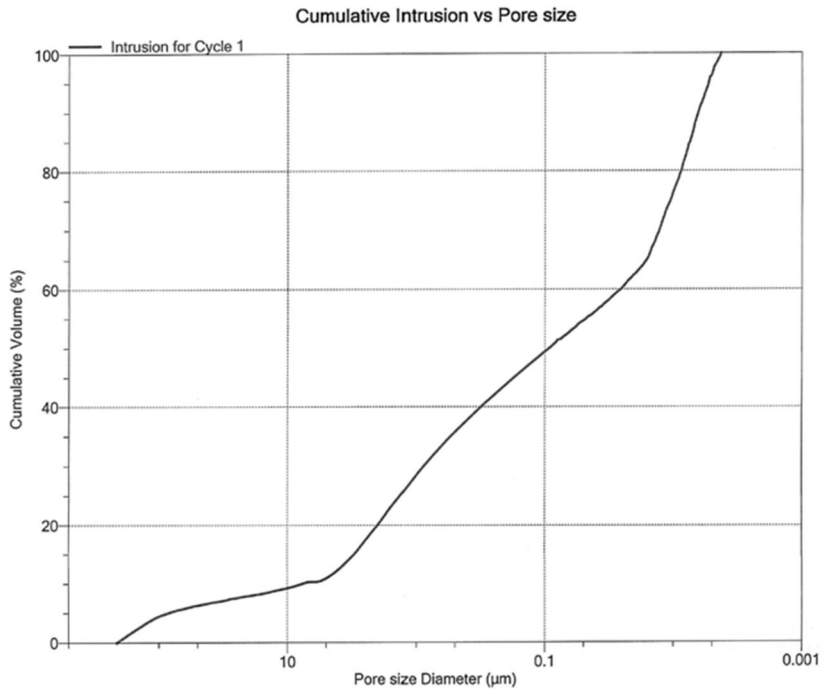

Figure 48 Cumulative mercury intrusion versus RAC intraparticle pore size. Source: Mercury Intrusion Porosimetry (MIP) analysis conducted by Particle Technology Labs, Downers Grove, IL, USA (Jan 31, 2022).

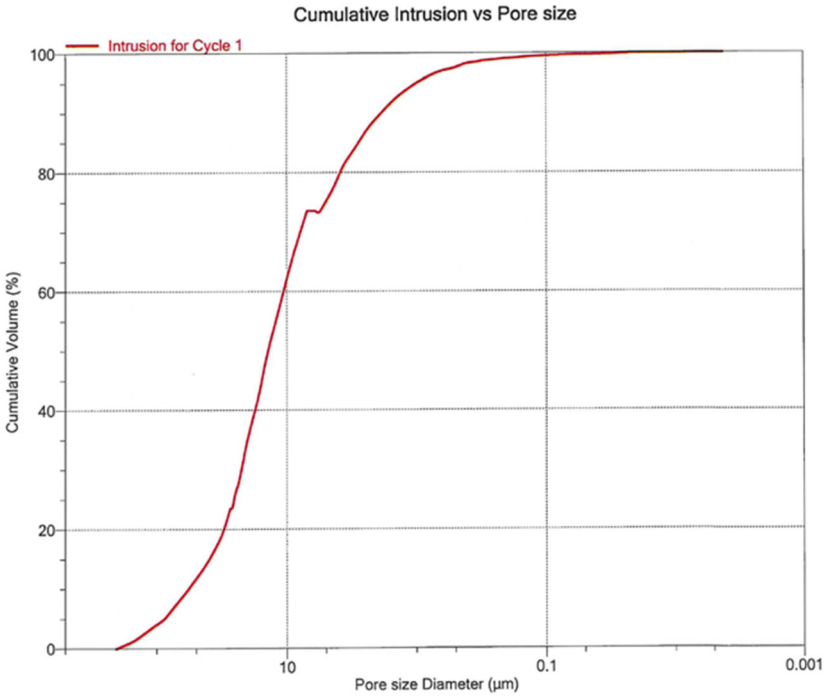

Figure 49 Cumulative mercury intrusion versus biochar intraparticle pore size. Source: Mercury Intrusion Porosimetry (MIP) analysis conducted by Particle Technology Labs, Downers Grove, IL, USA (Dec. 2, 2020).

1.2 Chemical Properties

All chemicals in this study were used as received. Chemical order information is shown below in Table 26. A standard mix containing 10 mg L^{-1} of cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, nickel, phosphorus, potassium, sodium, and zinc in 5% v/v HNO_3 was obtained from Inorganic Ventures, USA. Solubility and log K_{ow} properties for the hyphil-TrOCs are shown in Figure 50. Physical properties for the hyphil-TrOCs is shown below in Table 27.

TrOCs were quantified using liquid chromatography electrospray ionization tandem mass spectrometry (LC-MS/MS, Applied Biosystems API 3000) with a Shimadzu SCL-10AVP system controller and a SIL-20A autosampler (Shimadzu). LC-MS/MS parameters for the compounds are shown below in Table 28. Atrazine, benzotriazole, diuron, and imidacloprid were quantified in positive ionization mode; fipronil and mecoprop in negative mode. Aqueous samples were analyzed using a XBridge BEH C18 column (5 cm × 2.1 mm, 3.5 µm, Waters) equipped with a XBridge BEH C18 VanGuard cartridge (5 mm × 2.1 mm, 3.5 µm, Waters). The mobile phase consisted of HPLC-grade water (solvent A, Optima LC/MS grade, Fisher Chemical) and methanol (solvent B, Optima, > 99.9%, Fisher Chemical) each acidified with 0.1 v% formic acid. The eluent gradient for negative ionization mode was 10% B (at 0–0.2 min), linear increase to 55% B (at 1.5 min) and to 95% B (at 6 min), and 95% for 2 min at a flow rate of 200 µL min−1. The eluent gradient for positive ionization mode was 10% B (0–0.02 min) and linear increase to 95% B at 9 min and 95% B for 2.5 min at a flow rate of 200 µL min−1. Quantification of analytes was carried out using deuterated internal standards and external calibration standards ranging from 0.24 µg L^{-1} to 72 µg L^{-1}. The limit of quantification, shown in Table 29 was defined as the lowest concentration standard with a signal to noise ratio ≥5. Data analyses were performed with the Analyst 1.5.2 software (AB Sciex).

Table 26 Chemical Properties

Name	CAS	Purity	Supplier	Analysis Method
Atrazine	1912-24-9	≥97%	SCB	LC-MS/MS
Benzotriazole	95-14-7	99%	FS	LC-MS/MS
Diuron	330-54-1	98%	SA	LC-MS/MS
Fipronil	120068-37-3	≥97%	WVR	LC-MS/MS
Imidacloprid	138261-41-3	≥95%	SCB	LC-MS/MS
Mecoprop	93-65-2	98%	TRC	LC-MS/MS
Atrazine-d5	163165-75-1	99% D	SA	LC-MS/MS
Benzotriazole-d4	1185072-03-0	99.8% D	CDN	LC-MS/MS
Diuron-d6	1007536-67-5	99% D	CDN	LC-MS/MS
Imidacloprid-d4	1015855-75-0	99.7	LGC	LC-MS/MS
Fipronil Sulfide	120067-83-6		SA	LC-MS/MS
Fipronil-$_{13}$C2 $_{15}$N2			SCB	LC-MS/MS
Fluorene	86-73-7	98%	SA	GC-MS
Anthracene	120-12-7	≥ 98.0 %	SA	GC-MS
Fluoranthene	206-44-0	98%	SA	GC-MS

Pyrene	129-00-0	98%	SA	GC-MS
Benz[a]anthracene	56-55-3	98%	SA	GC-MS
Benzo[a]pyrene	50-32-8	96%	SA	GC-MS
PCB-52	35693-99-3	99.6%	LGC	GC-MS
PCB-77	32598-13-3	99.8%	LGC	GC-MS
PCB-101	37680-73-2	96.9%	LGC	GC-MS
PCB-118	31508-00-6	99.5%	LGC	GC-MS
PCB-126	57465-28-8	94.2%	LGC	GC-MS
Bifenthrin	82657-04-3	≥ 98.0 %	SA	GC-MS
Permethrin	52645-53-1	≥ 90.0%	SA	GC-MS
TNT	118-96-7	97%	SA	GC-MS
DNAN	119-27-7	98%	SCB	GC-MS
PCB-30	35693-92-6		US	GC-MS
PCB-204	74472-52-9		US	GC-MS
PCB-14	34883-41-5		US	GC-MS
PCB-65	33284-54-7		US	GC-MS
PCB-166	41411-63-6		US	GC-MS
naphthalene-d8	1146-65-2		US	GC-MS
acenaphthene-d10	15067-26-2		US	GC-MS
anthracene-d10	1719-06-8		US	GC-MS
pyrene-10	1718-52-1		US	GC-MS
chrysene-d12	1719-03-5		US	GC-MS
benzo[a]pyrene-d12	63466-71-7		US	GC-MS
2-fluorobiphenyl	321-60-8		US	GC-MS
terphenyl-d14	1718-51-0		US	GC-MS
Cadmium (II) chloride	7440-43-9	99.99%	SA	ICP-MS
Copper (II) chloride dihydrate	7440-50-8	Bioreagent	SA	ICP-MS
Nickel (II) choride hexahydrate	7440-02-0	Bioreagent	SA	ICP-MS
Lead (II) chloride	7439-92-1	99.99%	SA	ICP-MS
Zinc (II) chloride	7440-66-6	99.99%	SA	ICP-MS

SC = Santa Cruz Biotechnology, Dallas, TX, USA; FS = Fisher Scientific, Hampton, NH, USA; TRC = Toronto Research Chemicals, Toronto, ON, CA; SA = Sigma Alrich, St. Louis, MO, USA; VWR = VWR International, Radnor, PA, USA; CDN = CDN Isotopes, Pointe-Claire, QC, CA; US = Ultra Scientific (Agilent), Santa Clara, CA, USA

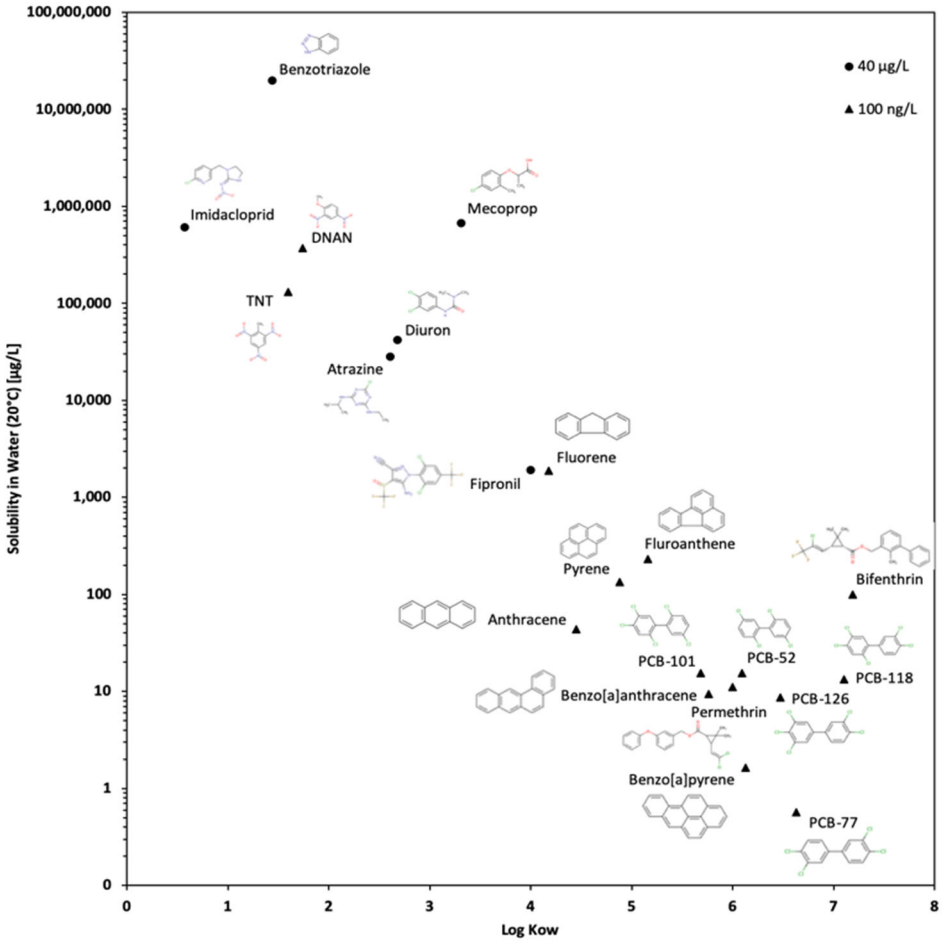

Figure 50 Aqueous solubilities and log K_{ow}s of TrOCs analyzed by LC-MS/MS and GC-MS included in this study.

Table 27 Physical properties of studied hyphil-TrOCs

Name	Atrazine	Benzotriazole	Diuron	Fipronil	Imidacloprid	Mecoprop
CAS	1912-24-9	95-14-7	330-54-1	120068-37-3	138261-41-3	93-65-2
Usage	Herbicide	Corrosion Inhibitor	Herbicide	Insecticide	Insecticide	Herbicide
Molecular Mass	215.69	119.127	233.09	437.14	255.66	214.65
pK_a	1.6 [a]	8.37 [a]	-		11.12 [a]	3.1 [a]
pK_b	12.4 [a]	5.63 [a]	13.8 [a]		2.88 [a]	10.9 [a]
Charge	neutral	neutral	neutral	neutral	neutral	anionic
Solubility	28.04	19.78	41.96	1.9	611.03	880
$logK_{ow}$	2.61 [b]	1.44 [b]	2.68 [b]	4.00 [b]	0.57 [b]	3.13 [b]
Molar Volume	169.9±3.0 cm^3 [b]	88.3±3.0 cm^3 [b]	178.6±7.0 cm^3 [b]	233.7±7.0 cm^3 [b]	160.1±7.0 cm^3 [b]	169.7±3.0 cm^3 [b]
Polar Surface Area [$Å^2$]	63 [b]	42 [b]	36 [b]	104 [b]	86 [b]	47 [b]

[a] Quest Database™ pKa and pKb Reference Table. AAT Bioquest, Inc., 1 Jun. 2022, https://www.aatbio.com/data-sets/pka-and-pkb-reference-table.

[b] ACD/Labs Percepta Platform – PhyChem Module, 1 Jun. 2022, https://www.acdlabs.com/products/percepta-platform/.

Table 28 LC-MS/MS and GC/MS parameters

	m/z Precursor mass	Product mass (Quantifier)	Product mass (Qualifier)	ESI[a] mode	DP[b] (V)	FP[c] (V)	CE[d] (V)	CXP[e] (V)
Atrazine	216.132	174.1		(+)	41	210	25	14
	216.132		96.1	(+)	41	210	33	8
Atrazine-d5	221.144	179.1		(+)	36	220	37	1
	221.144		101	(+)	36	220	35	8
Benzotriazole	120.034	65.1		(+)	76	370	31	4
	120.034		92.1	(+)	76	370	25	8
Benzotriazole-d4	124.077	69.1		(+)	76	370	33	4
	124.077		96.1	(+)	76	370	25	8
Diuron	233.067	72.1		(+)	51	250	37	6
	233.067		46.1	(+)	51	250	37	2
Diuron-d6	239.082	78.2		(+)	51	270	35	6
	239.082		52.1	(+)	51	270	37	2
Fipronil	434.908	329.7		(-)	-56	-270	-22	-11
	434.908		250	(-)	-56	-270	-36	-17
Fipronil Sulfide	418.853	382.9		(-)	-81	-350	-18	-13
	418.853		261.9	(-)	-81	-350	-38	-17
Fipronil-13C2 15N2	438.83	334		(-)	-66	-300	-22	-21
	438.83		251.9	(-)	-66	-300	-38	-17
Imidacloprid	256.091	208.9		(+)	51	290	21	16
	256.091		175	(+)	51	290	25	14
Imidacloprid-d4	260.109	212.9		(+)	46	250	23	16
	260.109		179.1	(+)	46	250	29	14
Mecoprop	212.88	140.7		(-)	-76	-330	-18	-9
	212.88		71	(-)	-76	-330	-14	-3

[a] Electrospray ionization [b] Declustering potential [c] Fragmentor voltage [d] Collision energy [e] Collision cell exit potential

Table 29 Limit of quantification for hyphil-TrOCs

	LOQ [µg L^{-1}]
Atrazine	0.24
Benzotriazole	0.24
Diuron	1.00
Fipronil	0.24
Imidacloprid	0.24
Mecoprop	0.24

2 Task 2 Column Experiment

2.1 Experimental Design

A detailed diagram of the column experimental setup with labeled pumps, flow rates, hydraulic retention times, tank volumes, and contaminant concentrations is shown below in Figure 51. Specifications for pumps and the large tank mixer are shown in Table 30.

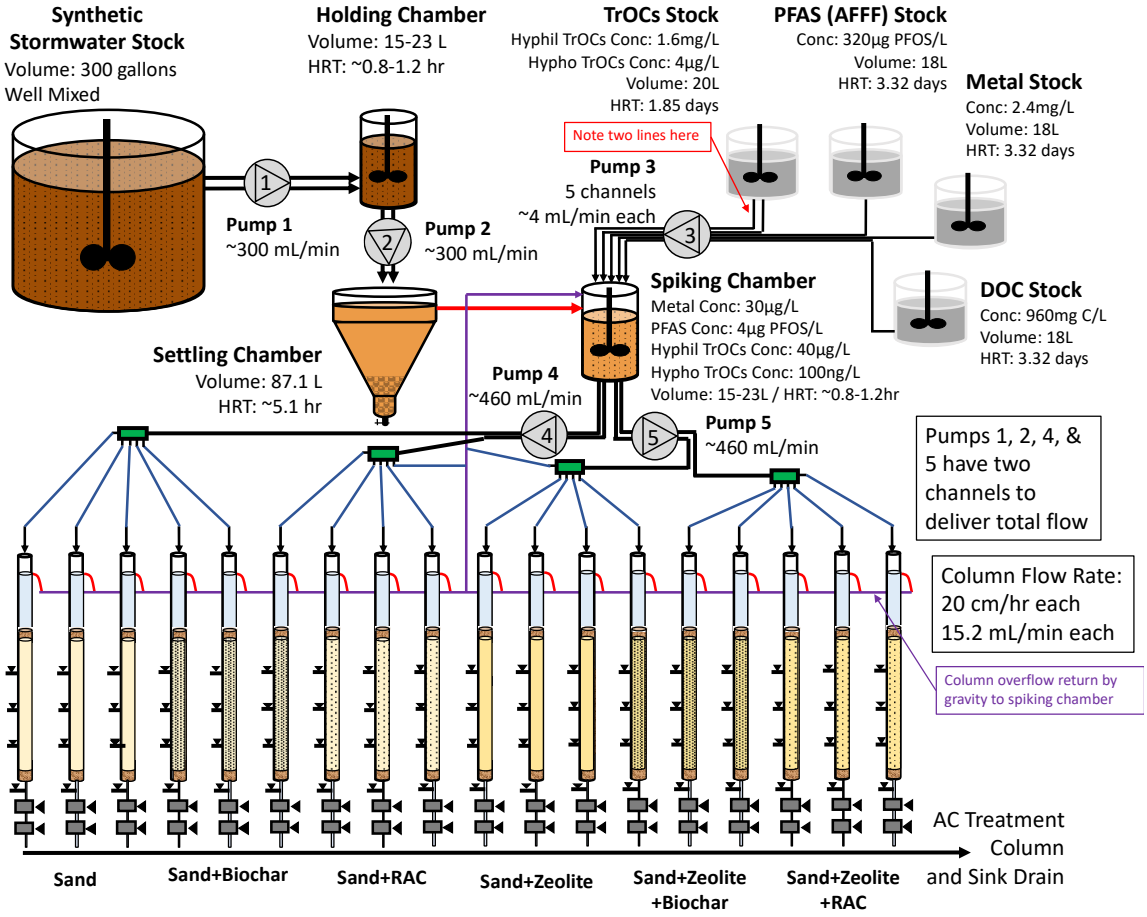

Figure 51 Diagram of the experimental set-up showing all flow lines, pumps, flow rates, hydraulic residence times, and concentrations.

Table 30 Specifications for pumps and mixers used in column experiment.

Part	Name	Part Number	Manufacture/Supplier
Pump 1, 2, 4, 5	Chemical Metering Pump	4NA16	Grainger
Pump 3	Masterflex L/S Variable-Speed Drive + Masterflex L/S Multichannel Pump Head for L/S High Performance Tubing	EW-07528-30; EW-07536-02; EW-07536-04	Cole Parmer
Large Tank Mixer	Pneumatic Stainless Steel Tank Mixer For Use With Open Top Tank	32V128	Grainger

2.2 Packing and Porosity

The columns were packed dry by adding lifts of 200 mL of material and vibrating the column with a hand-held massager to ensure adequate packing. The bulk density of each material was determined using a 1L beaker and used to determine the mass of each material added to the columns. Engineered media mixtures were mixed dry by hand in a 5 gallon bucket. In order to ensure homogenous mixing and distribution of zeolite/black carbon in the column, the 200 mL lifts of each material were checked by massing. The masses of each material added to the column are shown below in Table 31. The volumetric and mass content of each material in each engineered media mixture is shown in Table 32.

Table 31 Mass of Engineered Media Added to Each Column

Engineered Media Mixture	Sand		Zeolite		RAC		Biochar		Barrier Sand	
Sand	4,957.0	±33.0	-	-	-	-	-	-	1,300.7	±28.8
+Zeolite	3,468.0	±0	704.2	±0.3	-	-	-	-	1,297.8	±11.8
+RAC	4,458.8	±0.8	-	-	153.0	-	-	-	1,295.7	±2.5
+Biochar	3,716.5	±0	-	-	-	-	90.2	±0.3	1,298.2	±1.2
+Zeolite+Biochar	1,982.3	±0.8	703.8	±0.6	-	-	84.3	±0.3	1,299.7	±0.8
+Zeolite+RAC	2,972.8	±0.3	704.2	±0.3	153.0	-	-	-	1,307.2	±2.6
Bulk Density[a]	1.812		0.858		0.559		0.103		1.625	

[a] Bulk Density measured by filling 2L beaker, vibrating with massager to ensure adequate packing, and weighing; units: kg L^{-1}; Average value ± standard deviation (n=3)

Table 32 Volumetric and Mass Content of Engineered Media Mixtures

Mixture	% Volume			% Mass		
	Zeolite	Biochar	RAC	Zeolite	Biochar	RAC
Sand	-	-	-	-	-	-
+ Zeolite	30%	-	-	16.9%	-	-
+ RAC	-	-	10%	-	-	3.3%
+ Biochar	-	30%	-	-	2.4%	-
+ Zeolite + Biochar	30%	30%	-	25.4%	3.0%	-
+ Zeolite + RAC	30%	-	10%	18.4%	-	4.0%

[a] Average value ± standard deviation (n=3)

Engineered media mixture porosity was determined gravimetrically by massing the column immediately after packing (dry) and after saturation with DI water. The porosity of the barrier sand was measured separately (0.35) and used to calculate the porosities of the engineered media mixtures, shown in Table 4 in the main text.

2.3 Bromide Tracer Tests

Bromide tracer test were conducted by delivering a 30-sec pulse of bromide through the columns and sampling at pre-determined time intervals. The water level in the columns was maintained at the top of the barrier sand layer to eliminate standing water and prevent any initial dilution of the

tracer above the barrier sand. DI water was used in the tracer studies and was delivered to each column in order to maintain a face velocity of 20 cm hr^{-1}. Flow rate was confirmed at the beginning and end of the tracer test. The bromide tracer test parameters are shown in Table 33. The tracer tests results are shown below in Figure 52.

Table 33 Bromide tracer test parameters.

Mixture	Influent Concentration [mM]	Bromide Pulse [s]	Sampling Time [min]
Sand	5	30	186
+ Zeolite	5	30	186
+ Biochar	100	30	430
+ Zeolite + Biochar	100	30	430
+ RAC	200	30	700
+ Zeolite + RAC	200	30	700

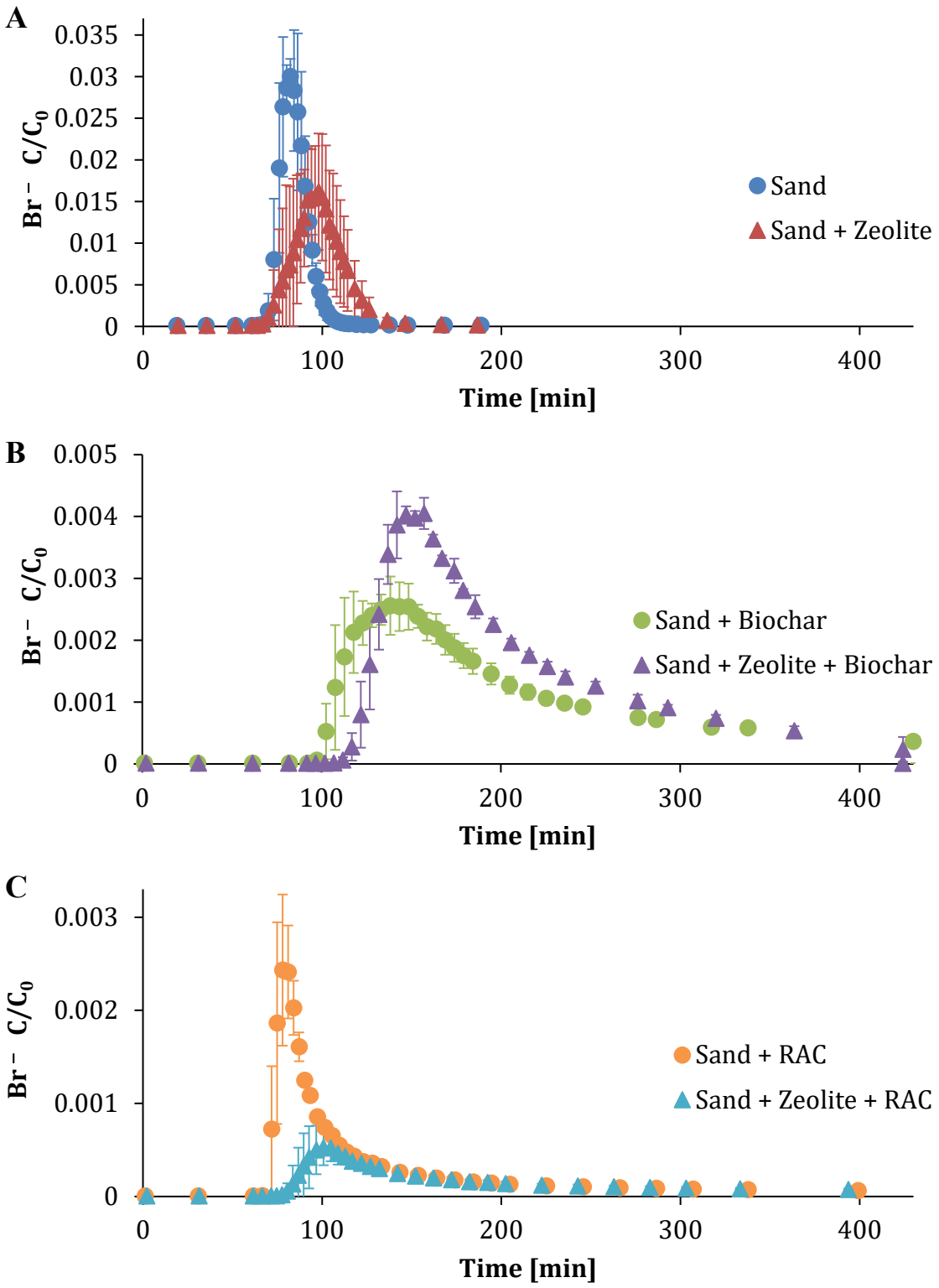

Figure 52 (A-C) Bromide tracer test results for columns. Average concentration for each mixture is plotted with error bars showing one standard deviation (n=3) above and below the average. Note that the y-axis differ.

2.4 Experiment Duration and Flow Rates

The column experiment consisted of three parts: preconditioning flush, conditioning, and the challenge test, as shown below in Table 34.

Table 34 Experiment Phases

SRT[a] Start	SRT[a] End	Experiment Phase	Flow Matrix
-133.1	-16.1	Pre-conditioning Flush	DI Water
-16.1	0	Conditioning	Synthetic Stormwater
0	62	Challenge Test	Synthetic Stormwater + Contaminants

[a] System run time [days]

Flow rates were measured gravimetrically over 20s and adjusted using outlet controls consisting of a needle valve and globe valve at the bottom of each column. Flow rates were checked periodically and adjusted to the target flow rate of 20 cm hr^{-1} (15.2 mL min^{-1}). Table 35 shows the average flow rate and empty bed volumes treated for each engineered media mixture over the course of the conditioning and challenge test. Figure 53 shows the flow rate over time for each engineered media mixture.

Table 35 Time Weighted Average Flow Rates and Empty Bed Volumes Treated

Mixture	Conditioning Face Velocity [cm hr^{-1}]		Flow Rate [mL min^{-1}]		EBVs	
Sand	16.36	±3.85	12.43	±2.93	114.7	±6.1
+ Zeolite	15.5	±3.57	11.78	±2.71	112.7	±5.7
+ RAC	15.95	±4.88	12.12	±3.71	113.9	±5.5
+ Biochar	16.03	±3.14	12.18	±2.39	113.6	±1.0
+ Zeolite + Biochar	14.9	±5.03	11.33	±3.82	111.5	±12.1
+ Zeolite + RAC	17.97	±2.58	13.66	±1.96	119.6	±3.2
Mixture	**Challenge Test Face Velocity [cm hr^{-1}]**		**Flow Rate [mL min^{-1}]**		**EBVs**	
Sand	18.44	±2.68	14.02	±2.03	476.6	±3.9
+ Zeolite	18.92	±3.40	14.38	±2.59	483.8	±4.1
+ RAC	18.71	±3.82	14.22	±2.90	480	±5.5
+ Biochar	18.9	±3.98	14.36	±3.03	481.2	±3.1
+ Zeolite + Biochar	17.87	±5.05	13.58	±3.84	459	±33.5
+ Zeolite + RAC	19.14	±3.80	14.55	±2.89	483.8	±5.2

Time weighted average ± standard deviation (n=3 columns × 32 timepoints, conditioning; n=3 columns × 115 time points, challenge test)

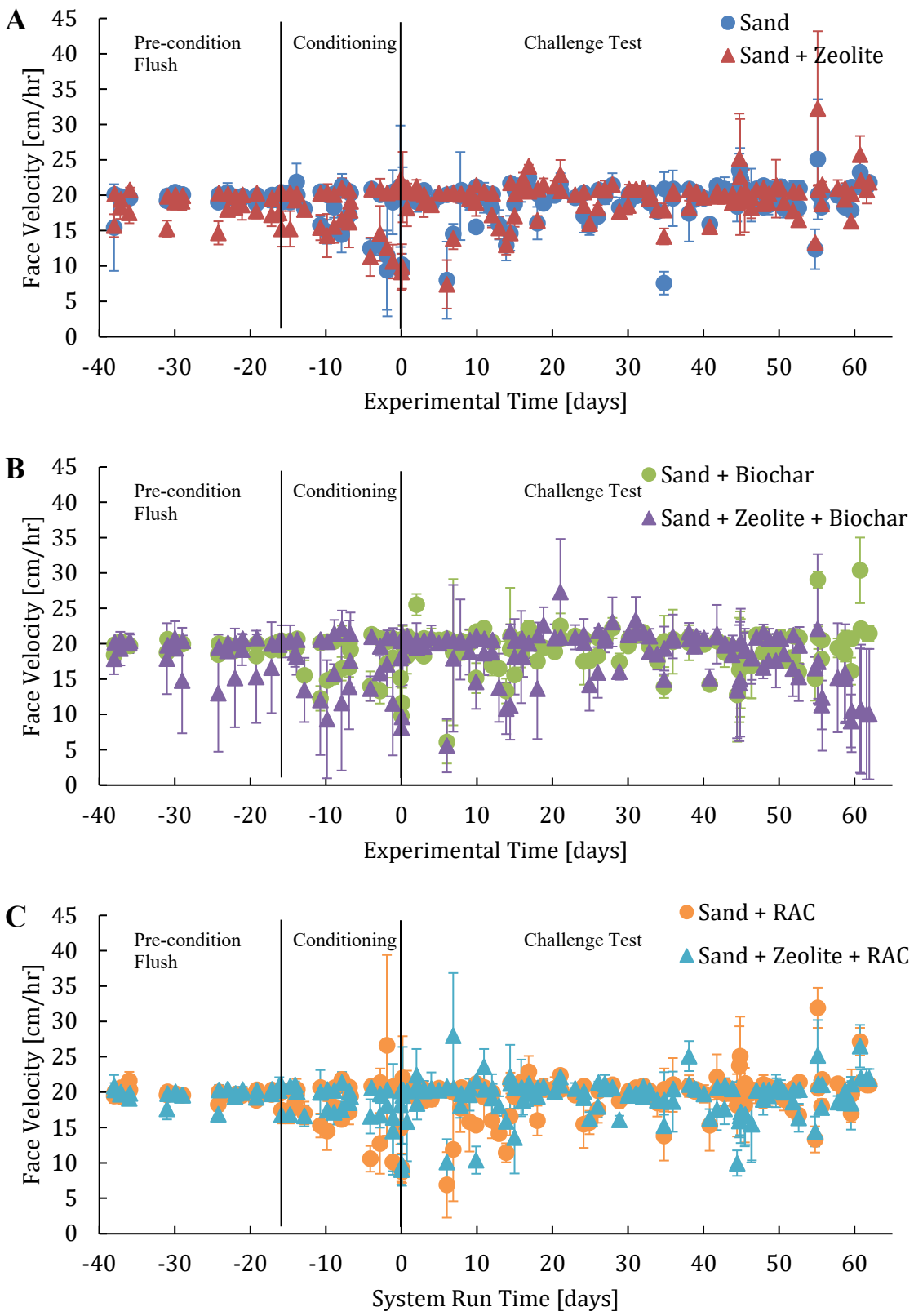

Figure 53 (A-C) Average flow rate over the course of the experiment. Points represent mean (n=3) and error bars indicate one standard deviation above and below the mean.

2.5 Hydraulic Conductivity

Hydraulic conductivity was measured using manometers attached to the column 25% and 75% sample ports. Specifically, the difference in height of water level in each manometer was measured and along with the distance between the manometers and flow rate, was used to calculate hydraulic conductivity using Darcy's Law:

$$K_s = \frac{Q}{A}\frac{\Delta z}{\Delta h} \qquad (1)$$

where K_s is the saturated hydraulic conductivity [cm s^{-1}], Q is the volumetric flow rate [mL s^{-1}], A is the cross section area [cm^2], Δz is the distance between manometers [cm], and Δh is the difference in manometer water level height [cm]. Figure 54 shows a picture of the hydraulic conductivity testing underway and a picture of a manometer. Table 36 contains measured hydraulic conductivity values over the course of the experiment for each engineered media mixture.

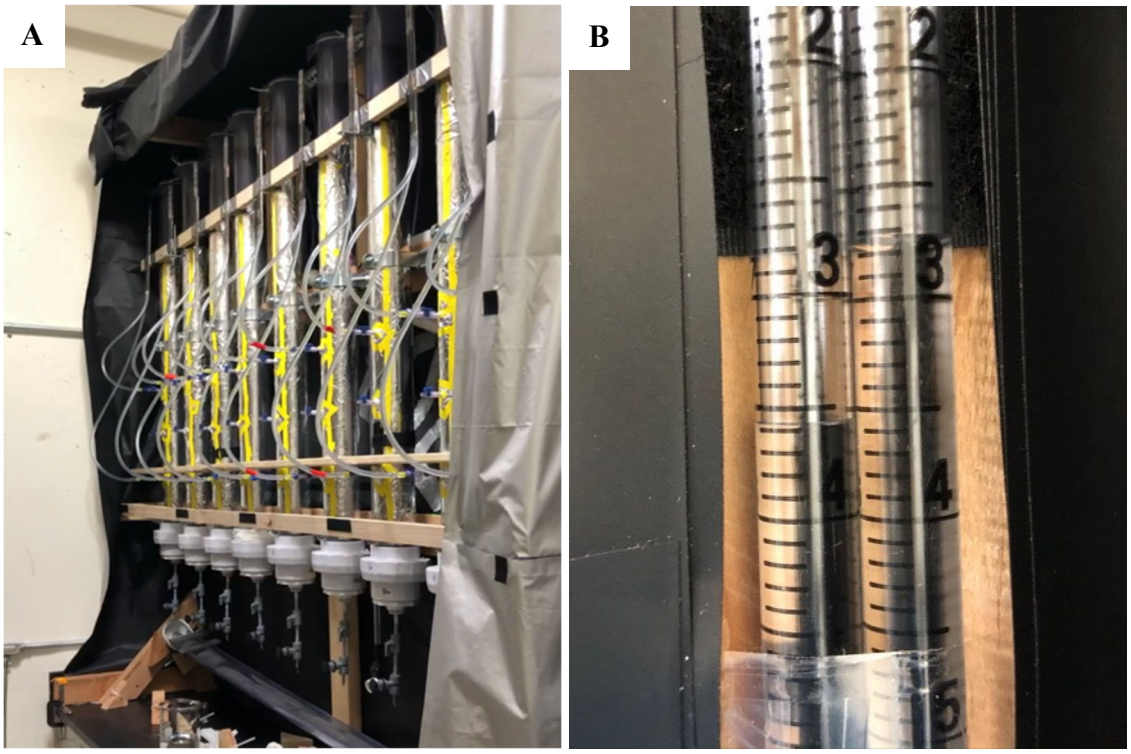

Figure 54 (A) Hydraulic conductivity test underway. (B) Manometer used to measure hydraulic head in the column. Note, 1 tick mark = 1.9mm +/- 0.05mm.

Table 36 Measured Hydraulic Conductivity [cm s^{-1}]

SRT[a]	Sand		Sand + Zeolite		Sand + RAC	
-29	0.69	±0.22	0.5	±0.07	0.42	±0.02
18	0.59	±0.27	0.51	±0.08	0.43	±0.02
30	0.44	±0.06	0.45	±0.05	0.44	±0.00
62	0.35	±0.04	0.37	±0.01	0.31	±0.03
SRT[a]	Sand + Biochar		Sand + Zeolite + Biochar		Sand + Zeolite + RAC	
-29	0.31	±0.01	0.47	±0.08	0.44	±0.00
18	0.39	±0.04	0.42	±0.05	0.3	±0.07
30	0.38	±0.04	0.38	±0.08	0.4	±0.05
62	0.21	±0.08	0.28	±0.08	0.33	±0.04

Average value ± standard deviation (n=3)

[a] System run time [days]; negative value indicates days before the start of the challenge test

2.6 Water Quality

2.6.1 Total Suspended Solids

Total suspended solids (TSS) were measured using a 0.55µm glass fiber filter (28497-153, Whatman Grade GF/A) with a vacuum filter assembly. Filters were oven dried at 60°C before and after filtering. Table 37 and Figure 55 shows measured TSS for each engineered media mixture over the course of the experiment.

Table 37 Total Suspended Solids [mg L^{-1}]

SRT [days]	Influent		Sand		Sand + Zeolite		Sand + RAC	
0	0.21	±0.01	0.95	±0.06	1.02	±0.11	0.79	±0.17
2	15.11	±0.36	1.29	±1.59	0.92	±0.29	0.33	±0.10
27	20	±4.39	0.88	±0.24	0.96	±0.05	0.73	±0.02
33	20.15	±1.26	0.23	±0.11	0.16	±0.13	0.09	±0.05
39	22.27	±0.57	0.12	±0.10	0.35	±0.07	0.05	±0.09
45	13.49	±0.67	0.21	±0.06	0.3	±0.22	0.2	±0.14
56	22.5	±0.91	0.22	±0.07	0.17	±0.07	0.06	±0.17
62	40.23	±1.08	0.56	±0.23	0.57	±0.34	0.28	±0.08

SRT [days]	Sand + Biochar		Sand + Zeolite + Biochar		Sand + Zeolite + RAC	
0	0.8	±0.19	0.73	±0.15	0.9	±0.19
2	0.41	±0.08	0.24	±0.20	0.57	±0.06
27	0.67	±0.07	0.34	±0.19	0.66	±0.18
33	0	±0.00	0.1	±0.08	0.22	±0.20
39	0.01	±0.02	0.06	±0.08	0.1	±0.07
45	0.22	±0.21	0.47	±0.60	0.14	±0.05
56	0.11	±0.04	0.14	±0.06	0.17	±0.08
62	0.35	±0.36	0.31	±0.09	0.42	±0.09

Average concentration ± standard deviation (n=3)

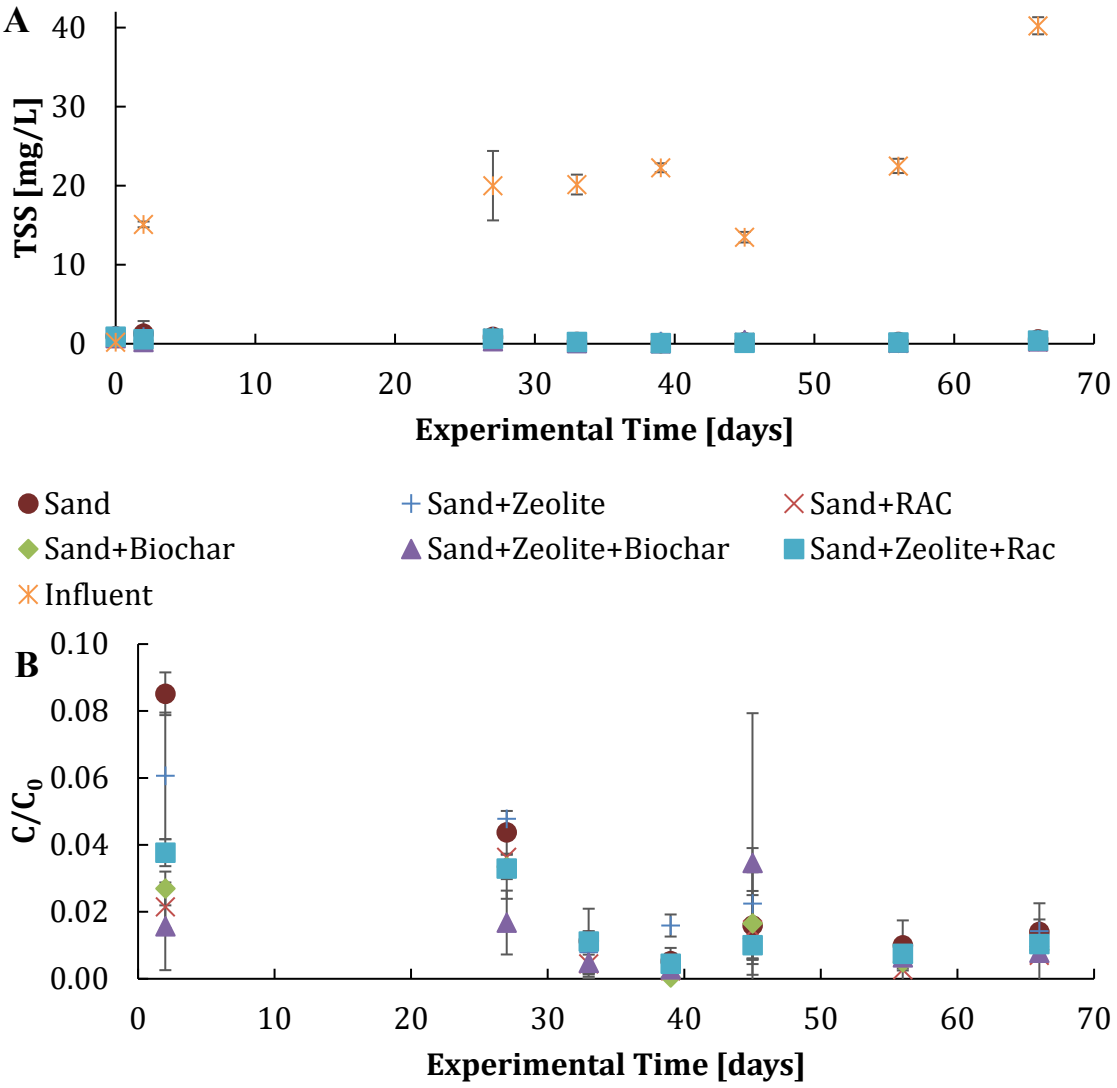

Figure 55 (A) TSS in the column influent and effluent. (B) TSS removal in column effluent. Points indicate mean and error bars show one standard deviation above and below the mean (n=3).

2.6.2 Dissolved Organic Carbon and Total Nitrogen

Dissolved organic carbon (DOC) was analyzed using a TOC-Analyzer using NPOC analysis after filtration using 0.45µm PES syringe filter.

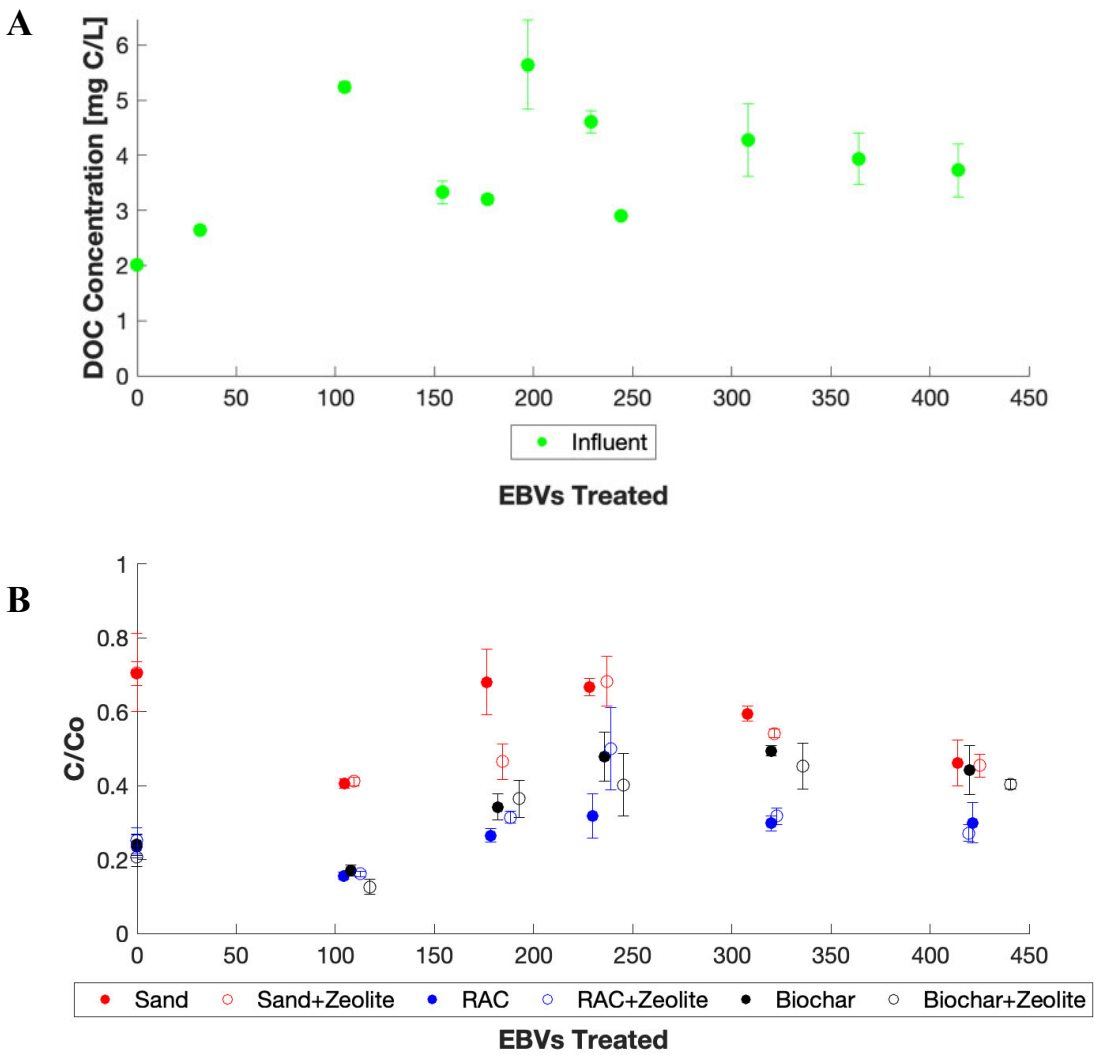

Figure 56 (A) DOC in the column influent. (B) DOC removal in the engineered media columns. Points represent mean (n=3) and error bars indicate one standard deviation above and below the mean.

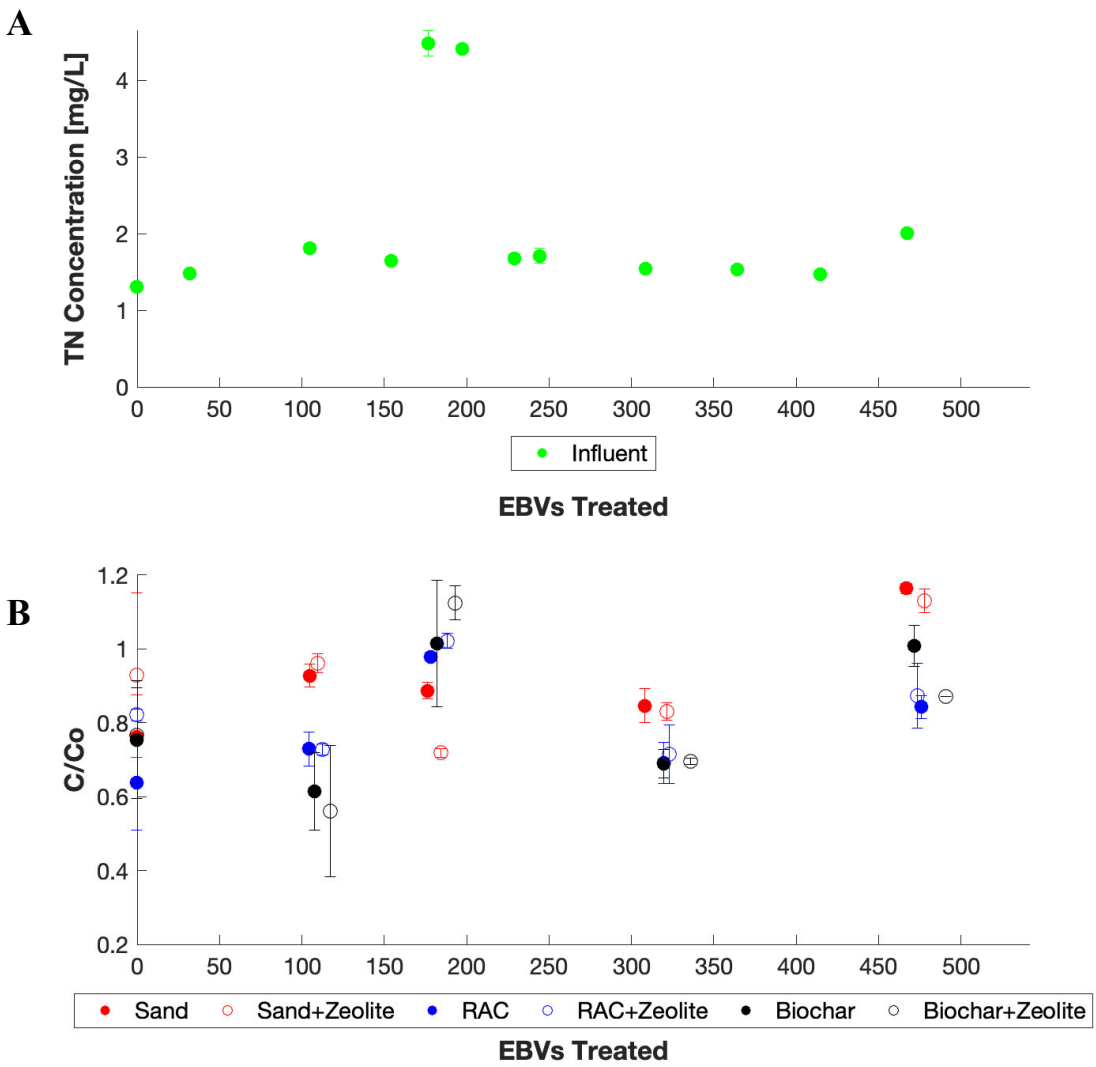

Figure 57 (A) Total nitrogen in the column influent. (B) Total nitrogen removal in the columns. Points represent mean (n=3) and error bars indicate one standard deviation above and below the mean.

2.6.3 Dissolved Oxygen

Table 38 Dissolved Oxygen [mg L^{-1} oxygen]

SRT [days]	Influent	Sand		Sand + Zeolite		Sand + RAC	
-17	8.34	8.1	±0.03	8.14	±0.03	7.89	±0.05
-6	3.15	0.63	±0.04	0.51	±0.16	0.59	±0.31
43	7.35	0.35	±0.04	0.29	±0.03	0.28	±0.01
56	7.68	0.4	±0.04	0.35	±0.06	0.34	±0.02

SRT [days]	Sand + Biochar		Sand + Zeolite + Biochar		Sand + Zeolite + RAC	
-17	7.77	±0.13	7.95	±0.14	7.72	±0.31
-6	0.23	±0.05	0.21	±0.04	0.63	±0.15
43	0.31	±0.00	0.31	±0.01	0.33	±0.04
56	0.32	±0.01	0.34	±0.01	0.35	±0.05

Average ± standard deviation (n=3)

[a] System run time relative to the start of the challenge test (-17 days = immediately before the conditioning period)

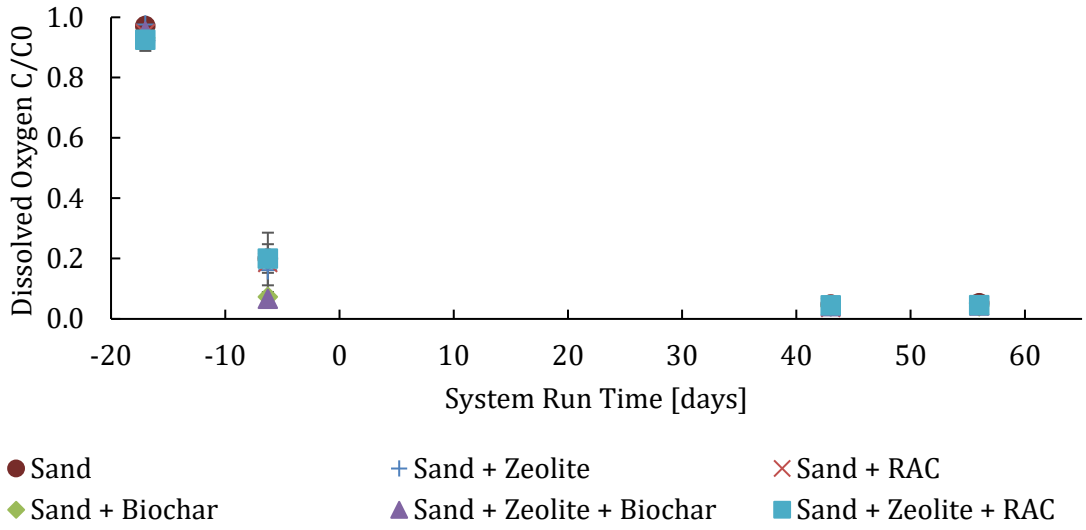

Figure 58 Dissolved oxygen in the column effluent normalized by the influent. Note that conditioning occurred for 16.1 days before the start of the challenge test. Points represent mean (n=3) and error bars indicate one standard deviation above and below the mean.

Table 39 Dissolved oxygen depth-profile in sand + biochar column at SRT= -6 days

Sample Location	Media Depth [a] [cm]	DO [mg L^{-1}]	C/C_0
Influent	--	3.15	--
25% Sample Port	6 + 15	1.49	0.47
50% Sample Port	6 + 30	0.30	0.1
75% Sample Port	6 + 45	0.22	0.07
Effluent	16 + 60	0.19	0.06

[a] Barrier sand depth + engineered media depth

2.6.4 Additional Water Quality Parameters

Additional water quality parameters were measured approximately 15 minutes after sample collection.

Table 40 pH for Synthetic Stormwater and Column Influent

SRT[a] [days]	Mix Tank		Spike Tank		Influent	
-17	7.53	±0.07	7.49	±0.06	5.60	---
-6	7.59	±0.06	7.26	±0.04	7.20	---
0	7.67	---	7.20	---	7.19	---
2	7.60	±0.03	7.27	±0.05	7.21	---
28	7.65	±0.05	7.06	±0.10	7.18	±0.03
32	7.57	±0.03	7.29	±0.07	7.40	±0.03
42	7.45	±0.42	7.48	±0.04	7.47	±0.03
50	7.59	±0.04	7.48	±0.02	7.56	±0.03
55	7.61	±0.15	7.36	±0.03	7.52	±0.04
62	7.43	±0.07	7.47	±0.05	7.44	±0.04
Avg	7.56	±0.16	7.34	±0.15	7.43	±0.13

Average ± standard deviation (n=3)

[a] System run time relative to the start of the challenge test (-17 days occurred immediately before the conditioning period) and consisted of DI water

Table 41 pH of Column Effluent

SRT[a]	Sand		Sand + Zeolite		Sand + RAC		Sand + Biochar		Sand + Zeolite + Biochar		Sand + Zeolite + RAC	
-17	6.51	±0.07	6.95	±0.16	6.43	±0.09	6.40	±0.07	6.91	±0.79	6.44	±0.24
-6	6.86	±0.05	6.96	±0.02	7.04	±0.01	6.99	±0.05	7.08	±0.01	7.00	±0.05
0	7.00	±0.03	6.99	±0.01	7.01	±0.03	7.03	±0.03	7.02	±0.06	7.06	±0.04
2	6.85	±0.01	6.87	±0.04	6.94	±0.01	6.94	±0.01	6.94	±0.06	6.90	±0.02
28	6.78	±0.04	6.87	±0.02	6.90	±0.01	6.79	±0.01	6.80	±0.02	6.82	±0.02
32	6.89	±0.05	6.95	±0.03	6.95	±0.01	6.99	±0.00	6.98	±0.01	6.92	±0.02
42	7.02	±0.04	7.00	±0.02	7.10	±0.02	7.09	±0.06	7.09	±0.03	7.06	±0.03
50	6.73	±0.12	6.93	±0.02	6.89	±0.02	6.91	±0.02	6.91	±0.03	6.86	±0.05
55	6.73	±0.12	6.88	±0.04	6.95	±0.04	6.91	±0.05	6.73	±0.22	6.83	±0.04
62	6.72	±0.10	6.63	±0.22	6.96	±0.05	6.99	±0.04	7.01	±0.09	6.85	±0.09
Avg	6.82	±0.12	6.87	±0.13	6.96	±0.07	6.95	±0.09	6.92	±0.14	6.89	±0.09

Average ± standard deviation (n=3)

[a] System run time [days] relative to the start of the challenge test (-16 days marks the beginning of the conditioning period)

Table 42 Conductivity [µS cm^{-1}] of Synthetic Stormwater and Influent

SRT[a]	Mix Tank		Spike Tank		Influent	
42	326	±2	344	±2	345	±2
49	356	±2	372	±3	372	±1
55	309	±3	306	±3	310	±2
62	344	±2	346	±1	347	±2
Avg	334	±19	342	±24	343	±23

Average ± standard deviation (n=3)
[a] System run time [days] relative to the start of the challenge test

Table 43 Conductivity [µS cm^{-1}] of Column Effluent

SRT[a]	Sand		Sand + Zeolite		Sand + RAC		Sand + Biochar		Sand + Zeolite + Biochar		Sand + Zeolite + RAC	
42	353	±6	351	±4	348	±1	352	±0	349	±3	346	±1
49	373	±2	358	±13	372	±2	372	±2	369	±7	372	±1
55	301	±12	307	±3	304	±7	308	±2	304	±11	298	±15
62	352	±5	354	±5	350	±3	348	±4	377	±21	368	±30
Avg	345	±29	343	±22	344	±26	345	±25	350	±31	346	±34

Average ± standard deviation (n=3)
[a] System run time [days] relative to the start of the challenge test

Table 44 Total Dissolved Solids [mg L^{-1}] in Synthetic Stormwater and Influent

SRT[a]	Mix Tank		Spike Tank		Influent	
42	163	±2	172	±1	172	±1
49	178	±1	186	±2	186	±0
55	155	±1	153	±2	155	±1
62	172	±1	173	±1	174	±1
Avg	167	±9	171	±12	172	±12

Average ± standard deviation (n=3)
[a] System run time [days] relative to the start of the challenge test

Table 45 Total Dissolved Solids [mg L^{-1}] in Column Effluent

SRT[a]	Sand		Sand + Zeolite		Sand + RAC		Sand + Biochar		Sand + Zeolite + Biochar		Sand + Zeolite + RAC	
42	177	±3	176	±2	174	±0	176	±0	175	±2	173	±1
49	186	±1	179	±7	186	±1	186	±1	185	±3	186	±0
55	151	±6	154	±1	152	±4	154	±1	152	±5	149	±8
62	176	±2	177	±3	175	±2	174	±2	189	±11	184	±15
Avg	173	±14	171	±11	172	±13	173	±12	175	±16	173	±17

Average ± standard deviation (n=3)
[a] System run time [days] relative to the start of the challenge test

Table 46 Temperature [°C] Synthetic Stormwater and Influent

SRT[a]	Mix Tank		Spike Tank		Influent	
42	20.16	±0.04	20.74	±0.18	20.97	±0.07
49	20.89	±0.03	21.04	±0.02	20.93	±0.17
55	19.70	±0.04	20.19	±0.11	20.60	±0.03
62	20.54	±0.09	20.72	±0.04	20.78	±0.06
Avg	20.32	±0.46	20.67	±0.33	20.82	±0.17

Average ± standard deviation (n=3)
[a] System run time [days] relative to the start of the challenge test

Table 47 Temperature [°C] of Effluent

SRT[a]	Sand		Sand + Zeolite		Sand + RAC		Sand + Biochar		Sand + Zeolite + Biochar		Sand + Zeolite + RAC	
42	20.98	±0.03	20.90	±0.02	21.06	±0.04	20.96	±0.08	20.83	±0.04	20.95	±0.05
49	21.14	±0.08	20.96	±0.14	21.06	±0.11	20.95	±0.02	20.76	±0.20	20.94	±0.06
55	20.42	±0.42	20.47	±0.05	20.55	±0.18	20.38	±0.26	20.12	±0.43	20.37	±0.21
62	20.61	±0.16	20.59	±0.17	20.62	±0.12	20.63	±0.05	20.40	±0.02	20.54	±0.05
Avg	20.79	±0.36	20.73	±0.24	20.82	±0.27	20.73	±0.28	20.53	±0.36	20.70	±0.28

Average ± standard deviation (n=3)
[a] System run time [days] relative to the start of the challenge test

Table 48 Turbidity [FNU] of Synthetic Stormwater and Influent

SRT[a]	Mix Tank		Spike Tank		Influent	
15	148	±6	24.4	±1.5	20.5	±0.3
27	173	±7	29.6	±6.4	25.5	±2.1
32	206	±9	30.4	±5.7	27.1	±1.3
42	131	±4	44.5	±0.6	32.6	±2.4
49	156	±1	26.1	±1.9	25.0	±1.5
55	414	±4	32.7	±0.3	29.7	±2.9
62	39.9	±0.6	28.6	±1.0	27.8	±0.4
Avg	181	±109	30.9	±6.9	26.9	±3.9

Average ± standard deviation (n=3)
[a] System run time [days] relative to the start of the challenge test

Table 49 Turbidity [FNU] of Column Effluent

SRT[a]	Sand		Sand + Zeolite		Sand + RAC		Sand + Biochar		Sand + Zeolite + Biochar		Sand + Zeolite + RAC	
15	1.71	±0.11	1.84	±0.20	1.76	±0.20	0.63	±0.11	0.68	±0.11	1.53	±0.26
27	1.79	±0.03	1.63	±0.06	1.62	±0.14	0.95	±0.06	1.00	±0.23	1.43	±0.12
32	2.04	±0.20	2.06	±0.01	1.76	±0.12	0.95	±0.06	0.98	±0.05	1.72	±0.04
42	1.36	±0.14	1.27	±0.09	1.16	±0.16	0.69	±0.05	0.89	±0.06	1.20	±0.26
49	1.31	±0.11	1.17	±0.24	0.76	±0.19	0.59	±0.06	0.92	±0.45	1.14	±0.28
55	2.22	±0.20	2.25	±0.58	1.35	±0.26	0.86	±0.09	0.77	±0.49	1.46	±0.33
62	1.41	±0.30	1.30	±0.40	0.93	±0.18	0.65	±0.03	0.48	±0.12	0.74	±0.23
Avg	1.69	±0.37	1.65	±0.47	1.33	±0.41	0.76	±0.16	0.82	±0.29	1.32	±0.36

Average ± standard deviation (n=3)
[a] System run time [days] relative to the start of the challenge test

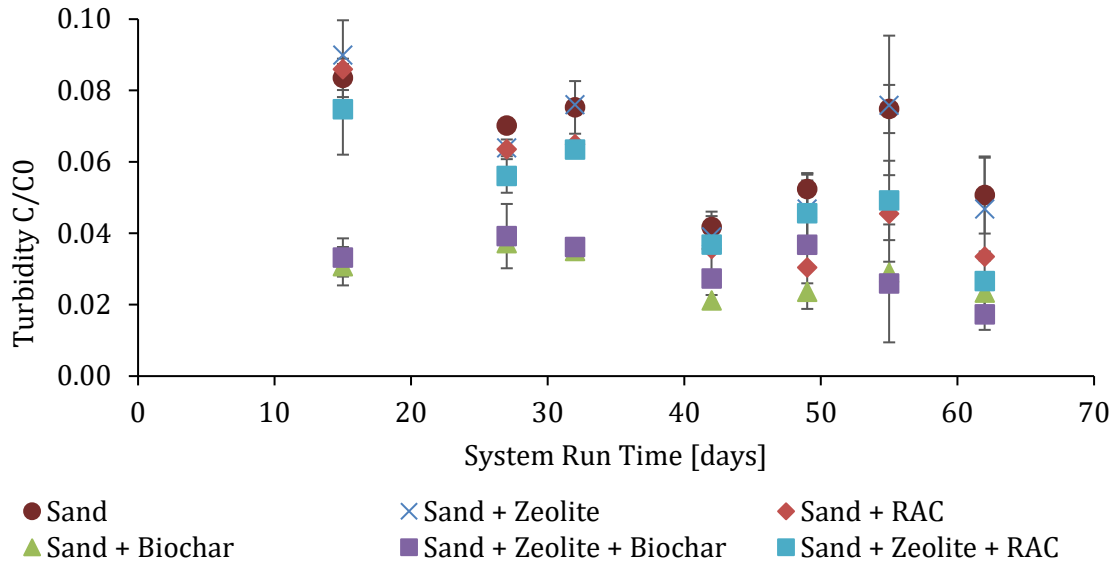

Figure 59 Turbidity removal in column effluent for the mixtures studied. Points represent mean (n=3) and error bars indicate one standard deviation above and below the mean.

2.7 Metal Removal in Column Experiment

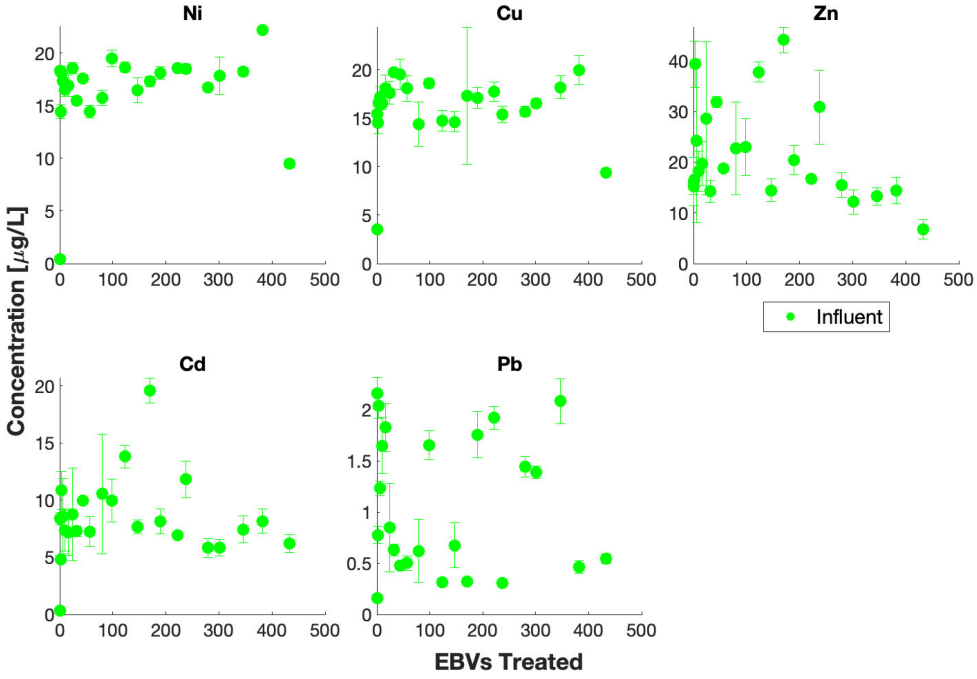

Figure 60 Dissolved metal concentration in column influent. Points represent mean (n=3) and error bars indicate one standard deviation above and below the mean.

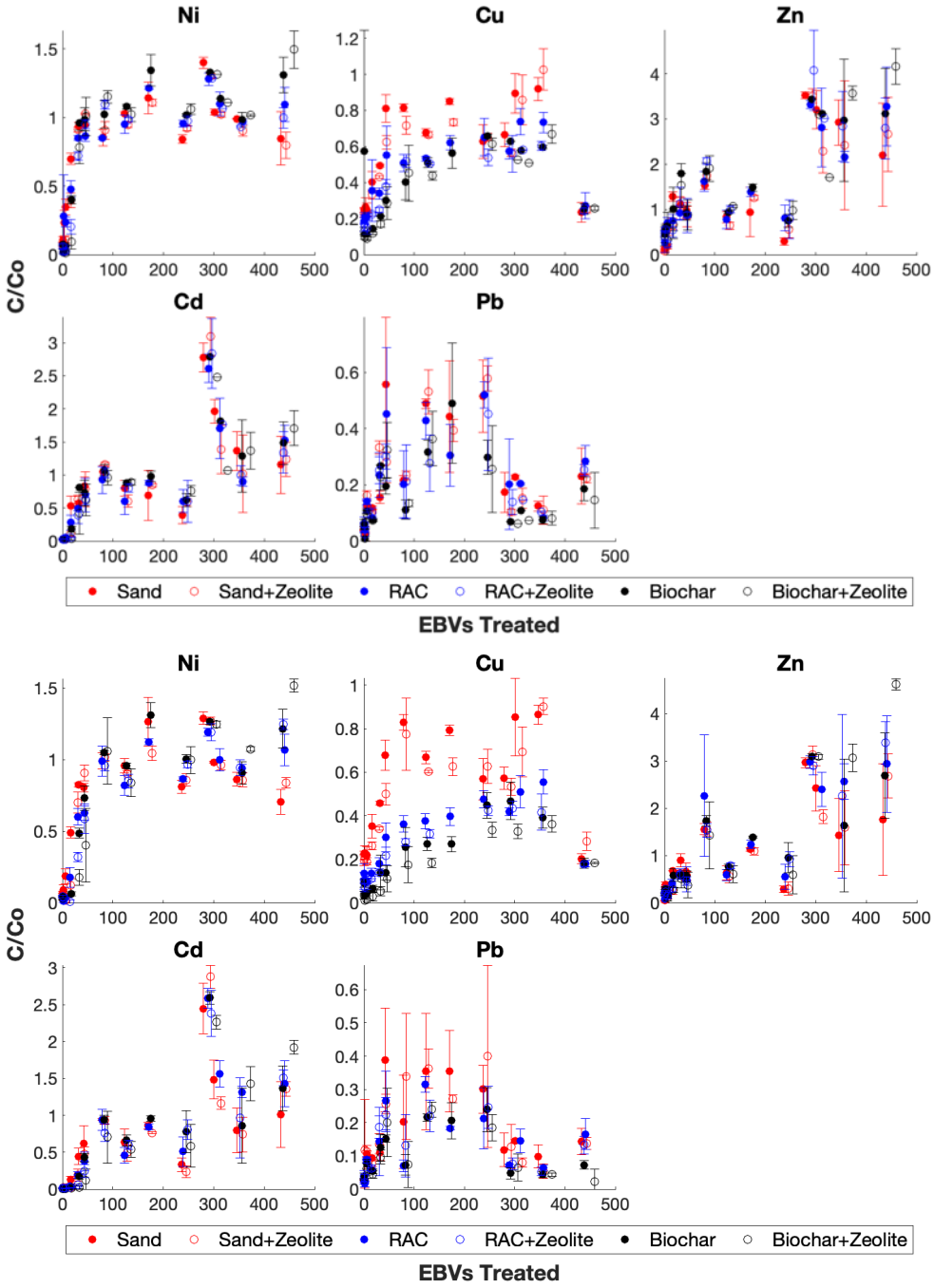

Figure 61 Dissolved metal breakthrough curves for the 25% sample port (top) and 50% sample port (bottom). Error bar indicates one standard deviation above and below the mean (n=3).

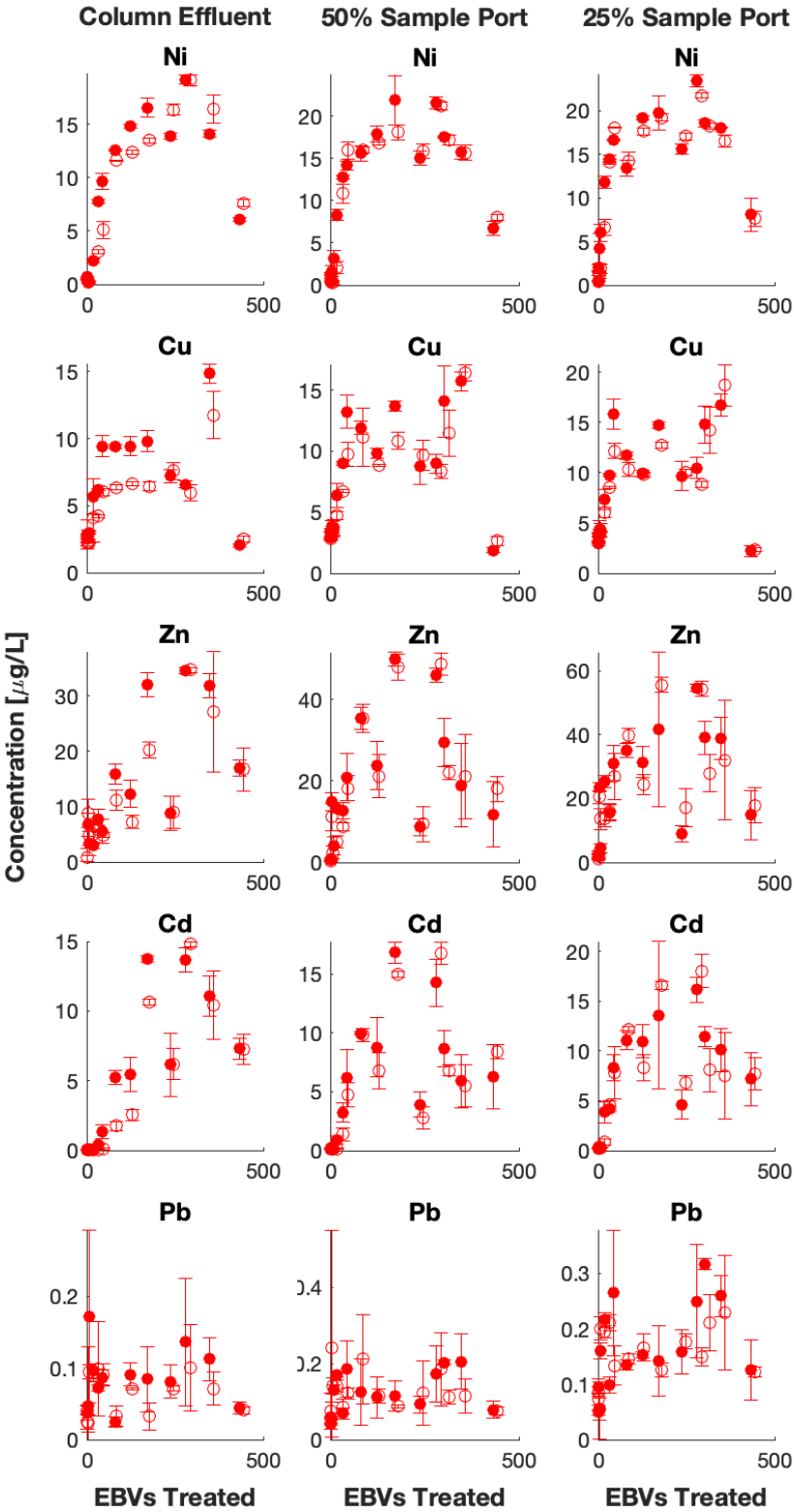

Figure 62 Dissolved metal breakthrough curves for sand (filled) and sand+zeolite (unfilled) at the column effluent (left), 50% sample port (middle), and 25% sample port (right). Error bars indicate one standard deviation above and below the mean (n=3).

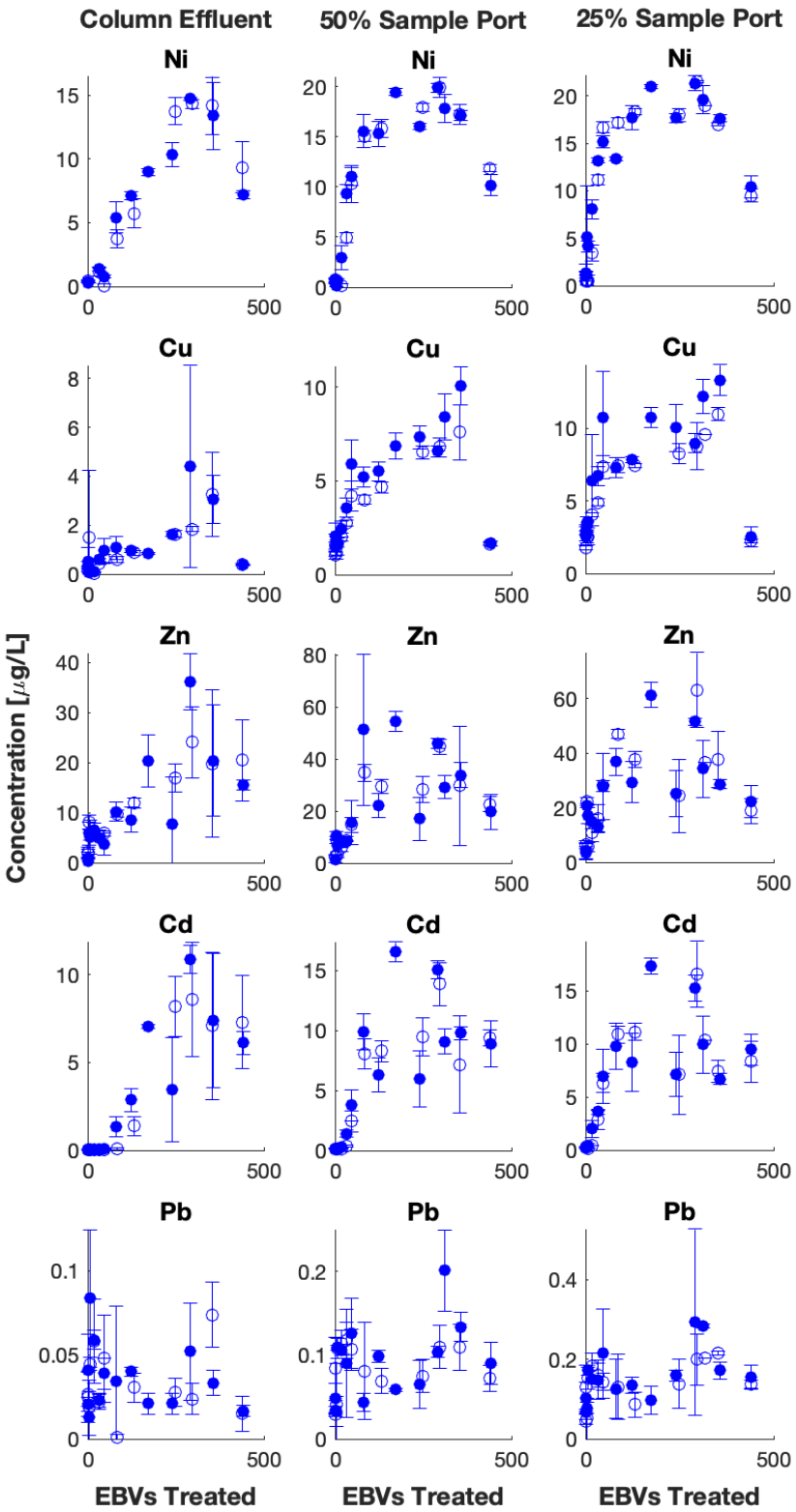

Figure 63 Dissolved metal breakthrough curves for RAC (filled) and RAC+zeolite (unfilled) at the column effluent (left), 50% sample port (middle), and 25% sample port (right). Error bars indicate one standard deviation above and below the mean (n=3).

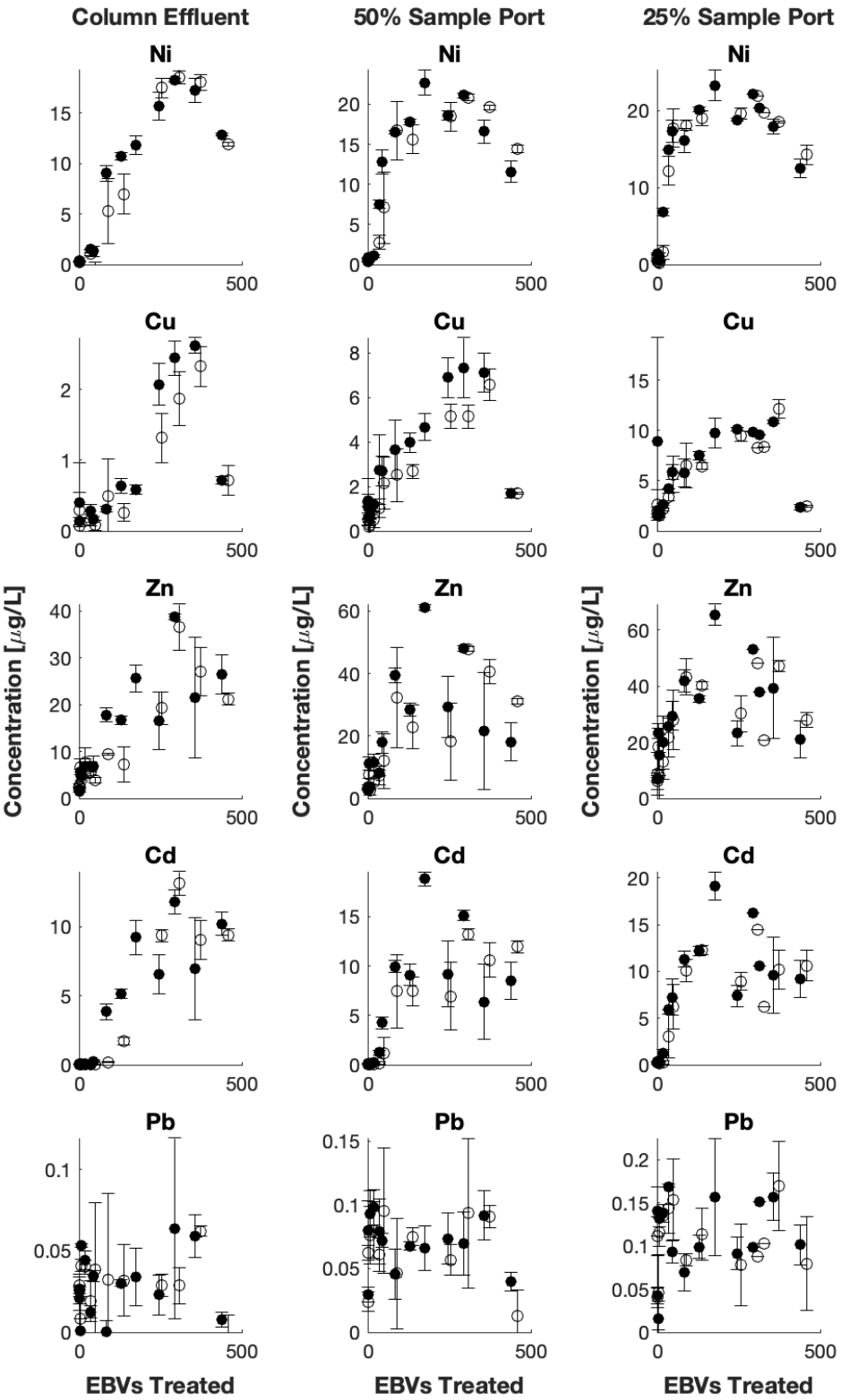

Figure 64 Dissolved metal breakthrough curves for biochar (filled) and biochar+zeolite (unfilled) at the column effluent (left), 50% sample port (middle), and 25% sample port (right). Error bars indicate one standard deviation above and below the mean (n=3).

2.8 Hydrophilic Organic Compounds

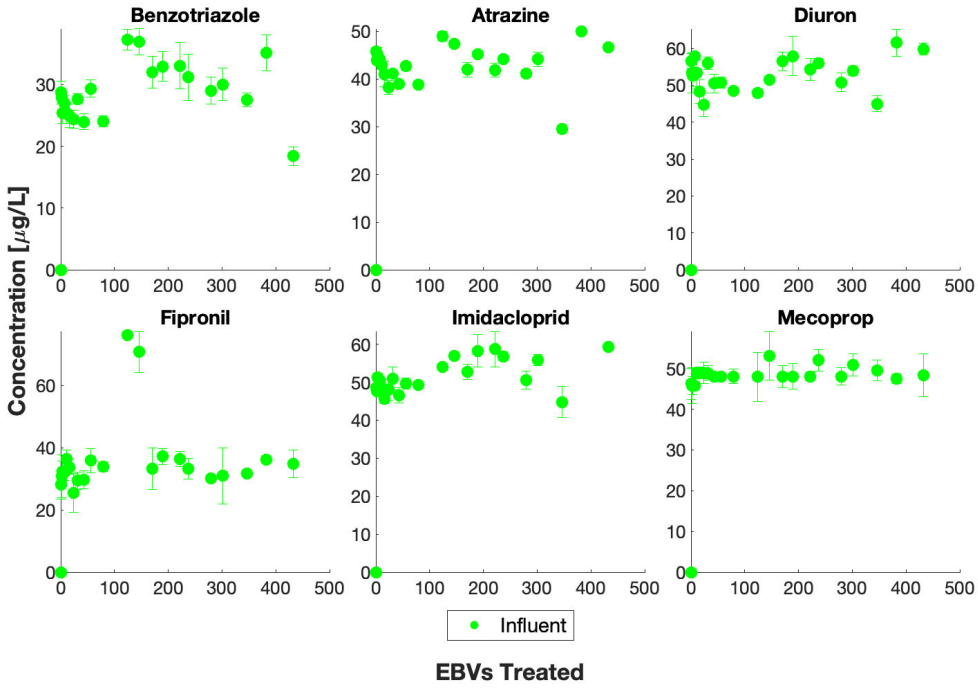

Figure 65 Dissolved TrOCs in column influent. Error bar indicates one standard deviation above and below the mean (n=3).

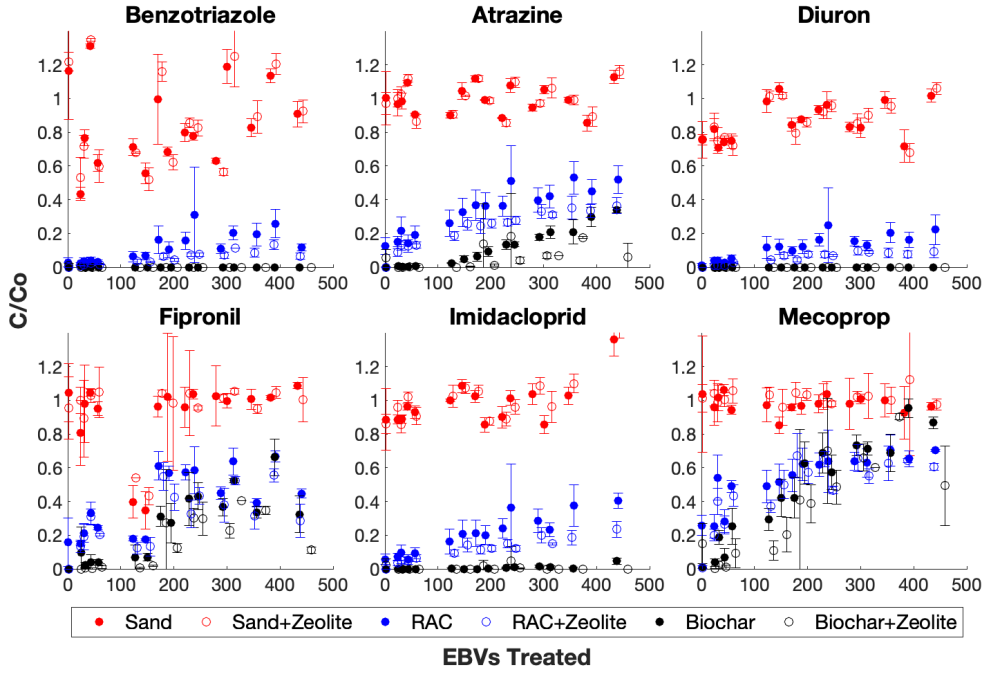

Figure 66 Dissolved TrOCs breakthrough at 50% sample port. Error bar indicates one standard deviation above and below the mean (n=3).

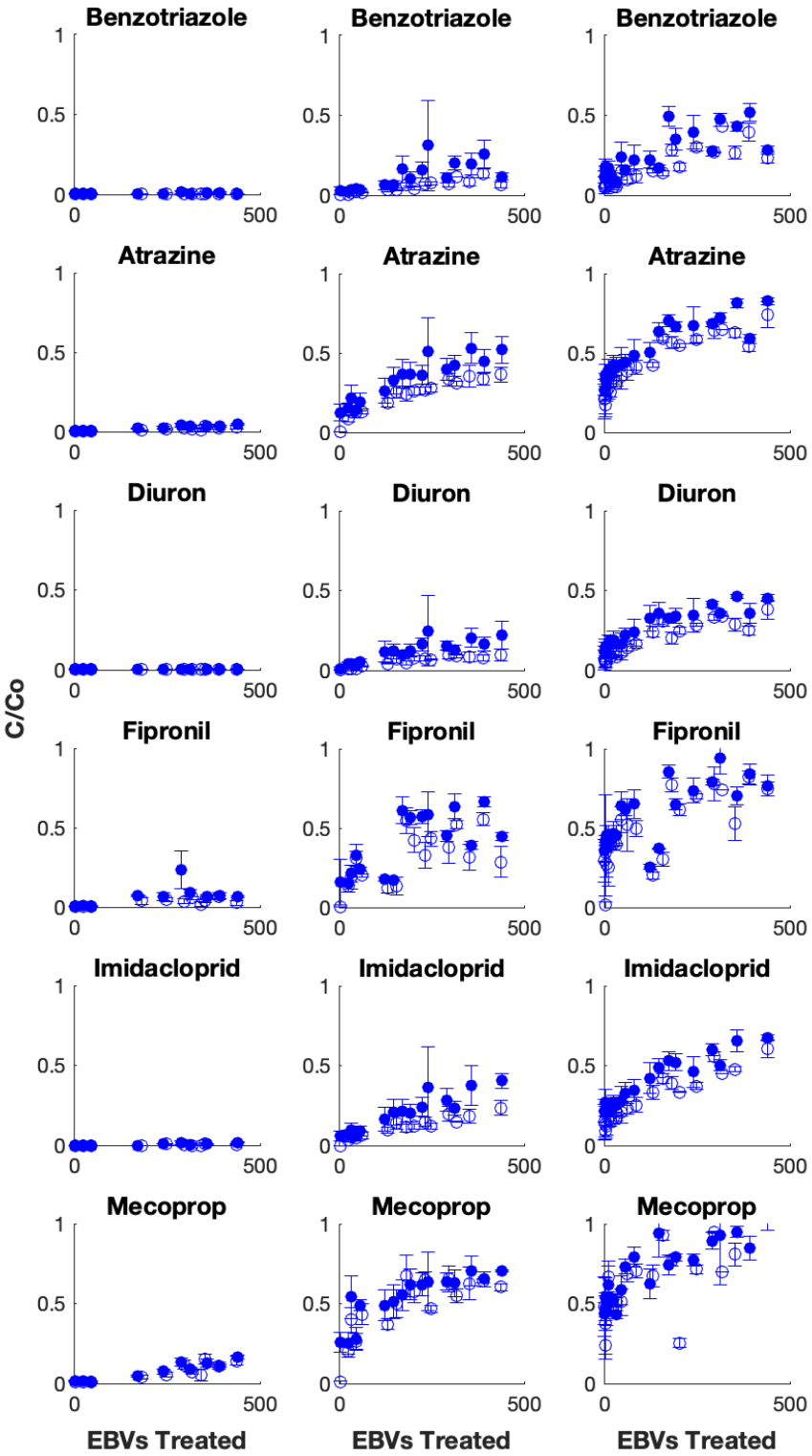

Figure 67 Dissolved TrOCs breakthrough curves for RAC (filled) and RAC+zeolite (unfilled) at the column effluent (left), 50% sample port (middle), and 25% sample port (right). Error bars indicate one standard deviation above and below the mean (n=3).

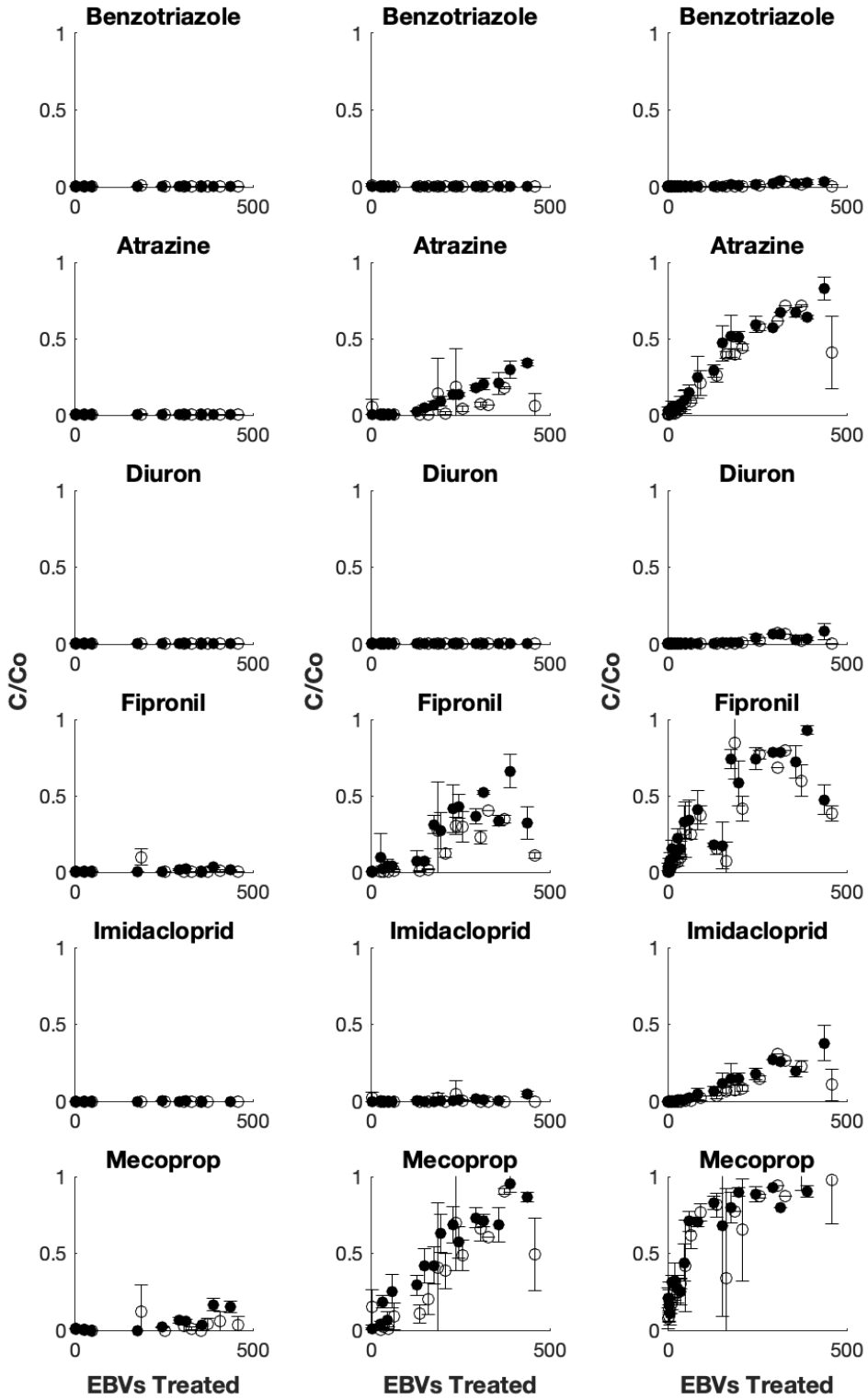

Figure 68 Dissolved TrOCs breakthrough curves for biochar (filled) and biochar+zeolite (unfilled) at the column effluent (left), 50% sample port (middle), and 25% sample port (right). Error bars indicate one standard deviation above and below the mean (n=3).

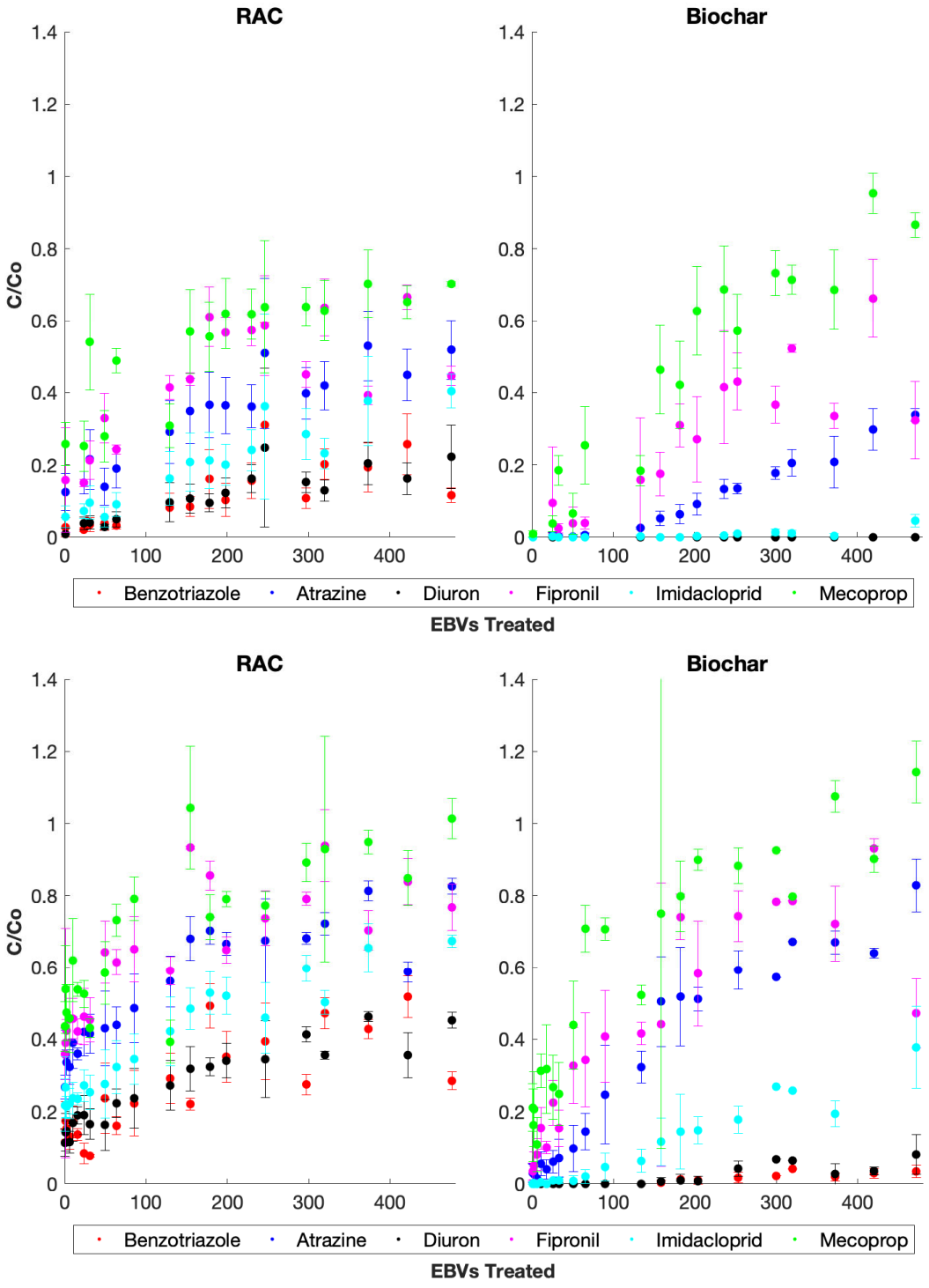

Figure 69 Dissolved TrOCs breakthrough curves for RAC (left) and biochar (right) at the 50% sample port (top), and 25% sample port (bottom). Error bars indicate one standard deviation above and below the mean (n=3).

2.9 PFAS

Table 50 Comparison of Empty Bed Volumes Treated for PFASs as Indicated by C/C_0=0.4 at the 25% Sample Port

	Volume Treated Until Breakthrough C/C_0=0.4 [b]					
Eng. Media Mixture	PFHxA		PFOA		PFHxS	
Sand	<1	±0	<1	±0	<1	±0
+Zeolite	<1	±0	<1	±0	<1	±0
+RAC	<1	±0	<1	±0	<1	±0
+Biochar	<1	±0	<1	±0	<1	±0
+Zeolite+Biochar	<1	±0	<1	±0	<1	±0
+Zeolite+RAC	<1	±0	<1	±0	<1	±0
Influent Conc. [a]	74.3	±14.9	98.1	±17.9	440.3	±68.1
	Volume Treated Until Breakthrough C/C_0=0.4 [b]					
Eng. Media Mixture	PFOS		Cl-PFOS		FHxSA	
Sand	<1	±0	<1	±0	<1	±0
+Zeolite	<1	±0	<1	±0	<1	±0
+RAC	37	±60	45	±74	<1	±0
+Biochar	19	±19	36	±16	<1	±0
+Zeolite+Biochar	25	±11	32	±14	<1	±0
+Zeolite+RAC	41	±27	81	±70	<1	±0
Influent Conc. [a]	2897.5	±595.5	47.3	±17.6	69.4	±30.1

[a] Time weighted average ± standard deviation (n=3) [µg L^{-1}].

[b] Mean ± standard deviation (n=3) [EBVs].

- Indicates no calculated value due to lack of observed contaminants in sample.

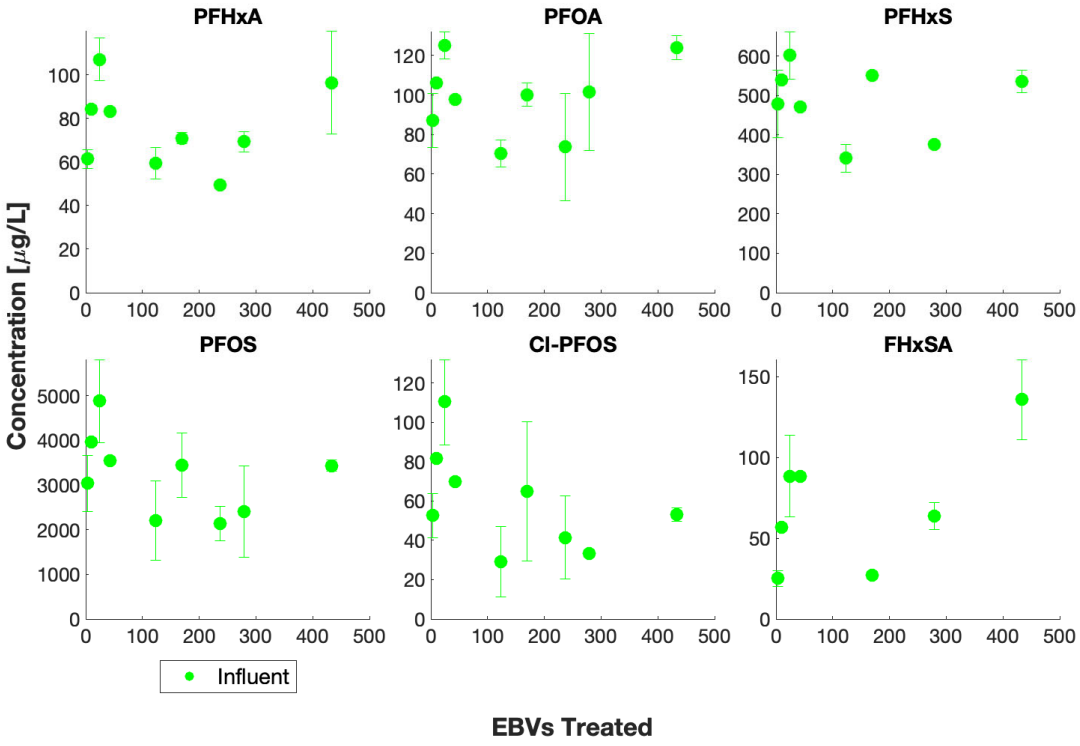

Figure 70 Dissolved PFAS in column influent. Error bar indicates one standard deviation above and below the mean (n=3).

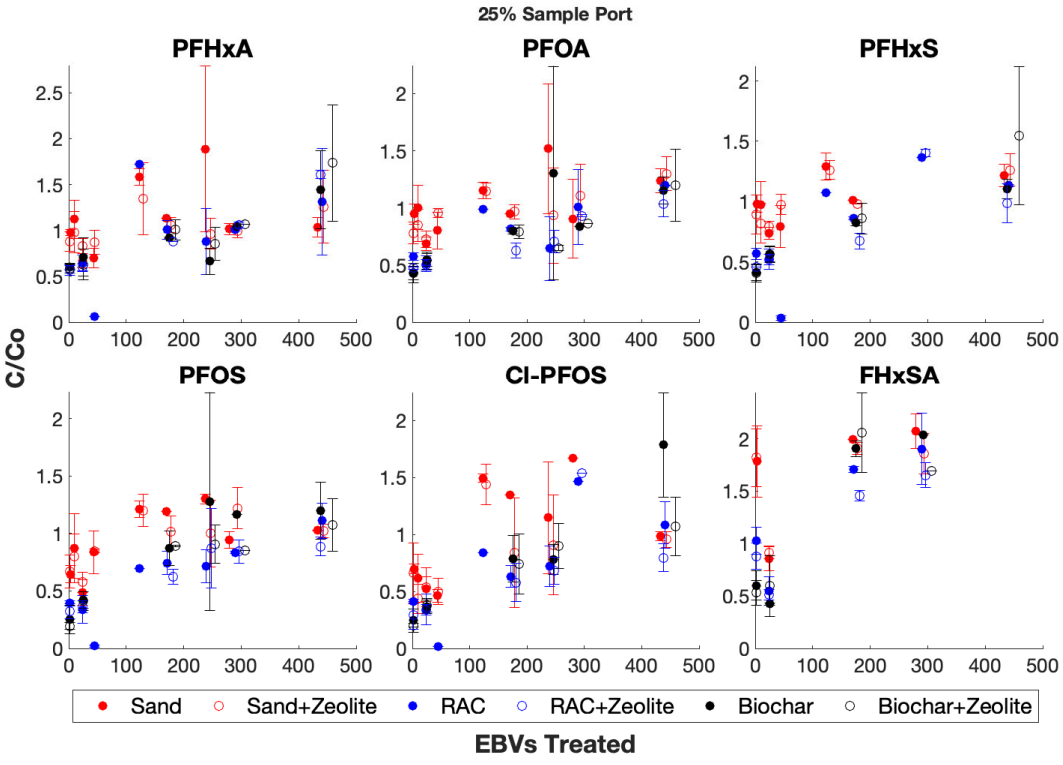

Figure 71 Dissolved PFAS breakthrough at 25% sample port. Error bar indicates one standard deviation above and below the mean (n=3).

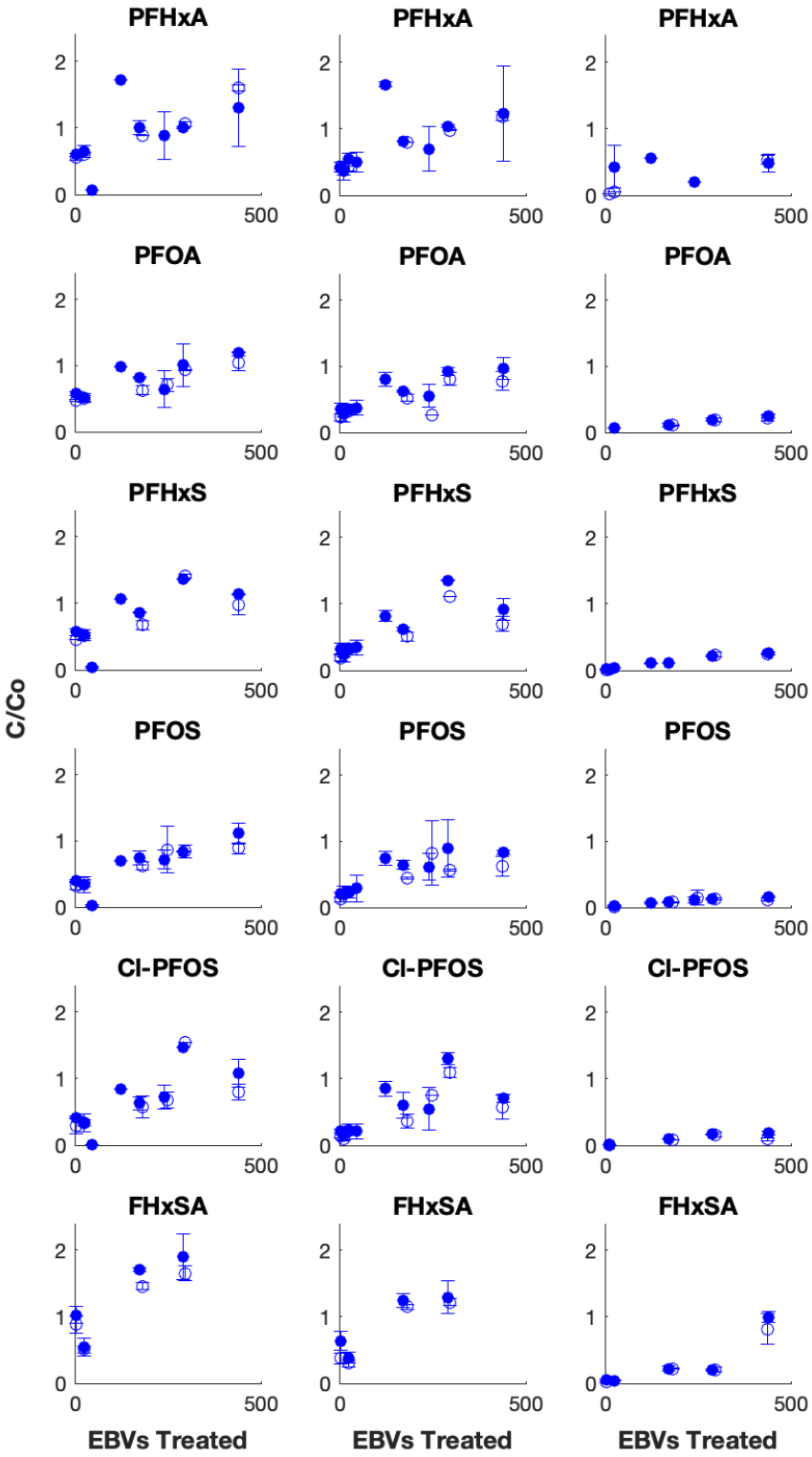

Figure 72 Dissolved PFAS breakthrough curves for RAC (filled) and RAC+zeolite (unfilled) at the column effluent (left), 50% sample port (middle), and 25% sample port (right). Error bars indicate one standard deviation above and below the mean (n=3).

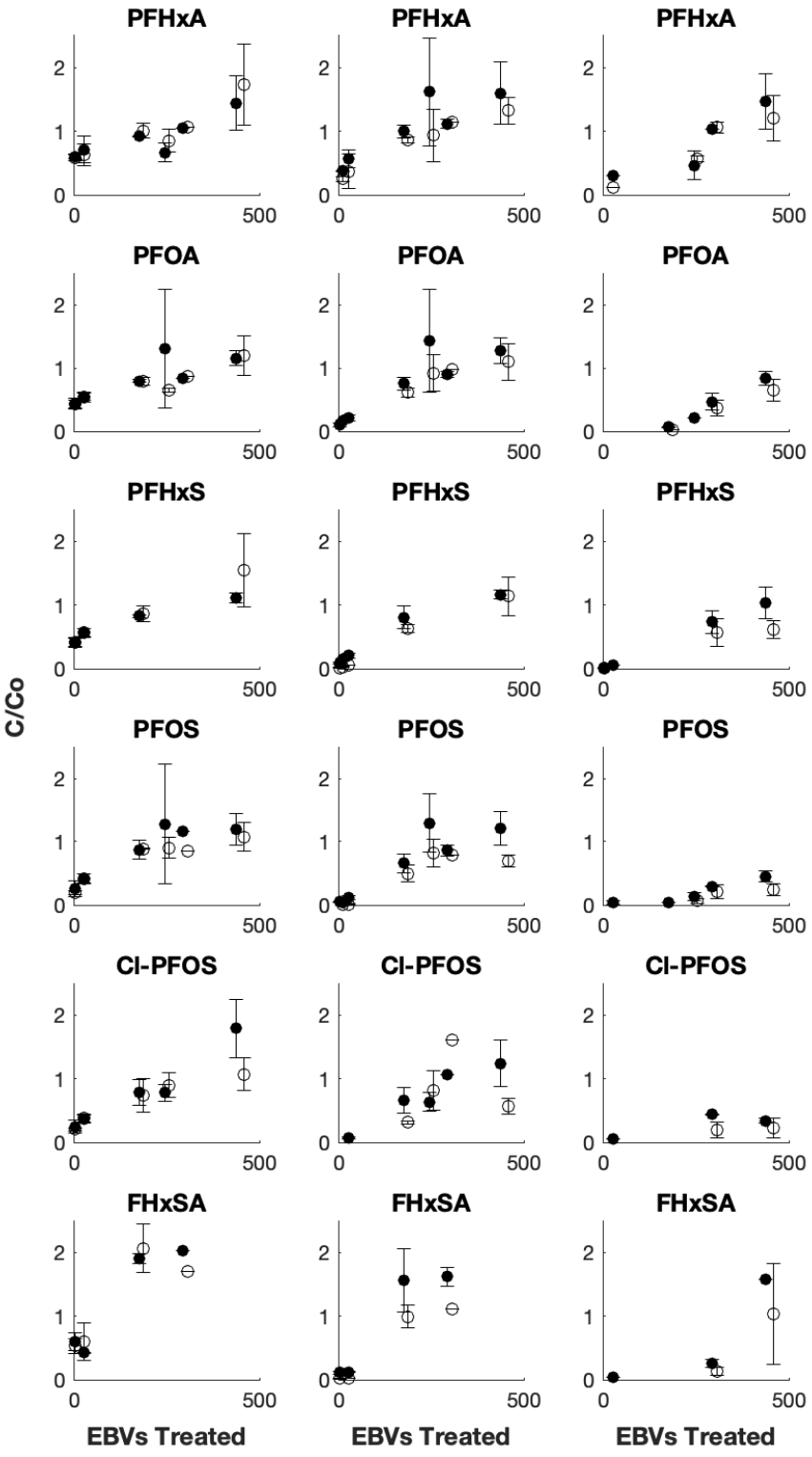

Figure 73 Dissolved PFAS breakthrough curves for biochar (filled) and biochar+zeolite (unfilled) at the column effluent (left), 50% sample port (middle), and 25% sample port (right). Error bars indicate one standard deviation above and below the mean (n=3).

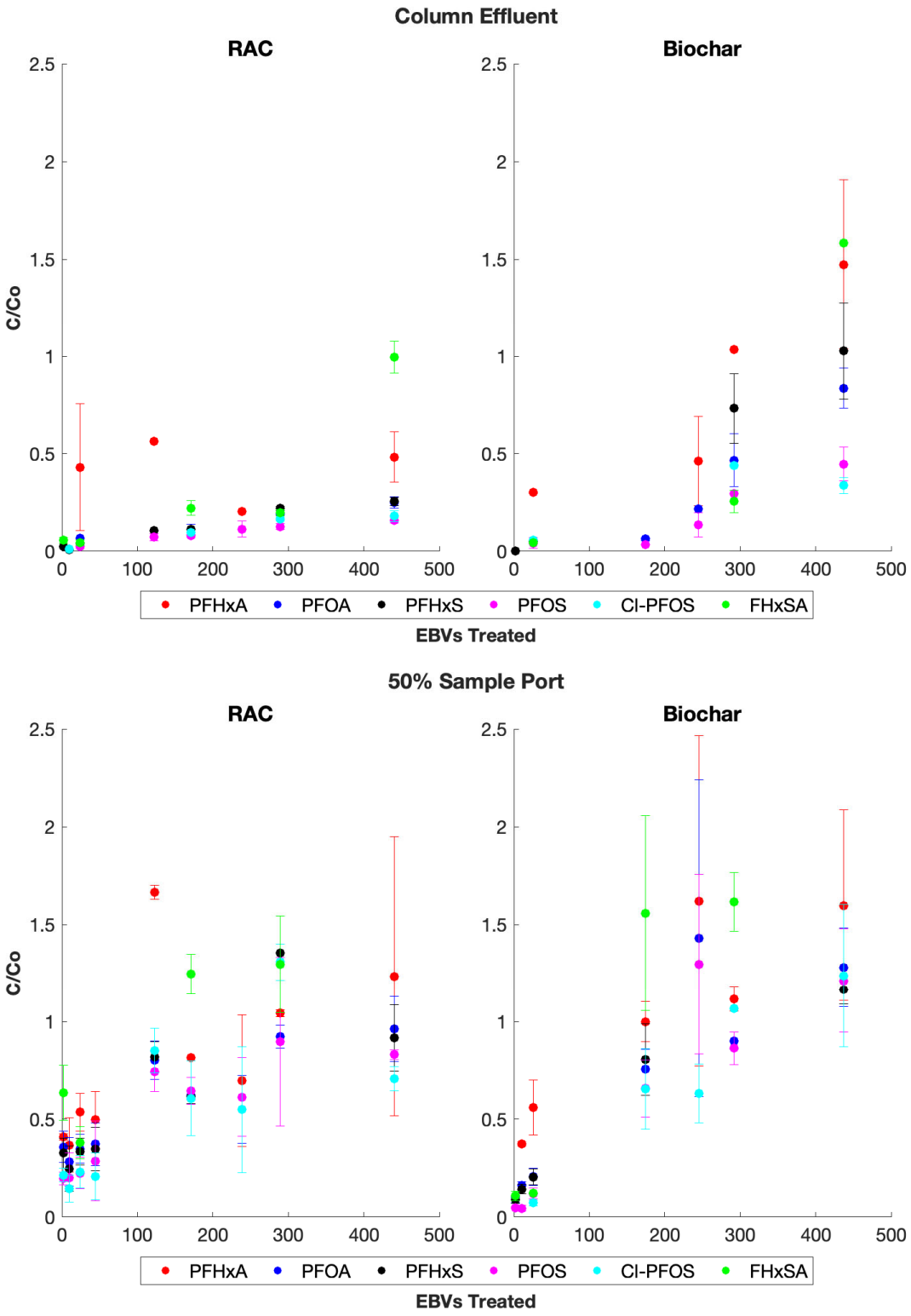

Figure 74 Dissolved PFAS breakthrough curves for RAC (left) and biochar (right) at the column effluent (top) and 50% sample port (bottom). Error bars indicate one standard deviation above and below the mean (n=3).

3 Task 3 Column Experiments and Predictive Modeling

3.1 Column Packing

Table 51 Mass of Material in Engineered Media Filters

Eng. Media Mix	Sand	RAC	Biochar	Barrier Sand	v% BC	wt% BC
Sand	4,999.50	-	-	1,731.30	-	-
+RAC	4,553.00	156.2	-	1,732.20	10%	3.30%
+Biochar	3,615.50	-	88	1,732.70	30%	2.40%
Bulk Density	1.812	0.559	0.103	1.625		

Mass measured [g]; Bulk density [g mL^{-1}]

3.2 Bromide Tracer Tests

Bromide test were conducted by delivering a pulse of bromide through the columns and sampling at pre-determined time intervals. The water level in the columns was maintained at the top of the barrier sand layer to eliminate standing water and prevent any initial dilution of the tracer above the barrier sand. DI water was used in the tracer studies and was delivered to each column to maintain a face velocity of 40 or 60 cm hr^{-1}. Flow rate was confirmed at the beginning and end of the tracer test. The bromide tracer test parameters are shown in Table 52. The tracer tests results are shown below in Figure 75.

Table 52 Bromide tracer test parameters.

Experiment	Mixture	Influent Concentration [mM]	Bromide Pulse [s]	Sampling Time [min]
40 cm hr	Sand	5	15	66
	+ Biochar	100	15	161
	+ RAC	100	15	163
60 cm hr	Sand	5	10	50
	+ Biochar	50	10	120
	+ RAC	125	10	120

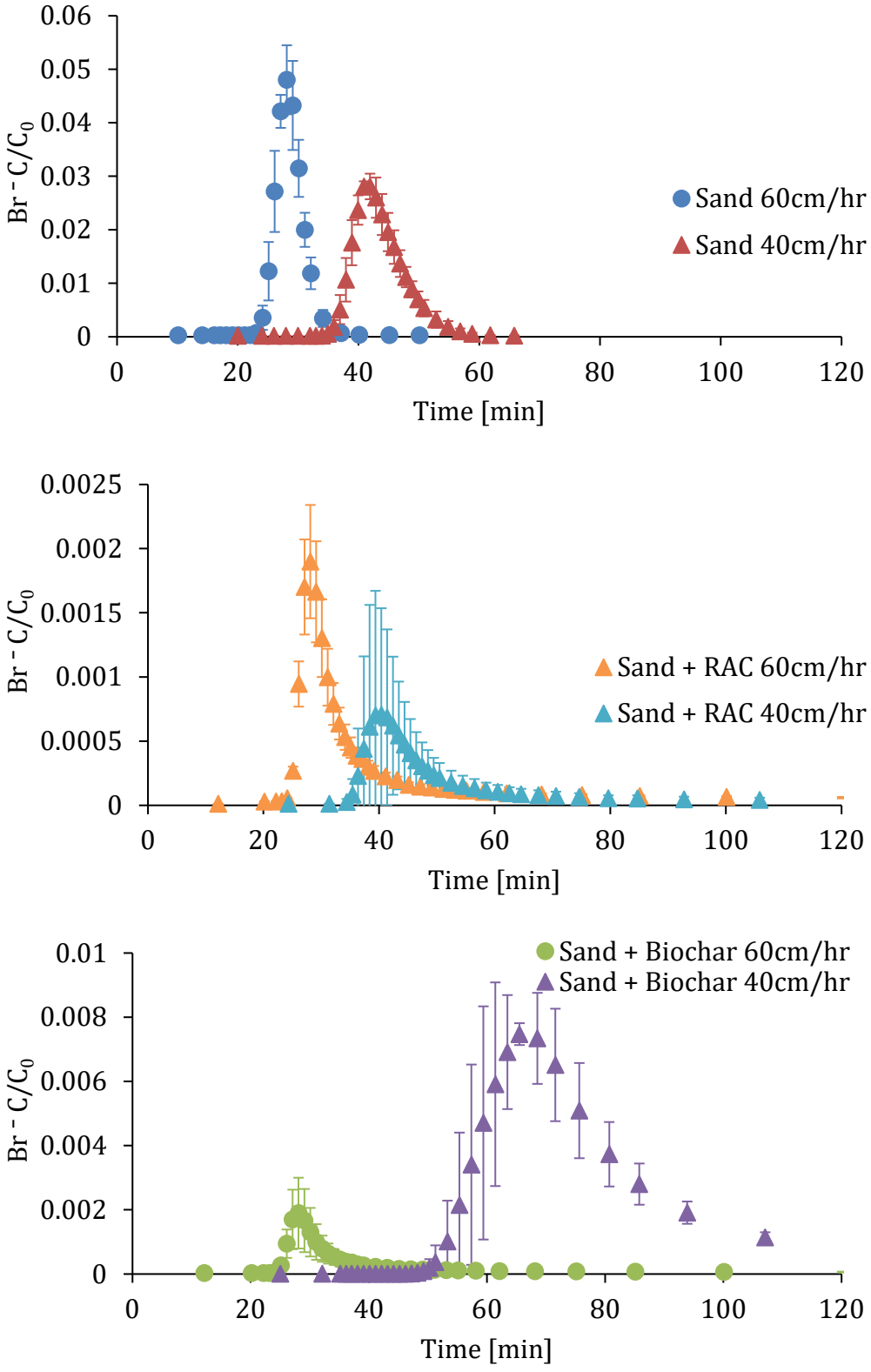

Figure 75 Observed tracer test results for sand (top), RAC (middle), and biochar (bottom) at 40 and 60 cm hr^{-1}. Note that the pulse concentration is different for each flow rate and material.

3.3 Experiment Duration and Flow Rates

The experimental timeline is shown below in Table 53 and Table 54. The hydraulic conductivity was not measured explicitly in this experiment, though it should be noted that all columns were always able to achieve the desired flow rates. Every 5-7 days, the barrier sand layer at the top of the columns, which would accumulate what appeared to be biomat and other materials, was replenished. This led to a substantial increase in the maximum flow rate attainable. Spikes in DO observed during the experiment were attributed to replenishing the top barrier sand layer.

Table 53 Experiment Phases – 40 cm hr^{-1}

SRT[a] [days] Start	End	Experiment Phase	Flow Matrix
-8	-6.8	Pre-conditioning Flush	DI Water
-6.8	0.0	Conditioning	Synthetic Stormwater
0.0	29.0	Challenge Test	Synthetic Stormwater + Contaminants

[a] System run time

Table 54 Experiment Phases – 60 cm hr^{-1}

SRT[a] [days] Start	End	Experiment Phase	Flow Matrix
-5.5	-4.3	Pre-conditioning Flush	DI Water
-4.3	0.0	Conditioning	Synthetic Stormwater
0.0	20.6	Challenge Test	Synthetic Stormwater + Contaminants

[a] System run time

Flow rates were measured gravimetrically over 20s and adjusted using outlet controls consisting of a needle valve and globe valve at the bottom of each column. Flow rates were checked periodically and adjusted to the target flow rate of 40cm hr^{-1} (30.4 mL min^{-1}) or 60 cm hr^{-1} (45.6 mL min^{-1}). Figure 76 shows the average empty bed volumes treated for each engineered media mixture over the course of the conditioning and challenge test. Figure 77 shows the flow rate over time for each engineered media mixture.

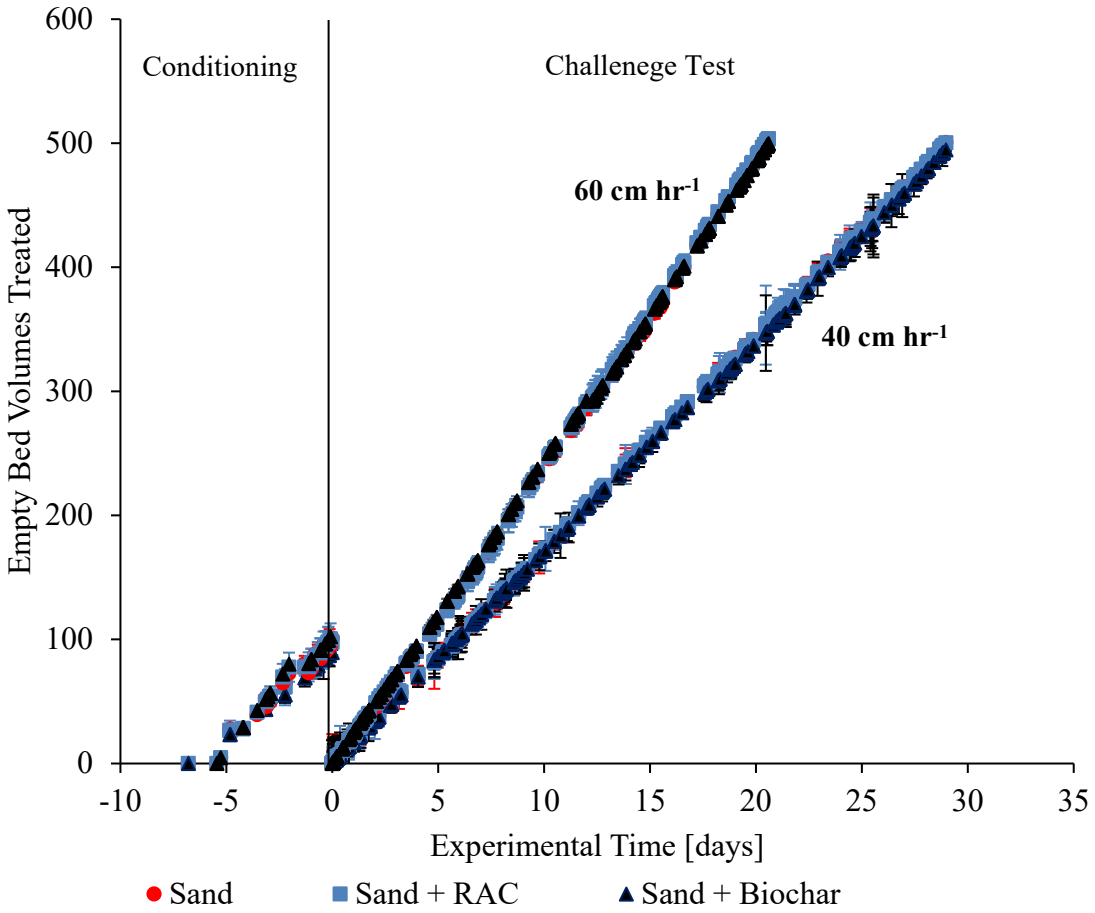

Figure 76 Empty bed volumes (EBVs) treated over time for the 40 cm hr^{-1} and 60 cm hr^{-1} experiments for the sand (red circle), RAC (blue square), and biochar (black triangle) columns. Note that each experiment consisted of a conditioning period of ~100 EBVs before a challenge test consisting of ~500 EBVs. Points indicate mean (n=3) and error bars indicate one standard deviation above and below the mean.

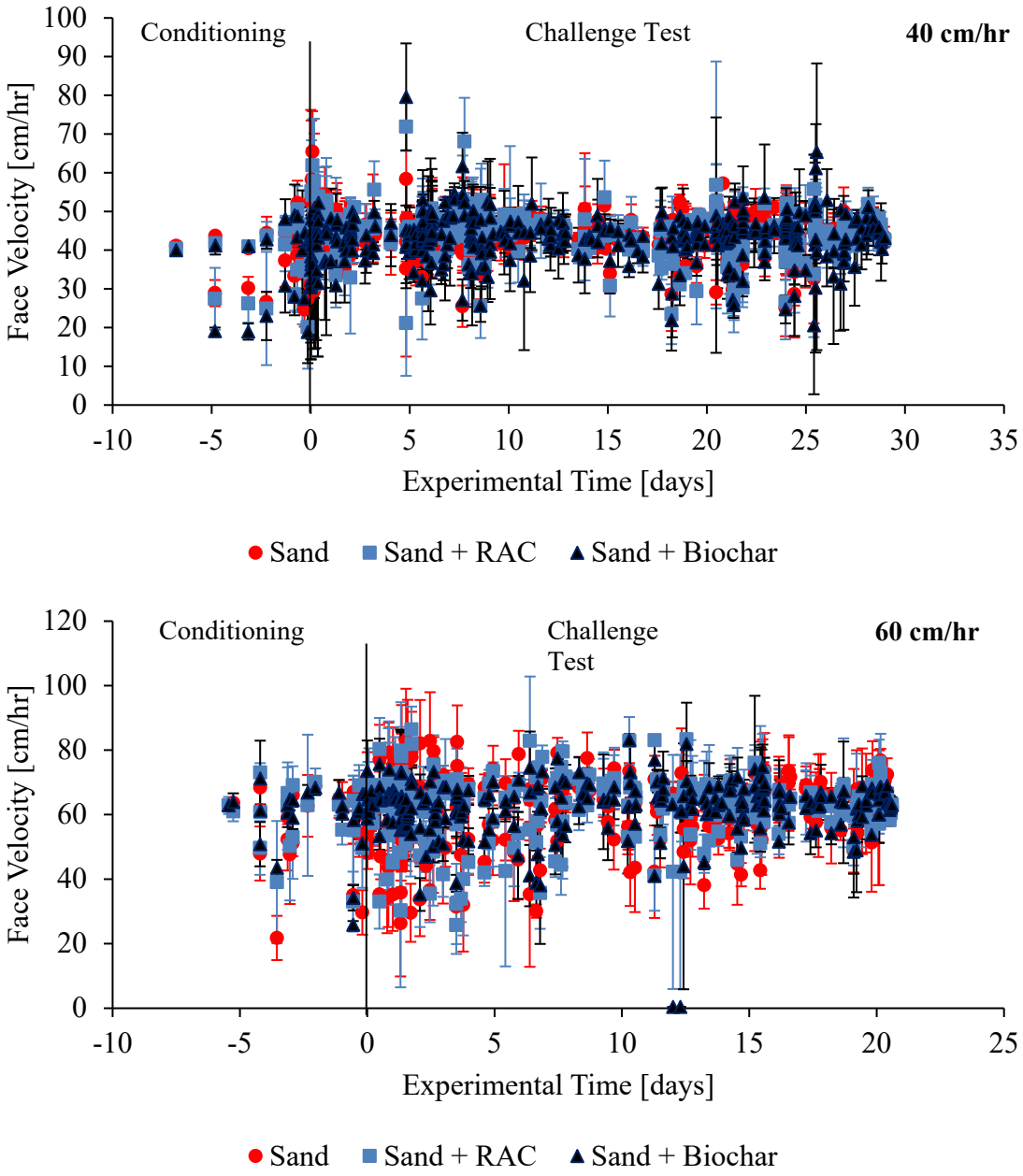

Figure 77 Face velocity over time for the 40 cm hr^{-1} (top) and 60 cm hr^{-1} (bottom) experiments for the sand (red circle), RAC (blue square), and biochar (black triangle) columns. Note that each experiment consisted of a conditioning period of ~100 EBVs before a challenge test consisting of ~500 EBVs. Points indicate mean (n=3) and error bars indicate one standard deviation above and below the mean.

3.4 Water Quality

3.4.1 Total Suspended Solids

Total suspended solids (TSS) were measured using a 0.55µm glass fiber filter (28497-153, Whatman Grade GF/A) with a vacuum filter assembly. Filters were oven dried at 60°C before and after filtering. Table 55 - Figure 79 shows measured TSS for each engineered media mixture over the course of the experiments. Units are mg L^{-1}.

Table 55 TSS 40 cm hr^{-1}

SRT [a]	Influent		Sand		Sand + RAC		Sand + Biochar	
0	12.81	±0.69	2.28	±0.06	1.95	±0.05	2.26	±0.47
3	16.52	±5.78	2.34	±0.12	2.29	±0.09	2.10	±0.24
9	11.33	±1.99	3.57	±0.48	2.92	±0.33	2.77	±0.65
13	16.99	±0.91	4.19	±0.16	3.64	±0.11	2.87	±0.62
17	14.63	±1.03	3.27	±0.11	2.74	±0.13	2.85	±0.71
21	34.44	±3.24	3.57	±0.19	2.74	±0.93	2.19	±0.25
25	17.10	±1.32	2.36	±0.61	2.10	±0.30	2.06	±0.13
29	31.33	±2.88	1.03	±0.08	0.59	±0.04	1.18	±0.27
30	70.09	±18.36	0.72	±0.08	0.62	±0.21	0.90	±0.73
Avg	25.03	±18.72	2.59	±1.18	2.18	±1.02	2.13	±0.70

Average ± standard deviation (n=3)
[a] System run time relative to the start of the challenge test [days]

Table 56 TSS 60 cm hr^{-1}

SRT [a]	Influent		Sand		Sand + RAC		Sand + Biochar	
0	10.74	±1.25	1.78	±0.51	1.43	±0.22	1.52	±0.49
3	6.08	±0.50	1.84	±0.68	1.49	±0.28	1.08	±0.20
7	13.55	±5.45	1.88	±0.40	1.86	±0.09	1.45	±0.08
10	19.93	±5.23	3.74	±0.89	3.12	±1.69	2.82	±0.75
13	21.60	±3.71	3.58	±1.51	3.25	±1.31	3.11	±1.27
17	45.69	±3.87	4.51	±0.59	3.59	±0.77	3.28	±0.12
20	37.03	±4.56	6.48	±0.25	5.71	±0.47	4.70	±0.17
22	58.04	±3.89	9.01	±0.76	8.68	±0.54	8.43	±0.83
23	63.96	±2.95	10.51	±0.81	9.29	±0.05	9.97	±0.39
Avg	30.73	±21.26	4.82	±3.21	4.27	±2.98	4.04	±3.15

Average ± standard deviation (n=3)
[a] System run time relative to the start of the challenge test [days]

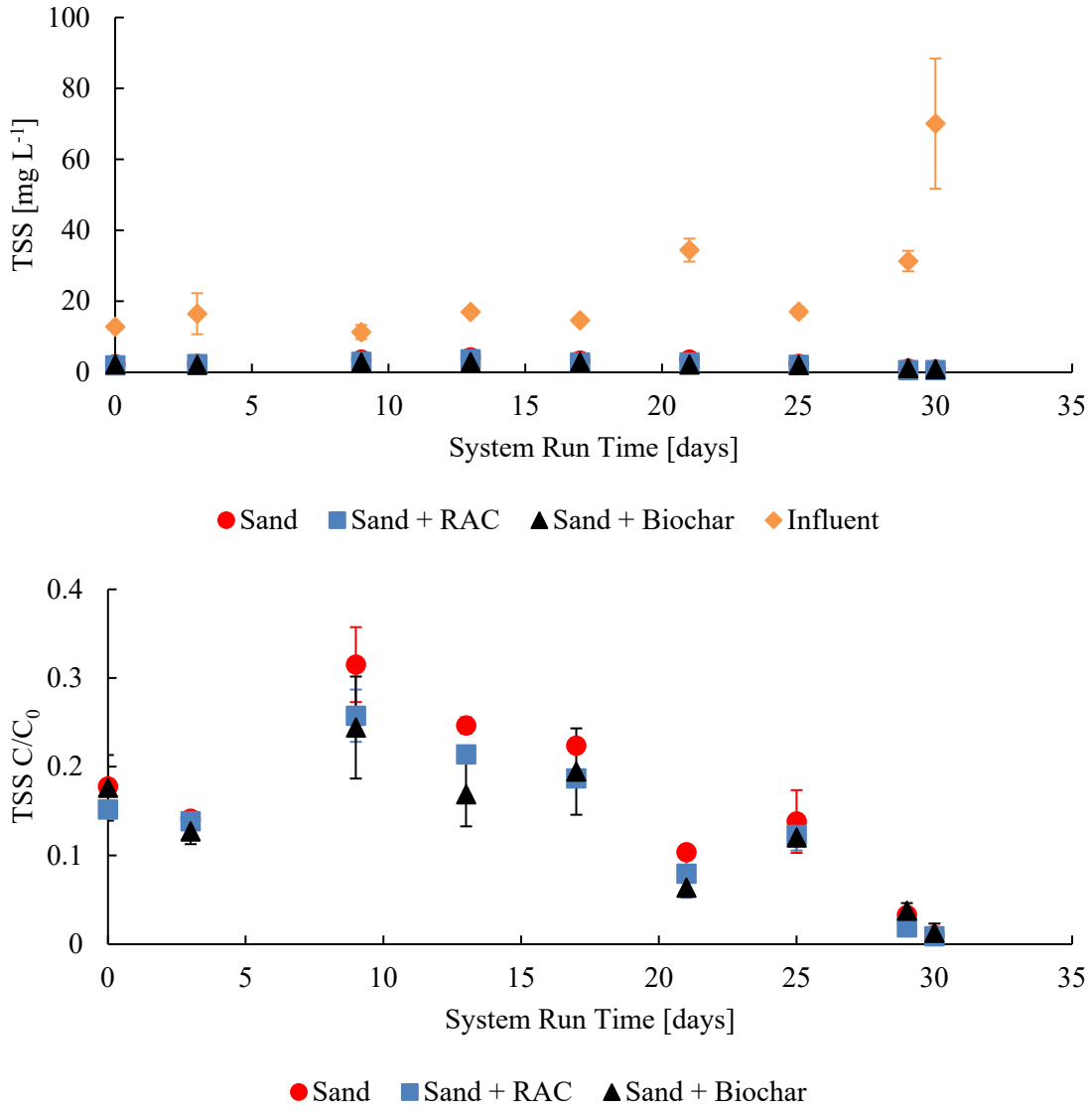

Figure 78 Total suspended solids over time for the 40 cm hr^{-1} experiment for the sand (red circle), RAC (blue square), and biochar (black triangle) columns. Influent is shown in the top plot (orange diamond). Points indicate mean (n=3) and error bars indicate one standard deviation above and below the mean.

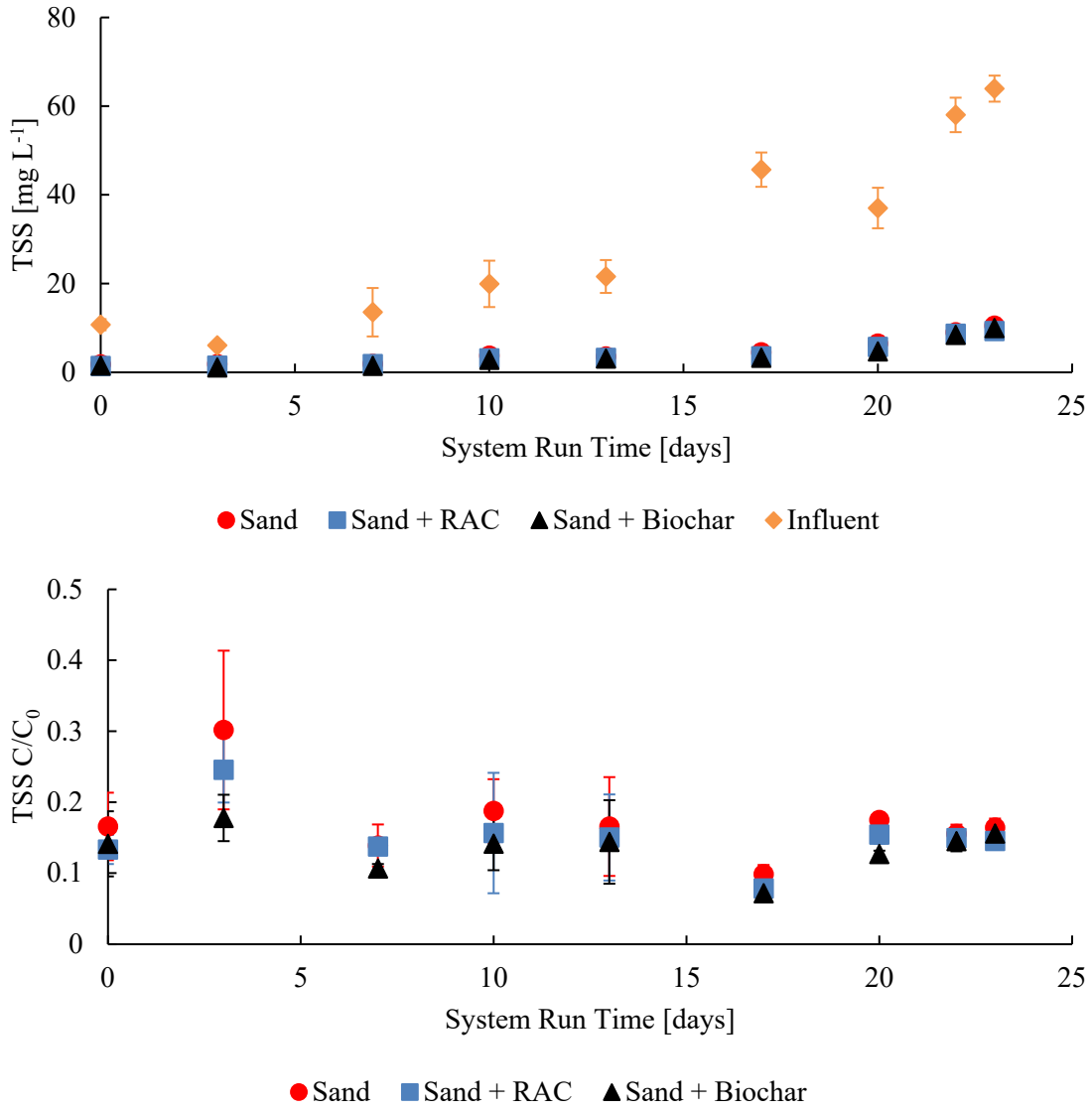

Figure 79 Total suspended solids over time for the 60 cm hr^{-1} experiment for the sand (red circle), RAC (blue square), and biochar (black triangle) columns. Influent is shown in the top plot (orange diamond). Points indicate mean (n=3) and error bars indicate one standard deviation above and below the mean.

Dissolved Organic Carbon and Total Nitrogen

Dissolved organic carbon (DOC) was analyzed using a TOC-Analyzer using NPOC analysis after filtration using 0.45µm PES syringe filter.

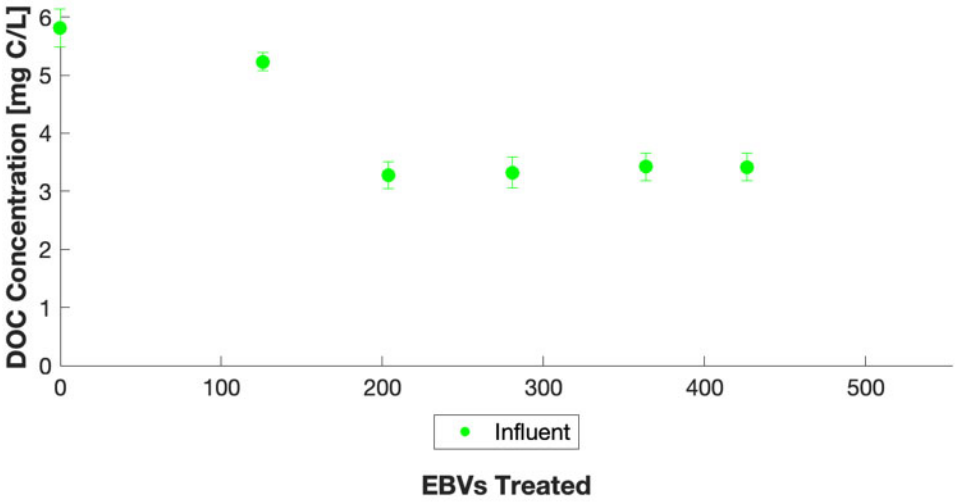

Figure 80 DOC in column influent in 40 cm hr^{-1} experiment. Point indicates mean (n=3) and error bars indicate one standard deviation above and below the mean.

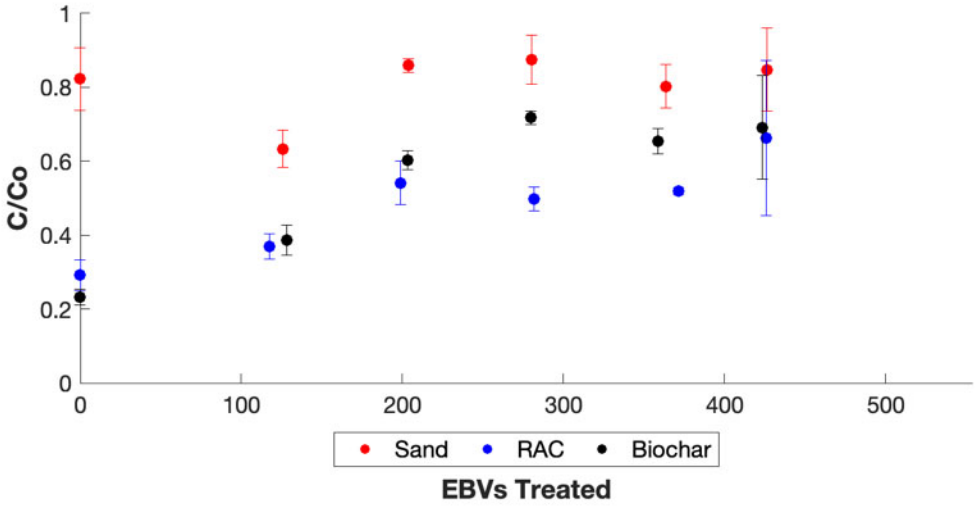

Figure 81 DOC in sand (red), RAC (blue), and biochar (black) column effluent in 40 cm hr^{-1} experiment. Point indicates mean (n=3) and error bars indicate one standard deviation above and below the mean.

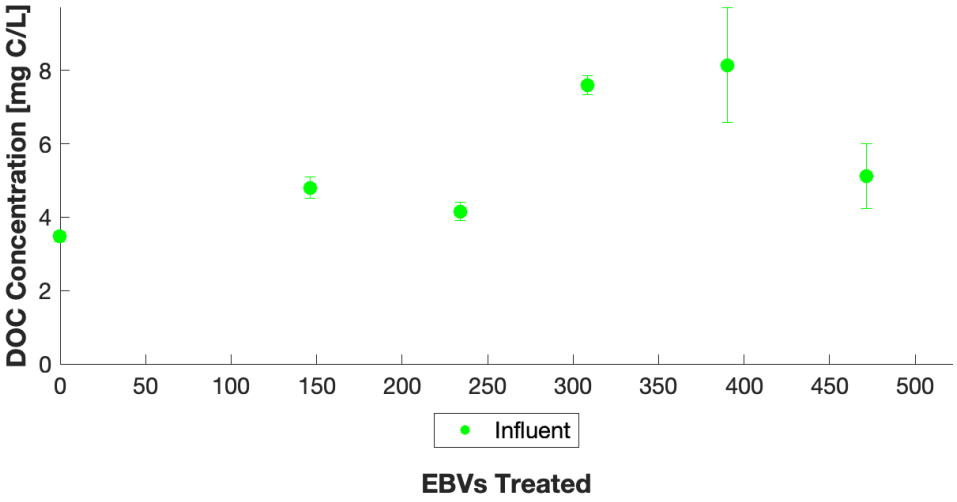

Figure 82 DOC in column influent in 60 cm hr^{-1} experiment. Point indicates mean (n=3) and error bars indicate one standard deviation above and below the mean.

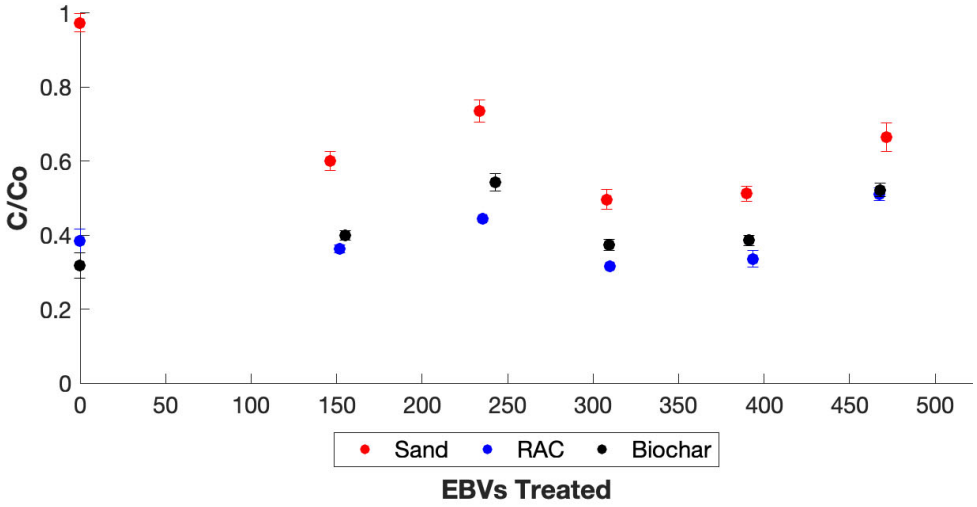

Figure 83 DOC in sand (red), RAC (blue), and biochar (black) column effluent in 60 cm hr^{-1} experiment. Point indicates mean (n=3) and error bars indicate one standard deviation above and below the mean.

3.4.2 Dissolved Oxygen

Table 57 Dissolved Oxygen in Column Effluent – 40 cm hr^{-1} [mg L^{-1} oxygen]

SRT[a]	Influent	Sand		Sand + RAC		Sand + Biochar	
-6.9	8.09	8.12	±0.04	7.57	±0.05	7.97	±0.00
-3.1	6.79	3.19	±0.16	2.54	±0.19	1.75	±0.20
0.0	7.96	3.00	±0.10	1.86	±0.47	1.36	±0.30
1.8	6.42	1.10	±0.14	0.35	±0.05	0.33	±0.05
5.9	5.72	0.31	±0.05	0.29	±0.01	0.31	±0.07
9.8	7.02	2.40	±3.23	0.35	±0.02	0.33	±0.04
13.4	5.92	0.41	±0.09	0.31	±0.01	0.33	±0.03
20.9	7.95	7.13	±0.12	5.84	±0.66	6.09	±0.77
23.8	5.77	0.38	±0.02	0.31	±0.02	0.39	±0.07
26.8	5.75	0.59	±0.37	0.27	±0.01	1.37	±1.74
28.9	6.10	0.34	±0.07	0.27	±0.01	0.27	±0.01

Average ± standard deviation (n=3)
[a] System run time relative to the start of the challenge test [days]

Table 58 Dissolved Oxygen in Column Effluent – 60 cm hr^{-1} [mg L^{-1} oxygen]

SRT[a]	Influent	Sand		Sand + RAC		Sand + Biochar	
-4.3	8.48	3.48	±0.31	0.45	±0.05	1.07	±0.49
-2.5	7.05	2.54	±0.56	1.23	±0.73	1.43	±0.26
0.5	8.42	0.37	±0.04	0.32	±0.00	0.30	±0.01
4.5	7.89	2.25	±0.29	1.50	±0.04	1.13	±0.35
7.6	8.13	1.46	±0.29	0.35	±0.10	0.43	±0.12
9.7	7.19	0.62	±0.29	0.35	±0.10	0.35	±0.03

Average ± standard deviation (n=3)
[a] System run time relative to the start of the challenge test [days]

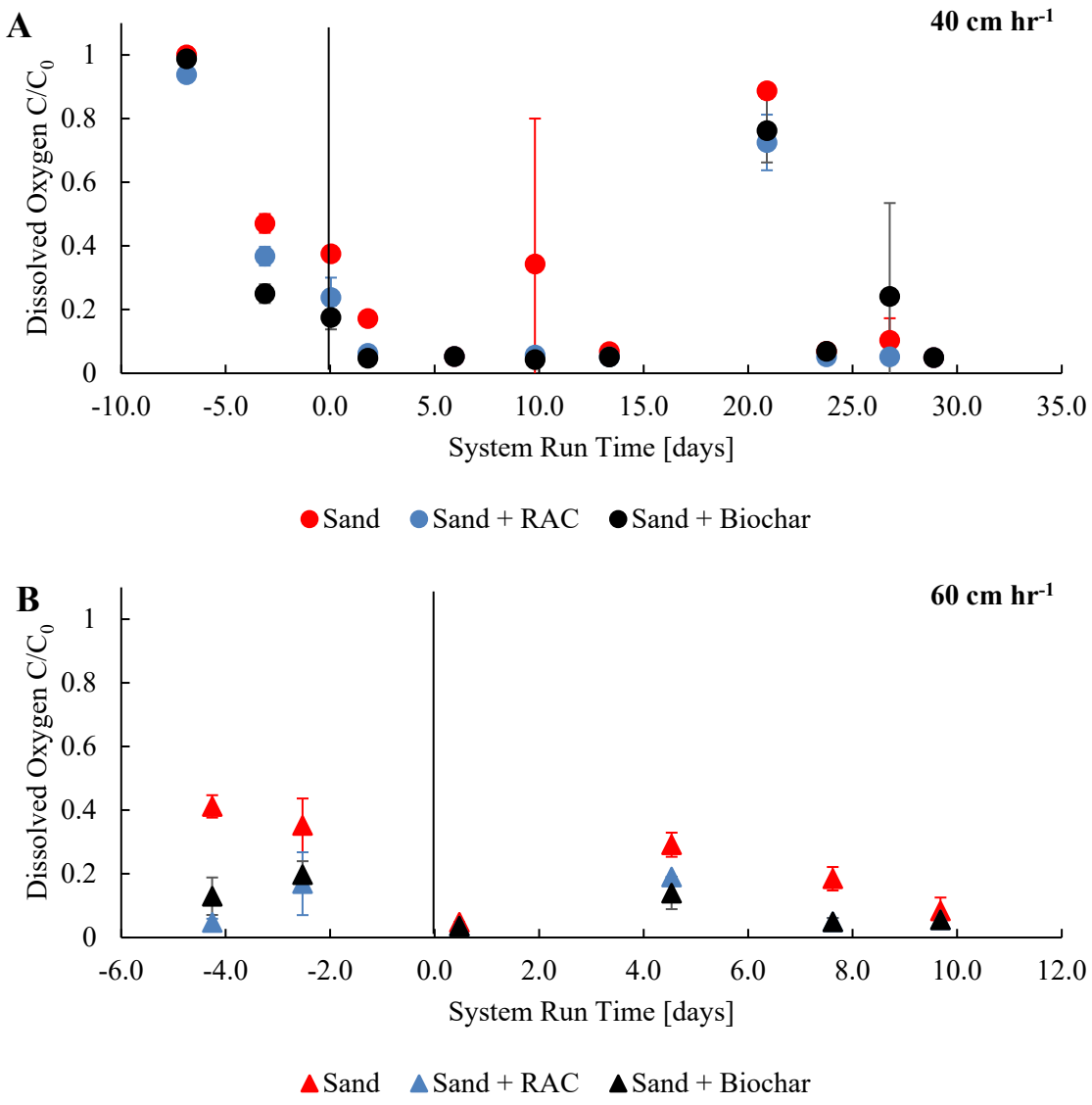

Figure 84 Dissolved oxygen over time in the 40 cm hr^{-1} (top) and 60 cm hr^{-1} (bottom) experiments for the sand (red), RAC (blue), and biochar (black) columns. Points indicate mean (n=3) and error bars indicate one standard deviation above and below the mean. Note that system run time<0 indicates conditioning period and system run time=0 indicates the beginning of the challenge experiment.

3.4.3 Additional Water Quality Parameters

Table 59 pH in Column Effluent – 40 cm hr^{-1} [-]

SRT[a]	Holding		Spike		Influent		Sand		Sand + RAC		Sand + Biochar	
-3.0	7.7	±0.2	7.5	±0.1	-	-	7.3	±0.0	7.3	±0.0	7.2	±0.0
-0.3	7.8	±0.1	7.7	±0.1	7.8	±0.1	7.3	±0.1	7.2	±0.0	7.2	±0.0
1.8	7.5	±0.1	7.1	±0.1	7.2	±0.0	6.8	±0.1	6.6	±0.1	6.7	±0.1
5.9	7.7	±0.1	7.2	±0.0	7.4	±0.0	7.0	±0.0	6.9	±0.0	6.9	±0.1
9.8	7.4	±0.2	7.3	±0.1	7.5	±0.0	7.0	±0.1	6.9	±0.1	6.9	±0.0
13.8	7.6	±0.2	7.2	±0.1	7.3	±0.1	7.0	±0.0	6.8	±0.1	6.5	±0.2
15.9	7.5	±0.3	7.2	±0.1	7.3	±0.0	7.0	±0.0	7.0	±0.0	7.0	±0.0
20.9	7.5	±0.2	7.2	±0.0	7.3	±0.1	7.3	±0.0	7.3	±0.1	7.1	±0.0
23.0	7.6	±0.2	7.3	±0.0	7.5	±0.0	7.1	±0.0	7.0	±0.1	7.1	±0.0
26.8	7.5	±0.2	7.2	±0.1	7.2	±0.2	7.1	±0.0	7.0	±0.0	7.0	±0.0
28.9	7.5	±0.1	7.2	±0.1	7.4	±0.0	7.1	±0.0	7.1	±0.1	7.0	±0.1
Avg[b]	7.6	±0.1	7.3	±0.2	7.4	±0.2	7.1	±0.2	7.0	±0.2	7.0	±0.2

Average ± standard deviation (n=3)
[a] System run time relative to the start of the challenge test [days]
[b] Average ± standard deviation (n=3) for duration of challenge test
- Indicates no measurement taken

Table 60 pH in Column Effluent – 60 cm hr^{-1} [-]

SRT[a]	Holding		Spike		Influent		Sand		Sand + RAC		Sand + Biochar	
-4.3	7.3	±0.2	6.6	±0.4	7.0	±0.2	6.9	±0.1	6.4	±0.6	6.9	±0.1
-2.5	7.6	±0.2	7.9	±0.7	5.8	±0.2	6.1	±0.7	6.7	±0.1	6.0	±0.7
0.5	7.7	±0.1	7.2	±0.1	7.3	±0.0	6.9	±0.0	6.9	±0.0	7.0	±0.0
4.5	7.5	±0.3	7.3	±0.0	7.4	±0.0	7.0	±0.0	7.1	±0.1	7.0	±0.0
7.6	7.7	±0.1	7.3	±0.0	7.4	±0.0	7.1	±0.0	7.0	±0.0	6.9	±0.1
9.7	7.3	±0.2	7.2	±0.0	7.3	±0.1	6.9	±0.1	6.9	±0.1	6.9	±0.1
Avg[b]	7.5	±0.2	7.3	±0.4	7.0	±0.6	6.8	±0.4	6.8	±0.3	6.8	±0.4

Average ± standard deviation (n=3)
[a] System run time relative to the start of the challenge test [days]
[b] Average ± standard deviation (n=3) for duration of challenge test

Table 61 Conductivity in Column Effluent – 40 cm hr^{-1} [µS cm^{-1}]

SRT[a]	Holding		Spike		Influent		Sand		Sand + RAC		Sand + Biochar	
-3.0	352	±2	381	±3	-	-	378	±3	378	±2	369	±12
-0.3	171	±1	198	±19	188	±2	241	±80	251	±33	257	±75
1.8	221	±81	339	±21	340	±7	296	±97	288	±60	284	±129
5.9	233	±91	307	±86	346	±13	314	±41	348	±11	296	±94
9.8	325	±5	180	±9	338	±2	327	±10	283	±87	321	±25
13.8	354	±21	307	±95	331	±51	354	±7	355	±5	345	±11
15.9	406	±62	213	±8	279	±101	379	±28	365	±68	384	±19
20.9	341	±2	233	±47	255	±75	277	±88	244	±76	325	±4
23.0	342	±2	191	±6	279	±86	226	±46	206	±31	226	±61
26.8	335	±1	223	±31	298	±92	244	±69	253	±67	295	±90
28.9	344	±3	344	±1	293	±67	270	±79	327	±17	294	±59
Avg[b]	311	±71	265	±72	295	±49	300	±55	300	±58	309	±47

Average ± standard deviation (n=3)
[a] System run time relative to the start of the challenge test [days]
[b] Average ± standard deviation (n=3) for duration of challenge test
- Indicates no measurement taken

Table 62 Conductivity in Column Effluent – 60 cm hr^{-1} [µS cm^{-1}]

SRT[a]	Holding		Spike		Influent		Sand		Sand + RAC		Sand + Biochar	
-4.3	250	±12	233	±56	195	±7	205	±4	244	±72	208	±11
-2.5	293	±1	311	±5	311	±2	313	±3	316	±2	315	±3
0.5	347	±2	359	±3	358	±1	346	±3	349	±2	350	±1
4.5	375	±30	376	±0	375	±1	377	±1	370	±2	373	±2
7.6	363	±1	380	±1	377	±0	377	±1	377	±1	376	±1
9.7	335	±15	346	±0	343	±1	344	±1	343	±1	342	±3
Avg[b]	327	±47	334	±55	327	±69	327	±65	333	±49	327	±63

Average ± standard deviation (n=3)
[a] System run time relative to the start of the challenge test [days]
[b] Average ± standard deviation (n=3) for duration of challenge test

Table 63 Total Dissolved Solids in Column Effluent – 40 cm hr^{-1} [mg L^{-1}]

SRT[a]	Holding		Spike		Influent		Sand		Sand + RAC		Sand + Biochar	
-3.0	176	±1	190	±2	-	-	189	±1	189	±1	185	±6
-0.3	85	±0	99	±10	94	±1	121	±40	126	±16	129	±38
1.8	110	±41	170	±10	170	±3	148	±48	144	±30	127	±39
5.9	117	±46	153	±43	173	±6	157	±21	174	±5	148	±47
9.8	162	±2	90	±5	169	±1	163	±5	141	±44	161	±13
13.8	177	±10	153	±47	166	±26	177	±4	177	±2	173	±6
15.9	203	±30	106	±4	140	±50	189	±14	182	±34	192	±10
20.9	171	±1	116	±24	127	±38	138	±44	122	±38	162	±2
23.0	171	±1	96	±3	139	±43	113	±23	103	±16	113	±30
26.8	167	±1	112	±16	149	±46	122	±34	126	±34	148	±45
28.9	172	±2	172	±0	147	±34	135	±40	164	±9	147	±30
Avg[b]	155	±35	132	±36	147	±24	150	±27	150	±29	153	±25

Average ± standard deviation (n=3)
[a] System run time relative to the start of the challenge test [days]
[b] Average ± standard deviation (n=3) for duration of challenge test

Table 64 Total Dissolved Solids in Column Effluent – 60 cm hr^{-1} [mg $L^{-1Black}$]

SRT	Holding		Spike		Influent		Sand		Sand + RAC		Sand + Biochar	
-4.3	125	±6	117	±28	97	±3	103	±2	122	±36	104	±6
-2.5	146	±1	156	±3	156	±1	156	±1	158	±1	157	±1
0.5	173	±1	179	±2	179	±1	173	±1	174	±1	175	±0
4.5	188	±14	188	±0	188	±1	189	±1	185	±1	187	±1
7.6	181	±1	190	±1	188	±1	188	±1	188	±1	188	±0
9.7	167	±8	173	±0	172	±1	172	±1	172	±1	171	±2
Avg	164	±24	167	±28	163	±35	164	±32	167	±24	164	±31

Average ± standard deviation (n=3)
[a] System run time relative to the start of the challenge test [days]
[b] Average ± standard deviation (n=3) for duration of challenge test

Table 65 Turbidity in Column Effluent – 40 cm hr^{-1} [FNU]

SRT	Holding		Spike		Influent		Sand		Sand + RAC		Sand + Biochar	
-3.1	67.5	±7.1	7.9	±0.2	-	-	0.8	±0.0	0.9	±0.1	0.5	±0.1
-0.3	63.6	±15.4	18.8	±0.5	17.8	±0.3	2.1	±0.1	2.1	±0.6	1.5	±0.3
1.8	154.7	±24.5	15.7	±1.7	17.5	±1.6	3.4	±0.3	3.5	±0.3	2.8	±0.3
5.9	75.7	±9.0	15.4	±0.1	14.0	±2.7	3.7	±0.1	3.8	±0.2	3.3	±0.2
9.8	64.1	±1.0	17.7	±0.3	15.0	±0.4	4.6	±0.1	4.4	±0.3	4.0	±0.3
13.8	89.4	±1.8	22.6	±0.8	20.7	±0.6	6.7	±0.4	6.5	±0.4	5.5	±0.3
15.9	147.0	±6.0	14.7	±0.5	19.3	±3.6	4.5	±0.2	4.1	±0.2	3.7	±0.1
20.9	100.2	±0.7	38.0	±0.6	41.7	±2.1	5.8	±0.3	5.2	±0.1	3.7	±0.2
23.0	104.3	±1.5	20.1	±2.3	16.1	±0.9	2.8	±0.1	2.7	±0.3	2.6	±0.3
26.8	237.7	±9.0	25.5	±1.5	28.0	±0.1	3.4	±0.2	3.5	±0.1	3.3	±0.5
28.9	123.3	±3.2	50.3	±3.5	38.6	±4.5	5.0	±0.1	4.8	±0.1	4.5	±0.1
Avg[b]	111.6	±52.6	22.4	±12.0	22.9	±9.9	3.9	±1.7	3.8	±1.5	3.2	±1.4

Average ± standard deviation (n=3)
[a] System run time relative to the start of the challenge test [days]
[b] Average ± standard deviation (n=3) for duration of challenge test

Table 66 Turbidity in Column Effluent – 60 cm hr^{-1} [FNU]

SRT	Holding		Spike		Influent		Sand		Sand + RAC		Sand + Biochar	
-4.3	38.9	±2.0	15.4	±0.4	13.1	±0.3	4.0	±0.1	4.3	±0.6	1.8	±0.3
-2.5	81.6	±3.9	17.2	±0.9	13.0	±0.2	2.7	±0.1	1.9	±0.3	1.3	±0.0
0.5	87.8	±1.6	14.3	±0.4	13.9	±0.5	4.1	±0.7	3.2	±0.2	2.9	±0.1
4.5	71.0	±3.0	11.0	±0.3	10.7	±0.9	2.7	±0.2	2.6	±0.1	2.2	±0.1
7.6	138.7	±0.6	26.0	±0.1	26.4	±1.4	7.2	±0.8	6.5	±0.4	5.0	±0.1
9.7	134.0	±2.6	28.3	±0.7	23.8	±2.1	5.3	±0.4	5.8	±0.2	4.8	±0.3
Avg[b]	92.0	±38.3	18.7	±6.9	16.8	±6.6	4.3	±1.7	4.1	±1.8	3.0	±1.6

Average ± standard deviation (n=3)
[a] System run time relative to the start of the challenge test [days]
[b] Average ± standard deviation (n=3) for duration of challenge test

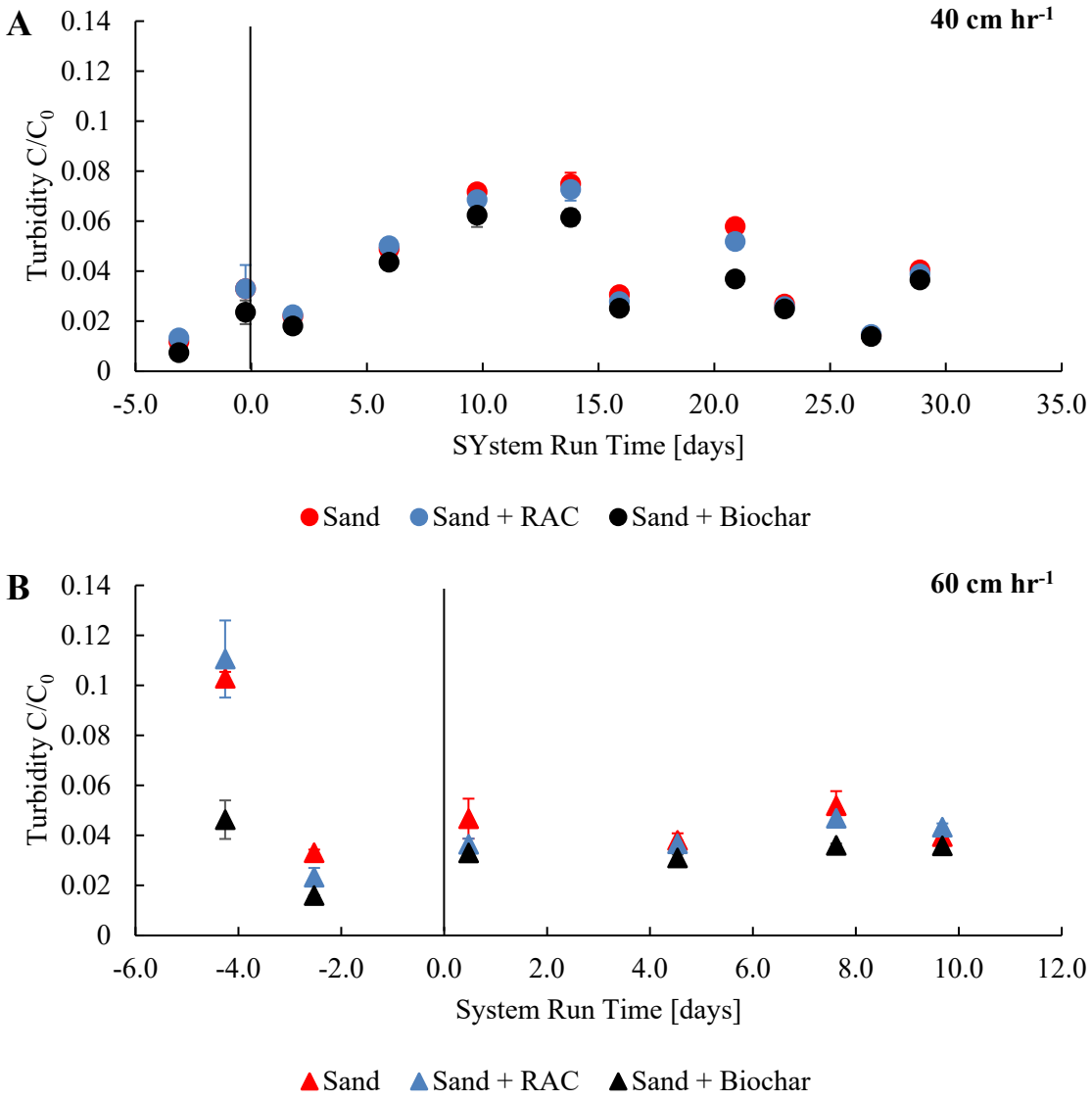

Figure 85 Turbidity over time in the 40 cm hr^{-1} (top) and 60 cm hr^{-1} (bottom) experiments for the sand (red), RAC (blue), and biochar (black) columns. Points indicate mean (n=3) and error bars indicate one standard deviation above and below the mean. Note that system run time<0 indicates conditioning period and system run time=0 indicates the beginning of the challenge experiment.

3.5 Metal Removal in Column Experiment

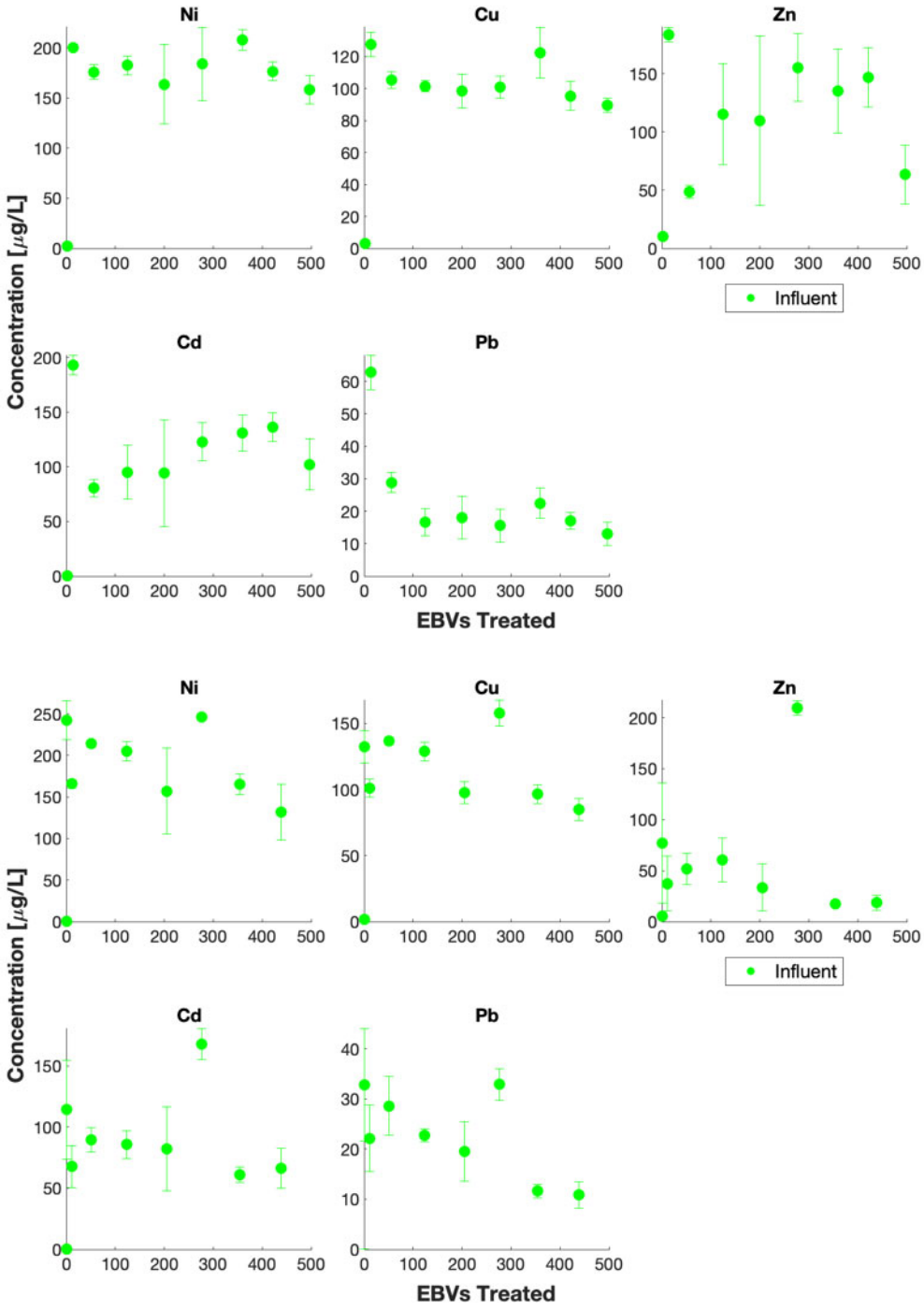

Figure 86 Dissolved metals in column influent during the 40 cm hr^{-1} (top) and 60 cm hr^{-1} (bottom) experiments. Point indicates mean (n=3) and error bars indicate one standard deviation above and below the mean).

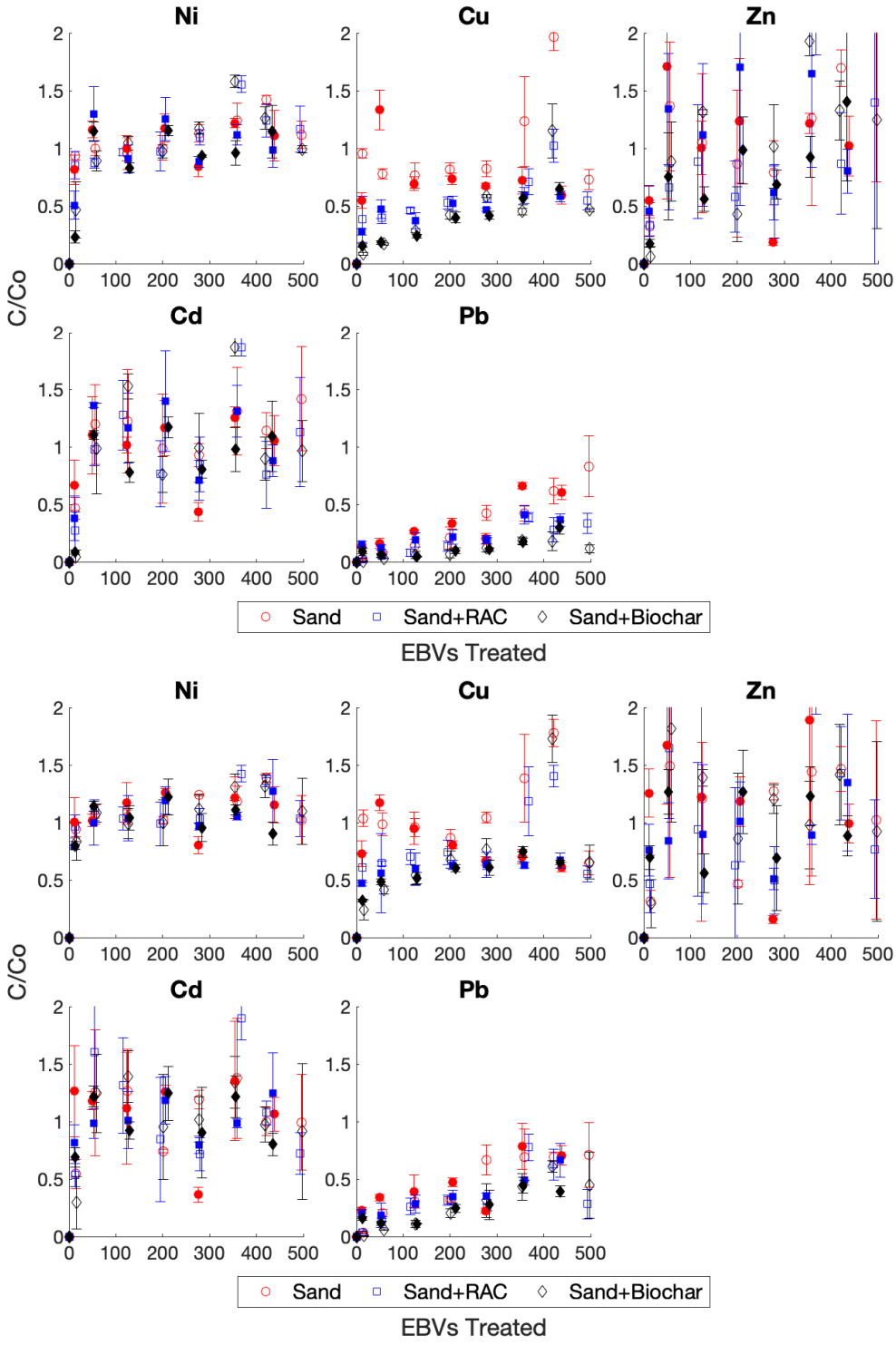

Figure 87 Observed metal breakthrough at the 50% sample port (top) and 25% sample port (bottom) at 40 cm hr^{-1} (unfilled) and 60 cm hr^{-1} (filled) flow rates for sand, sand+RAC, and sand+biochar columns. Point indicates mean (n=3) and error bars indicate one standard deviation above and below the mean).

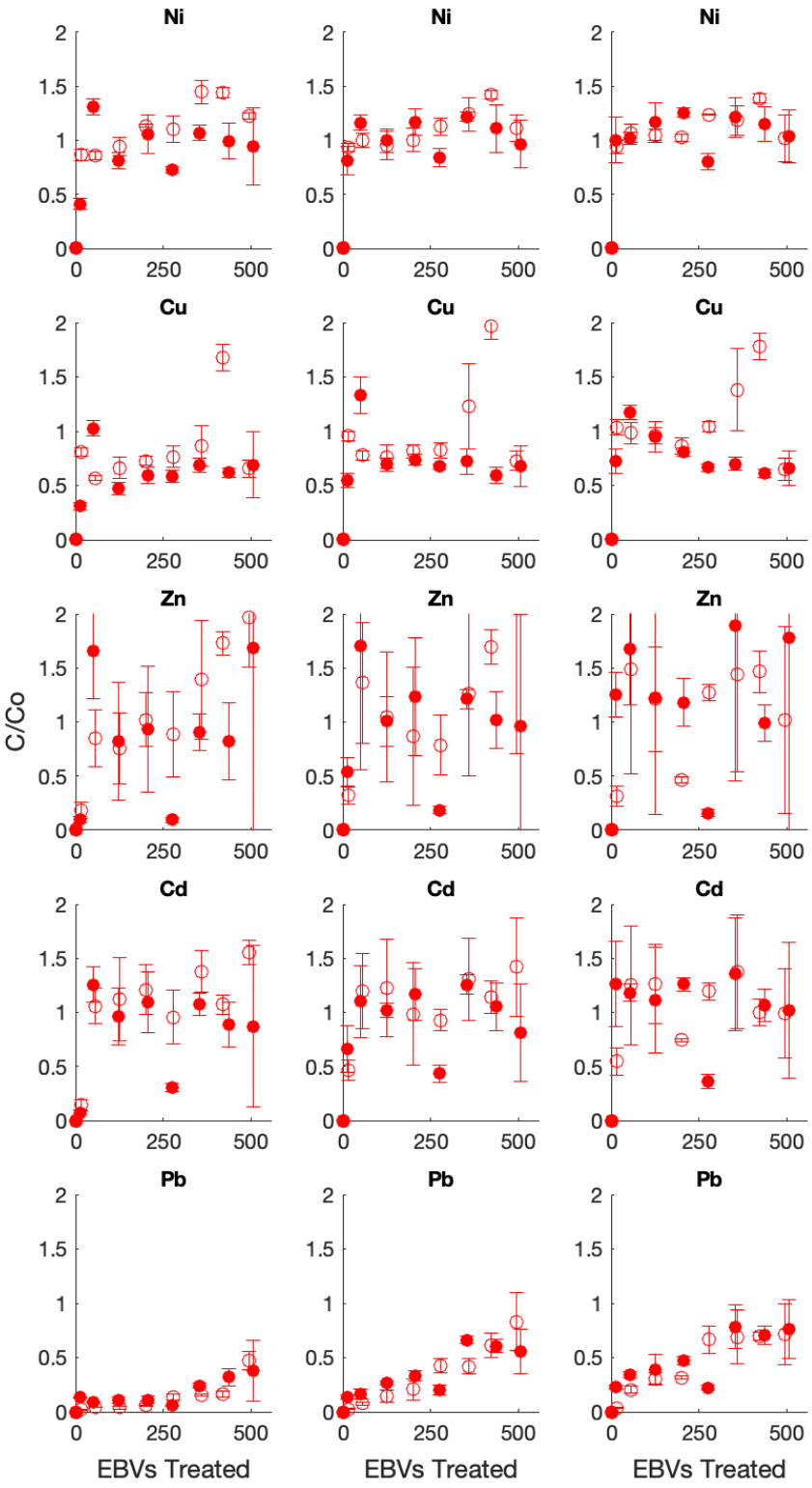

Figure 88 Contaminant breakthrough for sand columns in the effluent (left), 50% sample port (middle) and 25% sample port (right) at 40 cm hr^{-1} (unfilled) and 60 cm hr^{-1} (filled). Point indicates mean (n=3) and error bars indicate one standard deviation above and below the mean).

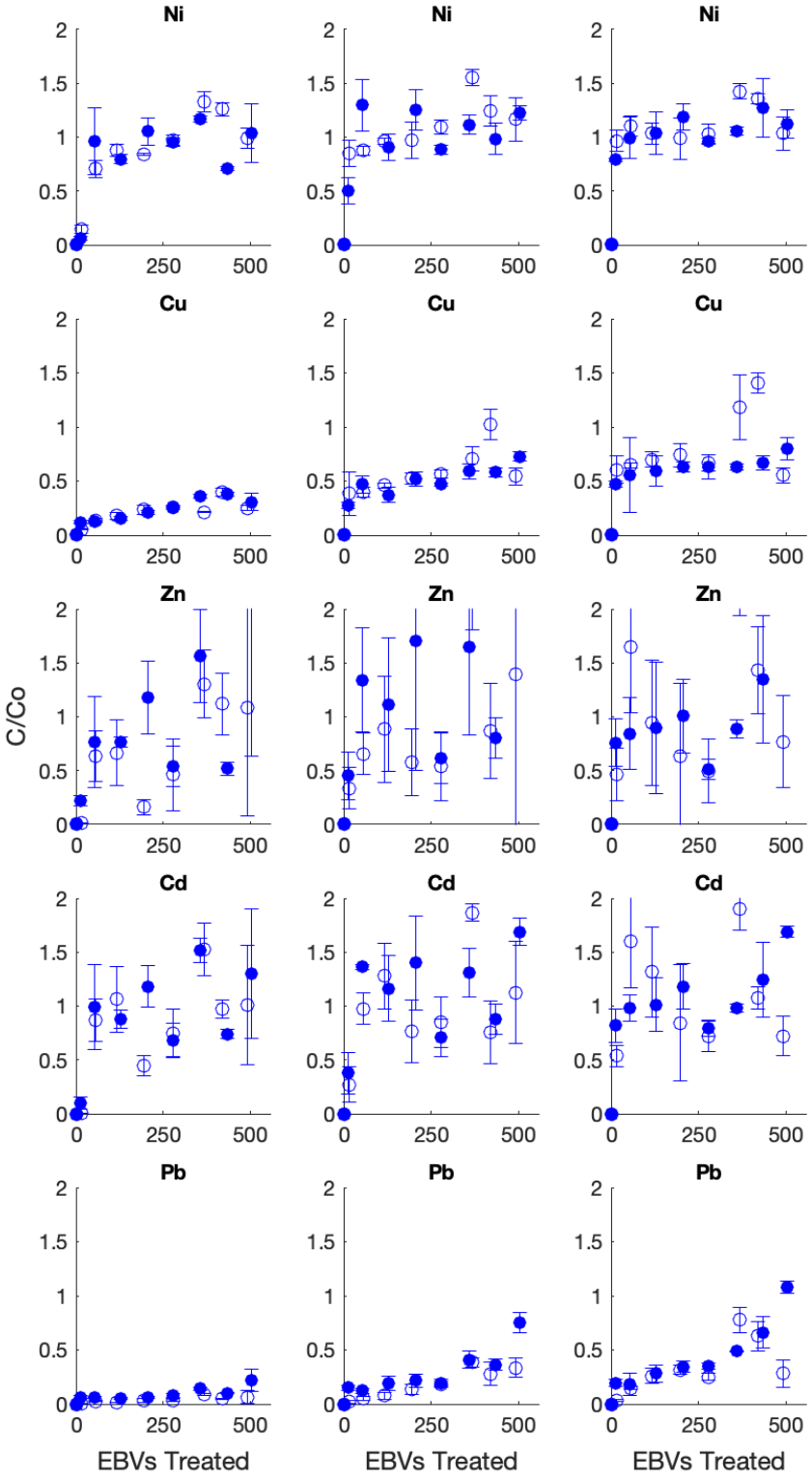

Figure 89 Contaminant breakthrough for RAC columns in the effluent (left), 50% sample port (middle) and 25% sample port (right) at 40 cm hr^{-1} (unfilled) and 60 cm hr^{-1} (filled). Point indicates mean (n=3) and error bars indicate one standard deviation above and below the mean).

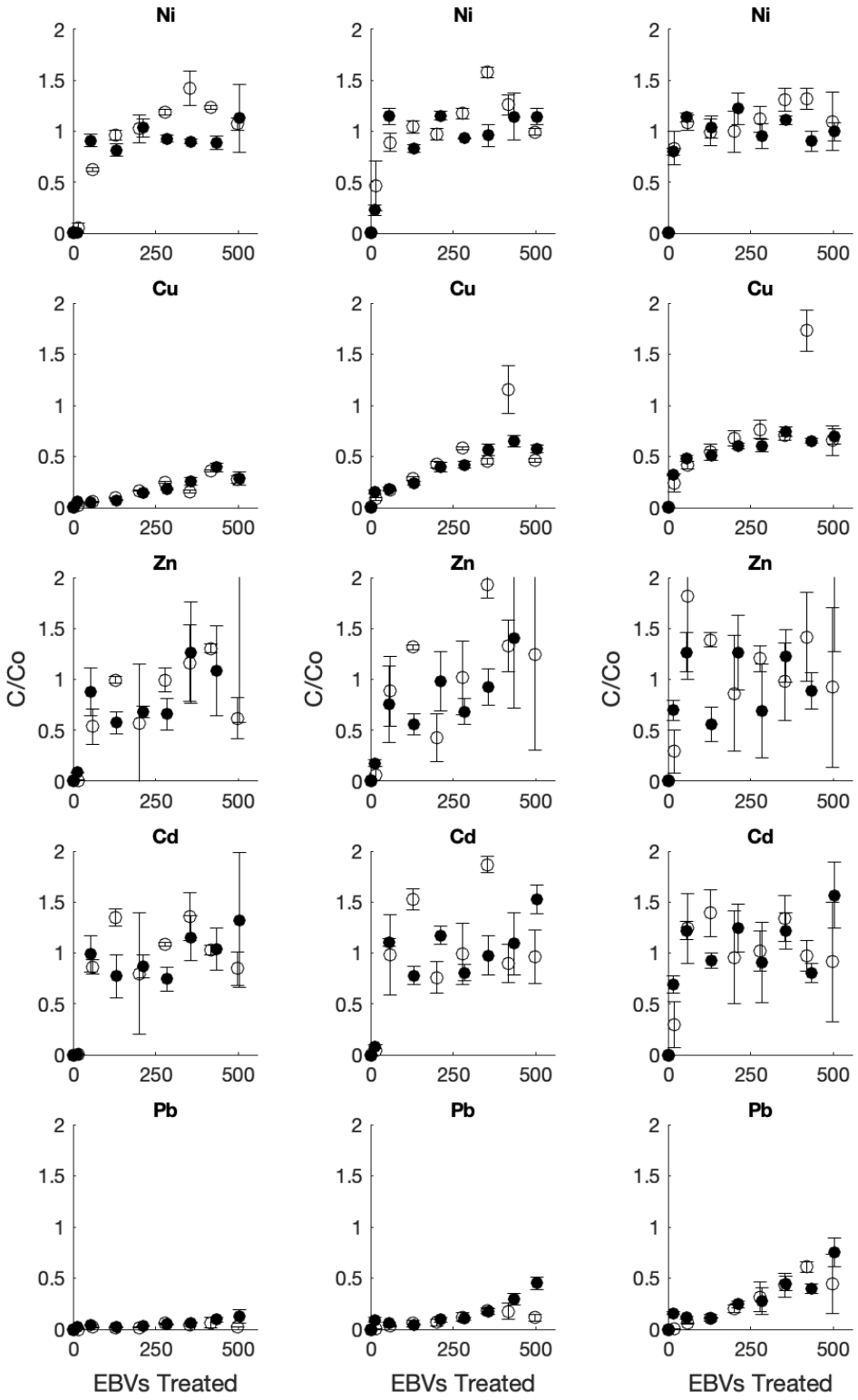

Figure 90 Contaminant breakthrough for biochar columns in the effluent (left), 50% sample port (middle) and 25% sample port (right) at 40 cm hr^{-1} (unfilled) and 60 cm hr^{-1} (filled). Point indicates mean (n=3) and error bars indicate one standard deviation above and below the mean).

3.6 Trace Organic Contaminant Removal in Column Experiment

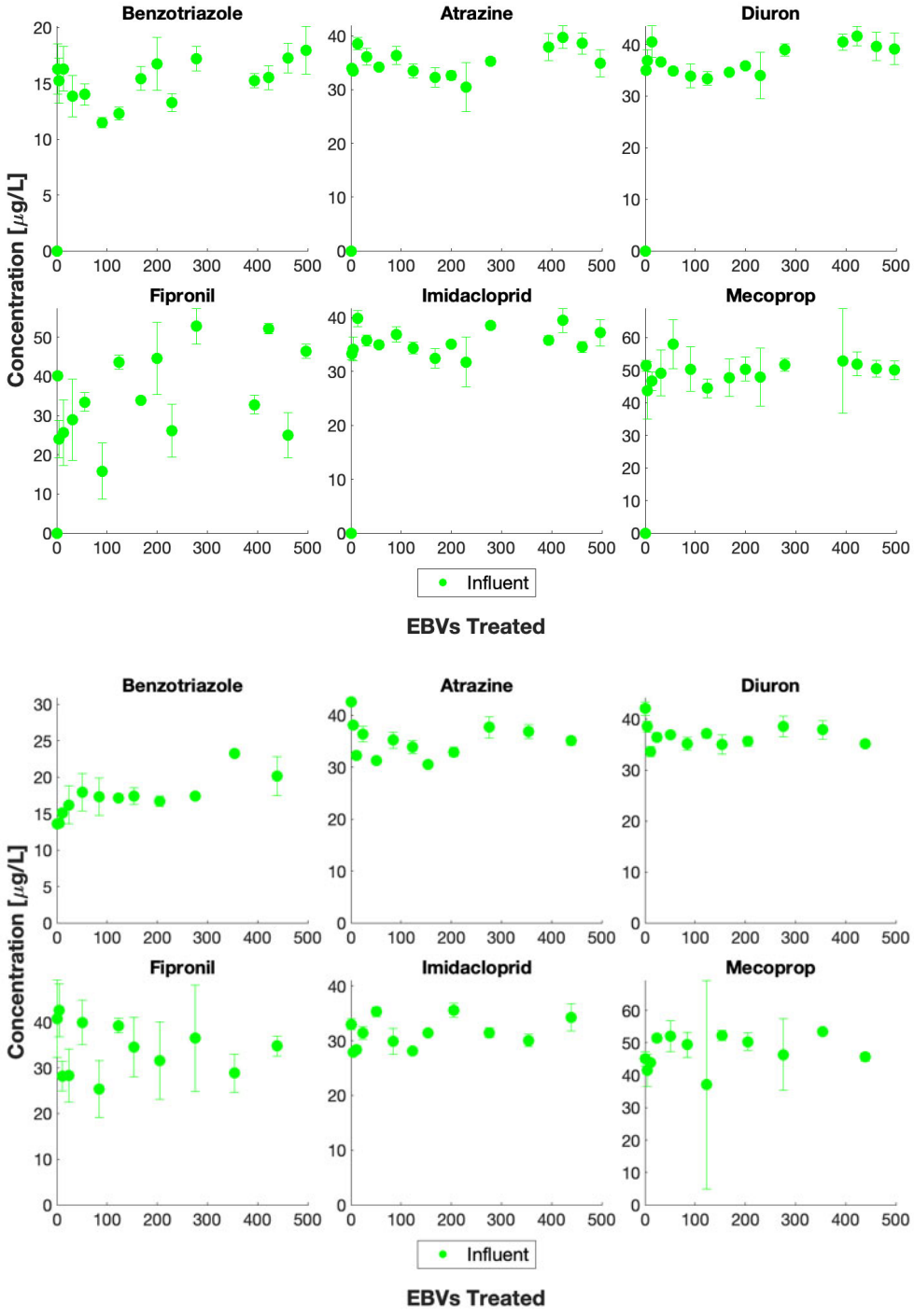

Figure 91 Dissolved metals in column influent during the 40 cm hr^{-1} (top) and 60 cm hr^{-1} experiment (bottom). Point indicates mean (n=3) and error bars indicate one standard deviation above and below the mean).

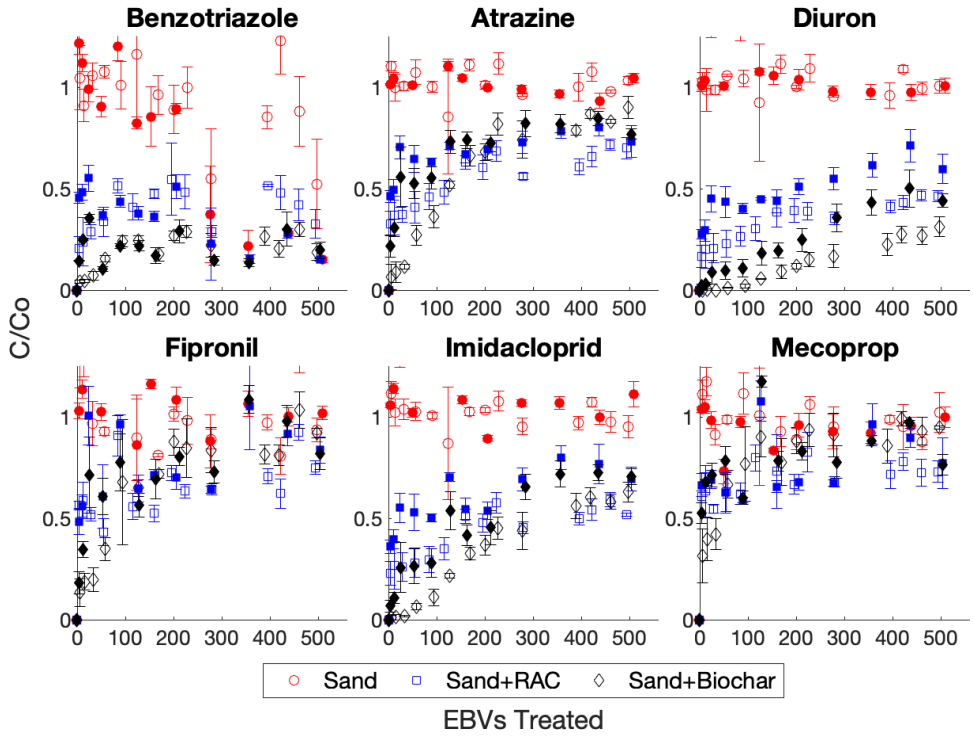

Figure 92 Observed hyphil-TrOCs breakthrough in the 25% sample port (bottom) at 40 cm hr^{-1} (unfilled) and 60 cm hr^{-1} (filled) flow rates for sand, sand+RAC, and sand+biochar columns. Point indicates mean (n=3) and error bars indicate one standard deviation above and below the mean).

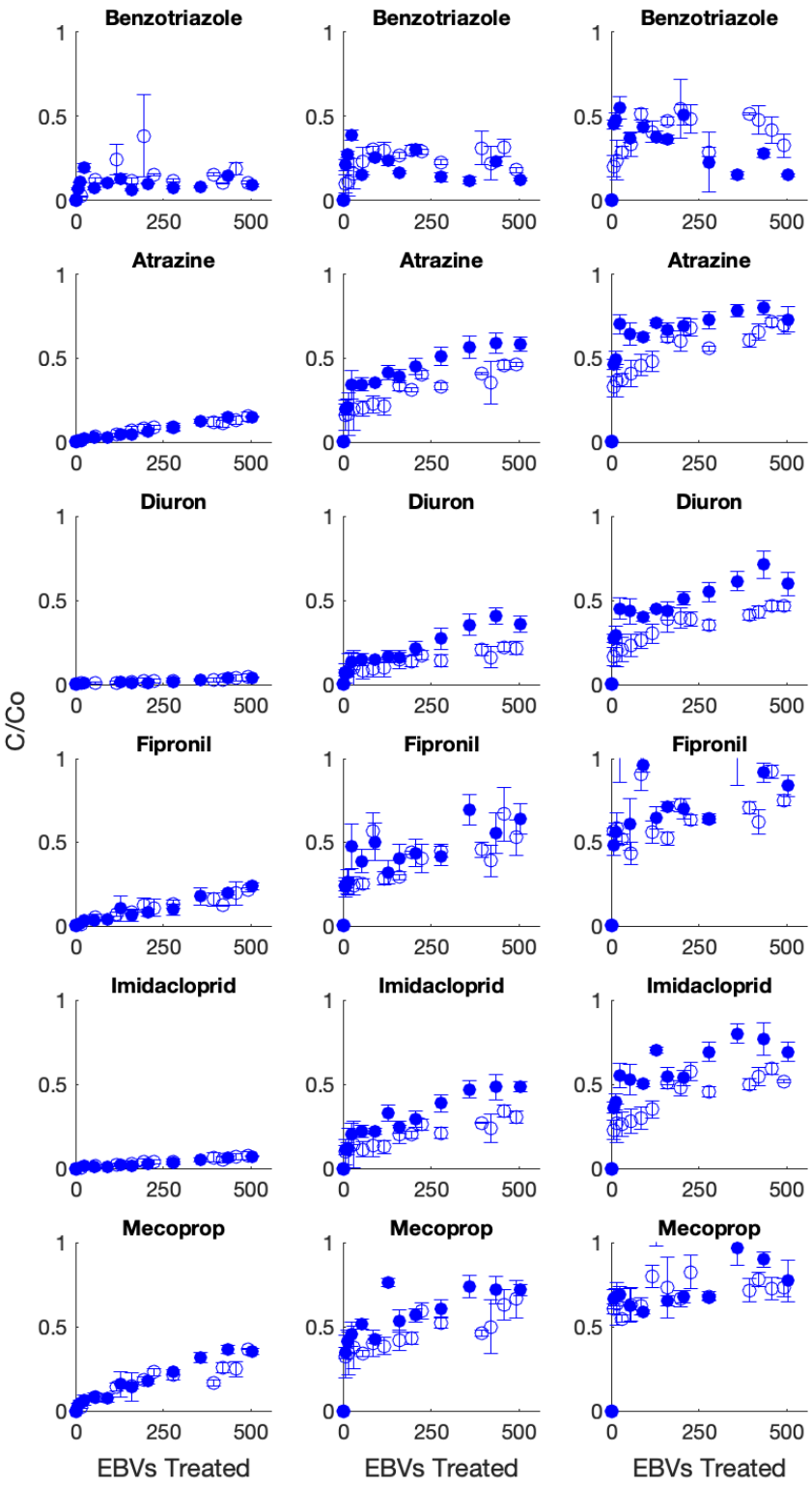

Figure 93 Contaminant breakthrough for biochar columns in the effluent (left), 50% sample port (middle) and 25% sample port (right) at 40 cm hr^{-1} (unfilled) and 60 cm hr^{-1} (filled). Point indicates mean (n=3) and error bars indicate one standard deviation above and below the mean).

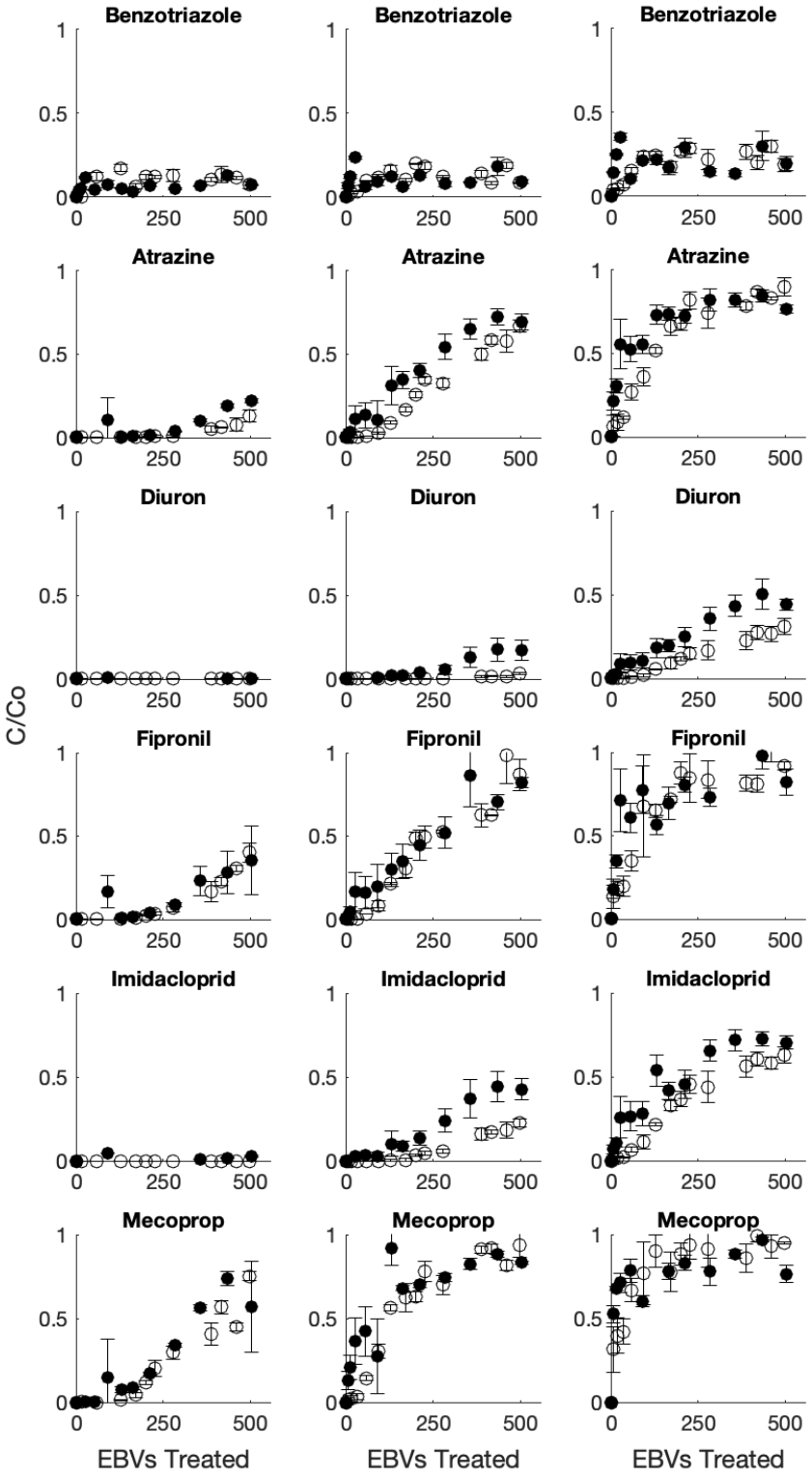

Figure 94 Contaminant breakthrough for biochar columns in the effluent (left), 50% sample port (middle) and 25% sample port (right) at 40 cm hr^{-1} (unfilled) and 60 cm hr^{-1} (filled). Point indicates mean (n=3) and error bars indicate one standard deviation above and below the mean).

3.7 Modeling Approach, Equations, and Parameters

Equations for the model approach may be found in the main text in section V.2.2 of this report.

Contaminant breakthrough curve fitting was conducted by fitting the Freundlich sorption parameters (K_f, 1/n) and tortuosity parameter (τ) using the fminsearch solver to minimize the NMSE. Initial guess parameters consisted of a tortuosity value of 2, K_f values of 0.1, 1, and 10, and a 1/n value of 2. Multiple rounds of fitting were conducted, using the optimal fit parameters from a single column replicate at each iteration as start parameters for all three of the column replicates in the next round of fitting, with fminsearch solver input parameters: maximum iterations = 40, 'TolX' = 0.001, and 'TolFun' = 0.01.

The optimal parameters found for the 25% sample port were used as start parameters for the fitting the breakthrough at the 50% sample port and for fitting the entire column.

Table 67 Sorption and tortuosity parameters fit at the 25% sample port.

Biochar	τ[a]			K_{fr}[b]			$1/n$[c]		
	B1	B2	B3	B1	B2	B3	B1	B2	B3
Atrazine	16.0	30.8	38.6	0.15	0.15	0.33	0.17	0.14	0.26
Benzotriazole	18.2	29.2	42.0	0.91	1.09	2.92	0.08	0.03	0.03
Diuron	17.4	36.7	30.1	1.09	2.03	4.83	0.09	0.07	0.02
Fipronil	16.3	25.2	24.7	0.08	0.11	0.11	0.29	0.26	0.35
Imidacloprid	13.2	18.1	20.6	0.57	0.33	0.67	0.19	0.17	0.27
Mecoprop	51.9	70.9	61.3	0.22	0.19	0.03	0.22	0.20	0.12
RAC	τ[a]			K_{fr}[b]			n[c]		
	B1	B2	B3	B1	B2	B3	B1	B2	B3
Atrazine	38.0	31.6	30.1	0.26	0.74	0.24	0.23	0.37	0.19
Benzotriazole	32.8	25.2	24.5	0.74	0.21	0.31	0.13	0.04	0.04
Diuron	0.0	17.8	15.7	0	4.39	1.61	###	0.41	0.29
Fipronil	31.8	24.9	14.4	0.13	0.12	0.05	0.26	0.30	0.25
Imidacloprid	27.3	21.8	19.7	0.47	0.93	0.29	0.19	0.34	0.17
Mecoprop	62.4	50.4	51.1	0.26	0.49	0.58	0.23	0.37	0.29

[a] Tortuosity [-]
[b] Freundlich sorption capacity coefficient $[(\text{mol L}^{-1})(\text{L mol}^{-1})^{1/n}]$
[c] Freundlich sorption intensity parameter [-]

Table 68 Sorption and tortuosity parameters fit at the 50% sample port.

Biochar	τ[a]			K_{fr}[b]			$1/n$[c]		
	B1	B2	B3	B1	B2	B3	B1	B2	B3
Atrazine	18.7	30.6	38.9	0.52	0.46	0.24	0.31	0.24	0.15
Benzotriazole	20.5	31.2	40.1	1.68	1.88	2.76	0.14	0.16	0.08
Diuron	17.4	36.7	28.1	1.09	2.03	2.64	0.09	0.07	0.12
Fipronil	20.8	26.2	52.8	0.12	0.06	0.09	0.23	0.11	0.12
Imidacloprid	28.4	22.6	34.3	0.72	0.41	0.98	0.03	0.15	0.17
Mecoprop	43.3	55.4	48.6	0.13	0.28	0.61	0.20	0.25	0.44
RAC	τ[a]			K_{fr}[b]			n[c]		
	B1	B2	B3	B1	B2	B3	B1	B2	B3
Atrazine	38.9	33.9	25.7	0.26	0.65	0.31	0.26	0.31	0.24
Benzotriazole	30.4	31.4	24.6	0.54	0.24	0.24	0.27	0.07	0.04
Diuron	2.3	18.1	15.8	1.28	1.39	0.74	0.33	0.33	0.24
Fipronil	23.9	26.5	24.0	0.21	0.29	0.29	0.34	0.34	0.35
Imidacloprid	24.3	22.6	16.5	0.47	0.41	0.36	0.29	0.22	0.22
Mecoprop	69.5	60.2	48.2	0.14	0.17	0.16	0.18	0.16	0.14
Biochar		τ[a]			K_{fr}[b]			$1/n$[c]	
	B1	B2	B3	B1	B2	B3	B1	B2	B3
PFHxA	58.2	49.6	12.9	0.0400	0.0365	0.0421	0.62	0.61	0.69
PFOA	51.6	64.6	72.1	0.0041	0.0017	0.0046	0.37	0.29	0.37
PFPeS	56.8	62.3	73.0	0.0100	0.0065	0.0100	0.43	0.39	0.44
PFHxS	51.2	62.3	67.3	0.0107	0.0077	0.0118	0.36	0.31	0.36
PFOS	20.2	39.4	43.3	0.0384	0.0259	0.0262	0.40	0.31	0.33
CL-PFOS	3.9	35.1	16.7	0.0189	0.0110	0.0075	0.58	0.45	0.45
FHxSA	44.3	49.6	59.2	0.0080	0.0040	0.0268	0.43	0.39	0.13
		τ[a]			K_{fr}[b]			$1/n$[c]	
	B1	B2	B3	B1	B2	B3	B1	B2	B3
PFHxA	63.6	47.1	52.7	0.0248	0.0283	0.0228	0.51	0.54	0.46
PFOA	51.4	31.9	33.9	0.0015	0.0035	0.0025	0.27	0.35	0.29
PFPeS	41.0	27.8	29.0	0.0034	0.0112	0.0042	0.33	0.42	0.29
PFHxS	48.0	29.8	33.0	0.0129	0.0482	0.0070	0.36	0.45	0.29
PFOS	30.9	21.6	22.0	0.0198	0.0233	0.0272	0.25	0.33	0.27
CL-PFOS	26.8	19.1	20.1	0.0038	0.0110	0.0112	0.34	0.43	0.36
FHxSA	77.0	39.4	49.9	0.0100	0.0081	0.0059	0.49	0.47	0.51

[a] Tortuosity [-]

[b] Freundlich sorption capacity coefficient $[(\text{mol L}^{-1})(\text{L mol}^{-1})^{1/n}]$

[c] Freundlich sorption intensity parameter [-]

3.8 Modeling Bromide Tracer Tests

Bromide test were conducted by delivering a 30s pulse of bromide through the columns and sampling at pre-determined time intervals. The water level in the columns was maintained at the top of the barrier sand layer to eliminate standing water and prevent any initial dilution of the tracer above the barrier sand. DI water was used in the tracer studies and was delivered to each column to maintain a face velocity of 20 cm hr^{-1}. Flow rate was confirmed at the beginning and end of the tracer test. The bromide tracer test parameters are shown in Table 69. The tracer tests results are shown below in Figure 95.

Table 69 Bromide tracer test parameters.

Mixture	Influent Concentration [mM]	Bromide Pulse [s]	Sampling Time [min]
Sand	5	30	186
+ Zeolite	5	30	186
+ Biochar	100	30	430
+ Zeolite + Biochar	100	30	430
+ RAC	200	30	700
+ Zeolite + RAC	200	30	700

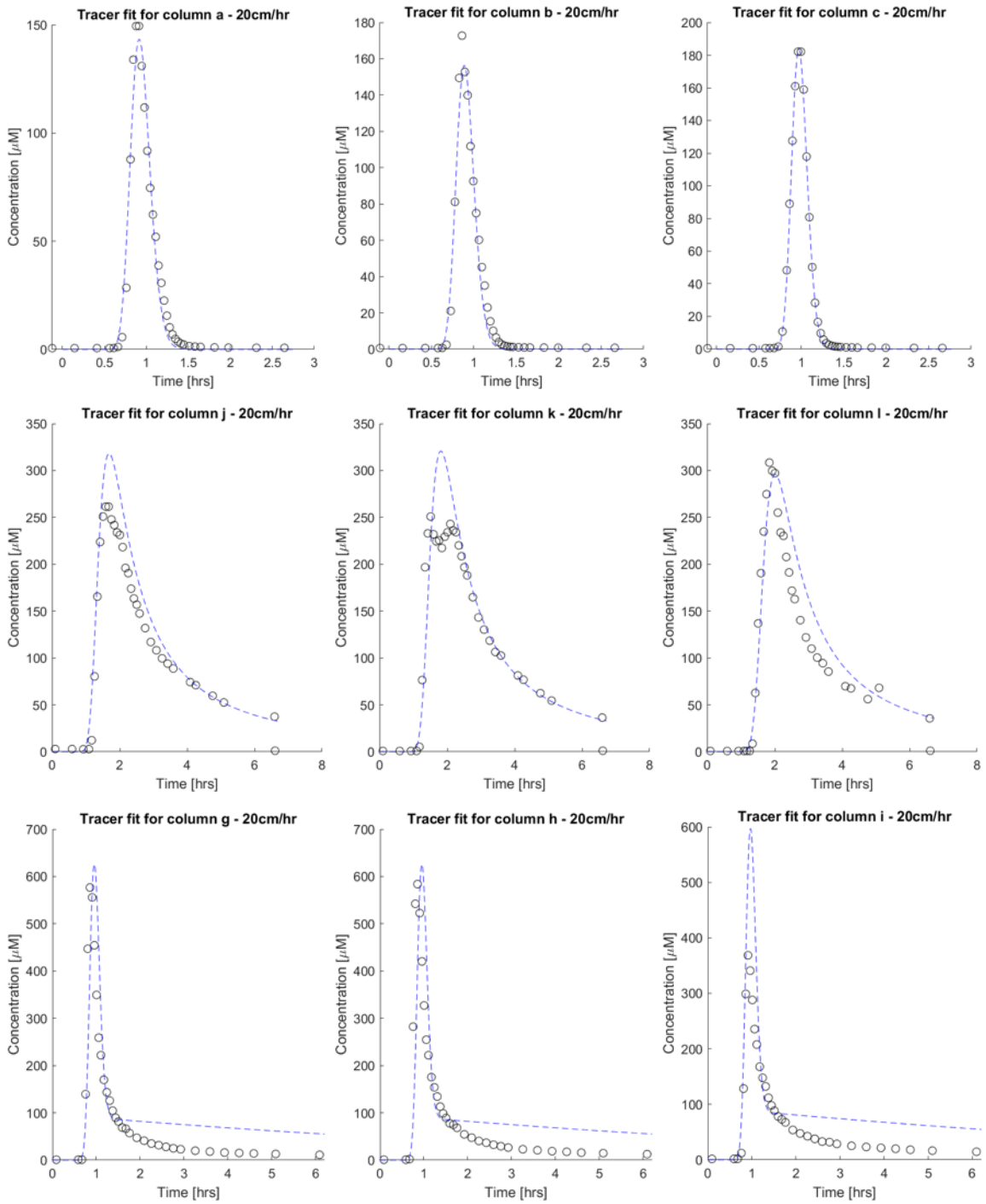

Figure 95 Predicted tracer breakthrough curves (dashed line) plotted with observed tracer breakthrough in column effluent (circles) for sand (top, a-c), biochar (middle, j-l), and RAC (bottom, g-i) columns. Note that the bromide pulse concentration differed for the sand (C_0 = 5mM), biochar (C_0 = 100mM), and RAC (C_0 = 200mM).

3.9 Contaminant Transport Modeling

Fit at 25% Sample Port:

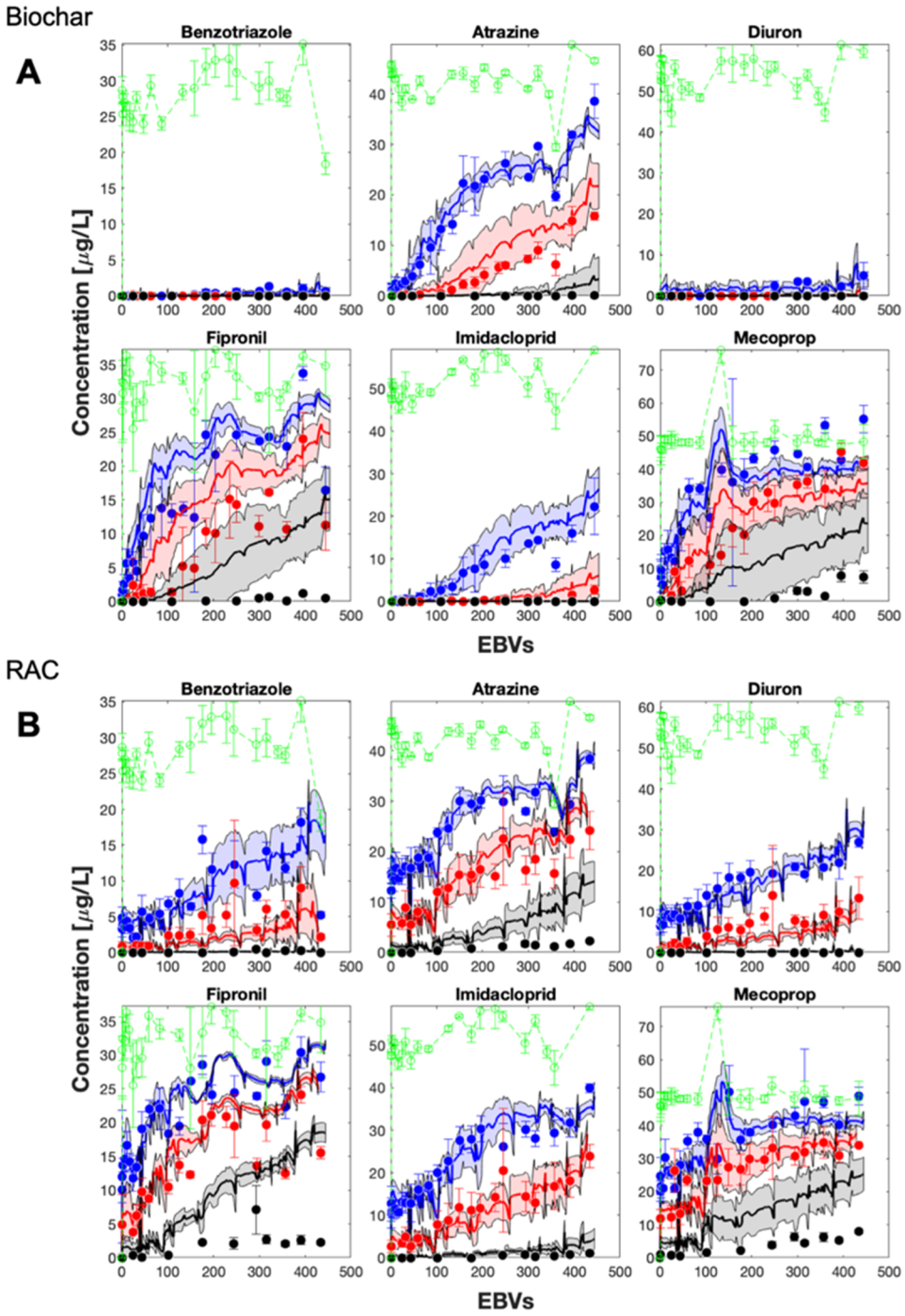

Figure 96 Observed (points) and predicted (line) and breakthrough curves for biochar (top) and RAC (bottom) at 20 cm hr^{-1} as found by fitting the observed breakthrough at the 25% sample port. Column breakthrough is shown at each the 25% sample port (blue), 50% sample port (red), and effluent (black). Shaded area shows the standard deviation on the predicted breakthrough curve. Mean observed influent (green) is plotted and error bars show one standard deviation above and below the mean.

Fit at 50% Sample Port:

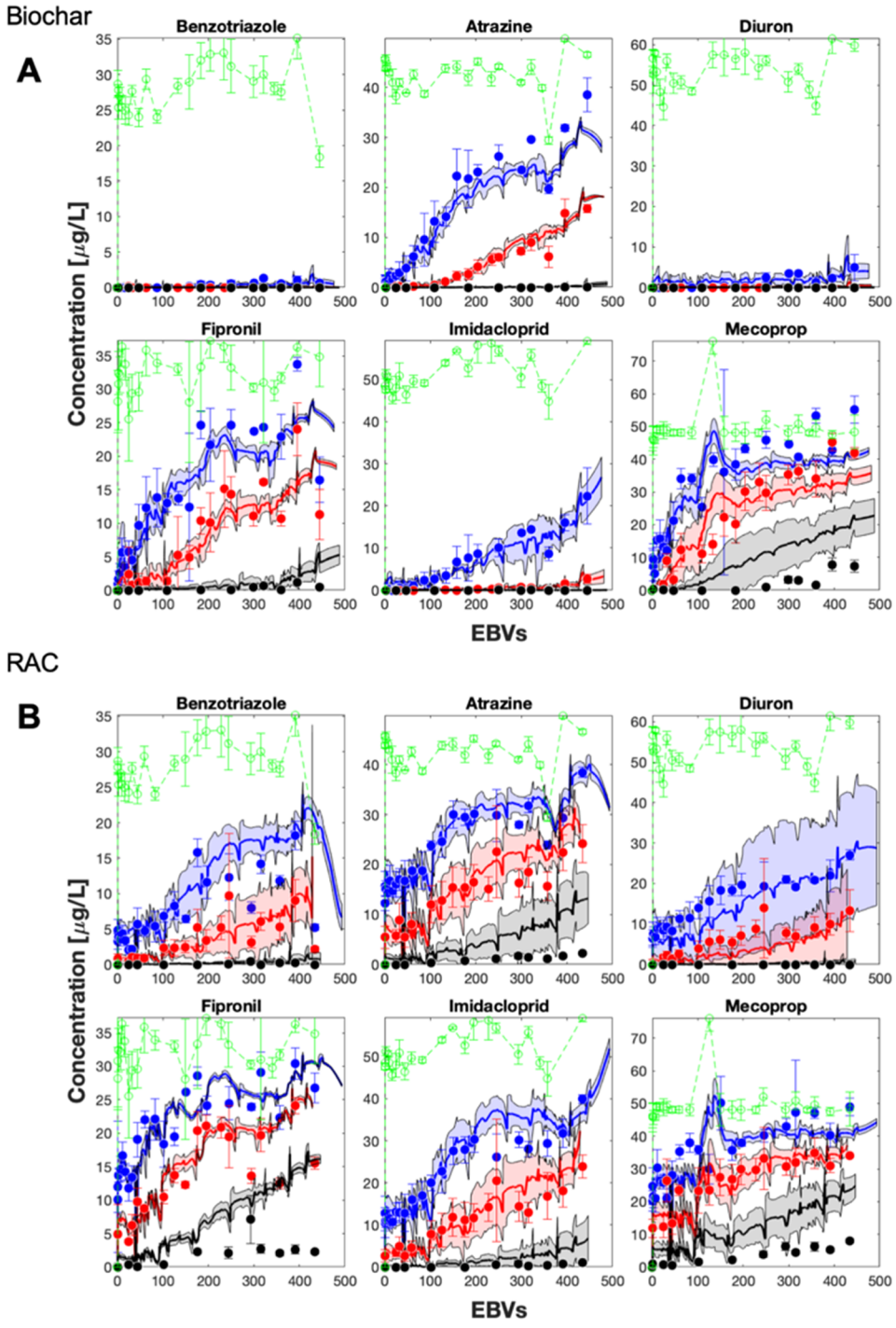

Figure 97 Observed (points) and predicted (line) and breakthrough curves for biochar (top) and RAC (bottom) at 20 cm hr^{-1} as found by fitting the observed breakthrough at the 50% sample port. Column breakthrough is shown at each the 25% sample port (blue), 50% sample port (red), and effluent (black). Shaded area shows the standard deviation on the predicted breakthrough curve. Mean observed influent (green) is plotted and error bars show one standard deviation above and below the mean.

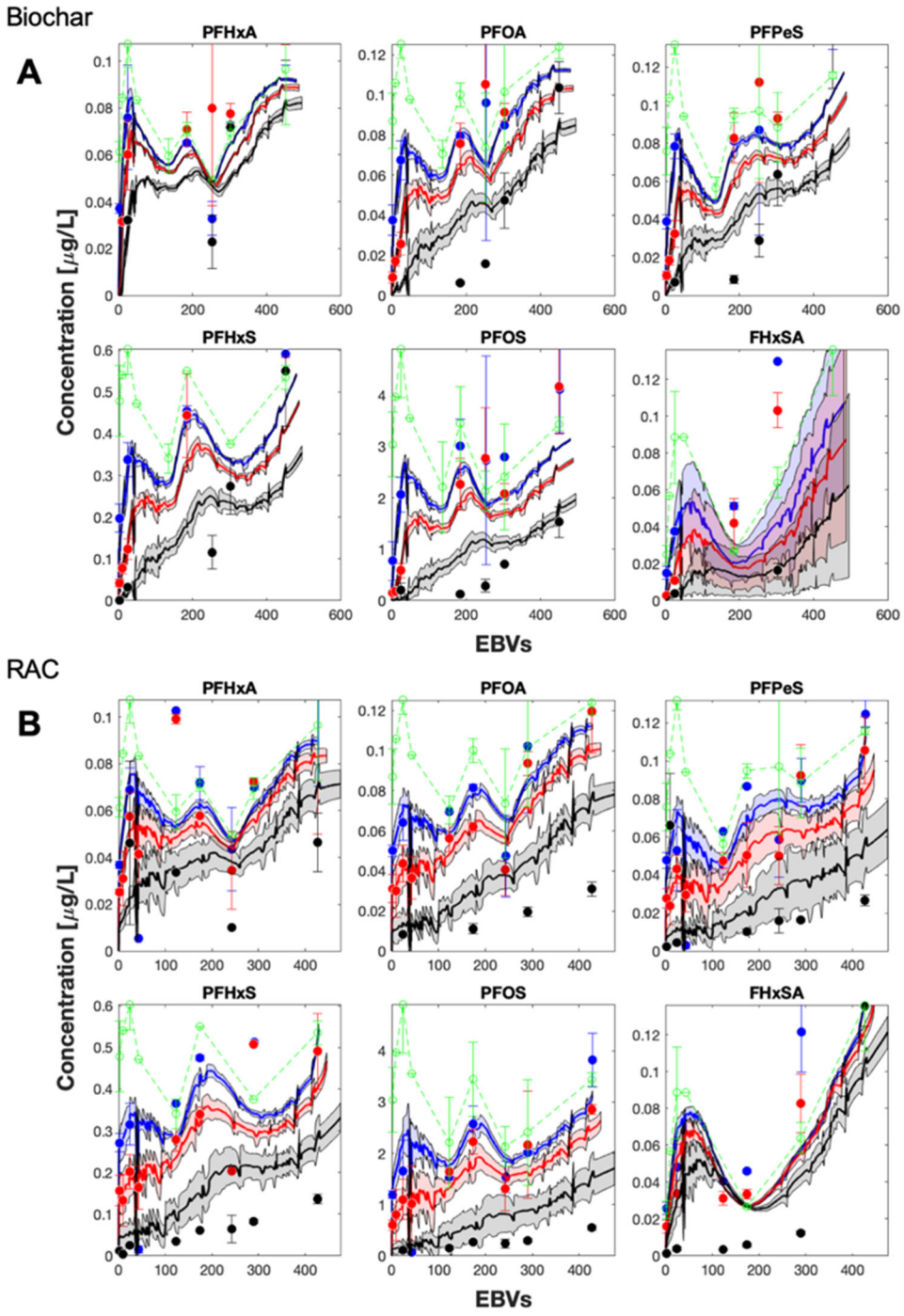

Figure 98 Observed (points) and predicted (line) and breakthrough curves for biochar (top) and RAC (bottom) at 20 cm hr^{-1} as found by fitting the observed breakthrough at the 50% sample port. Column breakthrough is shown at each the 25% sample port (blue), 50% sample port (red), and effluent (black). Shaded area shows the standard deviation on the predicted breakthrough curve. Mean observed influent (green) is plotted and error bars show one standard deviation above and below the mean.

Fit Using Isotherm Sorption Parameters:

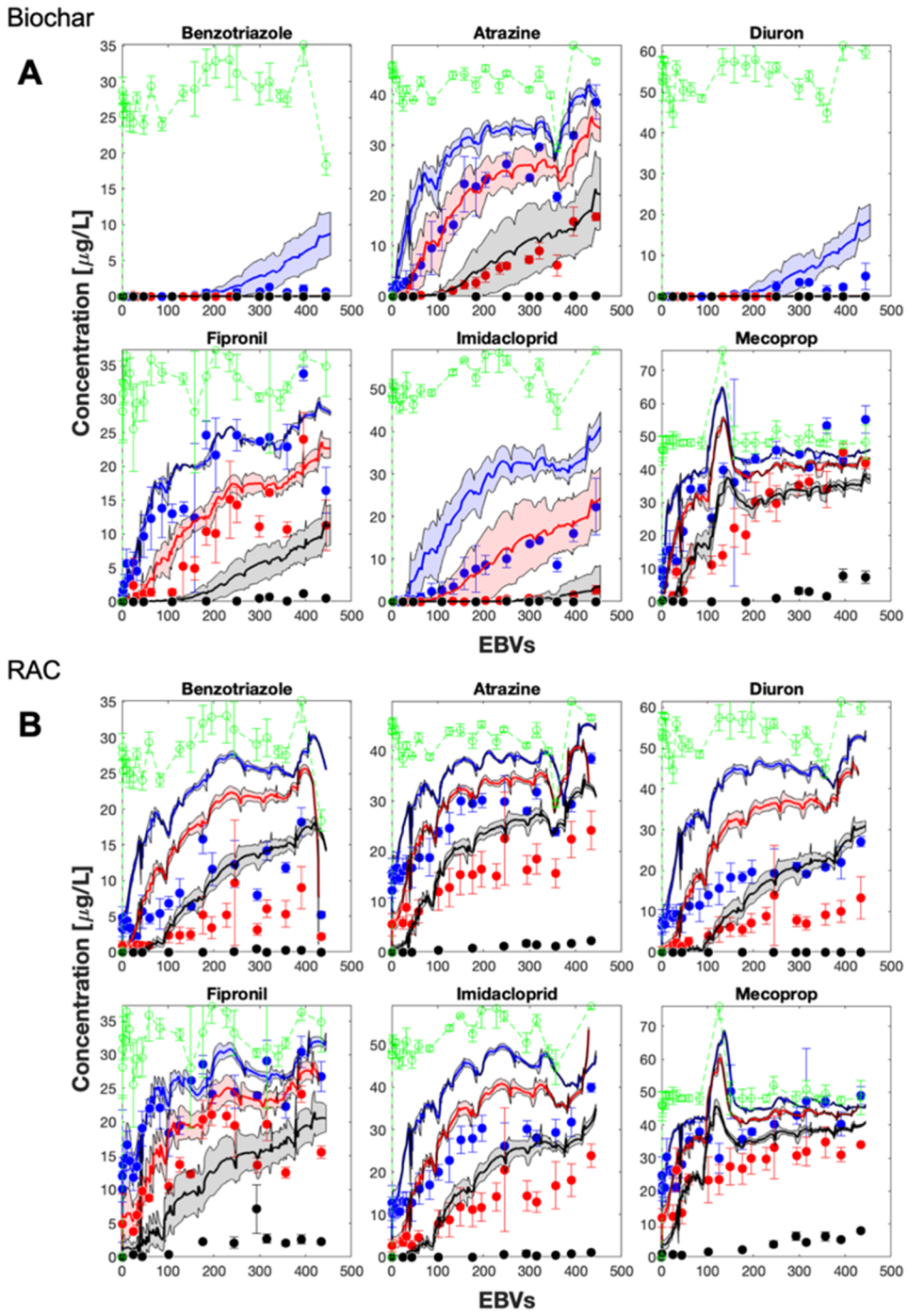

Figure 99 Observed (points) and predicted (line) and breakthrough curves for biochar (top) and RAC (bottom) at 20 cm hr^{-1} as found by using the isotherm parameters and fitting the tortuosity using the observed breakthrough from the full column. Column breakthrough is shown at each the 25% sample port (blue), 50% sample port (red), and effluent (black). Shaded area shows the standard deviation on the predicted breakthrough curve. Mean observed influent (green) is plotted and error bars show one standard deviation above and below the mean.

3.10 Comparison of Sorption and Tortuosity Parameters

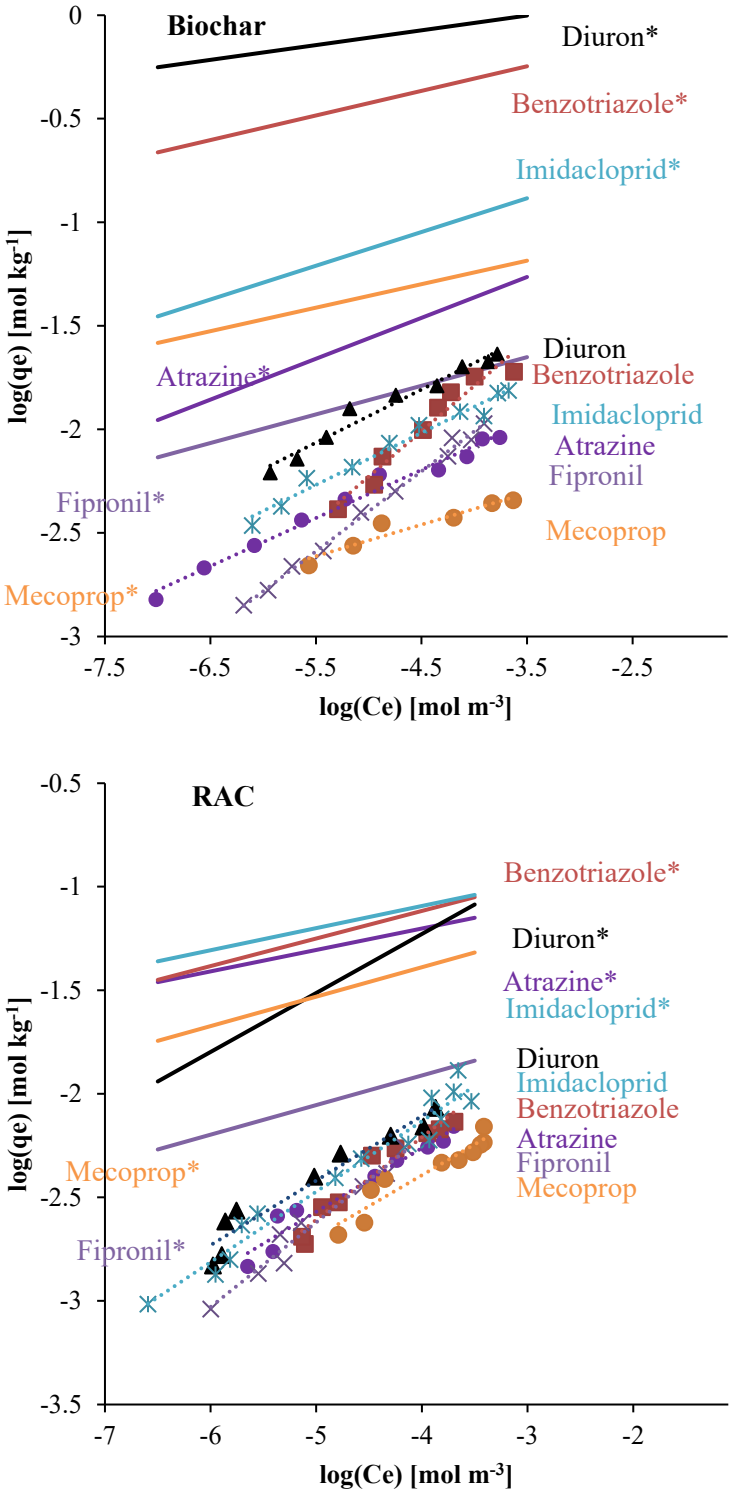

Figure 100 Batch isotherms (points) conducted with biochar (top) and RAC (bottom) plotted with isotherms derived fitting breakthrough curves observed from previous column experiments (line*).

Table 70 Freundlich Sorption Parameters Derived from Batch Isotherms and Column Experiment Breakthrough Curve-Fitting

	Isotherm			Fit from Column Experiment					
	K_{fr}^{b}	n [c]	r^2	K_{fr}^{b}			n [c]		
Biochar									
Diuron	0.22	0.26	0.98	0.70	0.72	1.49	0.12	0.12	0.10
Benzotriazole	0.92	0.44	0.97	0.76	0.43	0.37	0.13	0.11	0.15
Imidacloprid	0.13	0.25	0.99	0.61	0.35	0.64	0.10	0.12	0.18
Atrazine	0.07	0.23	0.99	0.31	0.34	0.48	0.24	0.20	0.20
Fipronil	0.34	0.39	1.00	0.12	0.07	0.06	0.22	0.15	0.12
Mecoprop	0.02	0.15	0.96	0.05	0.13	0.12	0.24	0.20	0.28
RAC									
Diuron	0.14	0.31	0.97	0.60	0.74	0.69	0.25	0.29	0.25
Benzotriazole	0.24	0.40	0.97	0.41	0.32	0.35	0.14	0.10	0.12
Imidacloprid	0.17	0.34	0.98	0.33	0.33	0.13	0.28	0.23	0.15
Atrazine	0.09	0.31	0.98	0.13	0.28	0.16	0.16	0.22	0.15
Fipronil	0.26	0.41	0.98	0.09	0.15	0.12	0.25	0.30	0.26
Mecoprop	0.06	0.30	0.95	0.03	0.11	0.2	0.16	0.18	0.24

[a] Triplicate values from individual replicate column fits
[b] Freundlich sorption capacity coefficient $[(\text{mol kg}^{-1})(\text{m}^3 \text{ mol}^{-1})^{1/n}]$
[c] Freundlich sorption intensity parameter [-]

3.11 Constant Empty Bed Contact Time Modeling

The model was used to test if four different filter designs with different bed depth and flow rate, but similar contact time and biochar content would yield similar breakthrough. The input parameters are shown below in Table 71 and the plot of the breakthrough is shown below in Figure 101.

Table 71 Model input parameters for constant EBCT experiment

EBCT=1hr		Trial 1	Trial 2	Trial 3	Trial 4
Face Velocity	cm hr^{-1}	20	40	60	120
Filter Length	[m]	0.20	0.4	0.6	1.2
Filter Volume	[L]	0.9	1.8	2.7	5.5
Mass BC	[kg]	0.033	0.066	0.099	0.199
Mass Sand	[kg]	1.070	2.140	3.211	6.421
Volume Sand	[L]	0.59	1.18	1.77	3.54
Volume BC	[L]	0.32	0.64	0.96	1.93
Biochar v%		35%	35%	35%	35%
Biochar wt%		3.0%	3.0%	3.0%	3.0%

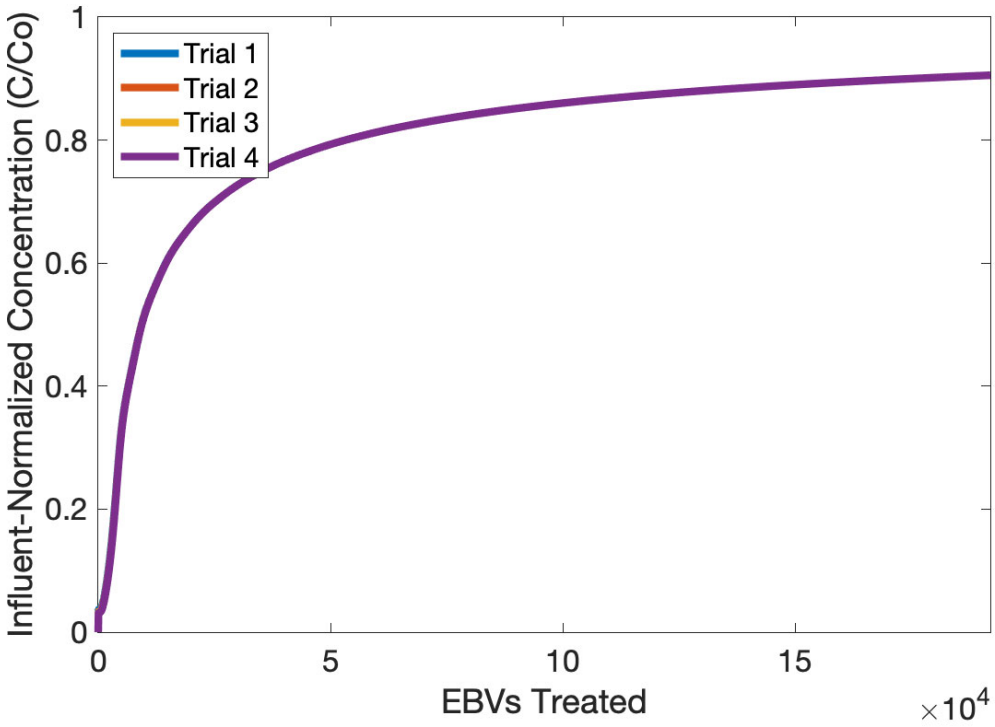

Figure 101 Predicted atrazine transport for various pairs of flow rate and filter depth (Table 71) with a constant empty bed contact time of 60 minutes and biochar content of 3 wt%.

3.12 Filter Performance Tables for TrOCs

Filter performance tables are shown below in XI. Appendix C. Note that values of 0 indicate that the level of breakthrough was unachievable and blank values indicate no breakthrough predicted.

4 Task 4 Saturated and Unsaturated Experiment

4.1 Bromide Tracer Test Results

Bromide tracer tests were conducted after the challenge test, as described in Section V.3.1.

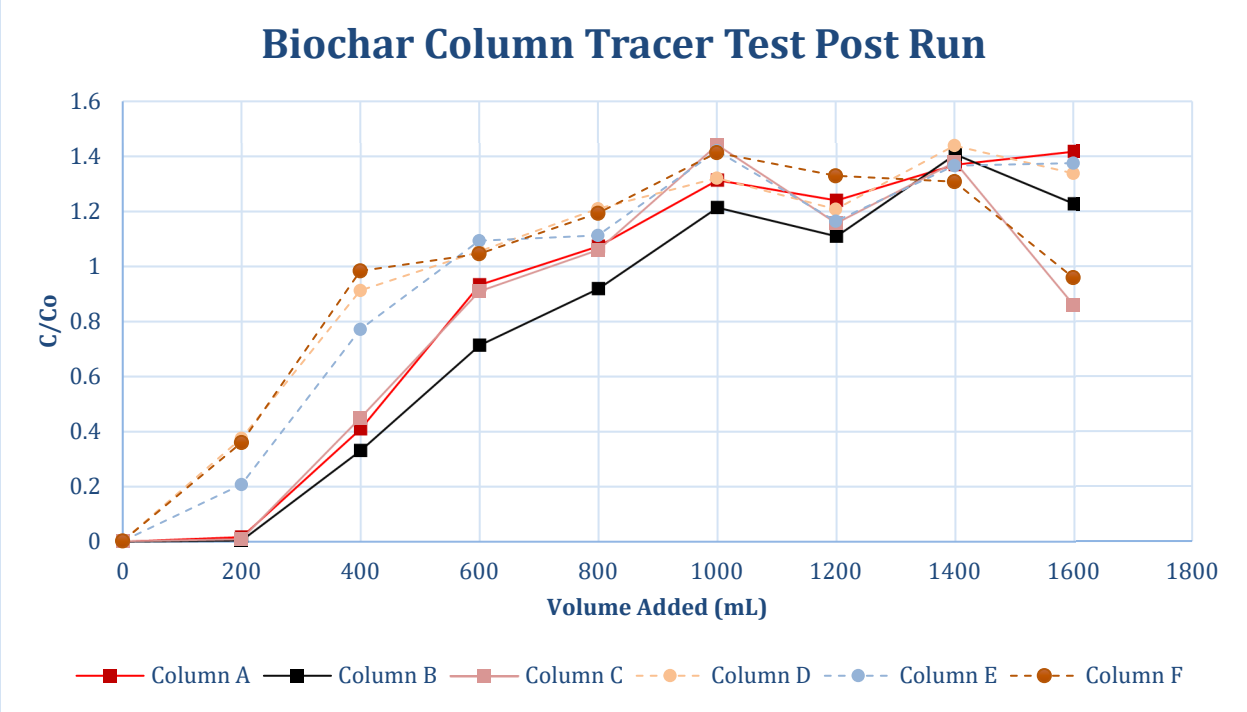

Figure 102 Results of the tracer test. Saturated columns shown with solid lines; unsaturated columns shown with dashed lines.

4.2 Water Quality Results

Table 72 Comparison of Influent and Effluent Concentrations Throughout the Challenge Test

Sample Location	DO [mg/L]	NO_3-N [mg/L]	pH	NH_3-N [mg/L]	Conductivity[µS]
Influent	5.48 (0.71)	2.46 (3.41)	7.72 (0.27)	1.75 (0.81)	430 (105)
Saturated effluent	*4.45 (0.39)*	*1.78 (0.29)*	7.73 (0.07)	*0.49 (0.15)*	450 (37)
Unsaturated effluent	*6.08 (0.33)*	*3.68 (0.55)*	7.85 (0.10)	*<0.015*	459 (77)

Confidence intervals (95%, two-tailed student's t-test) are indicated in parentheses. Cases where values for saturated effluent and unsaturated influent are statistically significant are indicated in italics.

4.3 PFASs Concentrations in Column Influent

Table 73 Mean Influent PFASs Concentration Throughout Experiment (n=3).

Contaminant	Concentration (ng/L)	Standard Deviation
PFPeS	127	127
PFHxS	643	448
PFHpS	113	116
PFOS	3996	1407
PFPeA	7	3
PFHxA	62	56
PFOA	133	116
Cl-PFOS	155	139
FBSA	152	152
FHxSA	6	3
PFEtCHxS	105	91

4.4 Metals Removal in Column Effluent

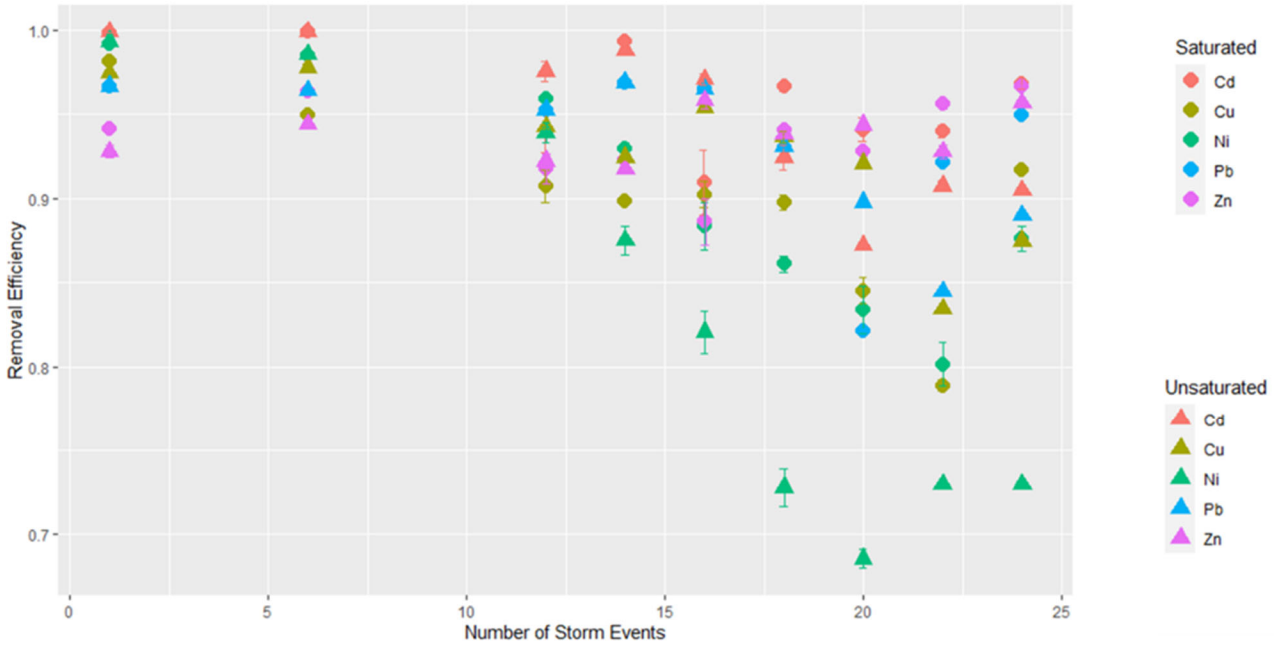

Figure 103 Average removal efficiency of metals. Error bars indicate one standard deviation above and below the mean (n=3).

5 Task 5 Column Experiments and Long-Term Predictive Modeling

5.1 Column Packing

Table 74 Mass of Material in Engineered Media Filters

Experiment	Sand	Biochar	Barrier Sand
Dynamic Flow	4,335.8	43.8	1,732.3
Dynamic Concentration	4,335.5	43.8	1,732.5
Low DOC	4,335.5	43.8	1,734.2
High DOC	4,335.5	43.8	1,746.3
Bulk Density	1.812	0.103	1.625

5.2 Bromide Tracer Tests

Bromide tests were conducted by delivering a 10 s pulse of 25 mM bromide through the columns and sampling at pre-determined time intervals. The water level in the columns was maintained at the top of the barrier sand layer to eliminate standing water and prevent any initial dilution of the tracer above the barrier sand. DI water was used in the tracer studies and was delivered to each column to maintain a face velocity of 60 cm hr^{-1}. Flow rate was confirmed throughout the tracer tests. The tracer tests results are shown below in Figure 104.

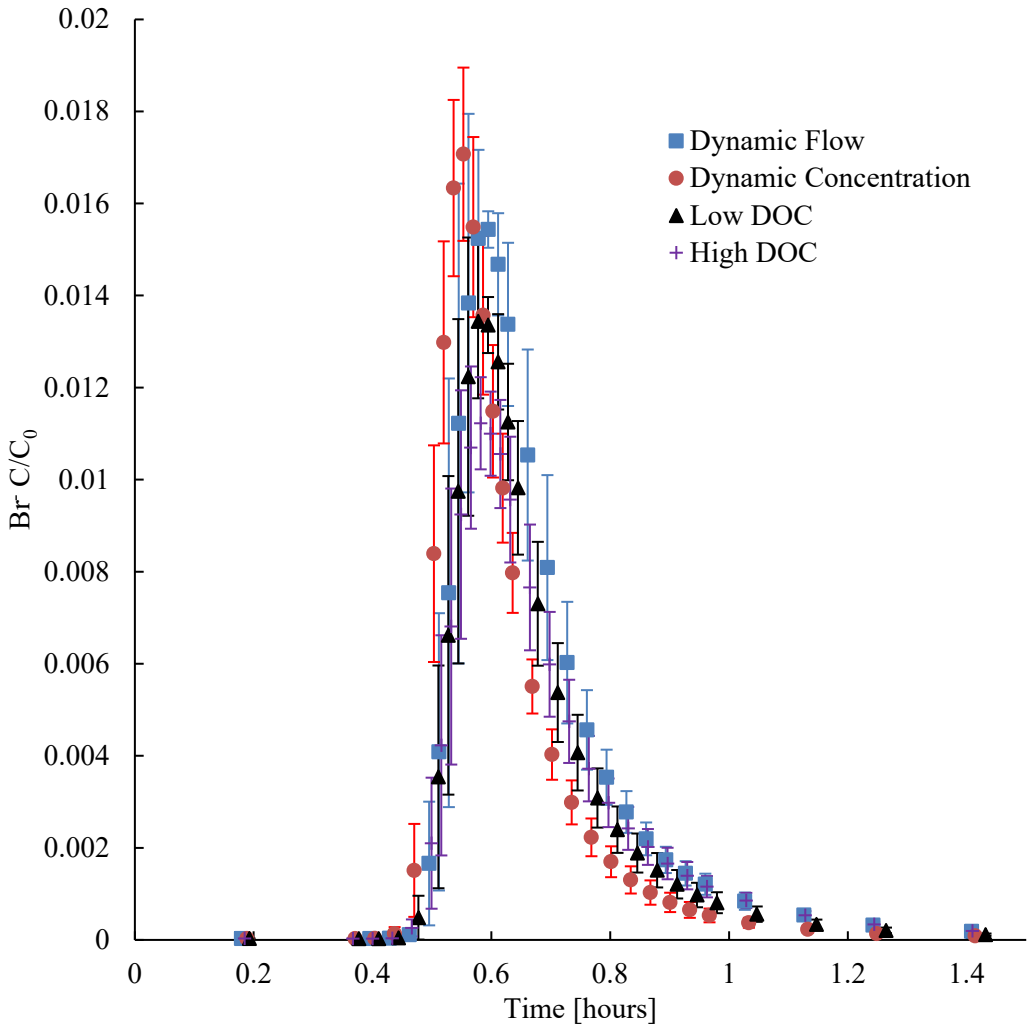

Figure 104 Tracer test results for each experiment conducted at a flow rate of 60 cm hr^{-1} with a 10s pulse of 25 mM bromide. Points indicate mean (n=3) and error bars represent one standard deviation above and below the mean.

5.3 Experiment Duration and Flow Rates

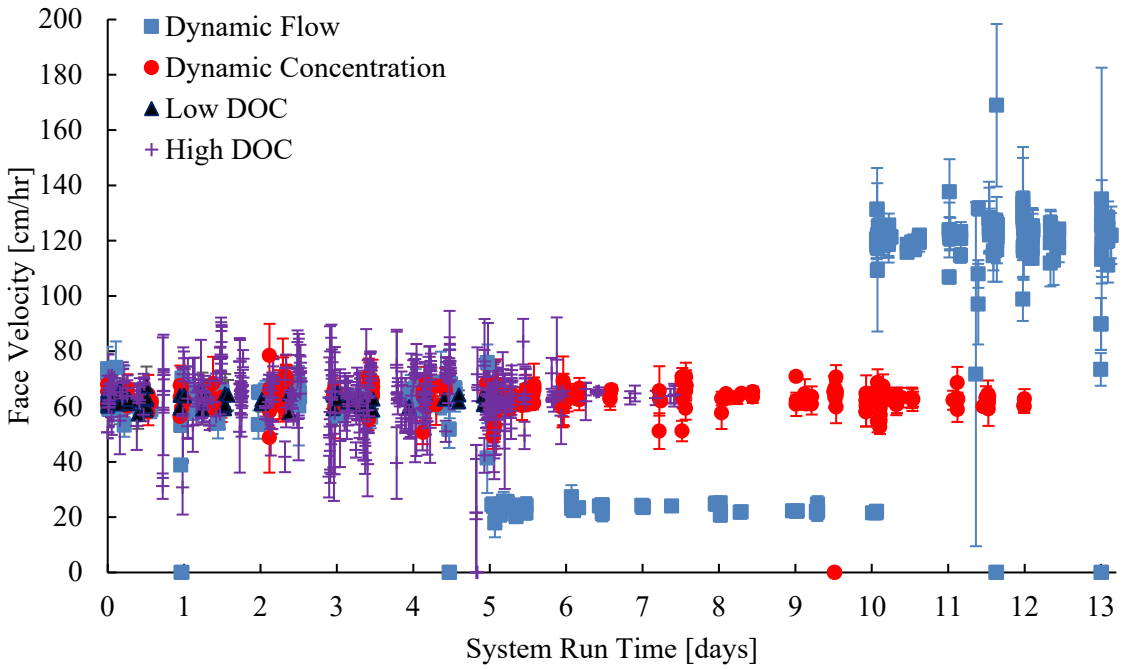

Figure 105 Flow rate for each column experiment measured gravimetrically for 20s. Error bars indicate one standard deviation above and below the mean.

5.4 Water Quality in Column Experiments

5.4.1 Dissolved Organic Carbon

Table 75 DOC measured in influent and effluent during column experiments – [mg C L^{-1}]

Dynamic Flow Experiment				
SRT[a]	Influent		Effluent	
8.3	7.7	±0.6	-	-
9.0	7.2	±0.6	-	-
10.5	8.3	±1.0	-	-
11.6	11.4	±0.6	-	-
12.1	8.5	±0.3	-	-
13.1	11.4	±0.1	-	-
Avg[b]	*8.5*	*±0.9*		

Dynamic Concentration Experiment				
SRT[a]	Influent		Effluent	
-3.5	10.6	±0.5	4.1	±0.5
0.0	8.8	±0.3	-	-
1.0	5.1	±0.5	-	-
2.3	7.5	±0.6	-	-
3.1	7.0	±0.4	-	-
4.2	6.3	±0.3	-	-
5.2	7.7	±0.5	-	-
5.3	7.2	±0.3	-	-
6.2	6.4	±0.3	-	-
7.2	7.8	±0.5	-	-
8.1	7.5	±0.6	-	-
9.1	6.2	±0.5	-	-
10.2	7.3	±0.1	-	-
11.1	6.6	±0.2	-	-
12.5	7.1	±0.4	-	-
Avg[b]	*6.9*	*±0.8*		

Low DOC Experiment				
SRT[a]	Influent		Effluent	
0.0	3.8	±0.3	-	-
0.0	3.9	±0.1	-	-
1.0	3.0	±0.1	-	-
1.5	3.2	±0.1	-	-
2.0	3.3	±0.0	-	-
3.1	3.3	±0.0	2.6	±0.1
4.1	2.6	±0.2	2.0	±0.1
5.1	2.9	±0.1	2.2	±0.1
Avg[b]	*3.1*	*±0.4*		

High DOC Experiment				
SRT[a]	Influent		Effluent	
0.0	16.3	±0.3	12.6	±0.3
0.0	24.3	±0.0	13.4	±0.4
1.8	14.8	±0.5	10.3	±0.4
2.4	11.4	±0.1	9.8	±0.2
3.2	15.8	±0.3	11.2	±0.2
4.2	18.5	±0.3	9.9	±0.3
5.0	26.0	±0.1	9.4	±0.3
5.1	2.2	±0.1	2.9	±0.2
5.1	2.1	±0.1	2.4	±0.1
5.3	1.9	±0.1	2.0	±0.1
5.8	1.9	±0.0	1.7	±0.1
6.4	1.7	±0.1	1.7	±0.3
6.8	2.3	±0.2	2.4	±0.1
7.4	1.8	±0.0	1.6	±0.0
Avg[c]	*18.4*	*±4.5*		
Avg[d]	*2.0*	*±0.2*		

[a] System Run Time [days]
[b] Time-weighted average
[c] Time-weighted average of high-DOC portion of High DOC Experiment
[d] Time-weighted average of low-DOC portion of High DOC Experiment
- Indicates no measurement taken

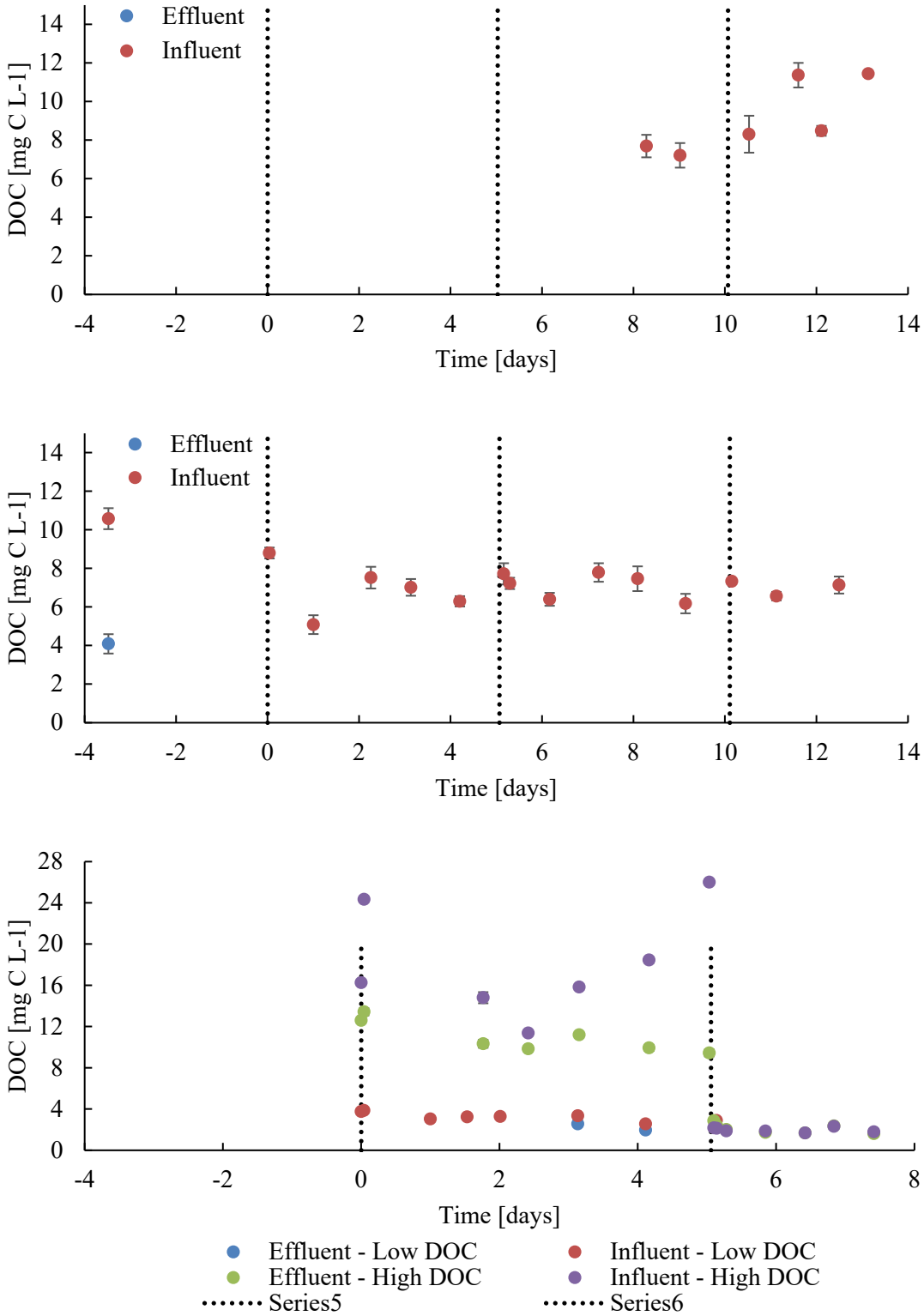

Figure 106 DOC in column influent and effluent during the Dynamic Flow (top), Dynamic Concentration (middle), and Variable DOC (bottom) experiments. Error bar signifies one standard deviation (n=3).

Table 76 SUVA measured in influent and effluent during column experiments – [L mg^{-1} m^{-1}]

Dynamic Flow Experiment				
SRT	Influent		Effluent	
8.3	3.3	±0.4	-	-
10.5	2.4	±0.2	-	-
11.6	1.9	±0.0	-	-
13.1	1.9	±0.2	-	-
Avg[a]	*2.4*	*±0.6*	-	-
Dynamic Concentration Experiment				
SRT	Influent		Effluent	
-3.5	2.3	±0.3	3.6	±1.9
0.0	2.2	±0.1	-	-
1.0	2.5	±0.2	-	-
2.3	2.4	±0.1	-	-
3.1	2.6	±0.2	-	-
4.2	3.0	±0.0	-	-
5.2	2.6	±0.2	-	-
8.1	2.6	±0.3	-	-
10.2	2.5	±0.2	-	-
11.1	2.7	±0.3	-	-
12.5	2.7	±0.2	-	-
Avg[a]	*2.6*	*±0.3*	*3.6*	*±1.9*
Low DOC Experiment				
SRT	Influent		Effluent	
0.0	2.7	±0.1	-	-
1.5	2.9	±0.1	-	-
3.1	3.1	±0.2	2.6	±0.1
5.1	3.1	±0.1	2.8	±0.2
Avg[a]	*3.0*	*±0.2*	*2.7*	*±0.2*
High DOC Experiment				
SRT	Influent		Effluent	
0.0	2.1	±0.0	2.5	±0.0
1.8	2.3	±0.1	2.6	±0.1
2.4	2.7	±0.1	2.8	±0.1
3.2	2.0	±0.1	2.4	±0.2
5.0	-	-	2.4	±0.0
5.1	3.1	±0.1	2.9	±0.0
5.1	3.1	±0.1	-	-
5.8	3.6	±0.0	3.5	±0.1
Avg[b]	*2.3*	*±0.3*	*2.5*	*±0.2*
Avg[c]	*3.3*	*±0.2*	*3.2*	*±0.3*

[a] System Run Time [days]
[b] Average of high-DOC portion of High DOC Experiment
[c] Average of low-DOC portion of High DOC Experiment
- Indicates no measurement taken

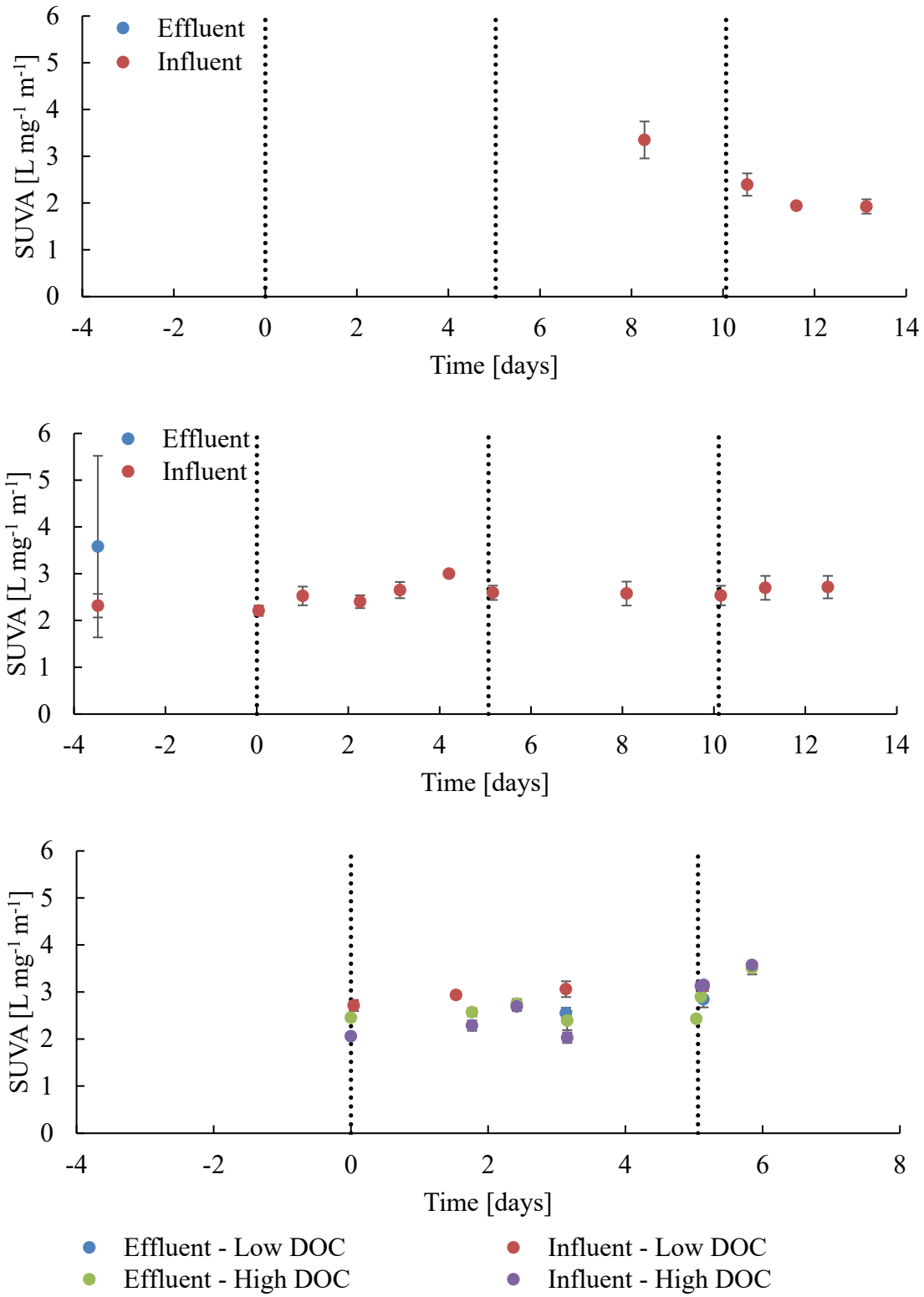

Figure 107 SUVA in column influent and effluent during the Dynamic Flow (top), Dynamic Concentration (middle), and Variable DOC (bottom) experiments. Error bar signifies one standard deviation (n=3).

5.4.2 Dissolved Oxygen

Table 77 DO measured in influent and effluent during column experiments – [mg L^{-1}]

Dynamic Flow Experiment			
SRT	Influent	Effluent	
2.5	-	0.49	±0.03
3.5	7.38	0.41	±0.04
4.5	7.11	1.34	±0.06
6.5	8.20	0.58	±0.10
7.5	8.30	0.35	±0.02
11.5	6.44	0.33	±0.04
12.5	6.75	0.34	±0.01
Dynamic Concentration Experiment			
SRT	Influent	Effluent	
-2.9	6.66	1.22	±0.52
-1.5	-	2.89	±0.74
2.5	-	1.78	±0.62
6.0	7.89	2.60	±0.26
9.5	-	3.10	±0.12
Low DOC Experiment			
SRT	Influent	Effluent	
2.5	8.60	8.05	±0.01
3.5	8.51	7.97	±0.02
4.5	8.67	8.05	±0.03
High DOC Experiment			
SRT	Influent	Effluent	
-3.1	8.60	1.47	±0.57
-1.4	5.02	0.35	±0.02
1.2	4.89	0.37	±0.03
2.4	6.35	0.35	±0.02
3.4	4.87	0.34	±0.01
5.0	7.07	0.35	±0.02
5.2	8.68	2.26	±0.85
5.9	8.92	7.19	±0.18
7.4	8.92	7.67	±0.17

[a] System Run Time [days]
- Indicates no measurement taken

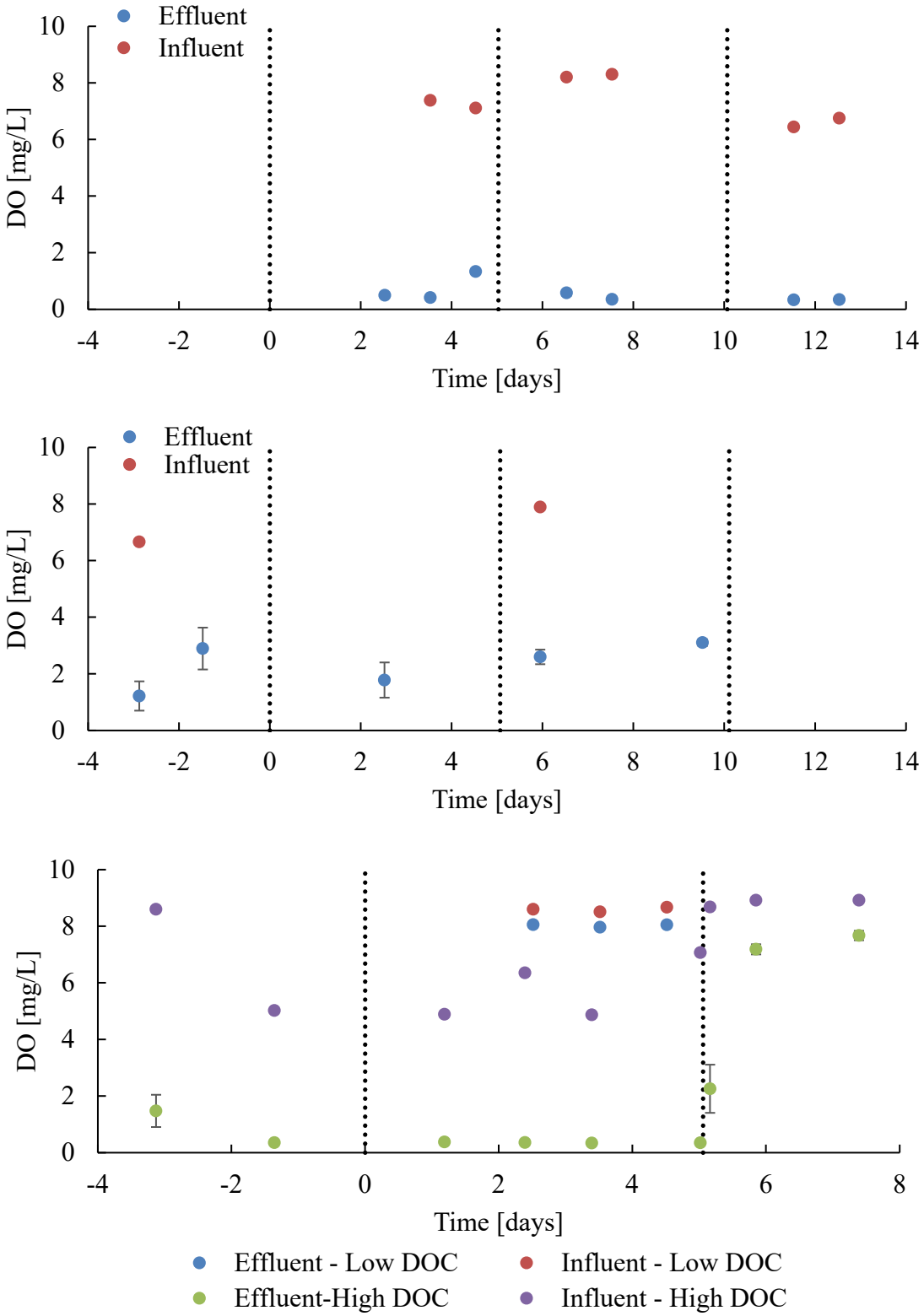

Figure 108 DO in column influent and effluent during the Dynamic Flow (top), Dynamic Concentration (middle), and Variable DOC (bottom) experiments. Error bar signifies one standard deviation (n=3).

5.4.3 Additional Water Quality Parameters

Table 78 pH measured in column influent and effluent

Dynamic Flow Experiment				
SRT[a]	Influent		Effluent	
2.5	7.01	-	6.57	±0.08
3.5	6.82	±0.08	6.36	±0.03
4.5	6.70	±0.06	6.39	±0.17
6.5	7.18	±0.06	6.78	±0.02
7.5	7.18	±0.06	6.78	±0.02
8.5	7.11	±0.05	6.66	±0.13
11.5	7.03	±0.06	6.77	±0.02
12.5	6.88	±0.07	6.35	±0.03
Dynamic Concentration Experiment				
SRT[a]	Influent		Effluent	
-3.5	6.89	±0.05	6.49	±0.10
2.5	6.75	±0.02	6.55	±0.32
6.0	6.96	±0.05	6.47	±0.07
9.5	6.79	±0.04	6.33	±0.06
Low DOC Experiment				
SRT[a]	Influent		Effluent	
2.5	6.70	±0.01	6.43	±0.10
3.5	6.90	±0.02	6.55	±0.09
4.5	6.93	±0.01	6.72	±0.02
High DOC Experiment				
SRT[a]	Influent		Effluent	
-1.4	7.05	±0.03	6.73	±0.01
1.2	6.95	±0.02	6.80	±0.06
2.4	6.89	±0.02	6.60	±0.03
3.4	6.91	±0.01	6.79	±0.02
5.0	6.99	±0.03	6.71	±0.05
5.2	7.10	±0.05	6.85	±0.08
5.9	6.98	±0.10	6.69	±0.02
7.4	6.80	±0.05	6.46	±0.03

[a] System Run Time [days]

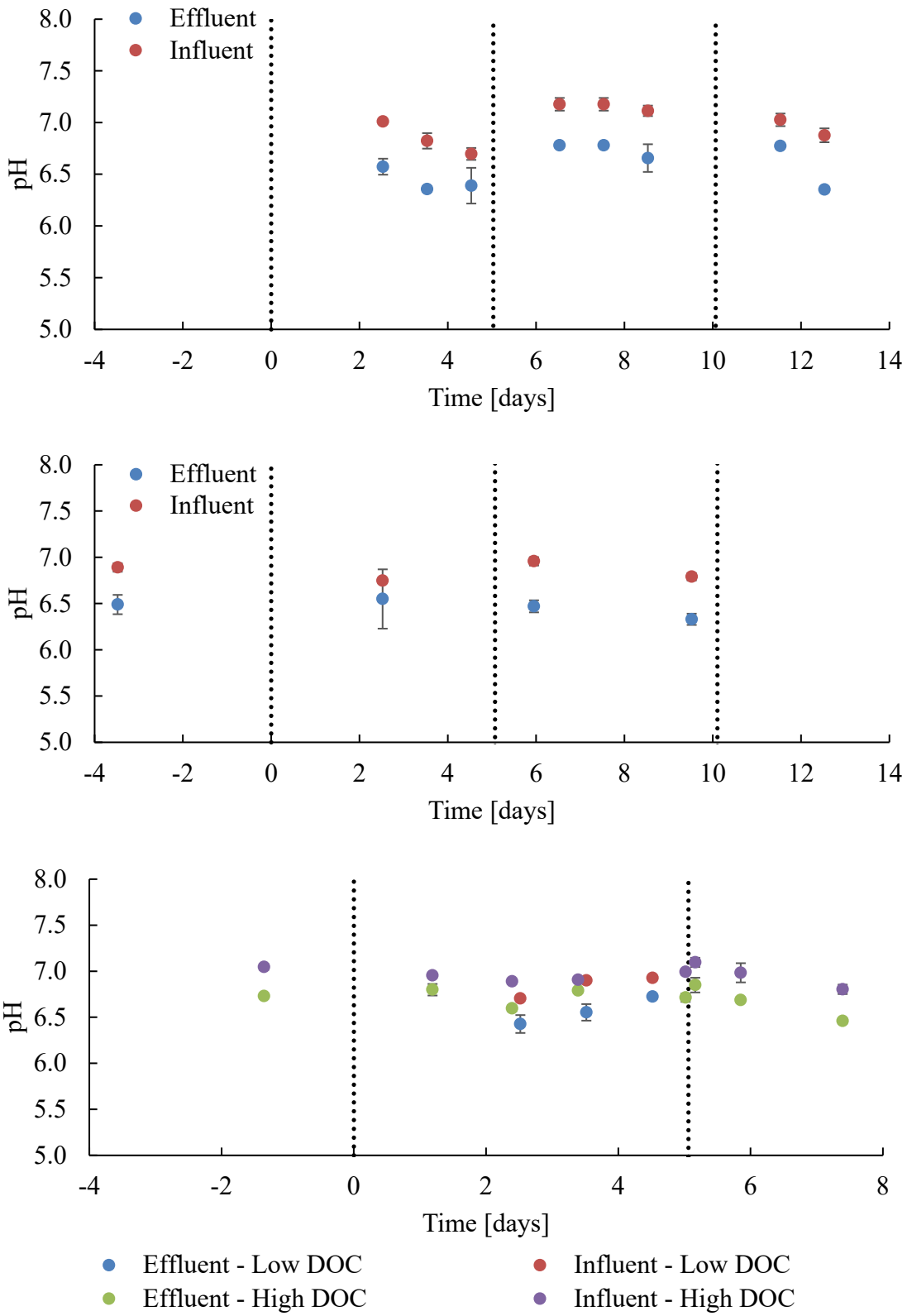

Figure 109 pH in column influent and effluent during the Dynamic Flow (top), Dynamic Concentration (middle), and Variable DOC (bottom) experiments. Error bar signifies one standard deviation (n=3).

Table 79 Conductivity measured in column influent and effluent – [µS cm^{-1}]

Dynamic Flow Experiment				
SRT[a]	Influent		Effluent	
2.5	550	-	561	±5
3.5	503	±2	506	±1
4.5	503	±5	506	±4
6.5	523	±1	527	±1
7.5	523	±1	527	±1
8.5	523	±6	544	±22
11.5	389	±15	434	±8
12.5	506	±21	529	±2
Dynamic Concentration Experiment				
SRT[a]	Influent		Effluent	
-3.5	565	±2	571	±12
2.5	518	±2	441	±145
6.0	234	±1	229	±8
9.5	408	±49	380	±118
Low DOC Experiment				
SRT[a]	Influent		Effluent	
2.5	402	±1	402	±2
3.5	423	±2	418	±1
4.5	425	±1	422	±2
High DOC Experiment				
SRT[a]	Influent		Effluent	
-1.4	487	±6	484	±3
1.2	519	±5	519	±3
2.4	444	±4	453	±1
3.4	507	±1	509	±2
5.0	505	±7	525	±1
5.2	418	±2	428	±2
5.9	414	±7	420	±1
7.4	318	±1	320	±0

[a] System Run Time [days]

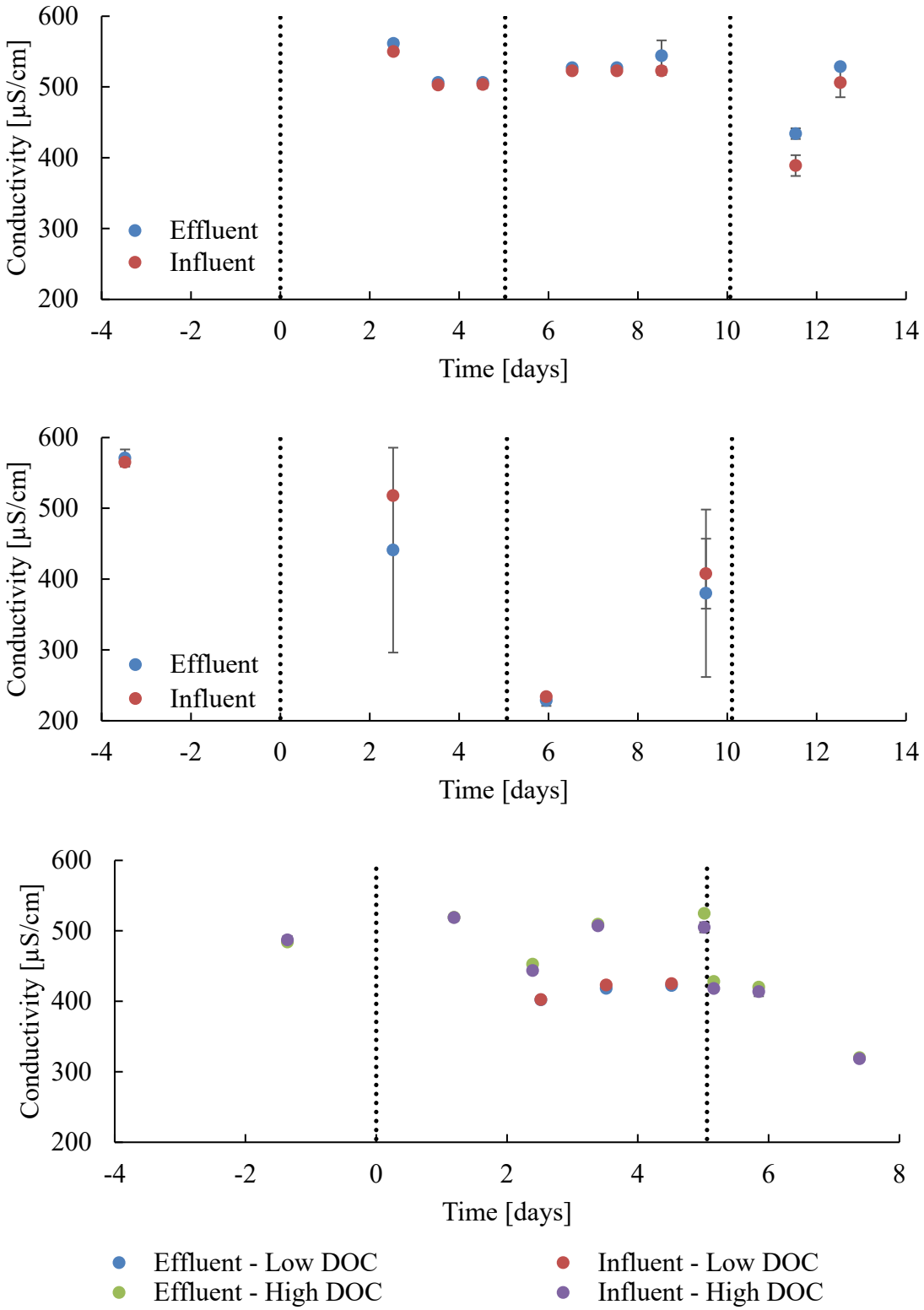

Figure 110 Conductivity in column influent and effluent during the Dynamic Flow (top), Dynamic Concentration (middle), and Variable DOC (bottom) experiments. Error bar signifies one standard deviation (n=3).

Table 80 TDS measured in column influent and effluent – [mg L^{-1}]

Dynamic Flow Experiment				
SRT[a]	Influent		Effluent	
2.5	275	-	281	±3
3.5	252	±1	253	±1
4.5	252	±3	253	±2
6.5	261	±0	263	±1
7.5	262	±2	263	±1
8.5	262	±3	266	±1
11.5	195	±7	217	±4
12.5	253	±10	264	±1
Dynamic Concentration Experiment				
SRT[a]	Influent		Effluent	
-3.5	282	±1	286	±6
2.5	258	±2	220	±72
6.0	117	±1	115	±4
9.5	204	±25	190	±59
Low DOC Experiment				
SRT[a]	Influent		Effluent	
2.5	201	±0	201	±1
3.5	211	±1	209	±0
4.5	213	±1	211	±1
High DOC Experiment				
SRT[a]	Influent		Effluent	
-1.4	244	±3	242	±1
1.2	259	±3	260	±2
2.4	222	±2	226	±1
3.4	254	±1	255	±1
5.0	252	±3	263	±1
5.2	209	±1	214	±1
5.9	207	±3	210	±0
7.4	159	±0	160	±0

[a] System Run Time [days]

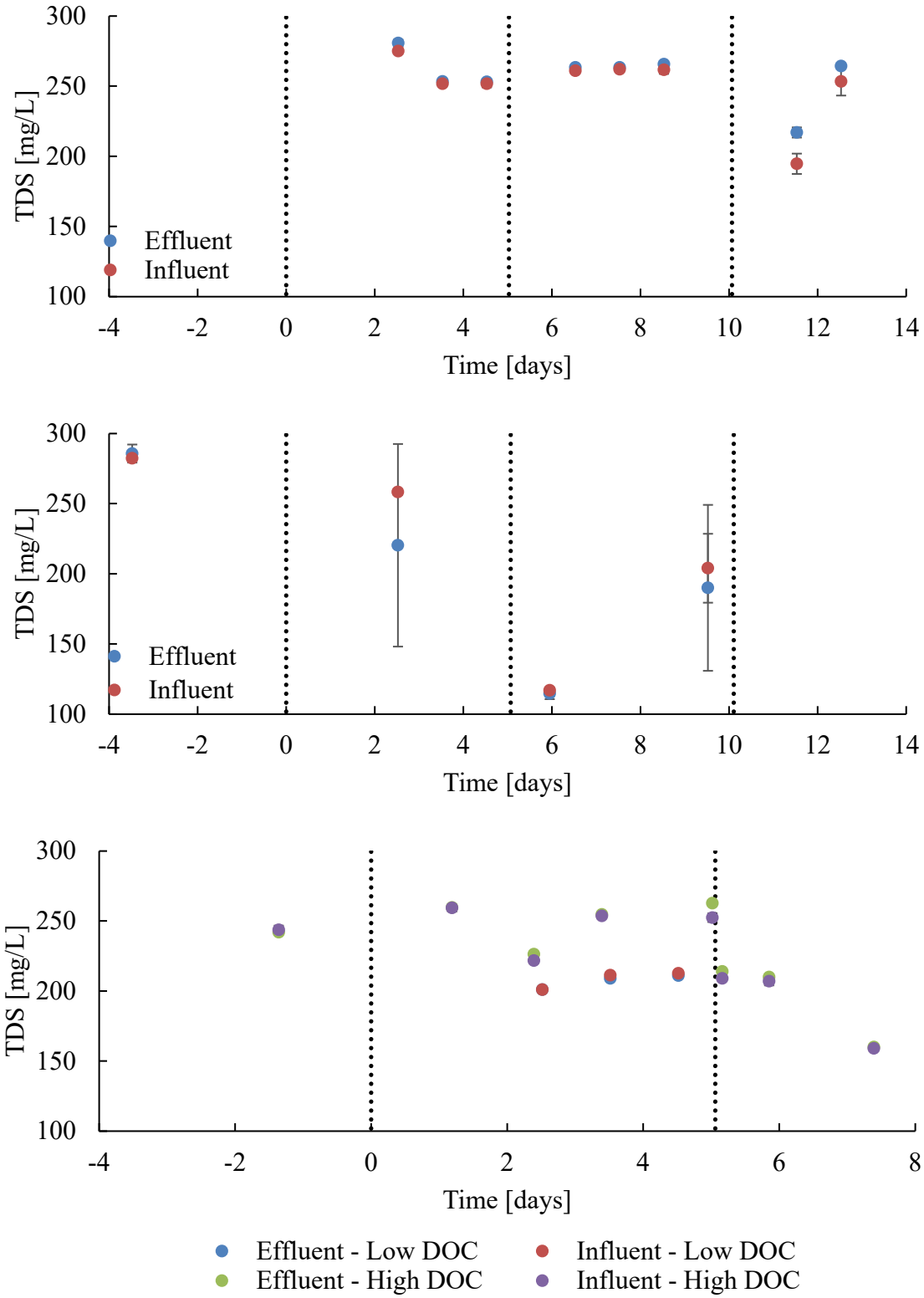

Figure 111 TDS in column influent and effluent during the Dynamic Flow (top), Dynamic Concentration (middle), and Variable DOC (bottom) experiments. Error bar signifies one standard deviation (n=3).

Table 81 Turbidity measured in column influent and effluent – [FNU]

Dynamic Flow Experiment				
SRT	Influent		Effluent	
2.5	8.0	-	4.2	±0.3
3.5	20.8	±0.6	2.5	±0.2
4.5	17.9	±1.6	2.9	±0.1
6.5	11.9	±0.2	2.5	±0.3
7.5	11.9	±0.2	2.5	±0.3
8.5	19.6	±0.6	2.9	±0.0
11.5	42.9	±1.6	5.1	±0.1
12.5	43.7	±2.1	4.9	±0.1
Dynamic Concentration Experiment				
SRT	Influent		Effluent	
-3.5	11.8	±0.4	1.7	±0.1
2.5	8.2	±0.5	1.7	±0.2
6.0	16.6	±1.0	3.0	±0.3
9.5	11.1	±0.6	1.2	±0.1
Low DOC Experiment				
SRT	Influent		Effluent	
2.5	26.9	±1.0	1.9	±0.0
3.5	27.1	±0.6	2.0	±0.0
4.5	25.9	±0.8	1.7	±0.0
High DOC Experiment				
SRT	Influent		Effluent	
-1.4	44.4	±7.6	6.3	±0.2
1.2	20.8	±0.8	4.4	±0.1
2.4	20.5	±0.6	6.3	±0.9
3.4	36.6	±0.9	6.5	±0.4
5.0	42.9	±1.6	5.3	±0.2
5.2	69.7	±1.3	3.8	±0.5
5.9	71.4	±1.5	5.9	±0.3
7.4	55.6	±0.6	6.1	±0.4

[a] System Run Time [days]

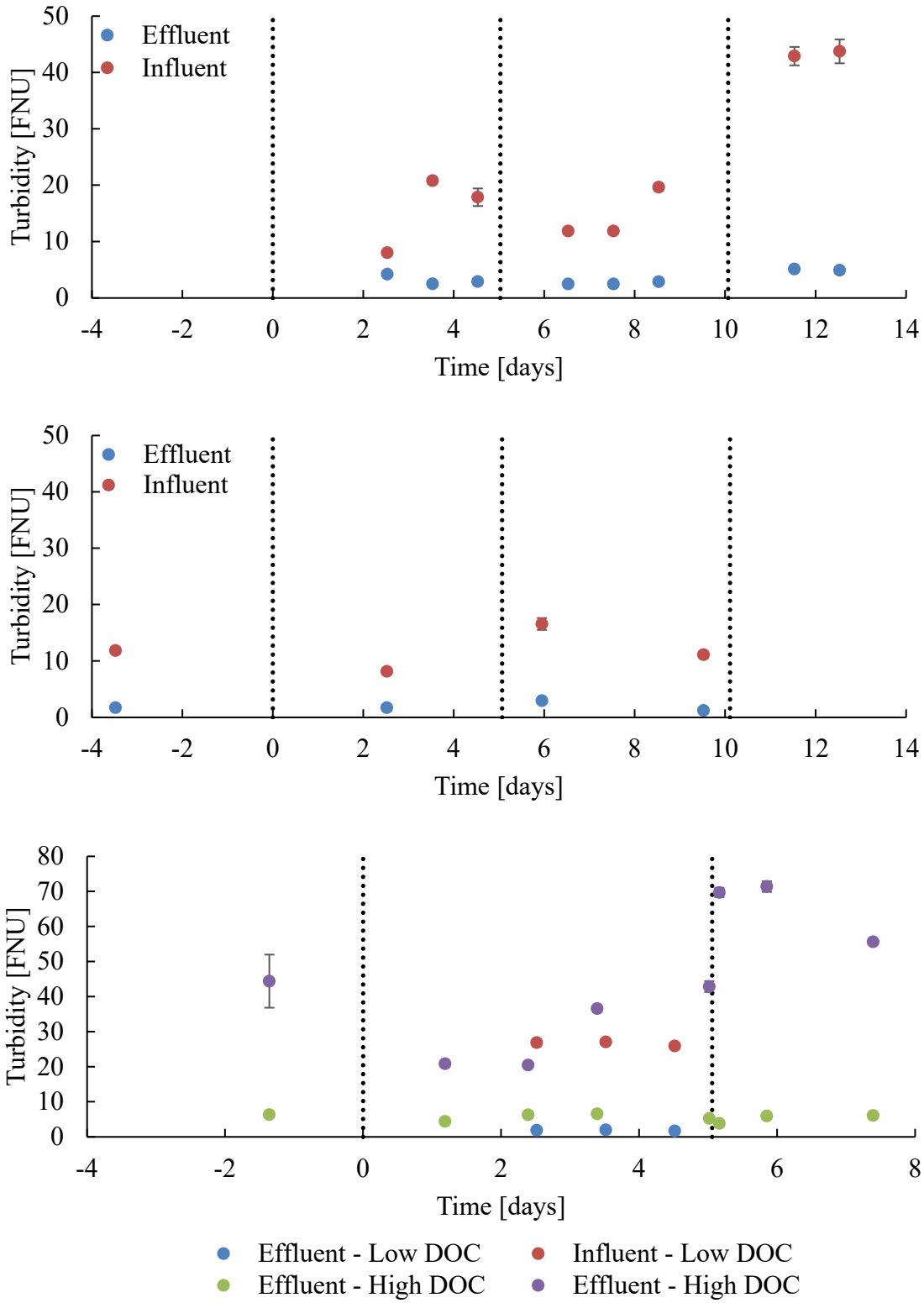

Figure 112 Turbidity in column influent and effluent during the Dynamic Flow (top), Dynamic Concentration (middle), and Variable DOC (bottom) experiments. Error bar signifies one standard deviation (n=3).

5.5 TrOCs Breakthrough in Column Experiments

5.5.1 Dynamic Flow Experiment

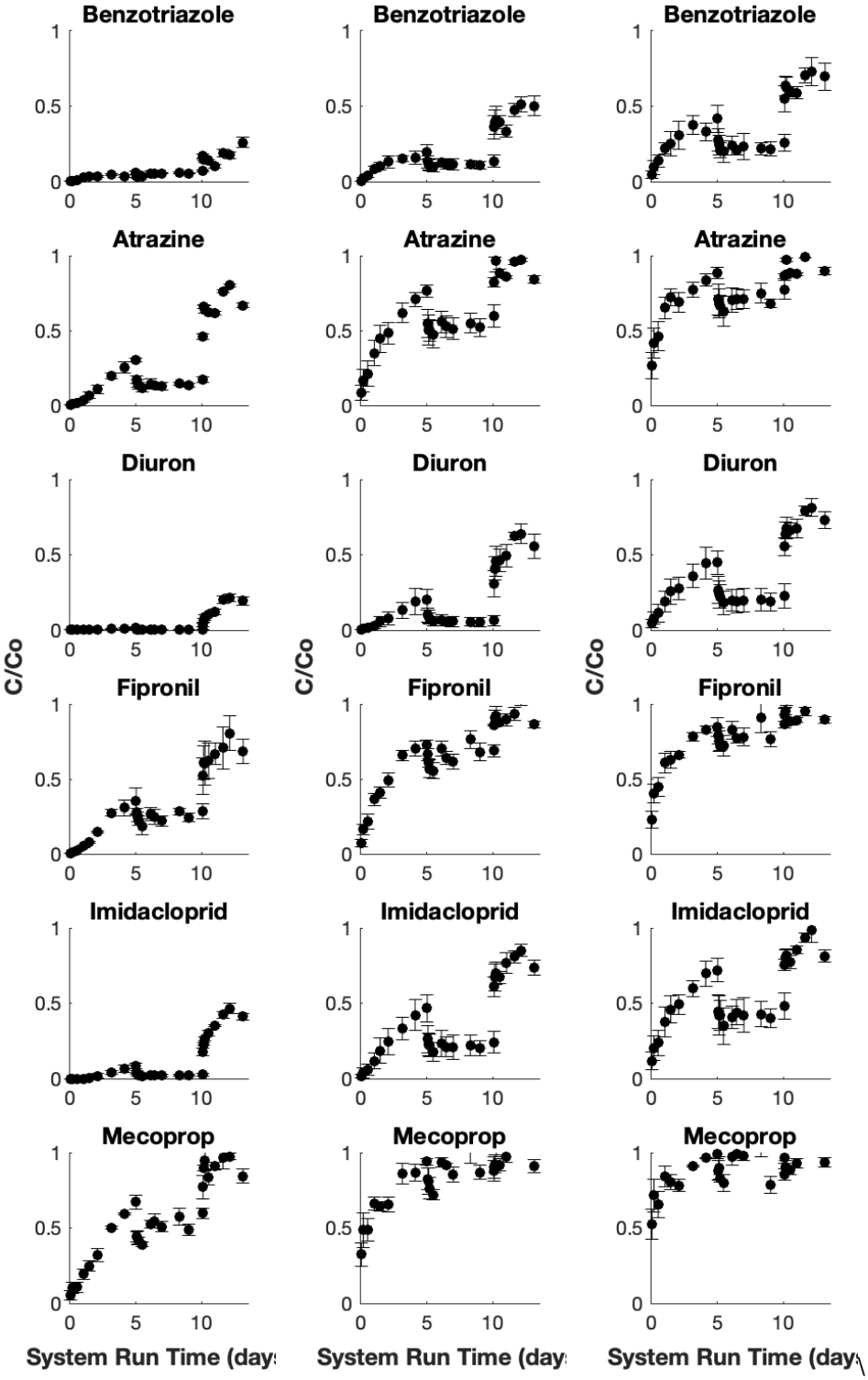

Figure 113 Observed TrOCs in column effluent (left), 50% sample port (middle) and 25% sample port (right) during dynamic flow experiment. Error bar signifies one standard deviation (n=3).

Time until equilibration from the change in flow rate was determined by counting the sample points since the flow rate was dropped from 60 cm hr^{-1} to 20 cm hr^{-1} until the falling contaminant concentration reached an inflection point and began to rise again.

Table 82 Observed Equilibration Time Observed After Decreasing Flow Rate to 20 cm hr^{-1} during Dynamic Flow Experiment

	25% Sample Port		50% Sample Port		Effluent	
	# Points	Time [hrs]	# Points	Time [hrs]	# Points	Time [hrs]
Benzotriazole	4	10.4	4	10.4	3	4.8
Atrazine	4	10.4	4	10.4	4	10.4
Diuron	4	10.4	4	10.4	4	10.4
Fipronil	4	10.4	4	10.4	4	10.4
Imidacloprid	4	10.4	4	10.4	4	10.4
Mecoprop	4	10.4	4	10.4	4	10.4
Average	10.4	±0.0	10.4	±0.0	9.4	±2.3

5.5.2 Dynamic Concentration Experiment

Time until equilibration from the change in flow rate was determined by counting the sample points since the influent concentration was reduced until the falling contaminant concentration reached an inflection point and began to rise again.

Table 83 Observed Equilibration Time Observed After Decreasing Influent Concentration during Dynamic Concentration Experiment

	25% Sample Port		50% Sample Port		Effluent	
	# Points	Time [hrs]	# Points	Time [hrs]	# Points	Time [hrs]
Benzotriazole	8	72.5	8	72.5	9	97.7
Atrazine	7	52.0	7	52.0	7	52.0
Diuron	7	52.0	7	52.0	7	52.0
Fipronil	5	26.3	7	52.0	7	52.0
Imidacloprid	7	52.0	7	52.0	7	52.0
Mecoprop	5	26.3	5	26.3	7	26.3
Average	46.9	±17.8	51.2	±14.7	55.4	±23.1

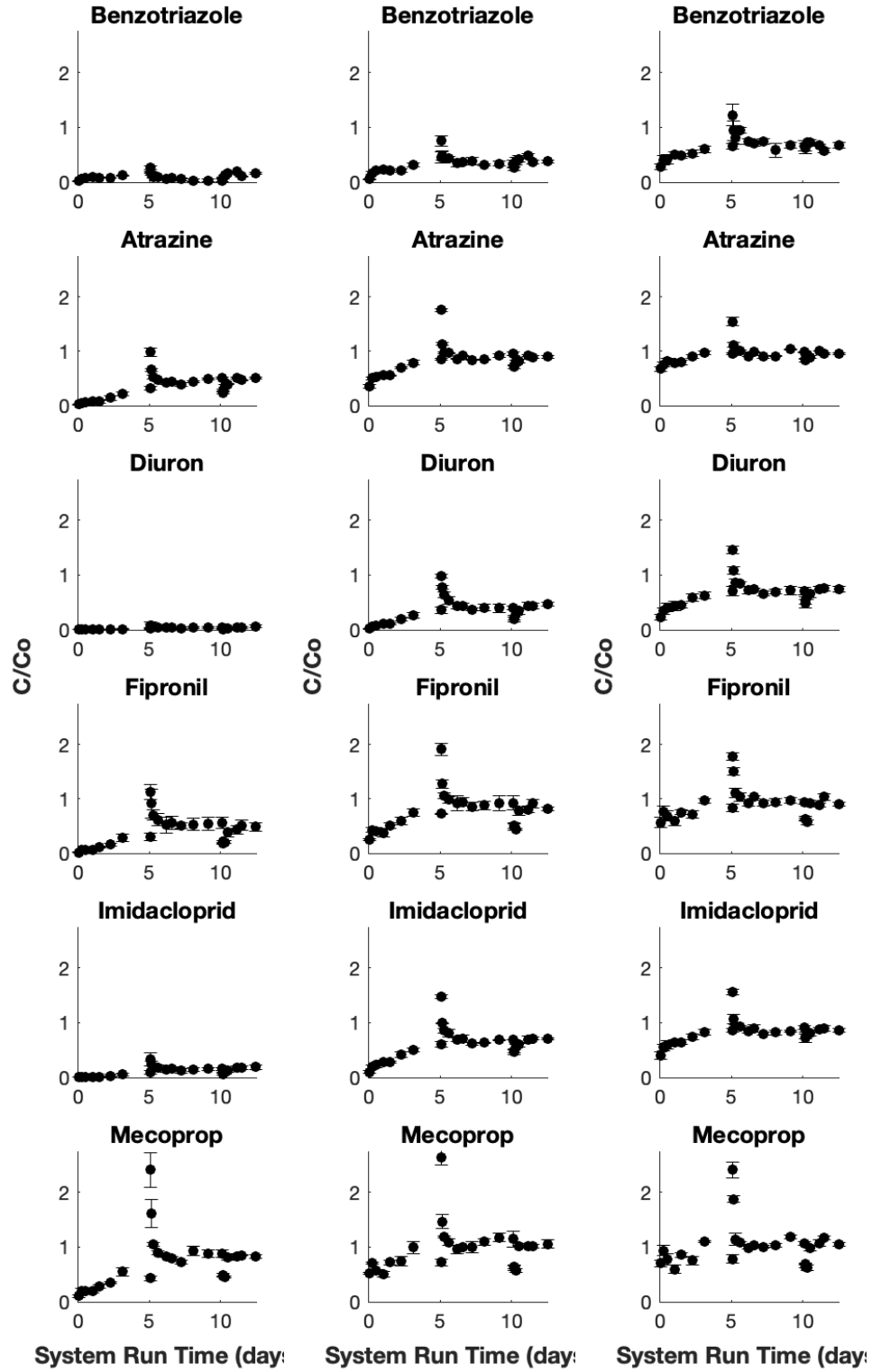

Figure 114 Observed TrOCs in column effluent (left), 50% sample port (middle) and 25% sample port (right) during dynamic flow experiment. Error bar signifies one standard deviation (n=3).

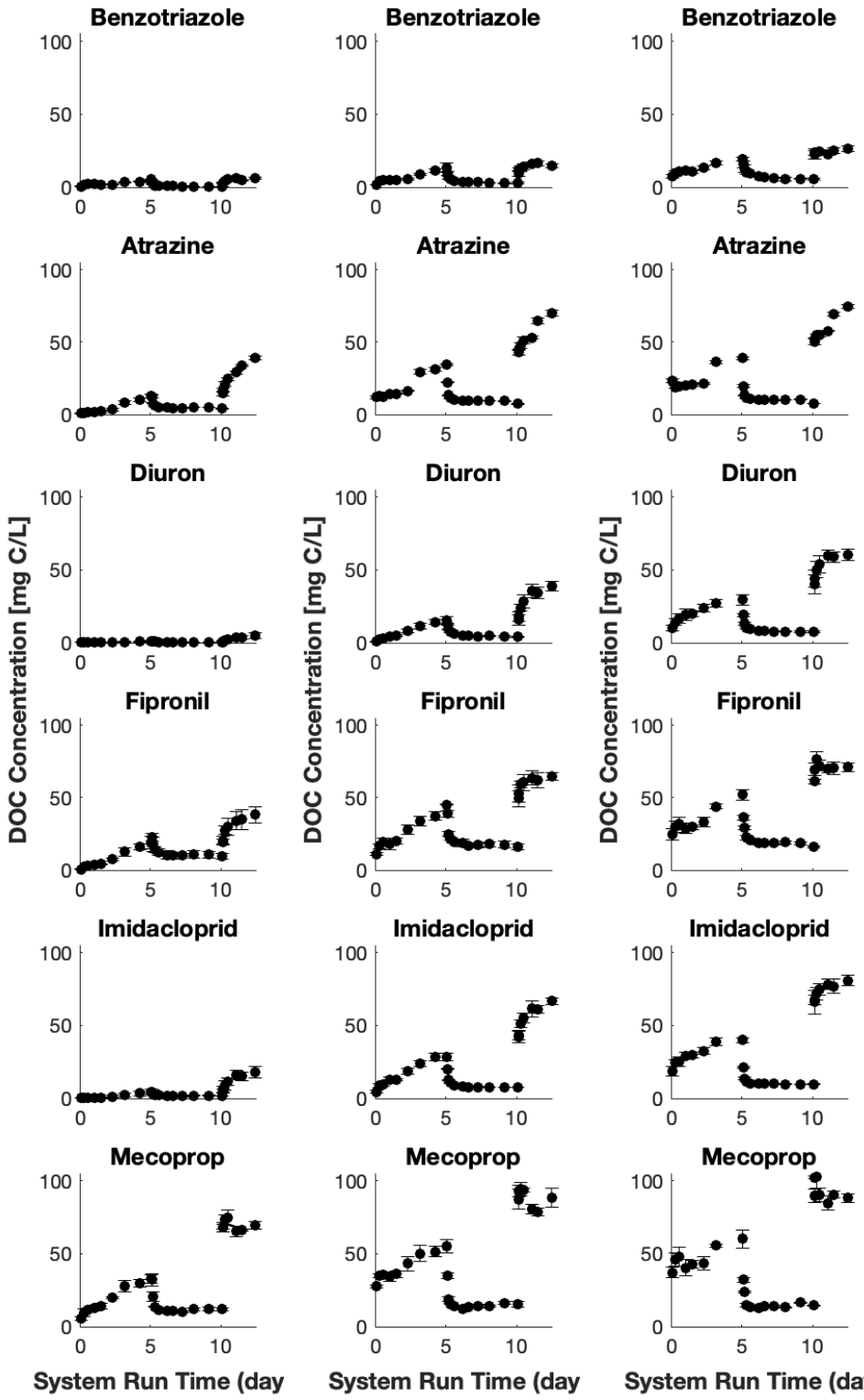

Figure 115 Observed TrOCs in column effluent (left), 50% sample port (middle) and 25% sample port (right) during dynamic flow experiment. Error bar signifies one standard deviation (n=3).

5.5.3 *Variable DOC Experiment*

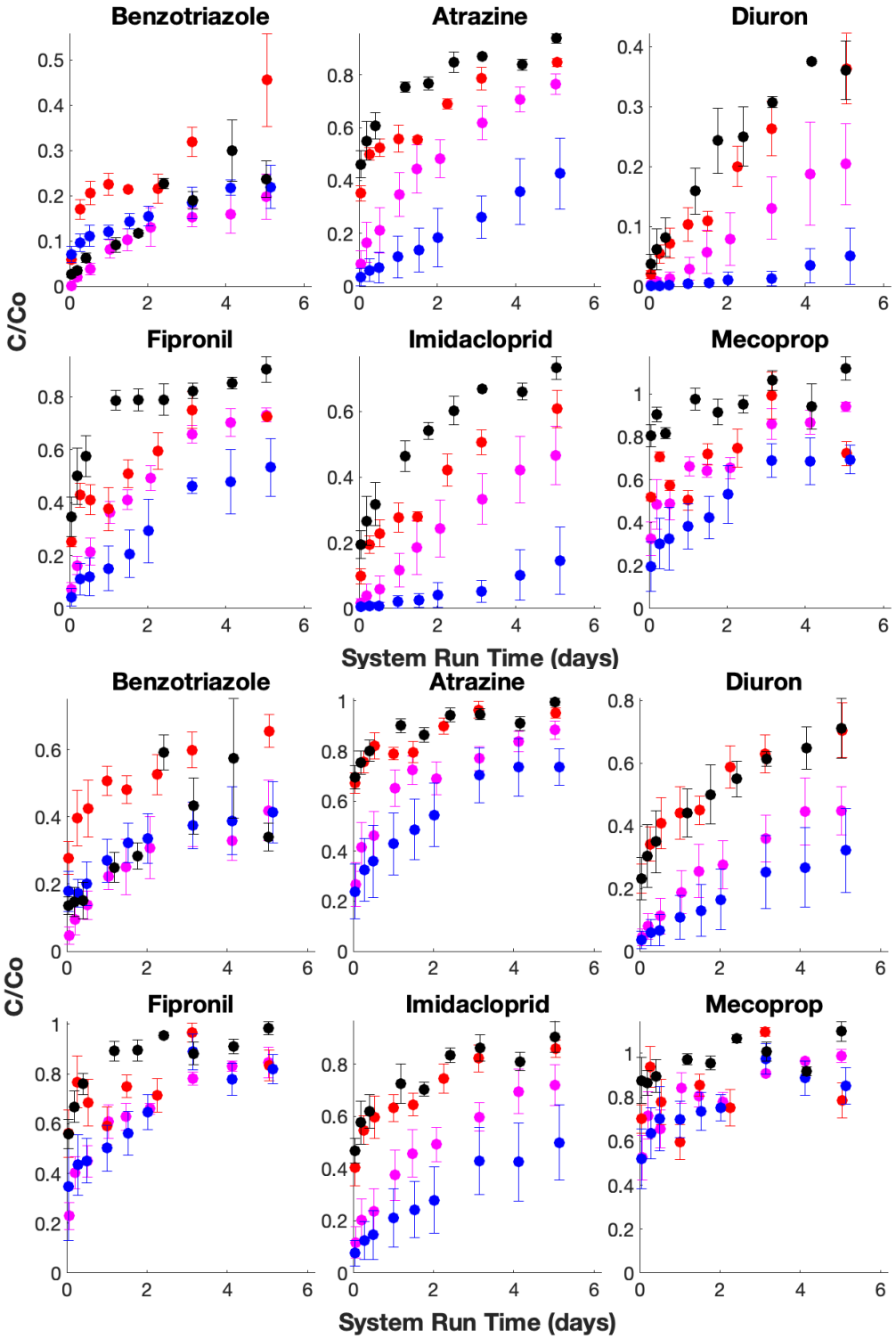

Figure 116 Observed contaminant breakthrough in the 50% sample port (top) and 25% sample port (bottom) as a function of background DOC for column filters operated at 60 cm hr^{-1} and normal contaminant loading as depicted in *Error! Reference source not found.*. DOC plotted include 18.4±4.5 mg C L^{-1} (black), 8.5±0.9 mg C L^{-1} (red), 6.9±0.8 mg C L^{-1} (pink), and 3.1±0.4 mg C L^{-1} (blue). Error bars indicate one standard deviation above and below the mean (n=3).

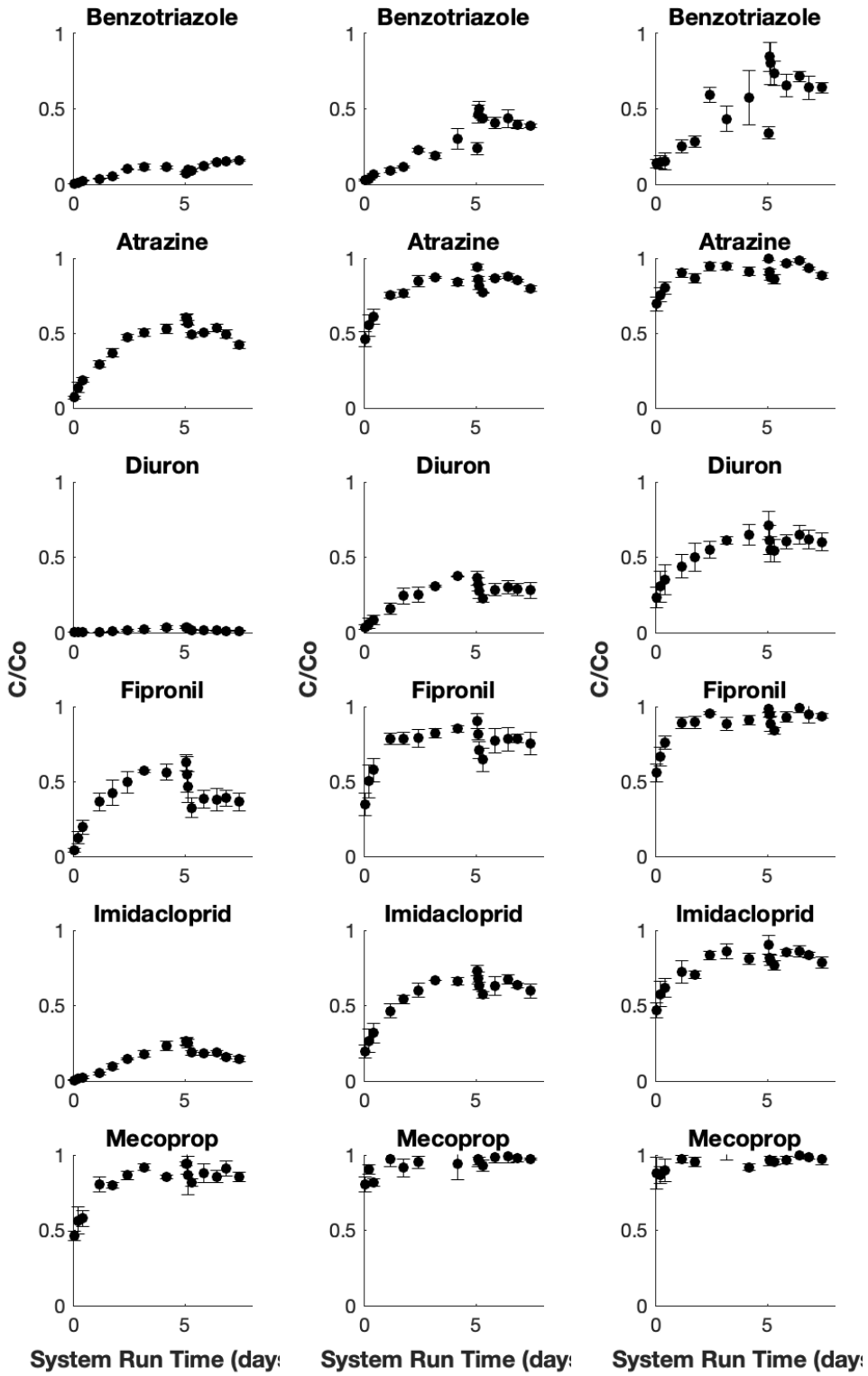

Figure 117 Observed TrOCs in column effluent (left), 50% sample port (middle) and 25% sample port (right) during high DOC experiment. Error bar signifies one standard deviation (n=3).

5.6 Batch Isotherms

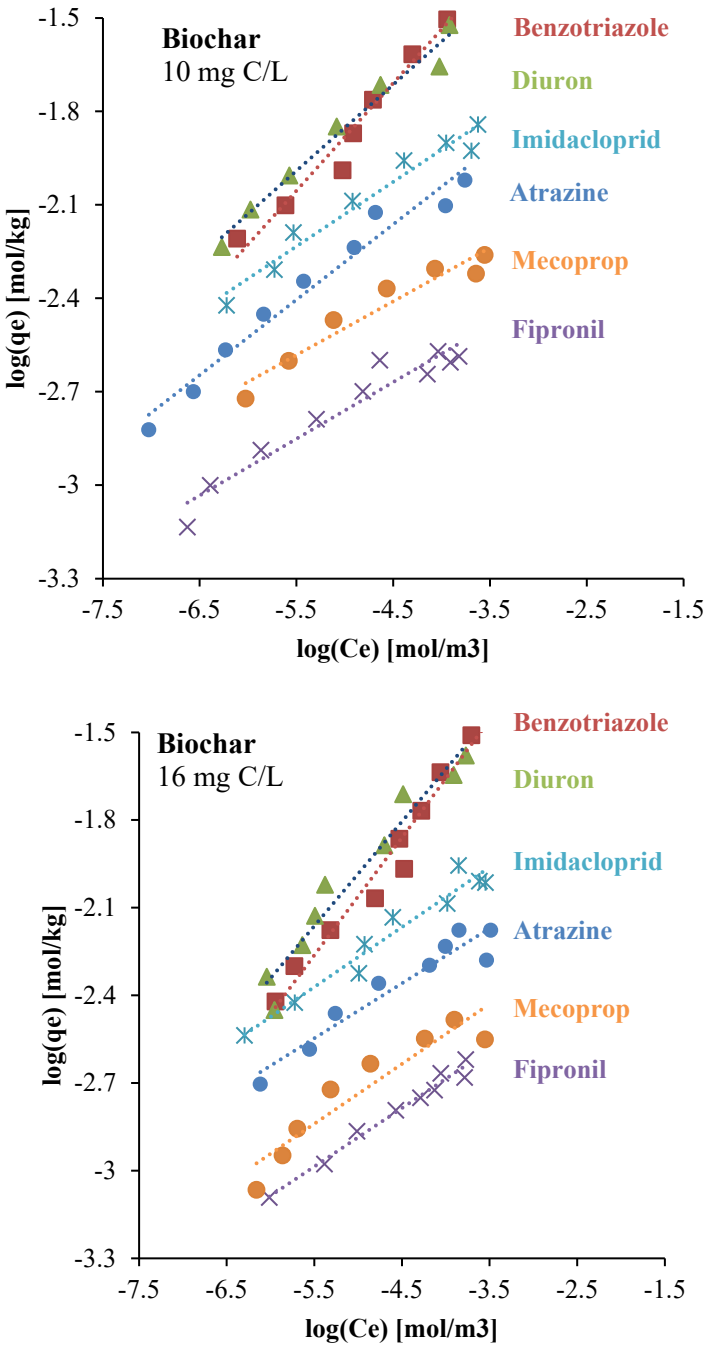

Figure 118 Batch isotherms conducted with biochar at 10 mg C L^{-1} (top left) and 16 mg C L^{-1} (top right).

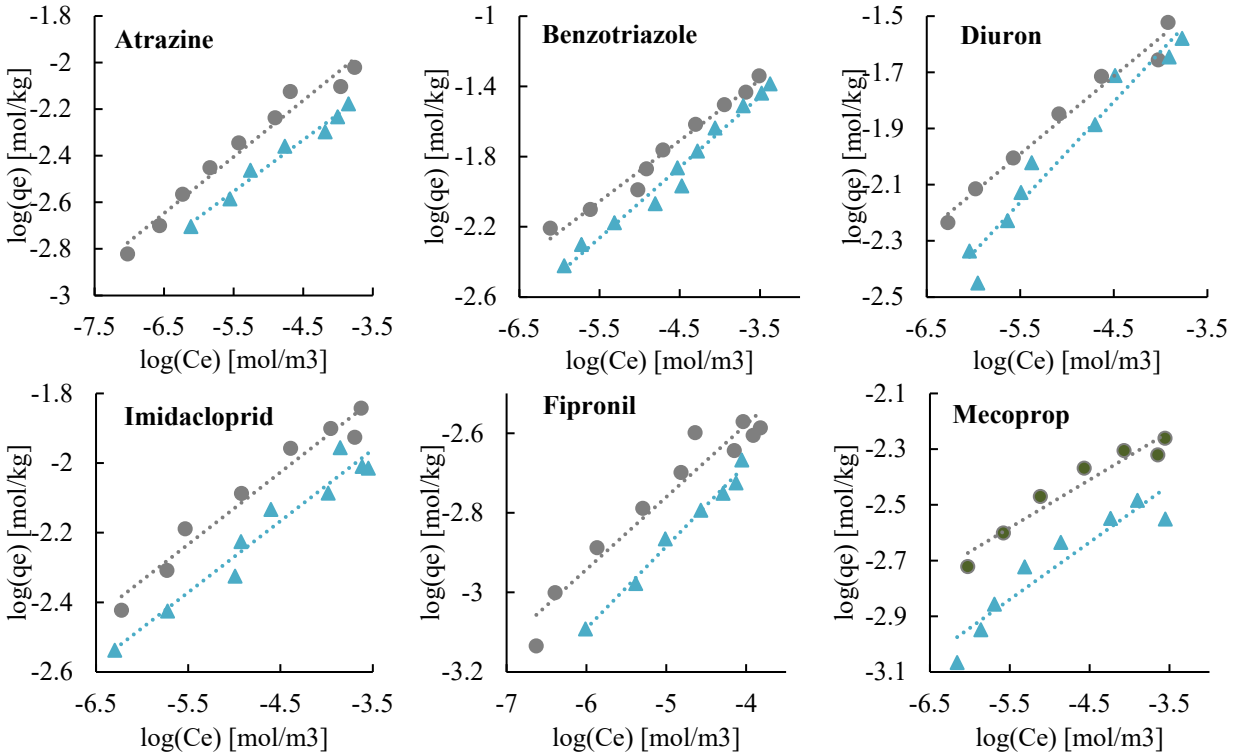

Figure 119 Batch isotherms conducted with biochar at 10 mg C L^{-1} (grey) and 16 mg C L^{-1} (top blue).

5.7 Modeling TrOCs Transport and Estimating Filter Lifetime

5.7.1 Column, Material, and Sorption & Tortuosity Parameters

Table 84 Model, Material, and Column Input Parameters

n_{sv}	# column sub-volumes	160	-	d_{bc}	BC skeletal density[c]	1,998[a]	kg m^{-3}
n_{bc}	# shells in black carbon	100	-			2,055[b]	kg m^{-3}
n_{ts}	# time steps	3,000	-	p_{bc}	BC intraparticle porosity[d]	0.465[a]	-
L_c	column length	0.6	m			0.838[b]	-
R_c	column radius	0.0381	m	R_S	radius of sand[e]	0.00100	m
α_L	longitudinal dispersivity	0.00368	m	R_{bc}	BC radius[e]	0.00080[a]	m
d_S	solid density of sand	2,650	kg m^{-3}			0.00088[b]	m

[a] Value for RAC
[b] Value for biochar
[c] Measured by helium pycnometry (Particle Technology Labs, Downers Grove, IL, USA)
[d] Measured by mercury intrusion porosimetry (Particle Technology Labs, Downers Grove, IL, USA)
[e] Measured by dry sieving particle size analysis

Table 85 Modeled Sorption and Tortuosity Parameters for Hyphil-TrOCs

Biochar	τ^a			$K_{fr}{}^b$			n^c		
	B1	B2	B3	B1	B2	B3	B1	B2	B3
Atrazine	15.7	30.7	39.1	0.41	0.26	0.18	0.30	0.18	0.12
Benzotriazole	21.0	30.4	41.7	1.13	1.17	2.43	0.09	0.14	0.13
Diuron	17.5	36.8	30.3	1.06	1.87	2.81	0.11	0.06	0.05
Fipronil	22.3	28.1	42.9	0.05	0.07	0.09	0.17	0.15	0.09
Imidacloprid	22.3	19.8	29.5	0.48	0.52	0.46	0.14	0.22	0.13
Mecoprop	66.7	68.8	74.1	0.15	0.16	0.18	0.10	0.13	0.11
RAC	τ^a			$K_{fr}{}^b$			n^c		
	R1	R2	R3	R1	R2	R3	R1	R2	R3
Atrazine	30.0	25.9	23.1	0.18	0.16	0.15	0.11	0.10	0.10
Benzotriazole	34.6	30.9	24.4	0.32	0.29	0.19	0.16	0.16	0.08
Diuron	21.6	17.9	15.8	0.56	1.44	0.67	0.25	0.36	0.25
Fipronil	18.0	19.3	16.0	0.08	0.04	0.03	0.23	0.09	0.11
Imidacloprid	21.6	19.8	17.2	0.18	0.2	0.28	0.05	0.11	0.16
Mecoprop	37.3	30.7	31.9	0.13	0.14	0.19	0.11	0.14	0.17

[a] Tortuosity [-]
[b] Freundlich sorption capacity coefficient [(mol L^{-1})(L mol^{-1})$^{1/n}$]
[c] Freundlich sorption intensity parameter [-]

5.8 Long-Term Performance Modeling

5.8.1 Equations

The model is used to find the time to breakthrough, t_{BT} [s], for any of the modeled contaminants. The time is found by linearly interpolating the breakthrough curve to find the time at which the concentration predicted is equal to the breakthrough concentration. The MatLab syntax for this equation is:

$$t_{BT} = \text{interp1}(y_p, t_p, y_{BT}, \text{'linear'}) \qquad (1)$$

where interp1 is the interpolation function, y_p is the array of predicted concentrations, t_p is the array of time associated with each predicted concentration, y_{BT} is breakthrough concentration, and 'linear' is the option to linearly interpolate. The time until breakthrough is then converted to filter empty bed volumes treated until breakthrough [-], EBV_{BT}, by:

$$EBV_{BT} = \frac{t_{BT} \times q}{d_{filter}} \qquad (2)$$

where q is the face velocity of the filter, and d_{filter} is the filter bed depth.

The volume of water treated each year in filter EBVs, $V_{treat,yr}$ [-], is calculated using:

$$V_{treat,yr} = \frac{A_{catch} \times R_{collect} \times ppt}{V_{filter}} \quad (3)$$

where A_{catch} is the catchment area [m], $R_{collect}$ is the proportion of the total precipitation that is captured by the filter [-], ppt is the annual precipitation [m], and V_{filter} is the filter volume [m^3]. Substituting FS, the filter/site surface area ratio in the equation yields:

$$EBV_{year} = \frac{ppt}{FS \times d_{filter}} \quad (4)$$

The filter lifetime, T_{BT} [years] can then be calculated by:

$$T_{BT} = \frac{EBV_{BT}}{EBV_{year}} \quad (5)$$

The combined and simplified equation is:

$$T_{BT} = \frac{interp1(y_p, t_p, y_{BT}, 'linear') \times q \times FS}{ppt} \quad (6)$$

The mean filter lifetime and standard deviation range of is found by first calculating the mean predicted concentration over time in the filter effluent and its associated standard deviation. Then, the mean concentration $y_{p,mean}$ and the standard deviation range $y_{p,mean+stdev}$ and $y_{p,mean-stdev}$ are used to calculate the mean filter lifetime, and the upper and lower standard deviation ranges using equation (6).

5.8.2 Input Parameters

Input design parameters are shown below. Breakthrough is assessed using aquatic health benchmarks, which may be found in the main text.

Table 86 Design parameters for long-term filter lifetime predictions for case study at NWSSB

Parameter	Value	Units
Filter : Area Ratio, FS	1	%
Filter Depth, d_{filter}	0.2-0.6	meter
BC Content	30	v% biochar
	10	v% RAC
Face Velocity, q	20	cm hr
Annual Precipitation, ppt	11.51	inch

X. Appendix B. List of Scientific/Technical Publications

Articles in peer-reviewed journals

Pritchard, J. C., K. M. Hawkins, Y. M. Cho, S. Spahr, S. D. Struck, C. P. Higgins, and R. G. Luthy. "Black Carbon Amended Engineered Media Filters for Improved Treatment of Stormwater Runoff." Environmental Science & Technology Environmental Au.

Pritchard, J. C., K. M. Hawkins, Y. M. Cho, S. Spahr, C. P. Higgins, and R. G. Luthy. "Modeling Trace Organic Contaminant Transport in Black Carbon Amended Engineered Media Filters for Improved Treatment of Stormwater Runoff." Environmental Science & Technology Engineering *submitted*.

Pritchard, J. C., K. M. Hawkins, Y. M. Cho, S. Spahr, S. D. Struck, C. P. Higgins, and R. G. Luthy. "Flow Rate and Kinetics of Trace Organic Contaminant Removal in Black Carbon Amended Engineered Media Filters for Improved Treatment of Stormwater Runoff." Water Research *in preparation*.

Pritchard, J. C., K. M. Hawkins, Y. M. Cho, S. Spahr, C. P. Higgins, and R. G. Luthy. "Dynamic Operation and Predictive Modeling of Black Carbon Amended Engineered Media Filters for Improved Treatment of Stormwater Runoff." Water Research *in preparation*.

Pritchard, J. C., E. Gallo, S. D. Struck, Y. M. Cho, R. G. Luthy, "TEMPEST: a tool for sizing and estimating dissolved organic contaminant removal performance and lifetime for black carbon-amended stormwater control measures." *in preparation*.

Hawkins, K. M., J. C. Pritchard, Y.-M. Cho, R. G. Luthy, and C. P. Higgins. Removal of PFASs in Simulated Bioretention Systems with Controlled Saturation Conditions. ACS ES&T. *in preparation..*

XI. Appendix C. Other Supporting Materials

Below is the list of other supporting materials, which are provided as separate files.

1 Design Manual

2 Performance Tables

3 TEMPEST design tool

Attached to this pdf.

4 Column Experiment Guidance Manual

Geosyntec consultants

engineers | scientists | innovators

Guidance for Evaluation and Implementation of Black Carbon-amended Engineered Media Filtration for Passive Treatment of Stormwater Runoff

SERDP Project ER18-1145

Prepared for

The Strategic Environmental Research and Development Program
4800 Mark Center Drive, Suite 16F16
Alexandria, Virginia 22350

Prepared by

Geosyntec Consultants, Inc.
924 Anacapa Street, Suite 4A
Santa Barbara, California 93101

December 2022

Geosyntec consultants

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ACRONYMS AND ABBREVIATIONS

µg/L	microgram per liter
AFCEC	Air Force Civil Engineer Center
AASHTO	American Association of Highway and Transportation Officials
AFFF	Aqueous Film Forming Foam
ASTM	American Society of Testing and Materials
BC	Black carbon-based
BCSMFs	BC-amended stormwater runoff media filters
CEC	cation exchange capacity
BMP	best management practice
BI+MP	bone char + ferrous-coated activated aluminum)
BSM	bioretention soil media
CoCs	constituents of concern
CWA	Clean Water Act
DOC	dissolved organic carbon
DoD	Department of Defense
EBV	empty bed volume
EISA	Energy Independence and Security Act
FOP	Field Operating Procedure
GAC	granular activated carbon
HQUSACE	Headquarters, U.S. Army Corps of Engineers
IBMPDB	International Stormwater BMP Database
ng/L	nanograms per liter
MDD	maximum dry density
mg/L	milligram per liter
NAVFAC	Naval Facilities Engineering Systems Command
NPDES	National Pollutant Discharge Elimination System
O&M	Operations and Maintenance
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PFASs	per- and polyfluoroalkyl substances
PFOS	perfluorooctanesulfonic acid
RAC	regenerated activated carbon
RPMs	Remedial Project Managers
SCMs	stormwater control measures

SCS	Soil Conservation Service
SERDP	Strategic Environmental Research and Development Program
SMFs	stormwater media filters
SOP	Standard Operating Procedure
TCLP	toxicity characteristic leaching procedure
TEMPEST	Treatment Engineered Media Performance and Sizing Tool
TMDL	Total Maximum Daily Load
TrOCs	trace organic contaminants
TSS	total suspended solids
UFC	Unified Facilities Criteria
USEPA	United States Environmental Protection Agency
WET	Waste Extraction Test

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1. INTRODUCTION

1.1 Background and Project Context

This Strategic Environmental Research and Development Program (SERDP) project, ER18-1145 - Prevention of Sediment Recontamination by Improved SCMs to Remove Organic and Metal Contaminants from Stormwater Runoff, is in response to the SERDP Statement of Need (ERSON-18-C3) to understand the impacts and control of stormwater on sediment recontamination and recovery. Stormwater runoff is a major pollution source (EPA 2007) that contains a highly variable mixture of particulate-bound and dissolved constituents of concern (CoCs), such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), per- and polyfluoroalkyl substances (PFASs), pesticides, corrosion inhibitors, and metals, as well as other dissolved organics, salts, and turbidity that can interfere with the removal of these CoCs in structural treatment controls. Several of these CoCs – notably current-use pesticides (including insecticides and herbicides), corrosion inhibitors, and PFASs – are understudied in published stormwater control measure (SCMs) and best management practice (BMP) performance studies and databases. Some of these stormwater CoCs can be sources of recontamination of receiving water sediments and a threat to receiving water quality (surface water and groundwater), and therefore they are a concern for Department of Defense (DoD) facilities (SERDP/ESTCP 2012). Additionally, changes in runoff patterns due to expected increases in the frequency and intensity of storms create increased unreliability in controlling sediment recontamination. Novel systems may be needed to prevent sediment recontamination and/or receiving water quality impacts.

The overall goal of SERDP Project ER18-1145 is to evaluate the efficacy and longevity of black-carbon (BC) and/or zeolite-amended engineered stormwater media filters (abbreviated to BCSMFs) for treating stormwater runoff at DoD facilities. While traditional sedimentation-based SCMs (e.g., retention and detention ponds) generally remove larger, settleable particles, these SCMs are limited in their ability to remove finer particulates and dissolved contaminants, posing risks for transporting these contaminants offsite. BC media amendments (i.e., biochar, granular activated carbon [GAC] and regenerated activated carbon [RAC]), and zeolite amendments have the potential to improve the removal of dissolved metals and trace organic contaminants (TrOCs) such as PCBs, PAHs, PFASs, pesticides, and corrosion inhibitors. This is particularly true when contact time controls are incorporated into the design.

Project objectives and tasks were designed to develop and build knowledge on performance and design tradeoffs for BCSMFs to maximize CoC removal performance and longevity. Specific objectives included: 1) Assessment of BCSMF media mixtures for removal of dissolved contaminants; 2) Development of performance curves with kinetic and flow rate design parameters typical of SCM designs; 3) Evaluation of engineered media filters under intermittent wetting/drying periods and saturation levels; 4) Long-term contaminant transport and performance modeling of engineered media filters based on typical stormwater media filter design criteria; and 5) Development of a technical design document for improved stormwater SCMs and recommended field demonstration testing for future studies.

This document serves as a product of the final objective, a technical design document to assist in selection and specification of media amendments to treat stormwater runoff for the CoCs studied. The document is accompanied by a design spreadsheet tool to assist in understanding the estimated reductions and longevity (time to exhaustion) for the studied CoCs based on BC amendments to engineered stormwater filtration media and target CoC removal.

A separate project, also completed for the SERDP Statement of Need, is also described in this guidance, which focused on control of separate constituents of concern normally bound to settleable particulates.

1.2 Purpose of this Guidance

The purpose of this guidance is to support DoD site managers and Remedial Project Managers (RPMs) in evaluating, designing, and implementing BCSMFs to address the CoCs covered in this study, namely the representative PFASs perfluorooctanesulfonic acid (PFOS) and perfluorooctanoic acid (PFOA), and pesticides atrazine, imidacloprid, and fipronil. While ER18-1145 evaluated more CoCs than this, these compounds were selected because they are representative of the range of studied PFASs and pesticide mobility within BC-amended filter media. Specifically, PFOS and PFOA were selected of the PFASs because of their regulatory relevance, with PFOS being indicative of less mobile PFASs and PFOA being representative of more mobile PFASs. Atrazine, imidacloprid, and fipronil were chosen because they are indicative of the range in mobility of the studied pesticides, with atrazine and imidacloprid representing moderate relative mobility and fipronil representing high relative mobility. Contaminant mobility within media filters is indicative of the rate at which the filter media is exhausted, with more mobile contaminants causing filter media exhaustion sooner.

This guidance is intended to distill key findings from ER18-1145 to help site managers and RPMs make key practical decisions about using BCSMFs as a stormwater treatment alternative, including: (1) whether BCSMFs should be considered for a site; (2) whether BCSMFs can meet their regulatory and/or treatment objectives with acceptable maintenance cycles, and if so; (3) how systems should be designed, constructed, and operated/maintained.

1.3 Limitations and Supporting References

This document is intended to provide guidance for how the findings of ER18-1145 can be included in BCSMF system planning, design, and implementation as a singular stormwater control measure or as part of a treatment train of measures to improve water quality through a reduction in CoC discharges. Testing as part of ER18-1145 was specifically conducted on selected biochar products and RAC. Therefore, the use of the term BC, henceforth specifically refers to the specifications of the evaluated biochar and RAC. These specifications are provided in Section 4.

Note that this document is not intended to be a comprehensive stormwater design manual. There are numerous existing guidance documents available for DoD site managers and their contractors related to stormwater management and SCM or BMP design. This guidance document is not intended to replace those comprehensive stormwater design guidance manuals but, rather, to be

used as a companion, with guidance specifically focused on BCSMF treatment systems for target CoCs.

The following references may be used as the primary basis for stormwater system design, including conveyance, pre-treatment, SCM design, and construction:

- Unified Facilities Criteria (UFC) [for Stormwater] Low Impact Development; https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-3-210-10.

  The UFC provides technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. The UFC is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD Memorandum dated 29 May 2002. UFC will be used for all domestic DoD projects and work for other customers where appropriate.

- United States Environmental Protection Agency (USEPA) Guidance for Implementing Section 438 of the Energy Independence and Security Act; https://www.wbdg.org/ffc/epa/criteria/epa-841-B-09-001

  The purpose of this document is to provide technical guidance and background information to assist federal agencies in implementing EISA Section 438. Each agency or department is responsible for ensuring compliance with EISA Section 438. The document contains guidance on how compliance with Section 438 can be achieved, measured and evaluated. In addition, information detailing the rationale for the stormwater management approach contained herein has been included. This document is intended solely as guidance.

- State and local guidance; (See state and local stormwater criteria and guidance); and

- Applicable Clean Water Act (CWA) waste discharge permits governing stormwater discharges for the site (including construction, industrial, and municipal stormwater National Pollutant Discharge Elimination System (NPDES) permits, and where applicable, Total Maximum Daily Load (TMDL requirements incorporated therein); https://www.epa.gov/cwa-404/clean-water-act-section-402-national-pollutant-discharge-elimination-system.

1.4 Organization

This document is organized into five sections.

- Section 1 provides an orientation to the overall project and the intended purpose of this guidance document.

- Section 2 includes an orientation to passive BCSMFs for stormwater treatment, including when they should be considered and what key questions need to be asked and addressed in evaluating potential project designs.
- Section 3 includes guidance for evaluating BCSMF system application and designs and introduces a design and performance estimation tool that can be used to support design variables to successfully construct and treat CoCs.
- Section 4 includes additional guidance, specifications, and considerations related to the design, construction, and Operation and Maintenance (O&M) of BCSMFs, as a subset of traditional biofiltration SCMs.
- Section 5 summarizes the findings of companion research [ER18-1371: Development of Tools to Inform the Selection of Stormwater Controls at DoD Bases to Limit Potential Sediment Recontamination that were in progress at the time of publication.

2. ORIENTATION TO BLACK CARBON-AMENDED ENGINEERED MEDIA FILTRATION FOR PASSIVE STORMWATER TREATMENT

Traditional media-based stormwater filtration systems have been widely used to treat stormwater runoff and are generally documented as a standard SCM type in stormwater technical guidance manuals nationwide, such as those used for post-construction (or new and re-development) SCM selection and design. The most basic stormwater media filters (SMFs) are sand filters, which rely primarily on physical filtration, followed by mixed media SMFs that typically involve sand mixed with an organic amendment such as compost or other organically rich soils containing humus (loam), typically ranging from 5 to 40% by volume (although other alternative organic amendments may be allowed). This mixture is often referred to as a bioretention soil media (BSM). Media amendments are also often sought when low numeric limits (e.g., for heavy metals such as copper, lead, and zinc) must be met in stormwater discharges, such as under NPDES permits for industrial stormwater discharges. Caution should be exercised when using these organic amendments as discharge of higher nutrient (nitrates and phosphates) concentrations have been documented with the first 3 to 5 years in use.

Where SMFs are unvegetated, these are typically referred to as media filters. Where SMFs are vegetated, these are often referred to as bioretention. More recently, bioretention has been further refined to bioretention without underdrains (i.e., no treated surface discharge) or bioretention with underdrains (also known as biofiltration), acknowledging whether volume losses through infiltration are included in the design. Depending on the underlying soil type and infiltration capability, bioretention with underdrains may also provide substantial infiltration, especially when the underdrain is raised within the system profile to allow accumulation of volume in the pore space beneath the underdrain. The baseline performance of bioretention systems for conventional pollutants is summarized as part of the International Stormwater BMP Database (IBMPDB)[1]. The performance data in the IBMPDB represents the discharge from the underdrains of bioretention (aka biofiltration). Readers are referred to the IBMPDB for comprehensive statistical evaluations of removal performance for "standard" or "typical" SMFs for a wide range of CoCs, although limited to no data may be available for many of the CoCs studied here.

DoD site managers and RPMs may encounter various site conditions and regulatory settings that require enhanced treatment of target CoCs. Some insecticides, herbicides, corrosion inhibitors, and PFASs can be challenging to treat because they are hydrophilic, meaning they readily dissolve in water, including stormwater runoff and groundwater, and are not particle-associated. Dissolved forms of pollutants in stormwater are difficult to remove through common or traditional treatment processes such as settling and physical filtration alone (i.e., without use of adsorption or cation exchange processes). Successful treatment options for these compounds can include passive engineered media treatment systems with amendments specifically selected to adsorb or absorb (together called sorption) the target CoCs. Other treatment approaches can include active media treatment systems and advanced treatment such as chemical oxidation. These treatment approaches

[1] https://bmpdatabase.org/performance-summary-reports

are effective because they are capable of either retaining or destroying the CoCs that often pass through a typically designed SCM.

Where treatment of the target CoCs requires enhanced levels of treatment beyond what is provided by standard SMFs, the use of passive BCSMF treatment systems (with or without vegetation) can be a desirable treatment option due to their simplicity, improved sustainability, and potential cost effectiveness compared to active treatment approaches, which typically require a power supply and containerized treatment unit operations.

When designing a BCSMF, adequate sorptive material (e.g., black carbon and/or other amendments) and contact time (often achieved through passive flow controls as part of the design) are needed to meet treatment objectives and provide acceptable longevity between maintenance cycles. The concentrations of CoCs must also be within a range that is treatable for passive BCSMF systems. For sites with a higher contaminant loading (e.g., those that are directly impacted with Aqueous Film Forming Foam [AFFF]), media breakthrough and exhaustion may be relatively rapid. Therefore, there is a range of hydrologic and constituent conditions where BCSMF treatment systems can be most effective. Beyond this range, an active or other treatment systems may be necessary and more cost effective.

This guidance is intended to support key decisions that site managers face when evaluating and designing BCSMFs, including:

Evaluation and Design of BCSMFs:

- Can BCSMFs meet a site's stormwater treatment objectives (e.g., necessary CoC removal rates)?
- Can BCSMFs perform sufficiently over maintenance intervals that are acceptable (e.g., reasonable time until media replacement)?

Key design parameters include the target CoCs, the amount and type of BC included in the media bed to treat those constituents, the footprint or area of the media bed, the depth of the media bed, a flow control such as pipe or orifice size to limit flow-through rate and to better calculate contact time, and the desired effluent concentration (and desired margin of safety) before media performance deterioration.

Other Considerations:

- What differences need to be considered in design and specifications of BCSMFs compared to traditional SCMs, especially bioretention?
- What differences should be considered in construction and operation of BCSMFs compared to traditional SCMs?

3. EVALUATION AND DESIGN OF BCSMFs

SCMs exist on a spectrum of design based on drainage area, dominant hydrologic processes, water quality (regulatory) goals, operational and capital cost, availability of construction materials, and the co-benefits that they offer. Therefore, design should consider many of these factors during the evaluation process. BCSMFs are one management tool in the suite of practices that can be used to manage stormwater runoff. These SCMs focus specifically on providing a high level of sorption capacity for target CoCs found substantially in a dissolved or colloidal form.

This section details the applicable constituents for which the design tools were developed along with a description of the treatment mechanisms/unit processes on which BCSMFs depend, relevant design variables, modeling efforts and tools supporting design, and estimated longevity of treatment based on various influent and design characteristics.

3.1 Applicable Constituents of Concern

The laboratory study performed in ER18-1145 included the following CoCs:

- Metals: nickel, copper, zinc, cadmium, and lead;
- Legacy hydrophobic contaminants and pythrethroids: PCBs, PAHs, bifenthrin, and permethrin;
- Pesticides and corrosion inhibitor: atrazine, benzotriazole, diuron, fipronil, imidacloprid, and mecoprop; and
- PFASs derived from AFFF: PFOS and PFOA, as well as other PFASs.

Full-scale columns (24-inch depth, 3-inch diameter), operated in gravity driven downflow configuration, with sample ports at 6-inch intervals, were used to investigate the performance of BC- and zeolite-amended media. The laboratory-based experiments were designed to be representative of field conditions by using catch basin material obtained from Naval Weapons Station, Seal Beach, CA, dissolved organic carbon (DOC) concentrate derived from straw, and salts to provide realistic synthetic stormwater quality. Additionally, columns were conditioned with synthetic stormwater before challenge testing with added contaminants to allow for growth of biofilms and initial media fouling. Column study and contaminant transport modeling results for selected CoCs (PFOS, PFOA, atrazine, imidacloprid, and fipronil) were then used to develop the design and performance information to support this guidance document.

Contaminant transport was modeled using an advection-dispersion model with retardation due to intraparticle pore diffusion-limited sorption using Freundlich sorption parameters. These parameters, along with effective tortuosity, were then fit by minimizing the normalized mean squared error of the difference between the model prediction and observed values greater than the limit of quantification using a multi-parameter solver. Additional long-term column experiments validated the modeling approach for predicting contaminant transport at higher flow rates, different influent concentration levels, and at different BC contents. Experimental results are included in

the ER18-1145 Final Report and are also published in peer-reviewed journal articles, such as Pritchard et al. (2022). BCSMF system performance tables were then constructed using the contaminant transport model to determine the effects of:

- Flow rate (related to contact time; governed by ponding depth and pipe or orifice controls on discharge);
- Inflow CoC concentration(s);
- Type and percent of BC by volume;
- Media depth; and
- Desired effluent concentration (to determine target removal percentage).

These parameters can be used to predict the removal performance and, therefore, the effluent concentration from a BCSMF for the selected CoCs. Additionally, annual volume treated and filter lifetime (or time until actual removal is anticipated to drop below target removal) are also calculated. Filter lifetime is particularly important to evaluate for these lesser-studied hydrophilic trace organics and PFASs. With some hydrophobic organics and heavy metals, studies have shown in the lab and field that solid loading can lead to clogging prior to exhaustion of filter lifetime. However, with the hydrophilic trace organics and PFASs, media exhaustion (actual discharge concentration exceeds discharge limit) can precede clogging. Moreover, even with inclusion of BC materials, removal of hydrophilic organics and PFASs is governed by the rate of contaminant sorption rather than the media sorption capacity. Therefore, a tool that can estimate the contaminant removal level and lifetime of performance for specific SCM designs and scenarios is useful to better achieve water quality discharge goals. This guidance assists SCM designers in creating effective designs and in writing an informed SCM operations and maintenance plan (i.e., to understand lifecycle costs and anticipate media replacement). A lifecycle cost analysis can be useful to budget projects as well as to compare treatment alternatives and identify a lowest cost solution.

The results of this effort were included in a design tool called the Treatment Engineered Media Performance and Sizing Tool (TEMPEST). This tool assists BCSMF system designers to calculate the various treatment lifetimes for specific BCSMF designs based on site runoff characteristics (average annual rainfall, 85th and 95th percentile rainfall volumetric or flow capture, impervious area, inflow concentration) using the filter performance tables and a desired treatment objective expressed as ratio of effluent concentration to modeled concentration of full exhaustion. For example, a value of 1.0 is where effluent concentration is equal to influent concentrations representing complete exhaustion, while a value of 0.5 is where effluent concentration is 50% of the influent concentration. Specifying a specific CoC treatment objective permits users to select a BCSMF design that represents a reasonable estimated media lifetime for a defined (but predicted) CoC removal or discharge concentration.

TEMPEST does not include predicted results for all the above CoCs. The included compounds were selected because they are representative of the range of studied PFASs and pesticides.

Specifically, PFOS and PFOA were selected of the PFASs because of their regulatory relevance, with PFOS being indicative of less mobile PFASs and PFOA being indicative of more mobile PFASs. Atrazine, imidacloprid, and fipronil were chosen because they are indicative of the range in mobility of the studied pesticides, with atrazine and imidacloprid representing moderate relative mobility and fipronil representing high relative mobility. Contaminant mobility within media filters is indicative of the rate at which the filters are exhausted, with more mobile contaminants causing filter exhaustion sooner.

3.2 Hydrologic Considerations

The primary considerations in the drainage area of a SCM are the size and imperviousness of the area, which strongly affect the flow and volume of stormwater runoff entering the system. The drainage area, CoCs, and impervious area may impact which type of SCM is best suited or how many units or sizes of the practice are needed. Consideration of the drainage area is crucial for ensuring that the system is functional and will maximize the lifespan. Media in undersized practices can become exhausted much quicker, while oversized practices are less cost efficient.

Due to the typical size of an engineered media biofiltration system, they are applied in drainages that have a relatively small contributing area (less than 5 to 10 acres). The engineered media biofiltration system surface area may range between 2% to 12% of the contributing area depending on the imperviousness of the contributing drainage area, depth of media, and discharge rate. The TEMPEST tool can help determine the combination of media depth and footprint to size the BCSMF that can achieve a defined and desired target reduction in CoC concentration.

Clogging is always a concern in filtration-based systems. While much of the BCSMF treatment is based on sorption capacity, clogging due to particulate matter and other solids in the influent often controls maintenance cycles in traditional SCMs. For hydrophilic and dissolved compounds, solids management may be more challenging. Pretreatment to reduce solids loading should always be included in the design treatment train to reduce the time to surface clogging due to solids deposition, allowing increased treatment of the targeted hydrophilic and dissolved CoCs. Pretreatment system maintenance should consider the potential rate and type of accumulated solids, associated CoCs, and proper disposal. While clogging was not the focus of this research, typical solids loading and pretreatment settling was included in the column study design. Maintenance of the surface media was completed several times during the experiment.

3.3 Treatment Unit Processes in BCSMFs

Sorption is the primary design parameter and most influential removal mechanism for BCSMF treatment systems. In addition, sedimentation and physical filtration play a part in the overall treatment. Each unit process is provided in this section with more detail.

3.3.1 Settling and Sedimentation

Settling and sedimentation are not the primary unit treatment processes within BCSMF treatment systems, although some settling does occur. Sedimentation includes deposition or settling of particles within a SCM system. The sedimentation rate can vary based on factors such as the

particle size, density and diameter, water temperature, and the balance between settling and mixing. The sedimentation rate increases as density and size of particles increases. The mass of particles that settle on the media surface are dependent upon the inflow mass loading. Drainages with high mass loading will require maintenance sooner than those with lower mass loading. Pretreatment systems that have good observability to inspect maintenance needs, have relatively easy access, and require simple equipment to maintain are recommended prior to all SCMs to reduce the frequency of maintenance and extend the lifetime of operation between maintenance cycles.

3.3.2 Physical Filtration

SCMs that include granular or sand-based media as part of their design use filtration as a physical process to remove suspended solids and sediment-bound pollutants. As stormwater infiltrates the granular media (typically by way of gravity in passive systems), solids and pollutants are trapped between the media particles of the system, removing them from the stormwater.

Filtration efficiency of a SCM is expressed as a ratio between the concentrations of pollutants in the stormwater at the top of the filter bed (influent concentration; Co) to the concentration at the discharge locations (effluent concentration; C). Factors such as particle size, media type, media filter design/depth, and infiltration rate strongly impact the filtration efficiency.

The trapped solids and pollutants accumulate within the media particles over time, eventually clogging the filter and reducing the flow rate of the SCM. Sediment should be removed by backwashing, surface scraping, or media replacement to ensure the functionality of the SCM in maintained.

3.3.3 Adsorption/Absorption (Sorption)

Adsorption is a process in which the pollutant adheres to the surface of media, while absorption is the mechanism where the pollutant is completely dissolved or diffused in the media particle. These processes often happen together, collectively resulting in the term sorption.

The speed at which CoCs undergo sorption to the media is dependent upon many factors, including the constituent chemical characteristics and concentration, temperature, pH, water hardness, sodium, or other competing ions, for example. The bench study supporting this guidance evaluated various rates of flow and media depth that correlate to media contact times to understand the influence of this design parameter. Figure 1 shows an example of how a longer contact time results in lower outflow concentrations. In this example, if the BCSMF treatment system was designed for 240 minutes of contact time (using an orifice control), then the media would treat decades worth of volume before reaching an effluent concentration requiring media replacement.

The percentage of black carbon is also a primary design variable to determine the amount of sorption that can occur within BCSMF treatment systems. Figure 2 demonstrates how the percentage of biochar can affect the treated volume (as represented by empty bed volumes, the total volume of the media bed).

For these performance estimations to be consistent with the modeling effort, biochar and RAC that have nearly the same specifications as that used in the study, should be used. See Section 4 for media specifications to develop media to achieve modeled treatment goals.

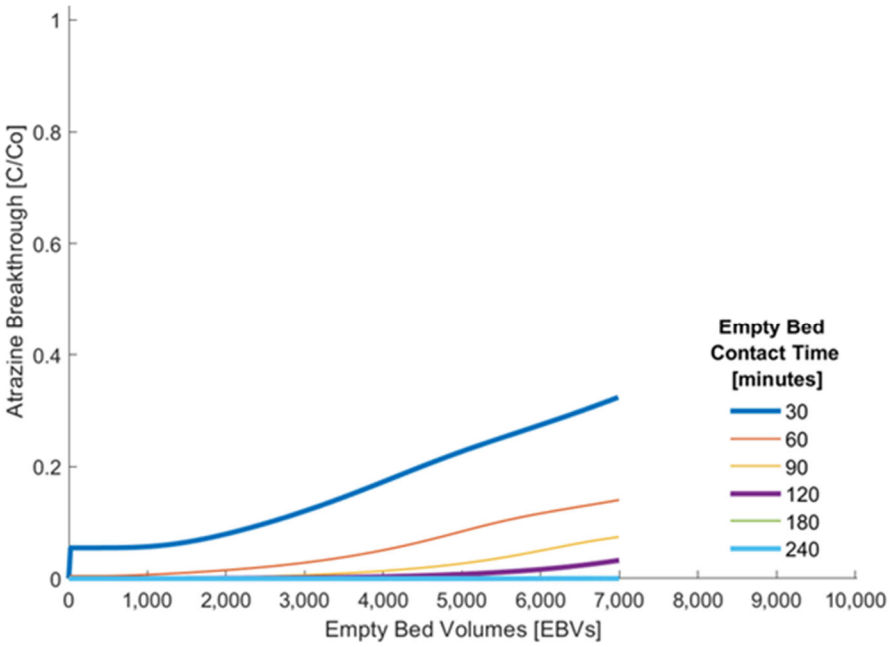

Figure 1. Example from the empirically developed model demonstrating how contact time impacts the ratio of outflow concentration versus inflow concentration for atrazine with an influent concentration of 1 µg/L and 30% biochar (by volume).

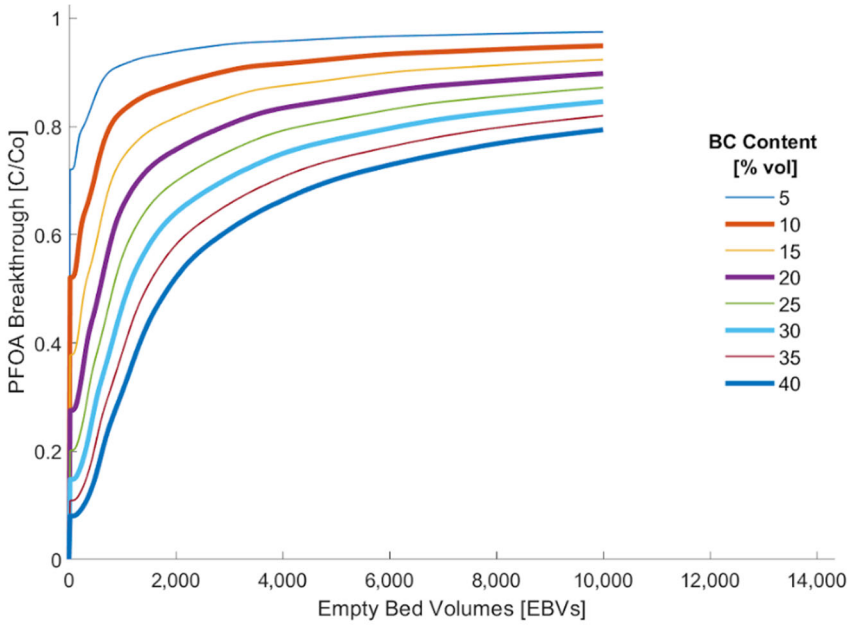

Figure 2. Example from the empirically developed model demonstrating how percent of black carbon (BC; in this case biochar) impacts the ratio of outflow concentration versus inflow concentration for PFOA with an influent concentration of 100 ng/L and 30% biochar (by volume).

3.3.4 Ion exchange

Black carbon and natural zeolites are also used in industrial processes for their ion exchange properties. While also related to sorption, the internal structure, including interconnected cavities and channels of molecular dimensions, allow for reactive surface functional groups to readily contribute to ionic exchange and transfer and distribution of solutes between a fluid phase and the media particles. Thus, the media can reduce CoCs through cation exchange similar to water purification and wastewater treatment.

3.3.5 Phytoremediation and Biodegradation

Many traditional SCMs include vegetation in their design, such as aquatic plants in wetlands and ponds, grasses and native vegetation in rain gardens, bioretention systems, and biofiltration systems, as plants often add beneficial treatment characteristics. Although vegetation is known to uptake and transform TrOCs, the contact time or hydraulic residence time to achieve phytoremediation may be much longer than the time required for other treatment unit processes (e.g., sorption and ion exchange). As such, the role of phytoremediation and biodegradation of CoCs was not studied in as part of ER18-1145.

3.3.6 Summary

The unit operations and process that can treat constituents of concern are primarily adsorption/absorption (sorption), ion exchange (for cationic CoCs only), and possible biodegradation and/or phytoremediation as shown in Table 1.

Table 1. Summary table of the unit processes that may occur within a BCSMF treatment system, including vegetated systems.

Processes	Description in the context of stormwater treatment	Potential CoCs Targeted	Media Parameters to Evaluate
Filtration/ Straining	Straining/entrapment of particles into the interstitial spaces	Particulate-bound CoCs	Particle size distribution
Sorption	Adsorption/absorption of dissolved pollutants to the media grains	Heavy metal, and trace organics	Absorption/absorption capacities, contact time, particle size, surface area
Ion Exchange	Exchange of deleterious ions for ions with no adverse environmental impacts	Heavy metals	Cation exchange capacity
Biodegradation	Degradation of contaminants through microbial action	Organics, nutrients, trace organics	Active biomass/g of media; pH
Phytoremediation	Plant uptake and transformation of contaminants	Trace organics, heavy metals	Plant health/species; plant toxicity

It is important to keep these processes in mind when considering media development, design, and implementation of BCSMFs.

3.4 Evaluation of BCSMF Performance and Longevity

3.4.1 Column Study BCSMF Performance Tables

Data from column studies were used to fit and calibrate an advection-dispersion model with sorption retarded intraparticle pore diffusion. The Freundlich isotherm was used to describe sorption of TrOCs to the BC materials. Sorption and effective tortuosity parameters were fit by minimizing the normalized mean squared error of the difference between the model prediction and observed values greater than the limit of quantification. The model-derived parameters were then validated in additional laboratory-based column experiments using different flow rates, influent concentrations, and BC contents. Results from the experiments are reported in the ER18-1145 Final Report and peer-reviewed journal articles such as Pritchard et al. (2022). BCSMF system performance tables were constructed using the contaminant transport model to determine the effects of flow rate and media depth (related to contact time), inflow concentration, and percent of black carbon on removal performance, as these are primary SCM design variables. This process

was completed for selected hydrophilic trace organics: atrazine, imidacloprid, fipronil, PFOS, and PFOA.

3.4.2 Treatment Engineered Media Performance and Sizing Tool (TEMPEST)

The filter performance tables were included in a BCSMF design tool called TEMPEST to assist BCSMF system designers in making decisions on filter design and engineered media based on their specific site conditions and treatment objectives. TEMPEST integrates the filter performance tables generated from the contaminant transport modeling with hydrologic modeling and SCM sizing for design storm events, to estimate BCSMF performance and filter media lifetimes (the time at which predicted effluent concentration is greater than the target effluent concentration defined by the target removal) and filter media costs. By allowing users the flexibility of inputting watershed and SCM specific inputs to evaluate the impact on filter lifetime and media cost, the preliminary design and decision-making process is streamlined.

TEMPEST, included in APPENDIX D of the ER18-1145 Final Report is a Microsoft Excel based tool. Users should follow instructions outlined in the "Read Me" and "Instructions" tabs. The instruction tab describes in detail each sheet of the tool that requires user input, provides a step-by-step process for inputting data into the tool, lists data that are either required, provided, or optional, and summarizes author notes and key assumptions. See below section for the key subwatershed characteristics and SCM design parameters users are required to obtain.

3.4.3 TEMPEST Components

The Soil Conservation Service (SCS) curve number method is used to calculate runoff volume based on rainfall design storm event and drainage area physical properties. Two options exist for DoD facilities for estimating the required volume of runoff that needs to be retained on-site using low impact development BMPs to comply with Energy Independence and Security Act (EISA) Section 438. One option is to retain runoff from the 95th percentile rainfall event (EPA 2007, United States Army 2013). The tool offers default 85th and 95th percentile 24-hour event rainfall depths and mean annual rainfall depths (1981 to 2010) for 206 cities across the contiguous United States (Shresthra 2013, NOAA 2022, and US Climate Data 2022) . Users may also input their own design storm and mean annual rainfall depths. The minimum required data for the hydrologic components of the tool include drainage area, land use breakdown of the drainage area, and watershed surface area flow properties (flow length and slope). The hydrologic component of the tool determines SCM size and the total volume of runoff that will move through the media filter over the course of a year. Both values impact filter lifetime and cost.

While SCM design parameters and sizing are based on volume-capture only, users have the flexibility to design the SCM to either fully capture the specified design storm runoff volume within the ponding layer or insert specific SCM dimensions, regardless of the design storm runoff volume. TEMPEST assumes outlet-controlled SCMs where water flows into the SCM at a faster rate than it does through and out of the SCMs. Flow is controlled at the outlet of the SCM using either orifice design parameters (preferred design due to better long-term control) or a user-specified SCM media outflow rate. The minimum required data for the SCM design component of

the tool include ponding depth, media filter depth, and orifice width. SCM design parameters are used to estimate the empty filter flow through rate and empty filter contact time, which is a design variable in the BCSMF performance tables and a parameter that impacts total empty bed volumes until media exhaustion. Media filter volume is used to estimate empty bed volumes per year and thus filter lifetime and cost. While TEMPEST includes several flags/suggestions and specific ranges of design parameters to assist in designing a SCM with respect to common design practices, users should refer to local and state requirements.

SCM performance parameters include all the parameters necessary to utilize the BCSMF performance tables. TEMPEST allows the user to select from five CoCs (atrazine, fipronil, imidacloprid, PFOA, and PFOS) and two media filter materials (Biochar and RAC) for SCM media performance design. Required data for the SCM performance table include CoC influent concentration. Every SCM performance parameter impacts media filter lifetime and media cost.

3.4.4 TEMPEST Outputs

TEMPEST generates key outputs to assist users in assessing the effectiveness of their SCM design parameters and evaluate the filter lifetime-cost tradeoffs.

Target effluent concentration. The target effluent concentration is calculated using CoC influent concentration and target removal and can be used to confirm that target removal is possible with the user-specified SCM design (sizing and performance). If the mean predicted EBVs is 0, the target removal is not possible. Users may either decrease target removal, increase material content, increase media flow through time, or try a different media material to increase EBVs and thus, media filter lifetime.

Mean Filter Lifetime (in EBVs). Mean EBV represents the mean number of empty bed volumes treated until media exhaustion (until effluent concentration is greater than user-defined target effluent concentration given the SCM design parameters). The BCSMF lookup tables report mean EBV for 14 media flow-through time values (empty filter flowthrough time) ranging from 30 minutes to 360 minutes and 8 BC volume contents ranging from 5% to 40%. TEMPEST assumes a linear interpolation for cases when the media flow through time falls between two of the lookup table values.

Mean Filter Lifetime (in years). The mean EBVs until exhaustion and the estimated SCM EBV/year are used to estimate the mean filter lifetime in years. If a filter lifetime is projected to last greater than 25 years, required media replacement will likely be governed by clogging and not sorption capacity.

Filter Lifetime Uncertainty. BCSMF performance tables report mean EBV standard deviations. The standard deviation represents the portion of the uncertainty stemming from the contaminant transport modeling of the estimated mean filter media lifetime. The mean filter media lifetime is found by averaging the estimated lifetimes of three independent column replicate-derived models. Instances of low relative standard deviation (<25%) indicate a higher degree of confidence in the estimated filter media lifetime. Instances of larger relative standard deviation (>50%) indicate

higher degrees of uncertainty in the estimated filter media lifetime. Uncertainty can be decreased by decreasing the flow through rate or increasing the BC content. Instances when the mean estimated filter lifetime minus the standard deviation is greater than 25 years tare noted specifically in the TEMPEST results table. The filter lifetime standard deviation does not account for uncertainty related to background DOC or other discrepancies of laboratory versus real world conditions.

Media purchase cost. Finally, media purchase cost[2] was included to assess the tradeoffs between filter media performance and filter material. RAC generally outperforms biochar on a percent volume basis as RAC is five times more dense than biochar, thus equivalent volumes of RAC and biochar would contain five times more RAC by mass (sorption is typically on a per mass basis). However, biochar is 1/3 the price of RAC on a volume basis and so depending on cost, biochar may outperform RAC on a cost basis. See Table 2 for cost estimates for BC amendment used in the column test study. Default costs are based on manufacturer data reported in the column studies and does not include shipping. Costs will depend on the quality and sources of BC. Additionally, transport and mixing are variable and may be a substantial component of the costs. Users may input their own cost data for BC and sand.

Table 2. Media purchase costs used as default values in TEMPEST. Biochar and RAC costs (in 2022 USD) are specific to the manufacturers used for lab column tests. Users are encouraged to manually enter costs in TEMPEST for the three materials based on their specific manufacturers/suppliers.

Parameter		Biochar[a]	RAC[b]	Sand
Cost by Mass	$ kg^{-1}	2.54	1.50	0.05
Density	$kg\ m^{-3}$	103	510	1,600
Cost by Volume	$ m^{-3}	262	763	85.11
Cost by Volume	$ ft^{-3}	7.42	21.61	2.41

[a] Biochar Supreme Environmental Ultra, WA; [b] Norit GAC 830R;

3.4.5 TEMPEST Scenario Example

Two scenarios are provided as an example to compare biochar and RAC performance with identical hydrologic, SCM sizing, and target removal inputs. The example is for treatment of PFOS at an influent concentration of 0.1 micrograms per liter (µg/L) (or 100 nanograms per liter [ng/L]) with a target removal of 95% (i.e., target effluent concentration of 0.005 ug/L (or 5 ng/L). The results for predicted media filter lifetime and cost are compared. Table 3 lists the input values used to set up the scenarios.

[2] Default media purchase costs in TEMPEST are specific to the manufacturer used for lab column tests. Biochar Manufacturer: Biochar Supreme Environmental Ultra, WA. RAC Manufacturer: Norit GAC 830R

Table 3. TEMPEST Input Parameters for the Two Provided Scenario Examples.

TEMPEST Parameter	Value Inputted
State (For default rainfall depth values)	California
City (For default rainfall depth values)	Los Angeles
Recurrence Interval for Default Design Storm	95th Percentile 24-hr Event
95th Percentile Rainfall depth (in)	2
Dominant Hydrologic Soil Type	C
Drainage area (acres)	1
Area of Streets and Roads (acres)	0.2
Industrial Area (acres)	0.8
95th Percentile Rainfall volume (ac-ft)	0.10
Mean Annual Volume of Runoff (ac-ft)	0.64
Design SCM to capture full 95th percentile storm event runoff?	Yes
Ponding Depth (ft)	1.5
Media Filter Depth (in)	18
BMP Footprint (ft^2)	2,994
Orifice Diameter (in)	3.25
Orifice Coefficient	0.61
CoC	PFOS
BC Media Content (% Volume)	20
Influent Concentration (ug/L)	0.1
Target Removal (%)	95%
Default Cost values for Sand and BC?	Yes

Table 4 displays the TEMPEST outputs considering the parameter inputs specified above. Scenario 1 (Biochar) has a shorter predicted filter lifetime (12 years) but lower initial media purchase cost ($15,000); whereas, Scenario 2 (RAC) has a longer lifetime (>25 years) but higher media cost ($28,000). While there exists uncertainty in the RAC filter lifetime, the lower bound of the standard deviation still predicts a filter lifetime of +25 years.

Table 4. TEMPEST outputs for the two provided scenario examples looking at the difference between Biochar and RAC.

	Empty Filter Flow Through Time (min)	Target Effluent Concentration (ng/L)	Mean Filter Lifetime (EBVs)	Mean Filter Lifetime (years)	Filter Lifetime Uncertainty	Media Purchase Cost (Sand and BC)
Scenario 1 (Biochar)	112	5	73	12	> +/- 50%	$15,000
Scenario 2 (RAC)	112	5	9045	+ 25 years	Entire Range Still + 25 Years	$28,000

3.4.6 Key Assumptions and Limitations of TEMPEST

While TEMPEST assists BCSMF designers to estimate effluent concentrations and filter media lifetimes based on pollutant, site, and BCSMF design parameters, users should be aware of local regulations, recognize TEMPEST's limitations and assumptions, and use TEMPEST at their own risk. A list of key assumptions are included below:

- TEMPEST performs volume-based SCM sizing of the BCSMF using a runoff volume produced for a selected design event. Flow-based SCM sizing is not fully supported. However, a user can do a flow-based design outside the tool and then enter the SCM footprint, depth, and flowrate in the tool to simulate this scenario in order to estimate CoC removal and filter lifetime performance.
- TEMPEST assumes outlet- (or orifice-) controlled SCMs by default, no media-flow-controlled SCM calculations are used in this tool.
- Solids pretreatment is recommended for any filtration-type SCM, including BCSMFs. TEMPEST's media lifetime estimates are based on modeling calibrated to results of lab column experiments, which used pretreated influent total suspended solids (TSS). Therefore, the contaminant transport modeling and TEMPEST assume that the CoCs are primarily dissolved and/or colloid-associated. This tool does not predict the estimated time to clogging from solids accumulation.
- TEMPEST assumes 100% of the design volume of runoff is treated through the SCM and media filter. Note that this volume is different from the mean annual runoff volume. As defined in the UFC design manual, this volume achieves the requirements defined as the "maximum extent technically feasible" criterion.
    - To estimate EBV/year, TEMPEST uses the total mean annual volume of runoff. In practice a portion of the mean annual runoff volume is anticipated to bypass the treatment system during large and/or back-to-back storms. These bypass flows will remain untreated. The EBV/year used in calculating the lifetime of the media is an

overestimate of actual treatment volume, resulting in this estimate as a conservative value.

- TEMPEST includes five CoCs for evaluation: atrazine; fipronil; imidacloprid; PFOS; and PFOA. Future work could expand this to incorporate other CoC types.
- Increased dissolved organic carbon (DOC) may result in faster contaminant transport and reduced sorption capacity. The lab column experiments used DOC concentration of 5 to 9 mg carbon per liter. Thus, the assumed DOC for the modeling, and used in TEMPEST, is 5 mg carbon per liter. Caution should be used when using the tool in watersheds where DOC concentrations are much greater than this value. The impact of background DOC on estimated filter lifetime is still a topic of academic study, and thus safety factors are encouraged for instances in which background DOC is significantly higher than 9 mg carbon per liter.
- The BCSMF performance table standard deviation represents the uncertainty in the model-estimated mean filter media lifetime. The mean filter media lifetime is found by averaging the estimated lifetimes of three independent replicate-derived models. Uncertainty can be decreased by decreasing the flow through rate or increasing the BC content. This does not account for uncertainty related to DOC.
- The contaminant transport modeling results are specific to the BC media studied in the laboratory experiments. The TEMPEST tool should only be used when using BC material of similar specifications, as reported in section 4.1. Use of larger sized BC media than is recommended below will reduce the CoC removal performance and is not supported by TEMPEST. Additionally, the contaminant transport modeling assumed saturated conditions with continuous flow. Unsaturated conditions and intermittent flow are not expected to affect metal or pesticide and corrosion inhibitor removal performance and may even improve PFASs removal performance.

As with any model, estimated performance is just that and there is an associated uncertainty with the estimates. While the reported standard deviation quantifies the uncertainty resulting from the contaminant transport modeling, including experimental and sampling error and error associated with conducting the parameter fitting, other sources of uncertainty are possible. Laboratory-based experiments, regardless how representative of field conditions, are inherently laboratory based, and may deviate when transferred to the field. To account for this, standard engineering practice for SCM design is to incorporate safety factors such as using a higher target removal percent (which determines desired effluent concentration) and/or to monitor effluent concentration. The same is recommended here with BCSMF design. Therefore, when applying information from TEMPEST for the purpose of BCSMF design, the ability to apply a safety factor has been included and should be used. For example, it is recommended that BCSMF designers understand how either a change in the % carbon used or change in media contact time affects the reported lifetime values provided by TEMPEST. As with any estimated result, the best way to assure that target effluent concentration is achieved is to monitor the effluent to determine whether media replacement may be nearing.

4. OTHER DESIGN, CONSTRUCTION, AND OPERATION CONSIDERATIONS FOR BCSMFS

The focus of this section is on differential guidance compared to traditional biofiltration or media filtration SCMs.

4.1 Specifications for BCSMF media

Specifications for media amendment materials are necessary to obtain a product that performs as expected, as well as to populate notes in for-construction design plan sets (which are needed to support construction bidding, accurate cost estimation, and proper construction). Additionally, there are important testing and rinsing aspects that are either necessary or are helpful to get the longest life from the media. The following are example media specifications and testing guidance that are recommended for BCSMFs.

4.1.1 Filter Media Mixing and Delivery

One of the most important aspects to creating a functional treatment media blend is to determine a qualified supplier. A supplier, typically a landscaping company that provides media for other applications, should be able to mix up to four media amendments. The supplier should also be capable of washing materials at the site of storage or mixing. It is recommended that filter media components be thoroughly mixed off site prior to delivery. Mixing should be performed using a drum mixer or another approved blending method. Proportions of individual components in filter media should be controlled using individual hopper feeds to a continuous mixing system. Batch blending methods may be approved by the Engineer or Engineer's designated representative. Filter media should not be mixed using a bucket loader.

Blended filter media should be delivered to the Site and should either be immediately placed in the treatment facility or should be properly stored on site. If the duration until placement is longer than one week, the media should be properly covered and contained to prevent dispersion or separation from wind or rain. Filter media should be delivered to the Site for infiltration rate testing.

4.1.2 General Filter Media Requirements

The BCSMF filter media should consist of the following components by volume:

- Clean fairway top dressing filter sand or any other sand meeting requirements specified below;
- Biochar or RAC; and
- Zeolite (optional, effective for heavy metals).

Blended filter media should conform to the specifications shown in Table 5.

Table 5. Blended Filter Media Specifications and Test Methods.

Parameter	Test Method	Requirement
Total porosity	ASTM D1557	> 35% @ 85% of maximum dry density (MDD)
Maximum dry density	ASTM D1557	< 105 lb/ft^3 @ 85% MDD
Permeability	ASTM D2434	> 8 in/hr @ 85% MDD
Percent Passing 200 sieve	ASTM D422	< 3%; all materials passing the 200 sieve should be non-plastic
Coefficient of Uniformity (D60/D10)	ASTM D422	< 4
pH		6.0 to 8.0
Chloride		< 300 ppm
Salinity		< 3.0 mmho/cm (<3.0 mS/cm) as electrical conductivity

Quantities of biochar should be determined using the companion treatment engineered media performance and sizing tool (TEMPEST). Translating between percent volume and weight can be accomplished using bulk density information. Quantities by weight are not included in this specification guidance.

Prior to or after placement (in situ), the media should be rinsed until turbidity is reduced and stabilizes. Wash water from this activity should be monitored for turbidity and other constituents of concern. Discharge of wash water should conform with regulatory guidelines for waste discharge.

4.1.3 Filter Sand

Filter sand should consist of clean, washed silica sand, similar to golf course top-dressing sand. It should conform to Table 6 as determined by an accredited laboratory. In general, materials passing #12 x #40 mesh sieves are acceptable.

Table 6. Sieve Size Analysis Results for Filter Sand.

Sieve Size	Percent Passing
No. 4	100
No. 10	95-100
No. 18	80-100
No. 35	20-70
No. 60	5-25
No. 100	0-5
No. 200	0-2

4.1.4 Biochar

Biochar should consist of material that is made via 1) slow-pyrolysis with temperature greater than 700° C for 2 hours, or 2) fast-pyrolysis with temperature greater than 900 ° C in an air-fed updraft gasifier and uses a wood feedstock (ideally pine wood). It may be advantageous to search for a local manufacturer that can make the product to the specifications below.

Biochar should be rinsed and/or sieved material conforming to the requirements in Table 7. In general, materials passing #12 x #40 mesh sieves are acceptable.

Table 7. Biochar Specifications.

Parameter	Requirement
Feedstock	Should be produced from a wood feedstock (preferably a soft wood such as pine). May not be produced from grass or other friable feedstocks
Production Temperature Regime	Should be produced under 1) slow-pyrolysis with oxygen limited conditions at least 700 °C for at least 2 hours or 2) fast-pyrolysis at 900-1000 °C in an air-fed updraft gasifier
Post-production treatment	May be treated after production to upgrade or otherwise alter material. All other required parameters must still be met
Post-production processing	Should be either rinsed or sieved to remove very fine and coarse particles
Brunauer Emmete Teller (BET) Specific Surface Area	>500 m^2/g
pH	< 10
Total Ash	<10%; dry weight basis
Organic Carbon	> 70%; dry weight basis
Percent passing #12 mesh sieve	> 95%
Percent passing #40 sieve	< 5%

4.1.5 Regenerated Activated Carbon

RAC should consist of GAC that has been regenerated and is designated for high performance water treatment, such as for industrial or municipal wastewaters. RAC should be sieved to confirm to the requirements in Table 8 below. Materials passing #8 x #30 mesh sieves are acceptable. Cabot Norit 830R regenerated granular activated carbon was used in the column studies and contaminant transport modeling. Similar RAC products meeting the specifications of Table 8 are acceptable.

Table 8. RAC Specifications.

Parameter	Requirement
Use purpose	Designed to provide high level of treatment for industrial and municipal wastewater
Density	31.2 - 38.0 lb/ft^3
Brunauer Emmete Teller (BET) Specific Surface Area	>900 m^2/g
Percent passing #12 mesh sieve	> 95%
Percent passing #40 sieve	< 5%

4.1.6 Other Media Amendments

Other alternative organic and ion exchange amendments may be added in place of biochar, regenerated activated carbon, and/or standard zeolite; however, their performance has not been evaluated here, and their performance should not be estimated with TEMPEST. While the added benefits of these may be limited, some have proven promising in other studies at removing other CoCs; therefore, they may offer potential improved treatment capability for a broader suite of CoCs. There is no requirement to include these alternative amendments. The additional costs of these materials should also be recognized.

4.1.6.1 Coconut Coir

Coconut coir is made of brown coconut fibers with high lignin and phenolic content. Coconut coir can provide additional water holding capacity and some organic carbon to support microbial and vegetation growth. There are many suppliers of coconut coir, but in general it should have the properties shown in Table 9.

Table 9. Coconut coir specifications.

Parameter	Requirement
Moisture	Up to 8%
Impurities	<3%
Length	50-200 mm
Diameter	50 to 300 µm

4.1.6.2 Clinoptilolite Zeolite

Clinoptilolite zeolite is a mineral-based additive. Zeolite has a high internal and external surface area that results in a high ion holding capacity. This large surface area and ion holding capacity also helps to retains heavy metal cations, including zinc (Zn), copper (Cu), silver (Ag), lead (Pb),

cobalt (Co) and nickel (Ni). It can also enhance nutrients removal (especially ammonia) through precipitation and ion exchange. Because zeolite is a mineral material, its presence also can help to maintain water permeability/hydraulic conductivity.

Many suppliers are available in the western US. Zeolite should be sieved to a size fraction that aids in the above benefits and should conform to the requirements in Table 10. It is best if zeolites can be rinsed prior to media mixing to remove very fine particles.

Table 10. Recommended Zeolite Specifications.

Parameter	Requirement
Percent passing #8 sieve (2.38 mm)	98% - 100%
Percent passing #20 sieve (0.84 mm)	0% - 2%
Cation exchange capacity (CEC)	> 1.3 mg eqv./ (full exchange >1.8 mg eqv./g)
Surface area	> 20 m^2/g
Pore diameter	> 5 nm
Chemical Composition SiO_2	>70%
Al_2O_3	> 9.0%
Si:Al ratio	> 5.5:1
Elemental Analysis Cd	< 1 ppm
Cr	< 10 ppm
Cu	< 4 ppm
Pb	< 18 ppm
Hg	< 1 ppm

4.1.7 Test Methods

Sieves for Testing Purposes Test sieves should be made of either: (1) woven wire cloth conforming to ASTM E11; or (2) square-hole, perforated plates conforming to ASTM E323.

Field test procedures may be either a Standard Operating Procedure (SOP) or a Field Operating Procedure (FOP) for an AASHTO or ASTM test procedure. A Field Operating Procedure is a technically equivalent abridged version of an AASHTO or ASTM test procedure for use in field conditions.

4.1.8 On-Site Infiltration Rate Testing

Filter media should be tested following delivery to site and prior to placement for verification of infiltration rate compliance.

i. For every 30 cubic yards of media to be installed, a filtration rate test should be performed on a representative media sample by the Engineer or Engineer's designated representative.

ii. The final media installed should be from the same batch as the representative sample tested.

iii. The constant head infiltration rate should be a minimum of 8 inches per hour, field measured. If the infiltration rate is less than 8 inches per hour, the contractor should not install the media and should contact the Engineer for a remedy.

4.1.9 Media Acceptance

Filter media should be tested according to these specifications prior to placement. If the media does not meet the requirements as outlined in these specifications, the contractor should contact the Engineer.

Media may be rejected if in non-compliance with the specifications and removed from the Site by the Contractor.

4.1.10 Media Placement

Media should be placed in the treatment facility via any method that does not generate unnecessary compaction, pulverization, or excessive dust. Use of a conveyor belt system with as short a drop as possible is recommended. A front-end loader, with operation to avoid excessive dump height, is also acceptable.

No equipment should be placed on the media after it has been placed in the treatment facility.

4.2 Outlet Control

Separate from traditional design approaches for bioretention, the BCSMF system media flow through-rate is not limited by the media, but rather using underdrain and orifice flow controls to achieve system design hydraulics and target contact time. Minimum media hydraulics should be satisfied through use of the specified materials. As such, underdrain linear open area, pipe flow, or orifice restrictions are recommended for controlling outlet flow rate. TEMPEST applies the orifice flow equation to outflow rate and allows for orifice sizes between 0.375 inches (3/8 inch) to 4 inches.

4.3 Vegetation

Vegetation can be beneficial to BCSMFs, mostly for providing resistance to clogging and maintaining hydraulic throughput through root growth. The roots may add organic matter and provide increased microbiological or mycorrhizal growth that may add to treatment capabilities. However, a full life cycle assessment should be done to understand irrigation and fertilization requirements or other vegetation operation and maintenance needs prior to selecting and planting vegetation. Some aspects of establishing and maintaining vegetation may lead to nutrient export such as fertilization and use of compost.

4.4 Media Testing and Disposal

When media exhaustion is nearing, the media can be tested for proper disposal methods. Media material should be properly disposed of or salvaged. Follow local/state requirements for solid waste characterization, transport, and disposal.

Typically, testing can be completed using standard toxicity characteristic leaching procedure methods (SW-846 Test Method 1311) and/or Waste Extraction Test (WET) methods to determine the proper disposal methods for media materials. A solid waste profile report should be provided based on TCLP results.

If materials do not require hazardous disposal, materials may be salvaged and used for other beneficial uses or disposed of in a standard solid waste disposal facility. Caution should be used if materials are salvaged and used again.

4.5 Additional Factors Not Specific to BCSMFs

Much of the BCSMF design is independent of whether BC is present. For example, pre-Treatment should be included whether BC is present, as clogging dynamics are the same. To maximize time until clogging and to make maximal use of the chemical removal performance of your media, pretreatment should be included in the design.

Regular maintenance should also occur. This can include solids removal, surface scarification, and vegetation maintenance at the minimum. Regular inspections for clogging assessment should be done regularly (typically after events larger than 0.5 inches and quarterly. Any accumulation of solids should be addressed in a regular maintenance cycle.

As influent velocity can scour any filtration SCM, energy dissipation should be included to protect the filtration layer and prevent scouring within the surface of the treatment system.

Underdrain design is similar, although using an underdrain with known discharge per linear foot is useful in design. Also, it is best practice to avoid filter fabrics between media types as this can lead to premature clogging. Instead, use gravel (e.g., pea gravel or squeegee) as a bridging/choking layer to limit media movement between layers and into the underdrain.

As BCSMFs are anticipated to treat stormwater runoff with CoCs, a liner is recommended between the base of the system and surrounding native soil.

As with any SCM, the way to understand performance and whether discharge requirements are met is to monitor the effluent (for discharge requirements) and influent (for system performance). In this way, an owner can demonstrate and be assured that they know whether regulatory limits are achieved. This may also inform necessary operation and maintenance such as media replacement.

5. COMPANION RESEARCH: ER18-1371 - DEVELOPMENT OF TOOLS TO INFORM THE SELECTION OF STORMWATER CONTROLS AT DOD BASES TO LIMIT POTENTIAL SEDIMENT RECONTAMINATION

5.1 Application

An associated study (SERDP ER18-1371) led by Texas Tech University with Geosyntec (in progress) is currently developing a set of tools to inform the selection of stormwater controls at DoD bases to reduce recontamination of bed sediment cleanup sites in receiving waters. Multiple SCMs currently in place at DoD facilities are being evaluated based on their performance to reduce pollutant loads and prevent sediment recontamination across a range of particle sizes for a suite of pollutants including metals, PAHs, PCBs, and PFAS. SCMs being evaluated include:

1. Retention Pond – At the Reese Technology Center in Lubbock, TX
2. Biofilter (hardwood mulch over proprietary engineered media) and media filter (bone char + ferrous-coated activated aluminum) hybrid – At Naval Base Point Loma
3. Vegetated Bioswale – At Naval Base San Diego
4. Vegetated Biofilter – At Naval Based San Diego
5. Hydrodynamic separator – At Puget Sound Naval Shipyard
6. Two Hydrodynamic separator + cartridge filters (zeolite, perlite, and GAC) – At Puget Sound Naval Shipyard

For sediment recontamination to occur, two criteria must be satisfied: 1) the mass loading of settleable solids (i.e., particles sizes that may settle in the near field zone, where receiving water bed sediment cleanup sites are more likely to be susceptible to long-term impacts of ongoing stormwater discharges) must be high enough to result in appreciable deposition of sediment (e.g., > 1mm per year); and 2) the concentration of the sediment cleanup CoCs per mass of settleable suspended solids (i.e., pollutant "particulate strength") must be above relevant sediment screening or cleanup criteria. The study focuses on heavy metals, hydrophobic trace organics commonly associated with contaminated bed sediment sites (e.g., PCBs, PAHs), and PFASs.

5.2 Results to date

Preliminary results demonstrate that coarse solids are effectively being removed in the tested stormwater management systems. Thus, stormwater contaminants that are associated with coarse silts and sand particles are effectively removed by most SCM types, including basic pretreatment devices that rely primarily on sedimentation processes and exclude filtration or chemical adsorption or cation exchange processes. This is critical in evaluating sediment recontamination potential because in the SCMs evaluated in this study, large particles have been shown to be the primary contributor to sediment loading near stormwater outfalls.

5.3 Relation to ER18-1145

A framework is currently being developed to quantify the sediment recontamination risk for various stormwater contaminants based on loading and pollutant particulate strength of settleable solids. This framework will inform the design and selection of SCMs at DoD facilities to target pollutants that are or may be capable of driving sediment recontamination. Thus, the framework will assist with evaluating the sediment recontamination reduction benefit of SCM implementation scenario alternatives, so that when paired with costs, a reproducible, data-based cost-benefit comparison is enabled for RPMs to support stormwater management decision making. Because this associated study focused on particle-associated pollutants and their pollutant strengths, it is non-duplicative with the studies described in this document, which focused primarily on the removal of hydrophilic pollutants, or those that are able to pass through standard lab filters.

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Atrazine Filter Performance Table

BC	C/C	BC	Inf	Empty Bed Contact Time [minutes]																													
Material	o	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	1	5	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	5	0.1	33670	18371	43023	21917	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	5	0.1	10723	4954	12873	5628	13334	6260	15488	8628	20398	11136	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	10	0.1	31346	17460	43307	22941	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	5	0.1	2371	4107	5810	5255	7545	3332	8713	3847	9316	4386	10324	5433	12754	6951	14247	7754	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	10	0.1	17566	7772	19195	9325	23362	12704	28638	15581	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	15	0.1	31403	16578	43172	23478	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	20	0.1	57848	31448	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	5	0.1	1687	2922	1817	3146	3966	3450	4978	3304	6115	2698	6874	3145	7413	3585	7931	4026	8991	4813	10579	5773	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	10	0.1	10058	6603	12923	5729	14493	6870	15930	8094	19870	10775	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	15	0.1	20834	9556	23998	12202	29738	16123	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	20	0.1	32134	16351	42754	23336	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	25	0.1	49947	27091	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	5	0.1	0	0	1303	2257	1451	2513	1533	2655	3599	3141	4623	2303	5193	2373	5663	2644	6269	3092	6826	3500	7425	3904	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	10	0.1	3083	5341	7484	6540	10006	4625	11365	5310	13194	6662	14888	7830	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	15	0.1	13981	6980	17102	7996	19759	9973	22386	11776	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	20	0.1	22875	10703	27517	14128	32963	17715	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	25	0.1	33109	16726	41298	22198	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	30	0.1	45105	23749	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	5	0.1	0	0	0	0	982	1702	1160	2008	1307	2265	2723	2368	3222	2792	4037	2075	4521	2169	4992	2415	5497	2755	6859	3636	-1	-1	-1	-1	-1	-1
Biochar	0.4	10	0.1	2327	4030	2698	4674	6185	5357	8088	4165	9562	4586	11010	5519	12490	6504	13734	7283	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	15	0.1	8167	7109	12153	6269	14302	6862	16538	8292	19717	10372	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	20	0.1	16230	8387	20064	9723	23966	12349	27534	14606	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Atrazine Filter Performance Table

BC	C/C	BC	Inf	Empty Bed Contact Time [minutes]																											
Material	o	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.4	25	0.1	23919	11491	29995	15459	35581	18966	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	30	0.1	33211	16664	41399	21969	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	35	0.1	43674	22728	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	40	0.1	55327	29370	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	5	0.1	0	0	0	0	0	0	575	996	946	1638	1090	1887	1229	2129	2438	2148	2887	2510	3667	1982	4050	2083	5166	2665	-1	-1	-1	-1
Biochar	0.3	10	0.1	1097	1901	1989	3445	2355	4079	4865	4288	6901	3999	8101	4171	9266	4719	10332	5332	11843	6257	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	15	0.1	3268	5661	7276	6421	10282	6008	12152	6261	14710	7533	17214	9048	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	20	0.1	9673	8545	14656	7967	17653	8989	20668	10672	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	25	0.1	17105	10074	22069	11244	26797	13924	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	30	0.1	24306	12551	31007	16019	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	35	0.1	32191	16418	41468	21920	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	40	0.1	41350	21374	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	5	0.1	0	0	0	0	0	0	0	0	0	0	682	1181	851	1475	975	1689	1143	1979	2166	1986	2537	2260	3825	2151	4731	2561	-1	-1
Biochar	0.2	10	0.1	0	0	814	1409	1580	2736	1943	3365	2683	4062	5061	4509	6707	4000	7636	4297	8860	4836	10032	5405	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	15	0.1	2008	3477	2903	5028	3649	6319	7572	6747	10764	6200	12820	7037	14944	8057	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	20	0.1	3856	6679	8511	7857	12407	7942	15216	8575	18951	10267	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	25	0.1	6046	10472	15458	9941	19771	11028	23537	12759	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	30	0.1	15022	13395	22741	12834	28209	15297	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	35	0.1	22934	13934	30792	16838	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	40	0.1	30212	17073	39853	21514	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	446	772	644	1116	806	1395	961	1665	2135	2060	3181	2176	4010	2492
Biochar	0.1	10	0.1	0	0	0	0	0	0	865	1498	1447	2506	1906	3302	2365	4096	4242	4098	5681	4232	6913	4536	8008	4978	-1	-1	-1	-1	-1	-1
Biochar	0.1	15	0.1	0	0	1255	2173	2132	3692	2836	4913	5610	5708	7502	7001	10238	6752	11969	7446	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	20	0.1	1611	2790	3130	5422	4341	7519	8370	8109	12619	8672	15900	9900	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	25	0.1	3478	6024	5391	9337	11091	10579	15593	10766	20909	12827	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	30	0.1	5538	9592	12383	12037	18619	12885	23678	14766	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	35	0.1	7935	13744	19196	14835	26585	16783	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	40	0.1	16283	15883	26938	17826	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	408	707	563	976	985	1707	1921	2038	2766	2302
Biochar	0.1	10	0.1	0	0	0	0	0	0	0	0	552	956	1106	1916	1567	2714	1950	3377	2448	4239	4297	4379	5499	4601	-1	-1	-1	-1	-1	-1
Biochar	0.1	15	0.1	0	0	0	0	688	1191	1629	2821	2611	4522	3460	5992	6320	6474	8172	6893	10631	7610	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	20	0.1	0	0	1487	2575	2708	4691	3819	6614	7508	8030	10790	9185	14294	10187	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	25	0.1	0	0	3336	5778	5048	8743	9203	9913	14650	11600	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	30	0.1	3083	5339	5610	9717	10918	11817	15845	13806	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	35	0.1	5031	8713	8228	14251	16820	16591	24237	17466	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	40	0.1	7326	12690	16341	16834	25479	19095	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	282	488	633	1096	965	1672
Biochar	0	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	534	925	1001	1734	1466	2539	1906	3301	4170	4839	-1	-1	-1	-1
Biochar	0	15	0.1	0	0	0	0	0	0	0	0	0	0	1287	2229	2121	3674	2814	4875	3772	6533	6177	7193	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0	20	0.1	0	0	0	0	0	0	946	1638	2382	4125	3695	6400	5053	8753	8135	9506	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0	25	0.1	0	0	0	0	1444	2500	2877	4982	4990	8644	8516	10851	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0	30	0.1	0	0	1197	2074	3370	5838	5374	9309	10154	12993	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0	35	0.1	0	0	3041	5267	5799	10045	8396	14543	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0	40	0.1	1059	1833	5199	9005	8648	14980	15487	18366	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	5	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	10	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	15	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	20	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	25	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Atrazine Filter Performance Table

BC	C/C	BC	Inf	Empty Bed Contact Time [minutes]																													
Material	o	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	1	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	5	0.4	11310	5855	14364	6831	17314	8545	20099	10049	24725	12024	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	10	0.4	40616	20271	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	15	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	20	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	25	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	5	0.4	3576	1455	4302	1715	4428	1927	5146	2768	6783	3499	7783	3716	9011	4445	10122	5067	11460	5594	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	10	0.4	10413	5600	14438	7181	16932	8279	20349	10187	24714	12016	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	15	0.4	23660	11305	30684	15359	37048	18012	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	20	0.4	41126	20586	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	25	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	5	0.4	787	1364	1905	1719	2517	974	2918	1172	3103	1354	3433	1718	4262	2201	4744	2441	5403	2630	6002	2944	6734	3358	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	10	0.4	5881	2367	6385	2895	7777	4028	9534	4903	11502	5617	13515	6741	15596	7730	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	15	0.4	10440	5245	14374	7388	17242	8419	20344	10148	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	20	0.4	19260	9895	24285	11921	29836	14882	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	25	0.4	28966	14149	37411	18659	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	30	0.4	41120	20522	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	35	0.4	54944	27255	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	5	0.4	569	985	605	1048	1321	1150	1660	1031	2046	800	2299	963	2474	1114	2642	1261	2990	1518	3529	1826	3913	1987	5029	2498	6173	3081	-1	-1	-1	-1
Biochar	0.6	10	0.4	3354	2056	4330	1727	4840	2124	5305	2536	6631	3408	7850	3986	9089	4493	10081	5008	11594	5798	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	15	0.4	6968	2927	7992	3823	9924	5099	11812	5996	14443	7155	16824	8406	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	20	0.4	10701	5123	14261	7379	17356	8597	20253	10064	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	25	0.4	16668	8568	21757	10777	26256	13072	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	30	0.4	23838	12097	30521	15169	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	35	0.4	31962	15807	40989	20503	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	40	0.4	40878	20321	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	5	0.4	0	0	440	762	485	840	511	884	1186	1034	1547	696	1737	714	1894	809	2096	963	2278	1098	2473	1227	3286	1689	4044	2026	4719	2362	4719	2362
Biochar	0.5	10	0.4	1027	1779	2459	2145	3346	1388	3801	1624	4407	2086	4959	2461	5807	2981	6583	3384	7613	3829	8565	4288	9469	4739	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	15	0.4	4677	2111	5720	2447	6600	3122	7457	3701	9329	4808	11064	5589	12796	6408	14221	7117	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	20	0.4	7650	3275	9182	4433	10979	5584	13214	6792	16330	8182	18985	9502	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	25	0.4	11059	5236	13755	6997	17213	8803	20341	10193	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	30	0.4	15024	7464	19895	10227	24445	12252	28549	14291	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	35	0.4	20343	10436	26860	13513	32548	16295	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	40	0.4	26623	13686	34545	17305	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	5	0.4	0	0	0	0	334	578	389	674	437	757	908	790	1062	919	1352	637	1512	661	1669	742	1839	858	2290	1145	2774	1426	3334	1713	3334	1713
Biochar	0.4	10	0.4	781	1353	901	1560	2042	1768	2708	1278	3196	1401	3683	1719	4174	2044	4585	2294	5200	2652	5935	3062	6685	3436	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	15	0.4	2725	2371	4070	1925	4781	2097	5532	2583	6587	3264	7564	3841	8852	4566	10036	5158	11560	5849	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	20	0.4	5435	2576	6707	2987	8013	3873	9191	4601	11186	5752	13391	6883	15557	7867	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	25	0.4	7996	3512	10030	4848	11872	5976	13922	7158	17493	8955	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	30	0.4	11110	5190	13821	6920	16724	8599	20119	10342	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	35	0.4	14599	7141	18299	9338	22861	11774	27048	13691	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	40	0.4	18471	9253	23865	12316	29594	15050	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	5	0.4	0	0	0	0	0	0	201	348	318	551	365	632	411	713	812	716	953	831	1229	619	1356	647	1728	832	2100	1053	2431	1241	2431	1241
Biochar	0.3	10	0.4	385	668	668	1157	788	1366	1620	1431	2313	1259	2713	1295	3100	1465	3457	1664	3963	1968	4427	2237	4872	2487	6347	3291	-1	-1	-1	-1	-1	-1
Biochar	0.3	15	0.4	1095	1897	2425	2143	3446	1893	4069	1944	4921	2344	5760	2841	6607	3338	7309	3732	8362	4313	9521	4937	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Atrazine Filter Performance Table

BC	C/C	BC	Inf	Empty Bed Contact Time [minutes]																											
Material	o	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.3	20	0.4	3225	2852	4912	2490	5907	2789	6914	3331	8442	4239	9747	4977	11250	5807	12696	6584	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	25	0.4	5733	3176	7385	3489	8966	4355	10503	5272	12671	6490	14892	7711	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	30	0.4	8140	3899	10374	5000	12606	6329	14626	7470	17967	9305	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	35	0.4	10771	5100	13877	6895	16676	8500	19525	10073	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	40	0.4	13835	6672	17721	8964	21347	10981	25402	13174	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	5	0.4	0	0	0	0	0	0	0	0	0	0	231	399	286	496	327	567	383	664	723	665	841	753	1283	682	1586	807	1870	943
Biochar	0.2	10	0.4	0	0	287	498	532	921	652	1130	960	1323	1677	1502	2250	1277	2561	1363	2970	1527	3361	1701	3743	1888	4877	2509	5931	3079	-1	-1
Biochar	0.2	15	0.4	680	1177	974	1688	1225	2121	2509	2248	3611	1973	4299	2224	5007	2536	5610	2830	6473	3295	7310	3761	8109	4198	-1	-1	-1	-1	-1	-1
Biochar	0.2	20	0.4	1294	2242	2843	2633	4161	2551	5104	2721	6352	3236	7472	3771	8700	4432	9740	5012	11153	5782	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	25	0.4	2029	3515	5184	3194	6631	3495	7889	4022	9741	4922	11477	5878	13279	6871	14805	7687	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	30	0.4	4980	4465	7629	4073	9455	4822	11188	5649	13832	7086	16187	8383	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	35	0.4	7694	4457	10325	5318	12706	6419	15054	7666	18506	9575	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	40	0.4	10136	5420	13354	6775	16424	8334	19424	9998	23769	12346	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	152	263	217	376	271	470	323	560	711	692	1069	711	1348	806
Biochar	0.1	10	0.4	0	0	0	0	0	0	295	511	487	843	642	1111	795	1378	1413	1376	1906	1390	2322	1476	2691	1611	3680	2016	4588	2428	-1	-1
Biochar	0.1	15	0.4	0	0	429	744	717	1243	955	1654	1879	1920	2492	2346	3439	2198	4022	2409	4788	2716	5507	3018	6199	3325	-1	-1	-1	-1	-1	-1
Biochar	0.1	20	0.4	553	957	1053	1824	1461	2531	2789	2724	4238	2833	5343	3204	6431	3640	7324	4015	8549	4563	9726	5120	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	25	0.4	1171	2028	1814	3143	3690	3551	5237	3519	7027	4143	8540	4757	10099	5435	11405	6040	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	30	0.4	1864	3229	4128	4045	6254	4212	7957	4779	10277	5723	12320	6613	14451	7614	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	35	0.4	2671	4626	6441	4880	8934	5441	11045	6279	14018	7557	16678	8796	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	40	0.4	5431	5339	9051	5807	11923	6889	14507	7965	18243	9664	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	138	240	190	329	332	575	642	687	929	764
Biochar	0.1	10	0.4	0	0	0	0	0	0	0	0	192	332	373	646	528	915	657	1138	824	1427	1433	1475	1846	1527	2886	1868	3793	2246	4628	2618
Biochar	0.1	15	0.4	0	0	0	0	244	423	549	951	880	1525	1165	2018	2108	2181	2743	2289	3574	2504	4308	2792	5001	3076	6937	3924	-1	-1	-1	-1
Biochar	0.1	20	0.4	0	0	506	876	913	1581	1287	2229	2512	2707	3622	3051	4806	3351	5717	3709	6942	4214	8109	4719	9224	5220	-1	-1	-1	-1	-1	-1
Biochar	0.1	25	0.4	0	0	1124	1947	1701	2946	3081	3342	4922	3842	6514	4381	8079	5015	9383	5566	11153	6352	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	30	0.4	1040	1801	1891	3276	3657	3984	5318	4590	7827	5262	9883	6093	12000	7001	13758	7790	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	35	0.4	1696	2937	2771	4800	5603	5585	8150	5752	11153	6955	13805	8079	16533	9306	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	40	0.4	2471	4279	5455	5675	8565	6307	11225	7315	14944	8872	18243	10336	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0	5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	96	166	214	371	326	564
Biochar	0	10	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	182	316	339	586	495	858	643	1114	1397	1636	2296	1979	3128	2335
Biochar	0	15	0.4	0	0	0	0	0	0	0	0	0	0	435	754	717	1242	950	1646	1273	2205	2070	2432	2633	2845	4673	3492	-1	-1	-1	-1
Biochar	0	20	0.4	0	0	0	0	0	0	324	562	806	1395	1248	2161	1706	2954	2727	3215	3906	3700	5079	4154	6189	4634	-1	-1	-1	-1	-1	-1
Biochar	0	25	0.4	0	0	0	0	491	850	973	1685	1685	2919	2869	3665	4146	4553	5588	4863	7341	5615	9041	6358	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0	30	0.4	0	0	417	722	1140	1975	1815	3144	3422	4388	5112	5559	7415	6127	9162	6884	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0	35	0.4	0	0	1029	1782	1959	3394	2835	4911	5624	6235	8435	7047	11146	8221	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0	40	0.4	395	685	1759	3047	2921	5059	5196	6213	8775	7693	12057	9092	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	5	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	10	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	15	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	20	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	25	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	30	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	5	1	5458	2712	6917	3126	8338	3932	9664	4624	11896	5506	13664	6217	15576	7074	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	10	1	19530	9326	24928	11638	30063	13668	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	15	1	41699	18951	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	20	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	25	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	30	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Atrazine Filter Performance Table Page 5

BC	C/C	BC	Inf	Empty Bed Contact Time [minutes]																											
Material	o	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.9	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	5	1	1722	633	2074	771	2128	876	2473	1295	3257	1608	3745	1702	4335	2042	4867	2329	5511	2566	6247	2909	6866	3184	-1	-1	-1	-1	-1	-1
Biochar	0.8	10	1	5002	2618	6946	3294	8138	3804	9784	4682	11888	5504	13783	6392	15863	7239	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	15	1	11385	5178	14754	7059	17820	8250	20750	9621	25161	11435	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	20	1	19774	9461	25296	11784	30404	13900	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	25	1	29975	13883	38131	17433	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	30	1	41961	19448	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	35	1	55955	25540	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	5	1	377	654	904	814	1212	422	1408	526	1493	616	1650	795	2052	1017	2280	1124	2601	1206	2886	1352	3239	1544	4162	1948	5055	2346	-1	-1
Biochar	0.7	10	1	2838	1063	3070	1322	3739	1866	4582	2258	5535	2580	6501	3099	7501	3550	8344	3906	9570	4460	10687	4931	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	15	1	5018	2429	6907	3401	8297	3867	9786	4666	11944	5614	13933	6503	15976	7376	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	20	1	9255	4555	11680	5476	14349	6840	16775	7853	20445	9485	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	25	1	13939	6500	17991	8576	21765	10172	25486	11825	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	30	1	19778	9437	25293	11842	30647	14220	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	35	1	26426	12518	33870	15784	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	40	1	33899	15872	43249	19952	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	5	1	275	476	291	503	632	550	798	471	986	351	1109	434	1191	508	1271	580	1436	701	1698	843	1882	914	2420	1149	2970	1416	3468	1633
Biochar	0.6	10	1	1612	940	2090	768	2332	965	2552	1165	3191	1575	3775	1834	4374	2063	4850	2303	5577	2667	6294	2989	6960	3277	-1	-1	-1	-1	-1	-1
Biochar	0.6	15	1	3360	1320	3845	1757	4776	2356	5679	2759	6951	3289	8091	3866	9407	4469	10456	4923	11980	5599	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	20	1	5148	2355	6860	3409	8352	3946	9744	4628	12006	5725	13963	6574	16126	7533	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	25	1	8022	3959	10469	4947	12628	6010	14959	7135	18204	8540	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	30	1	11463	5567	14683	6976	17985	8579	21009	9892	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	35	1	15383	7261	19716	9431	23965	11310	28103	13134	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	40	1	19667	9346	25438	12083	30822	14423	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	5	1	0	0	213	368	233	404	245	425	565	492	745	310	837	317	913	364	1010	440	1097	505	1190	565	1581	780	1946	932	2271	1087
Biochar	0.5	10	1	493	854	1169	1018	1613	615	1832	732	2123	957	2385	1133	2793	1377	3167	1562	3664	1761	4122	1973	4556	2180	5918	2811	-1	-1	-1	-1
Biochar	0.5	15	1	2254	941	2757	1102	3179	1433	3586	1704	4487	2221	5324	2572	6159	2948	6842	3275	7887	3782	8885	4221	9835	4635	-1	-1	-1	-1	-1	-1
Biochar	0.5	20	1	3688	1476	4421	2038	5279	2576	6357	3136	7859	3763	9134	4372	10618	5092	11858	5634	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	25	1	5327	2403	6614	3228	8281	4060	9789	4688	11917	5706	14017	6699	16158	7625	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	30	1	7226	3438	9570	4721	11764	5635	13736	6577	16923	8087	19721	9296	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	35	1	9783	4820	12925	6216	15662	7500	18482	8865	22589	10665	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	40	1	12807	6318	16626	7964	20214	9694	23805	11312	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	5	1	0	0	0	0	162	280	188	325	210	364	435	378	505	438	652	287	729	297	804	335	886	392	1103	528	1334	658	1604	791
Biochar	0.4	10	1	376	652	433	750	973	843	1306	577	1540	630	1775	785	2011	940	2207	1057	2501	1224	2855	1415	3218	1586	4179	2014	5100	2452	-1	-1
Biochar	0.4	15	1	1305	1137	1962	869	2304	943	2666	1180	3172	1503	3639	1772	4258	2110	4830	2381	5564	2694	6272	3023	6947	3346	-1	-1	-1	-1	-1	-1
Biochar	0.4	20	1	2620	1163	3232	1350	3861	1778	4425	2121	5380	2657	6445	3178	7488	3623	8367	4034	9578	4611	10829	5192	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	25	1	3853	1581	4833	2226	5714	2756	6696	3306	8419	4131	9885	4768	11402	5493	12767	6139	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	30	1	5355	2371	6654	3190	8043	3971	9683	4775	11930	5755	13918	6705	16167	7756	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	35	1	7034	3284	8801	4309	11002	5438	13019	6305	15928	7676	18709	8980	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	40	1	8893	4266	11481	5691	14243	6936	16776	8090	20563	9888	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	5	1	0	0	0	0	0	0	99	171	153	266	176	305	198	343	389	344	455	397	593	283	654	295	833	380	1012	485	1171	573
Biochar	0.3	10	1	190	328	322	558	379	657	776	686	1115	579	1308	590	1494	668	1666	761	1910	905	2133	1032	2346	1149	3055	1521	3786	1852	4455	2160
Biochar	0.3	15	1	527	913	1161	1028	1661	872	1962	886	2371	1070	2776	1305	3184	1540	3520	1724	4024	1993	4582	2282	5147	2546	6696	3246	-1	-1	-1	-1
Biochar	0.3	20	1	1545	1369	2368	1140	2847	1270	3332	1523	4068	1954	4694	2299	5414	2683	6110	3043	7104	3502	8032	3910	8929	4329	-1	-1	-1	-1	-1	-1
Biochar	0.3	25	1	2763	1464	3559	1588	4321	1995	5062	2430	6101	2998	7166	3564	8425	4176	9467	4633	10887	5281	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	30	1	3924	1777	4999	2287	6075	2917	7044	3451	8646	4301	10296	5095	11982	5836	13396	6495	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	35	1	5191	2323	6688	3173	8032	3926	9397	4655	11751	5829	13860	6756	16051	7778	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	40	1	6667	3052	8539	4136	10276	5074	12225	6090	15229	7453	17865	8663	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	5	1	0	0	0	0	0	0	0	0	0	0	112	193	138	239	158	273	185	320	346	320	402	361	619	316	765	372	901	434
Biochar	0.2	10	1	0	0	142	245	257	444	314	544	474	631	801	721	1085	594	1235	631	1433	704	1620	783	1804	868	2351	1160	2858	1425	3368	1682

Atrazine Filter Performance Table

BC	C/C	BC	Inf	Empty Bed Contact Time [minutes]																											
Material	o	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.2	15	1	329	570	470	813	590	1022	1199	1078	1742	915	2073	1027	2414	1167	2704	1302	3121	1519	3525	1738	3908	1942	5060	2527	-1	-1	-1	-1
Biochar	0.2	20	1	624	1080	1364	1267	2005	1193	2462	1260	3063	1490	3602	1735	4194	2044	4696	2316	5375	2676	6048	3018	6743	3368	-1	-1	-1	-1	-1	-1
Biochar	0.2	25	1	978	1694	2498	1494	3198	1616	3804	1853	4695	2265	5533	2714	6401	3179	7134	3558	8204	4098	9330	4650	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	30	1	2379	2142	3680	1886	4560	2221	5393	2599	6669	3272	7803	3879	9012	4498	10106	5049	11733	5832	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	35	1	3710	2076	4980	2453	6125	2953	7257	3535	8921	4430	10420	5201	12131	6059	13682	6801	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	40	1	4888	2510	6439	3119	7917	3839	9365	4621	11454	5714	13463	6727	15774	7836	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	74	128	105	181	131	227	156	270	341	333	515	336	650	378
Biochar	0.1	10	1	0	0	0	0	0	0	143	248	235	407	310	536	384	665	677	663	919	660	1120	696	1299	756	1776	938	2214	1125	2629	1318
Biochar	0.1	15	1	0	0	209	361	346	599	461	798	903	926	1192	1129	1659	1037	1941	1131	2311	1269	2658	1405	2992	1544	3945	1978	4871	2443	-1	-1
Biochar	0.1	20	1	269	466	508	880	705	1221	1336	1313	2044	1339	2578	1504	3104	1700	3535	1869	4126	2117	4693	2371	5252	2634	6888	3457	-1	-1	-1	-1
Biochar	0.1	25	1	565	978	875	1516	1766	1711	2525	1664	3391	1942	4122	2218	4874	2525	5504	2800	6381	3205	7246	3630	8099	4063	-1	-1	-1	-1	-1	-1
Biochar	0.1	30	1	899	1558	1978	1950	3016	1993	3840	2244	4960	2668	5946	3071	6974	3527	7854	3941	9096	4559	10309	5176	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	35	1	1288	2232	3102	2320	4311	2557	5331	2933	6766	3511	8048	4075	9417	4722	10598	5313	12245	6149	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	40	1	2603	2574	4366	2739	5754	3223	7002	3708	8804	4481	10440	5242	12206	6121	13714	6886	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	67	116	92	159	160	278	308	332	447	365
Biochar	0.1	10	1	0	0	0	0	0	0	0	0	94	163	180	312	255	442	317	549	398	689	687	712	889	730	1392	883	1831	1055	2235	1224
Biochar	0.1	15	1	0	0	0	0	120	209	265	459	425	736	562	974	1011	1053	1321	1095	1724	1189	2079	1320	2414	1448	3351	1835	4217	2215	5031	2584
Biochar	0.1	20	1	0	0	245	425	440	763	621	1076	1206	1307	1744	1460	2319	1591	2759	1754	3351	1982	3916	2212	4455	2441	5982	3115	-1	-1	-1	-1
Biochar	0.1	25	1	0	0	542	939	821	1422	1480	1614	2372	1834	3143	2076	3900	2363	4531	2614	5387	2972	6206	3327	6998	3677	-1	-1	-1	-1	-1	-1
Biochar	0.1	30	1	502	870	913	1581	1757	1924	2560	2198	3777	2494	4771	2870	5795	3283	6645	3643	7813	4152	8937	4655	10028	5152	-1	-1	-1	-1	-1	-1
Biochar	0.1	35	1	818	1418	1337	2316	2684	2695	3932	2733	5384	3279	6667	3789	7986	4350	9094	4834	10620	5518	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	40	1	1193	2066	2616	2741	4131	3003	5417	3459	7217	4167	8811	4834	10471	5558	11868	6183	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46	80	103	179	157	273
Biochar	0	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	88	153	164	283	239	415	311	538	671	791	1107	949	1510	1114
Biochar	0	15	1	0	0	0	0	0	0	0	0	0	0	210	364	346	600	459	795	615	1065	995	1176	1264	1375	2255	1666	3125	2035	3944	2392
Biochar	0	20	1	0	0	0	0	0	0	158	273	389	674	603	1044	824	1427	1310	1555	1882	1780	2449	1989	2987	2211	4520	2864	-1	-1	-1	-1
Biochar	0	25	1	0	0	0	0	238	411	470	814	814	1409	1382	1772	1990	2202	2694	2334	3542	2682	4365	3024	5158	3365	-1	-1	-1	-1	-1	-1
Biochar	0	30	1	0	0	203	352	551	954	877	1518	1649	2121	2453	2688	3576	2936	4421	3285	5592	3778	6720	4266	7814	4746	-1	-1	-1	-1	-1	-1
Biochar	0	35	1	0	0	497	861	946	1639	1369	2372	2700	3015	4068	3378	5380	3920	6491	4389	8021	5053	9499	5704	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0	40	1	197	341	850	1472	1411	2444	2497	3005	4231	3694	5818	4340	7481	5040	8882	5647	10817	6499	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	5	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	10	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	15	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	20	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	25	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	30	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	35	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	40	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	5	4	1799	832	2277	944	2744	1196	3173	1408	3910	1661	4487	1871	5114	2129	5699	2311	6432	2553	7117	2769	7760	2955	-1	-1	-1	-1	-1	-1
Biochar	0.9	10	4	6413	2840	8185	3522	9877	4111	11459	4646	13652	5370	15577	5930	17488	6429	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	15	4	13697	5700	17280	7006	20470	8053	23450	8924	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	20	4	23160	9390	28816	11200	33796	12576	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	25	4	34418	13534	42380	15766	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	30	4	47409	18025	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	35	4	61737	22712	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	40	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	5	4	567	173	684	226	699	262	812	406	1067	488	1232	515	1424	620	1598	707	1811	778	2053	880	2255	962	2872	1186	3438	1376	3950	1534
Biochar	0.8	10	4	1642	821	2282	998	2673	1158	3212	1422	3906	1663	4527	1932	5212	2179	5760	2378	6526	2639	7251	2870	7929	3078	-1	-1	-1	-1	-1	-1
Biochar	0.8	15	4	3745	1567	4844	2144	5854	2492	6815	2908	8266	3440	9544	3876	10847	4298	11915	4625	13337	5026	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	20	4	6492	2873	8312	3564	9988	4187	11584	4781	13911	5564	15915	6177	17931	6743	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	25	4	9848	4194	12527	5251	15014	6156	17343	6940	20631	7940	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Atrazine Filter Performance Table

BC	C/C	BC	Inf	Empty Bed Contact Time [minutes]																											
Material	o	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.8	30	4	13782	5878	17472	7210	20858	8345	23959	9298	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	35	4	18383	7690	23103	9339	27414	10695	31310	11795	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	40	4	23424	9664	29355	11615	34604	13165	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	5	4	123	213	291	260	399	114	465	153	492	184	542	245	675	311	748	342	855	365	949	411	1064	469	1367	590	1661	709	1937	810
Biochar	0.7	10	4	937	310	1010	399	1228	575	1503	687	1820	784	2136	942	2464	1077	2742	1184	3144	1349	3510	1489	3887	1625	4904	1980	5829	2268	-1	-1
Biochar	0.7	15	4	1649	750	2265	1036	2729	1175	3215	1419	3924	1702	4577	1968	5248	2227	5840	2442	6619	2720	7366	2973	8080	3200	-1	-1	-1	-1	-1	-1
Biochar	0.7	20	4	3036	1387	3838	1664	4712	2078	5511	2380	6717	2866	7800	3262	8908	3654	9833	3969	11087	4366	12257	4712	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	25	4	4584	1975	5909	2605	7149	3080	8373	3573	10141	4227	11704	4763	13306	5285	14616	5687	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	30	4	6497	2869	8310	3589	10068	4297	11741	4910	14132	5749	16217	6422	18338	7057	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	35	4	8680	3798	11128	4774	13404	5618	15537	6383	18623	7405	21266	8199	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	40	4	11137	4810	14207	6025	17088	7072	19769	7979	23569	9165	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	5	4	90	156	95	165	205	178	261	142	326	97	366	127	393	153	418	176	472	215	558	258	618	278	795	349	976	430	1140	495
Biochar	0.6	10	4	528	283	690	219	768	288	840	355	1049	482	1239	558	1438	626	1594	701	1832	811	2068	907	2287	994	2934	1247	3537	1467	4092	1655
Biochar	0.6	15	4	1108	388	1265	535	1570	722	1865	840	2285	1000	2657	1176	3091	1357	3435	1493	3936	1694	4406	1873	4870	2043	6153	2489	-1	-1	-1	-1
Biochar	0.6	20	4	1693	717	2253	1044	2745	1197	3202	1408	3945	1740	4588	1994	5298	2280	5882	2500	6701	2801	7468	3071	8210	3322	-1	-1	-1	-1	-1	-1
Biochar	0.6	25	4	2637	1213	3441	1500	4149	1828	4915	2169	5981	2588	6975	2986	8005	3364	8866	3678	10046	4080	11153	4438	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	30	4	3764	1694	4826	2122	5909	2607	6903	3001	8422	3605	9770	4098	11165	4595	12335	4990	13906	5489	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	35	4	5057	2204	6477	2869	7874	3432	9233	3975	11195	4709	12937	5332	14742	5938	16234	6408	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	40	4	6464	2844	8358	3668	10126	4367	11819	5025	14294	5928	16472	6664	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	5	4	0	0	70	121	76	132	80	139	182	158	246	89	276	90	301	107	333	132	361	154	391	172	519	239	640	283	746	331
Biochar	0.5	10	4	161	279	376	327	532	174	604	214	699	290	784	346	917	422	1040	478	1204	535	1355	601	1497	664	1945	854	2362	1019	2754	1168
Biochar	0.5	15	4	742	269	909	323	1047	434	1179	520	1474	680	1749	783	2025	897	2249	997	2591	1151	2920	1282	3232	1406	4141	1757	4984	2060	-1	-1
Biochar	0.5	20	4	1216	432	1455	620	1734	788	2088	960	2583	1144	3002	1332	3489	1549	3897	1711	4451	1931	5004	2150	5525	2344	7005	2869	-1	-1	-1	-1
Biochar	0.5	25	4	1754	729	2172	988	2721	1241	3217	1425	3916	1737	4606	2037	5310	2313	5918	2555	6750	2873	7551	3165	8315	3437	-1	-1	-1	-1	-1	-1
Biochar	0.5	30	4	2375	1049	3144	1445	3867	1714	4514	2003	5561	2459	6481	2820	7476	3215	8298	3521	9441	3937	10518	4308	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	35	4	3213	1476	4248	1890	5148	2285	6073	2698	7424	3236	8658	3726	9935	4201	11020	4595	12482	5097	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	40	4	4207	1933	5466	2424	6641	2951	7823	3436	9538	4117	11078	4701	12700	5290	14037	5749	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	5	4	0	0	0	0	53	93	62	107	69	119	141	123	163	141	215	84	240	86	265	99	292	118	363	161	438	202	527	242
Biochar	0.4	10	4	124	214	142	246	314	272	430	169	507	184	585	236	662	286	726	323	822	374	938	434	1058	485	1374	614	1676	746	1970	864
Biochar	0.4	15	4	424	370	646	255	759	275	879	354	1044	458	1196	542	1399	647	1587	729	1829	821	2062	922	2283	1020	2961	1299	3593	1548	4183	1767
Biochar	0.4	20	4	863	342	1064	397	1272	539	1456	648	1767	814	2118	972	2462	1104	2751	1230	3148	1405	3559	1580	3950	1733	5065	2169	6100	2545	-1	-1
Biochar	0.4	25	4	1269	461	1592	675	1879	842	2199	1013	2767	1263	3250	1453	3748	1675	4196	1869	4819	2121	5410	2354	5992	2582	7627	3182	-1	-1	-1	-1
Biochar	0.4	30	4	1764	712	2189	975	2642	1217	3182	1461	3923	1754	4575	2044	5314	2360	5930	2602	6774	2936	7603	3257	8389	3544	-1	-1	-1	-1	-1	-1
Biochar	0.4	35	4	2316	999	2891	1319	3616	1665	4279	1922	5236	2340	6149	2734	7104	3110	7906	3427	9028	3858	10091	4245	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	40	4	2925	1303	3772	1745	4682	2116	5516	2466	6758	3011	7913	3473	9113	3947	10144	4345	11536	4853	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	5	4	0	0	0	0	0	0	33	57	50	87	58	100	65	112	126	112	147	129	195	85	216	88	274	114	333	148	385	176
Biochar	0.3	10	4	64	110	106	183	124	216	252	224	367	176	431	176	492	199	549	229	629	275	702	316	772	352	1004	467	1245	566	1466	659
Biochar	0.3	15	4	173	300	377	335	546	266	646	264	781	320	914	396	1048	471	1158	528	1323	611	1506	700	1692	780	2203	990	2686	1197	3154	1383
Biochar	0.3	20	4	502	446	780	344	938	379	1097	458	1340	596	1545	704	1780	823	2008	934	2336	1072	2642	1193	2937	1321	3797	1686	4613	2004	-1	-1
Biochar	0.3	25	4	909	447	1172	474	1423	602	1667	741	2007	919	2355	1093	2770	1280	3113	1416	3581	1611	4027	1806	4476	1996	5766	2505	-1	-1	-1	-1
Biochar	0.3	30	4	1293	531	1646	688	2000	890	2318	1057	2841	1319	3385	1561	3940	1781	4406	1982	5047	2259	5697	2529	6320	2773	-1	-1	-1	-1	-1	-1
Biochar	0.3	35	4	1709	694	2202	964	2643	1203	3089	1427	3863	1786	4558	2063	5279	2373	5889	2636	6771	3001	7610	3327	8417	3642	-1	-1	-1	-1	-1	-1
Biochar	0.3	40	4	2195	918	2811	1264	3379	1556	4018	1868	5008	2277	5876	2643	6788	3037	7597	3373	8697	3802	9750	4213	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	5	4	0	0	0	0	0	0	0	0	0	0	37	64	45	79	52	90	61	105	113	105	130	118	204	97	252	113	297	132
Biochar	0.2	10	4	0	0	48	83	84	146	103	179	159	205	259	235	357	184	407	194	472	215	534	238	594	264	775	355	941	438	1108	516
Biochar	0.2	15	4	108	188	154	267	194	336	388	352	574	282	683	314	795	355	890	395	1028	464	1161	533	1287	596	1664	776	2063	950	2433	1100
Biochar	0.2	20	4	205	355	444	415	659	373	811	387	1009	454	1186	527	1381	624	1547	710	1770	822	1990	927	2218	1034	2920	1334	3570	1605	4181	1859
Biochar	0.2	25	4	321	556	821	467	1054	496	1253	564	1546	689	1822	830	2108	976	2348	1093	2698	1258	3069	1427	3436	1582	4461	2006	5428	2405	-1	-1
Biochar	0.2	30	4	771	699	1212	580	1502	676	1776	790	2196	1001	2569	1191	2965	1382	3324	1550	3859	1788	4377	2001	4872	2203	6281	2793	-1	-1	-1	-1
Biochar	0.2	35	4	1221	645	1640	749	2017	897	2390	1079	2938	1360	3429	1598	3989	1860	4501	2086	5202	2373	5870	2649	6516	2924	-1	-1	-1	-1	-1	-1
Biochar	0.2	40	4	1610	772	2121	948	2607	1170	3084	1416	3770	1755	4428	2065	5189	2403	5832	2666	6707	3027	7549	3384	8372	3723	-1	-1	-1	-1	-1	-1
Biochar	0.1	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	42	34	60	43	75	51	89	111	110	170	107	214	119

Atrazine Filter Performance Table

BC	C/C	BC	Inf	Empty Bed Contact Time [minutes]																											
Material	o	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.1	10	4	0	0	0	0	0	0	47	82	77	134	102	176	126	218	220	218	302	211	369	220	428	238	586	291	730	346	866	404
Biochar	0.1	15	4	0	0	69	120	114	197	151	262	294	305	387	370	546	328	639	355	761	395	876	435	986	476	1300	607	1605	750	1895	887
Biochar	0.1	20	4	89	154	167	289	232	401	434	431	672	426	849	473	1023	530	1165	579	1360	653	1547	729	1731	808	2270	1063	2780	1300	3270	1517
Biochar	0.1	25	4	186	322	288	498	574	561	831	530	1117	609	1358	689	1607	780	1814	862	2103	984	2388	1114	2669	1248	3472	1623	4249	1966	5017	2287
Biochar	0.1	30	4	296	512	643	640	992	635	1265	706	1635	829	1960	948	2299	1084	2588	1210	2997	1400	3398	1591	3785	1773	4908	2277	6028	2749	-1	-1
Biochar	0.1	35	4	423	733	1018	746	1420	806	1756	915	2230	1085	2653	1253	3103	1449	3492	1631	4036	1890	4559	2135	5070	2367	6596	3027	-1	-1	-1	-1
Biochar	0.1	40	4	847	846	1437	868	1896	1008	2308	1149	2902	1379	3441	1609	4022	1879	4520	2117	5206	2438	5873	2740	6535	3032	-1	-1	-1	-1	-1	-1
Biochar	0.1	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	38	30	52	53	91	101	109	147	118
Biochar	0.1	10	4	0	0	0	0	0	0	0	0	31	54	59	103	84	145	104	181	131	226	224	234	292	237	459	281	604	331	737	382
Biochar	0.1	15	4	0	0	0	0	41	70	87	151	140	242	185	320	329	347	433	355	567	381	685	420	795	458	1105	573	1391	687	1660	798
Biochar	0.1	20	4	0	0	81	140	145	251	204	354	393	431	572	474	763	510	908	558	1104	625	1291	694	1469	762	1974	964	2448	1164	2899	1360
Biochar	0.1	25	4	0	0	178	309	270	467	482	532	779	592	1034	663	1285	748	1494	822	1776	929	2047	1035	2309	1140	3055	1453	3767	1763	4447	2067
Biochar	0.1	30	4	165	286	300	520	573	634	839	714	1243	796	1572	907	1911	1030	2192	1138	2577	1290	2948	1441	3309	1591	4346	2039	5341	2483	-1	-1
Biochar	0.1	35	4	269	466	440	761	872	886	1293	877	1773	1038	2198	1189	2634	1357	3000	1502	3504	1708	3991	1912	4466	2115	5843	2724	-1	-1	-1	-1
Biochar	0.1	40	4	392	679	851	902	1358	966	1784	1101	2379	1310	2906	1510	3454	1727	3915	1915	4553	2181	5173	2447	5780	2712	7537	3495	-1	-1	-1	-1
Biochar	0	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	27	34	59	52	90
Biochar	0	10	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	51	54	93	79	136	102	177	219	261	364	309	497	359
Biochar	0	15	4	0	0	0	0	0	0	0	0	0	0	69	120	114	197	151	261	202	350	325	388	412	453	742	537	1030	649	1300	758
Biochar	0	20	4	0	0	0	0	0	0	52	90	128	222	198	343	271	469	428	513	617	582	805	646	983	713	1490	912	1966	1104	2414	1289
Biochar	0	25	4	0	0	0	0	78	136	155	268	268	464	452	584	648	726	885	760	1165	867	1437	971	1700	1074	2449	1377	3153	1667	3817	1941
Biochar	0	30	4	0	0	68	117	181	314	288	499	540	699	799	886	1175	954	1454	1060	1842	1210	2215	1358	2577	1504	3608	1927	4579	2329	-1	-1
Biochar	0	35	4	0	0	163	283	311	539	450	780	880	994	1336	1098	1770	1263	2138	1406	2644	1607	3133	1805	3607	1999	4960	2558	-1	-1	-1	-1
Biochar	0	40	4	67	116	280	484	464	804	816	991	1389	1204	1914	1401	2464	1614	2927	1798	3567	2057	4186	2310	4785	2557	6496	3266	-1	-1	-1	-1
RAC	1	5	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	5	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	5	0.1	41003	25656	41687	24008	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	5	0.1	0	0	21315	19582	27621	17258	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Atrazine Filter Performance Table

BC	C/C	BC	Inf	Empty Bed Contact Time [minutes]																													
Material	o	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.7	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	5	0.1	0	0	0	0	10960	15322	18171	13486	21217	13300	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	10	0.1	36616	27119	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	5	0.1	0	0	0	0	0	0	0	0	10043	13325	15976	10760	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	10	0.1	0	0	27563	21951	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	15	0.1	48232	32527	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	5	0.1	0	0	0	0	0	0	0	0	0	0	6848	9593	11252	9045	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	10	0.1	0	0	0	0	16406	21794	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	15	0.1	20454	28758	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5797	8028	9490	7669	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	10	0.1	0	0	0	0	0	0	11536	16014	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	15	0.1	0	0	17211	23944	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	20	0.1	22827	31831	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4694	6518	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	10	0.1	0	0	0	0	0	0	0	0	6501	11260	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	15	0.1	0	0	0	0	9377	16241	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	20	0.1	0	0	18259	25590	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	25	0.1	14895	25799	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	30	0.1	34738	46225	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4240	5739	-1	-1	-1	-1	-1	-1
RAC	0.1	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	4451	7709	8398	11385	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	15	0.1	0	0	0	0	0	0	0	0	10275	14603	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	20	0.1	0	0	0	0	0	0	16464	22398	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	25	0.1	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	30	0.1	0	0	24201	33047	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	35	0.1	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	40	0.1	31598	43322	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Atrazine Filter Performance Table

BC	C/C	BC	Inf	Empty Bed Contact Time [minutes]																											
Material	o	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.1	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3258	4500	-1	-1
RAC	0.1	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4110	7119	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	15	0.1	0	0	0	0	0	0	0	0	0	0	2795	4841	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	20	0.1	0	0	0	0	0	0	0	0	12550	17474	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	25	0.1	0	0	0	0	0	0	15213	21316	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	30	0.1	0	0	0	0	17925	25228	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	35	0.1	0	0	11686	20242	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	40	0.1	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RAC	0	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1
RAC	0	15	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3190	5525	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0	20	0.1	0	0	0	0	0	0	0	0	0	0	0	0	4627	8014	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0	25	0.1	0	0	0	0	0	0	0	0	0	0	10247	14935	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0	30	0.1	0	0	0	0	0	0	0	0	12140	17780	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0	35	0.1	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0	40	0.1	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	5	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	10	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	15	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	20	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	25	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	5	0.4	37965	25476	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	10	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	15	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	20	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	25	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	5	0.4	14681	8101	14848	7421	15001	7269	17431	9999	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	10	0.4	35481	20650	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	15	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	20	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	25	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	5	0.4	0	0	7737	6389	9884	5448	10143	5280	10466	5272	11284	5865	14078	8961	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	10	0.4	20422	10632	21347	10750	26461	16258	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	15	0.4	34321	17918	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	20	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	25	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	5	0.4	0	0	0	0	3941	5273	6552	4350	7589	4201	7908	4207	8265	4332	8714	4594	10000	5775	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	10	0.4	13198	8743	15462	8415	16308	8579	17499	9231	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	15	0.4	23935	12745	26357	13913	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Atrazine Filter Performance Table

BC	C/C	BC	Inf	Empty Bed Contact Time [minutes]																													
Material	o	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.6	20	0.4	35284	18641	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	25	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	5	0.4	0	0	0	0	0	0	0	0	3599	4532	5734	3441	6235	3514	6544	3614	6975	3812	7482	4107	8143	4571	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	10	0.4	0	0	9958	7121	12199	6985	13126	7251	14523	7944	16324	9168	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	15	0.4	17311	10404	19745	10913	21752	11902	24543	13789	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	20	0.4	26398	14600	30148	16572	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	25	0.4	36437	19954	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	30	0.4	49436	27814	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	5	0.4	0	0	0	0	0	0	0	0	0	0	2462	3301	4065	2940	4787	2933	5311	3095	5731	3287	6136	3503	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	10	0.4	0	0	0	0	5879	7411	9585	5879	11112	6413	12288	7018	13650	7805	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	15	0.4	7356	9902	14395	8839	16622	9599	18455	10543	21475	12299	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	20	0.4	19213	11815	23012	13217	26314	15040	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	25	0.4	27779	16058	32933	18829	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	30	0.4	37047	21186	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	35	0.4	47738	27336	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2083	2754	3427	2497	4139	2599	4594	2793	5744	3425	-1	-1	-1	-1	-1	-1
RAC	0.3	10	0.4	0	0	0	0	0	0	4144	5494	7741	5058	9185	5588	10444	6257	11487	6852	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	15	0.4	0	0	6185	8221	11526	7566	13774	8384	16474	9849	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	20	0.4	8204	10936	16521	10415	19961	12009	22969	13711	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	25	0.4	19157	12633	24949	15014	29622	17660	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	30	0.4	27525	16785	34449	20575	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	35	0.4	36261	21771	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	40	0.4	45921	27440	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1686	2235	2116	2659	4119	2626	5171	3232	-1	-1	-1	-1
RAC	0.2	10	0.4	0	0	0	0	0	0	0	0	2294	3972	4215	5302	7102	4673	8221	5243	9654	6070	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	15	0.4	0	0	0	0	3319	5749	6298	7930	11501	7424	13936	8789	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	20	0.4	0	0	6560	8790	12972	8891	16371	10453	20696	12949	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	25	0.4	5296	9173	16155	11101	21351	13568	25698	16087	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	30	0.4	12453	15723	24454	15630	30791	19282	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	35	0.4	24182	16102	33507	21105	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	40	0.4	32466	20770	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1520	1956	3066	2153	4053	2726	4053	2726
RAC	0.1	10	0.4	0	0	0	0	0	0	0	0	0	0	0	0	1580	2737	3011	3882	5329	3927	6792	4677	8091	5445	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	15	0.4	0	0	0	0	0	0	0	0	3688	5017	7227	5684	10034	6926	12087	8139	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	20	0.4	0	0	0	0	0	0	5905	7643	12137	8550	16050	10815	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	25	0.4	0	0	0	0	8065	10287	14972	10574	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	30	0.4	0	0	8682	11285	17861	12635	23881	16110	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	35	0.4	0	0	17935	13494	26640	18073	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	40	0.4	11339	14806	26354	18240	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1168	1538	2367	1852	2367	1852
RAC	0.1	10	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1444	2502	2805	3590	4701	3689	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	15	0.4	0	0	0	0	0	0	0	0	0	0	1092	1892	4087	5247	6974	5499	9806	7073	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	20	0.4	0	0	0	0	0	0	0	0	4502	5980	9197	7289	13220	9516	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	25	0.4	0	0	0	0	0	0	5457	7301	12778	9719	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	30	0.4	0	0	0	0	6431	8647	13490	10808	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	35	0.4	0	0	4177	7235	14014	12280	22265	16129	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Atrazine Filter Performance Table

BC	C/C	BC	Inf	Empty Bed Contact Time [minutes]																											
Material	o	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.1	40	0.4	0	0	10440	13482	22873	16897	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0	5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RAC	0	10	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2174	2821	-1	-1	-1	-1
RAC	0	15	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1160	2010	3197	4156	5715	5139	-1	-1	-1	-1	-1	-1
RAC	0	20	0.4	0	0	0	0	0	0	0	0	0	0	0	0	1665	2884	4179	5443	8551	7320	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0	25	0.4	0	0	0	0	0	0	0	0	0	0	3681	5141	8296	8294	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0	30	0.4	0	0	0	0	0	0	0	0	4361	6124	10801	10020	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0	35	0.4	0	0	0	0	0	0	0	0	9762	12481	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0	40	0.4	0	0	0	0	0	0	7705	10128	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	5	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	10	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	15	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	20	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	25	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	30	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	5	1	19166	11947	24185	11550	29595	16327	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	10	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	15	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	20	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	25	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	30	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	5	1	7419	3697	7491	3328	7560	3226	8795	4580	11419	6343	13088	6324	15362	8291	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	10	1	17912	9497	24459	12421	28999	14905	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	15	1	39791	19235	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	20	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	25	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	30	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	5	1	0	0	3933	3007	4994	2486	5119	2386	5277	2361	5684	2626	7104	4162	7939	4404	9077	4559	10138	5216	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	10	1	10308	4805	10761	4805	13362	7537	15960	8842	19305	9717	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	15	1	17288	8028	24066	13311	28934	14562	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	20	1	32257	17816	41033	21152	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	25	1	48614	24490	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	30	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	5	1	0	0	0	0	1990	2574	3320	2022	3834	1918	3991	1907	4169	1954	4393	2069	5045	2642	5849	3288	6561	3539	-1	-1	-1	-1	-1	-1
RAC	0.6	10	1	6688	4065	7808	3832	8228	3876	8822	4157	11067	6164	13161	7098	15198	7891	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	15	1	12081	5777	13287	6266	16569	9220	19801	10676	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	20	1	17789	8397	23635	13282	29118	15206	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	25	1	27817	15488	36493	19058	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	30	1	39961	21533	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	35	1	53451	27787	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	5	1	0	0	0	0	0	0	0	0	1818	2200	2900	1587	3150	1608	3304	1648	3520	1733	3774	1865	4106	2080	5462	2982	-1	-1	-1	-1
RAC	0.5	10	1	0	0	5051	3330	6164	3204	6627	3307	7327	3608	8232	4172	9641	5193	10944	5975	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Atrazine Filter Performance Table

BC	C/C	BC	Inf	Empty Bed Contact Time [minutes]																											
Material	o	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.5	15	1	8756	4800	9969	4976	10974	5406	12377	6275	15480	8431	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	20	1	13329	6658	15208	7525	18254	9653	21966	11993	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	25	1	18383	9064	22867	12096	28657	15615	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	30	1	24931	12661	33067	18055	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	35	1	33766	18160	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	40	1	44244	24157	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	5	1	0	0	0	0	0	0	0	0	0	0	1243	1611	2062	1376	2421	1356	2684	1423	2894	1507	3098	1604	3764	1954	4589	2453	-1	-1
RAC	0.4	10	1	0	0	0	0	2971	3599	4848	2719	5613	2944	6204	3214	6889	3570	7536	3914	8582	4514	9821	5342	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	15	1	3714	4836	7281	4088	8396	4407	9317	4828	10836	5623	12464	6522	14649	7956	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	20	1	9719	5465	11623	6062	13283	6883	15105	7851	18503	9903	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	25	1	14033	7373	16623	8617	19514	10160	23025	12316	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	30	1	18704	9704	22707	11812	27655	14795	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	35	1	24094	12509	30185	15900	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	40	1	30342	15796	39478	21477	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1052	1342	1737	1170	2093	1205	2322	1291	2901	1579	3437	1843	3966	2110
RAC	0.3	10	1	0	0	0	0	0	0	2093	2679	3918	2354	4642	2583	5276	2887	5802	3159	6523	3519	7226	3857	7948	4229	-1	-1	-1	-1	-1	-1
RAC	0.3	15	1	0	0	3123	4009	5834	3521	6962	3876	8322	4543	9519	5151	10787	5762	11922	6346	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	20	1	4142	5334	8357	4831	10087	5544	11603	6322	13816	7415	15898	8464	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	25	1	9696	5882	12606	6932	14962	8140	17190	9230	20687	11036	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	30	1	13913	7762	17401	9488	20629	11081	23852	12706	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	35	1	18321	10049	22833	12341	27184	14483	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	40	1	23196	12655	28915	15466	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	851	1089	1069	1290	2083	1220	2613	1500	3080	1733
RAC	0.2	10	1	0	0	0	0	0	0	0	0	1137	1969	2129	2573	3592	2177	4156	2437	4880	2819	5544	3162	6165	3470	-1	-1	-1	-1	-1	-1
RAC	0.2	15	1	0	0	0	0	1647	2853	3182	3849	5816	3454	7044	4082	8257	4714	9236	5200	10559	5872	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	20	1	0	0	3310	4286	6566	4155	8277	4860	10461	6010	12301	6929	14181	7884	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	25	1	2633	4560	8177	5188	10794	6306	12988	7467	16000	8977	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	30	1	6291	7633	12364	7268	15563	8951	18409	10378	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	35	1	12235	7510	16938	9804	20920	11835	24547	13665	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	40	1	16415	9660	21998	12578	26865	15008	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	768	950	1551	1009	2050	1275
RAC	0.1	10	1	0	0	0	0	0	0	0	0	0	0	0	0	785	1359	1520	1886	2697	1846	3435	2190	4092	2547	5828	3459	-1	-1	-1	-1
RAC	0.1	15	1	0	0	0	0	0	0	0	0	1859	2446	3661	2681	5075	3244	6113	3807	7466	4517	8719	5176	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	20	1	0	0	0	0	0	0	2981	3714	6140	4009	8117	5059	10038	6067	11595	6887	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	25	1	0	0	0	0	4073	4996	7574	4959	10758	6653	13426	8042	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	30	1	0	0	4383	5486	9036	5927	12078	7537	16159	9680	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	35	1	0	0	9080	6352	13473	8459	17201	10431	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	40	1	5723	7201	13330	8547	18425	11282	22944	13649	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	589	748	1198	875
RAC	0.1	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	714	1237	1417	1743	2379	1743	4184	2688	-1	-1	-1	-1
RAC	0.1	15	1	0	0	0	0	0	0	0	0	0	0	561	971	2063	2548	3530	2598	4960	3326	6242	4014	7451	4658	-1	-1	-1	-1	-1	-1
RAC	0.1	20	1	0	0	0	0	0	0	0	0	2270	2909	4655	3445	6687	4475	8279	5329	10410	6471	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	25	1	0	0	0	0	0	0	2751	3553	6465	4585	9244	6074	11980	7528	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	30	1	0	0	0	0	3242	4210	6829	5112	11108	7300	14706	9212	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	35	1	0	0	2079	3602	7103	5832	11263	7589	16498	10397	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	40	1	0	0	5270	6551	11571	7960	16211	10473	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RAC	0	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1097	1371	2719	2047	-1	-1
RAC	0	15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	580	1004	1613	2020	2893	2451	-1	-1	-1	-1	-1	-1
RAC	0	20	1	0	0	0	0	0	0	0	0	0	0	0	0	829	1435	2109	2645	4327	3484	6268	4545	8148	5578	-1	-1	-1	-1	-1	-1
RAC	0	25	1	0	0	0	0	0	0	0	0	0	0	1852	2506	4207	3970	6566	4981	9523	6604	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0	30	1	0	0	0	0	0	0	0	0	2193	2986	5470	4785	9075	6633	12031	8258	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Atrazine Filter Performance Table

BC	C/C	BC	Inf	Empty Bed Contact Time [minutes]																											
Material	o	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0	35	1	0	0	0	0	0	0	0	0	4932	6065	10233	7542	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0	40	1	0	0	0	0	0	0	3888	4925	10251	7824	15791	10867	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	5	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	10	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	15	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	20	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	25	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	30	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	35	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	40	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	5	4	6804	3700	8597	3317	10515	4907	11976	5009	14796	6495	17467	7584	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	10	4	24240	10086	31107	13331	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	15	4	53178	23086	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	20	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	25	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	30	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	35	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	40	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	5	4	2638	1082	2661	938	2685	891	3125	1357	4056	1899	4650	1820	5458	2474	6004	2677	6947	2957	7806	3419	8656	3735	-1	-1	-1	-1	-1	-1
RAC	0.8	10	4	6367	2834	8699	3631	10298	4376	12071	5377	14965	6543	17378	7499	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	15	4	14135	5537	18204	8098	22435	9808	26167	11291	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	20	4	24402	10842	31600	13837	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	25	4	37718	16498	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	30	4	52936	22842	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	35	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	40	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	5	4	0	0	1407	944	1775	727	1819	684	1874	664	2017	742	2522	1268	2819	1319	3225	1329	3600	1531	4019	1793	5206	2252	-1	-1	-1	-1
RAC	0.7	10	4	3662	1377	3822	1349	4749	2284	5668	2648	6857	2833	8065	3599	9335	4067	10438	4517	11983	5244	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	15	4	6134	2273	8547	3985	10277	4245	12138	5418	14887	6429	17466	7662	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	20	4	11456	5330	14572	6212	17813	7866	20987	9084	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	25	4	17266	7142	22336	9861	27305	11896	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	30	4	24526	10951	31645	13702	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	35	4	32876	14343	42406	18552	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	40	4	42414	18372	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	5	4	0	0	0	0	705	859	1183	616	1363	562	1418	550	1481	559	1560	591	1791	781	2077	990	2331	1053	2988	1289	3678	1639	4327	1887
RAC	0.6	10	4	2383	1239	2775	1116	2923	1112	3132	1188	3930	1854	4676	2111	5399	2324	5990	2584	6924	3084	7796	3435	8685	3787	-1	-1	-1	-1	-1	-1
RAC	0.6	15	4	4292	1668	4717	1790	5884	2772	7035	3175	8566	3682	10054	4449	11650	5140	13047	5690	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	20	4	6315	2400	8390	3997	10346	4486	12035	5194	14866	6622	17424	7600	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	25	4	9878	4657	12966	5623	15641	6797	18524	8254	22770	9971	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	30	4	14197	6404	18135	7830	22270	9922	26217	11437	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	35	4	18989	8187	24474	10908	29841	13008	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	40	4	24290	10493	31509	13885	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	5	4	0	0	0	0	0	0	0	0	646	731	1032	475	1119	473	1174	482	1250	504	1340	541	1458	608	1940	890	2390	1057	2803	1229
RAC	0.5	10	4	0	0	1801	1028	2191	948	2354	967	2602	1048	2922	1219	3423	1544	3886	1784	4508	2026	5058	2210	5623	2467	-1	-1	-1	-1	-1	-1
RAC	0.5	15	4	3114	1437	3542	1455	3897	1570	4394	1834	5496	2515	6554	2967	7556	3306	8445	3706	9744	4367	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	20	4	4735	1947	5400	2186	6480	2855	7800	3580	9647	4265	11273	4948	13119	5880	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	25	4	6528	2633	8118	3579	10178	4661	12017	5317	14735	6522	17328	7742	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	30	4	8850	3701	11742	5390	14442	6390	16952	7442	20920	9345	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	35	4	11987	5398	15900	7148	19292	8435	22832	10235	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	40	4	15712	7212	20395	8923	24984	11167	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	5	4	0	0	0	0	0	0	0	0	0	0	440	538	735	426	861	408	954	423	1028	446	1101	473	1336	575	1629	728	1956	904

Atrazine Filter Performance Table

BC	C/C	BC	Inf	Empty Bed Contact Time [minutes]																											
Material	o	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.4	10	4	0	0	0	0	1056	1195	1724	818	1995	873	2204	948	2447	1052	2676	1153	3046	1332	3487	1593	3923	1813	5111	2273	-1	-1	-1	-1
RAC	0.4	15	4	1314	1614	2589	1231	2983	1307	3310	1425	3848	1657	4425	1922	5201	2371	5889	2722	6808	3071	7670	3413	8544	3821	-1	-1	-1	-1	-1	-1
RAC	0.4	20	4	3456	1646	4129	1794	4718	2030	5363	2312	6569	2938	7857	3632	9162	4127	10233	4554	11795	5297	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	25	4	4986	2187	5904	2542	6928	2992	8174	3653	10274	4725	12088	5406	14008	6253	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	30	4	6644	2866	8062	3480	9818	4388	11803	5458	14588	6523	17115	7656	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	35	4	8556	3689	10715	4693	13410	6208	15927	7189	19559	8728	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	40	4	10773	4655	14017	6405	17413	7925	20514	9134	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	372	447	619	363	744	365	825	388	1031	472	1221	548	1408	625
RAC	0.3	10	4	0	0	0	0	0	0	741	893	1394	718	1650	777	1875	865	2061	945	2317	1049	2566	1146	2822	1254	3703	1712	4603	2121	-1	-1
RAC	0.3	15	4	0	0	1106	1336	2075	1075	2474	1166	2957	1360	3381	1538	3831	1712	4233	1881	4866	2199	5554	2568	6245	2903	-1	-1	-1	-1	-1	-1
RAC	0.3	20	4	1466	1778	2971	1464	3584	1663	4122	1892	4907	2207	5645	2509	6548	2965	7405	3424	8624	4002	9774	4474	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	25	4	3450	1797	4479	2079	5315	2435	6105	2748	7345	3273	8677	3973	10220	4755	11508	5305	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	30	4	4945	2336	6182	2840	7326	3299	8469	3768	10469	4796	12491	5810	14577	6679	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	35	4	6509	3012	8110	3682	9652	4296	11357	5138	14252	6633	16860	7734	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	40	4	8241	3789	10268	4596	12396	5566	14813	6852	18510	8534	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	301	362	380	428	740	371	929	454	1094	523
RAC	0.2	10	4	0	0	0	0	0	0	0	0	388	671	757	854	1277	666	1477	741	1734	855	1970	957	2190	1046	2806	1309	3413	1576	4051	1891
RAC	0.2	15	4	0	0	0	0	563	974	1131	1278	2067	1053	2503	1240	2934	1427	3281	1569	3751	1765	4205	1962	4656	2157	6085	2842	-1	-1	-1	-1
RAC	0.2	20	4	0	0	1171	1428	2335	1279	2942	1478	3717	1822	4370	2090	5038	2370	5603	2615	6406	2964	7238	3351	8109	3788	-1	-1	-1	-1	-1	-1
RAC	0.2	25	4	901	1561	2908	1598	3836	1917	4615	2264	5685	2705	6621	3104	7624	3537	8517	3937	9855	4592	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	30	4	2235	2534	4394	2212	5530	2714	6540	3131	7978	3740	9293	4309	10782	4992	12151	5677	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	35	4	4350	2301	6019	2977	7432	3574	8720	4109	10623	4934	12460	5768	14597	6841	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	40	4	5834	2940	7816	3808	9544	4518	11170	5219	13672	6325	16186	7564	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	272	316	551	312	728	392
RAC	0.1	10	4	0	0	0	0	0	0	0	0	0	0	0	0	268	465	539	626	959	575	1221	676	1454	784	2071	1056	2617	1306	3119	1536
RAC	0.1	15	4	0	0	0	0	0	0	0	0	656	815	1303	842	1803	1002	2172	1172	2653	1383	3099	1580	3518	1773	4680	2305	-1	-1	-1	-1
RAC	0.1	20	4	0	0	0	0	0	0	1057	1234	2182	1242	2885	1558	3567	1858	4120	2102	4860	2442	5558	2761	6229	3070	-1	-1	-1	-1	-1	-1
RAC	0.1	25	4	0	0	0	0	1445	1658	2692	1537	3823	2046	4771	2459	5722	2891	6502	3249	7566	3737	8588	4206	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	30	4	0	0	1553	1823	3211	1837	4292	2321	5742	2960	6988	3525	8254	4105	9313	4592	10771	5262	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	35	4	0	0	3230	1985	4788	2608	6112	3196	7938	4016	9521	4741	11164	5496	12549	6132	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	40	4	2027	2393	4737	2642	6547	3463	8154	4168	10397	5198	12377	6106	14450	7058	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	209	248	426	275
RAC	0.1	10	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	243	420	503	579	846	549	1487	832	2045	1087	2551	1326
RAC	0.1	15	4	0	0	0	0	0	0	0	0	0	0	198	343	732	846	1255	818	1762	1036	2218	1242	2648	1435	3823	1988	4894	2499	-1	-1
RAC	0.1	20	4	0	0	0	0	0	0	0	0	802	967	1655	1086	2376	1394	2942	1649	3700	1992	4408	2325	5082	2643	6967	3545	-1	-1	-1	-1
RAC	0.1	25	4	0	0	0	0	0	0	972	1181	2297	1438	3285	1886	4257	2321	5055	2693	6126	3197	7144	3682	8120	4149	-1	-1	-1	-1	-1	-1
RAC	0.1	30	4	0	0	0	0	1145	1400	2428	1613	3947	2267	5226	2839	6515	3443	7577	3945	9024	4635	10406	5298	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	35	4	0	0	712	1233	2529	1858	4002	2366	5863	3207	7484	3962	9130	4741	10502	5396	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	40	4	0	0	1868	2174	4112	2488	5760	3243	8048	4291	10043	5233	12097	6213	13816	7037	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RAC	0	10	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	389	455	966	648	1467	881
RAC	0	15	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	199	344	571	670	1028	786	2189	1316	3261	1831	4265	2321
RAC	0	20	4	0	0	0	0	0	0	0	0	0	0	0	0	283	491	747	878	1537	1111	2226	1431	2895	1743	4783	2652	-1	-1	-1	-1
RAC	0	25	4	0	0	0	0	0	0	0	0	0	0	651	834	1497	1284	2332	1578	3384	2067	4399	2551	5376	3023	-1	-1	-1	-1	-1	-1
RAC	0	30	4	0	0	0	0	0	0	0	0	770	994	1945	1539	3224	2091	4275	2581	5717	3272	7104	3945	8444	4600	-1	-1	-1	-1	-1	-1
RAC	0	35	4	0	0	0	0	0	0	0	0	1750	2013	3635	2381	5264	3142	6630	3798	8511	4711	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0	40	4	0	0	0	0	0	0	1375	1635	3641	2481	5612	3398	7657	4379	9379	5215	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Fipronil Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	1	5	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	5	0.1	5418	2877	7401	3992	8656	4686	10023	5267	12425	6677	14569	7783	16645	8897	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	10	0.1	20305	10668	26133	13955	31938	17153	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	15	0.1	44406	23746	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	5	0.1	2159	1261	2358	1452	2494	1425	2769	1480	3153	1636	4084	2210	4543	2453	4970	2647	5845	3122	6536	3507	7230	3855	-1	-1	-1	-1	-1	-1
Biochar	0.8	10	0.1	5585	2987	6993	3646	8841	4788	9996	5323	12533	6734	14516	7739	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	15	0.1	12431	6728	15079	8026	18790	10096	21857	11652	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	20	0.1	20220	10759	26460	14193	32242	17268	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	25	0.1	31587	16971	40434	21656	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	30	0.1	44217	23574	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	35	0.1	59325	31797	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	5	0.1	370	641	447	775	1474	863	1582	956	1681	979	1871	1011	2031	1079	2234	1169	2742	1471	3077	1659	3346	1795	4368	2337	5308	2837	-1	-1
Biochar	0.7	10	0.1	3184	1925	3481	1969	3962	2117	4492	2352	5909	3188	6714	3603	7782	4141	8758	4686	10011	5357	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	15	0.1	5676	3065	6776	3546	8856	4777	10105	5421	12486	6660	14581	7807	16855	9009	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	20	0.1	9085	4753	12440	6709	14781	7874	17608	9421	21473	11478	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	25	0.1	14876	8025	18535	9873	22852	12239	26762	14305	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	30	0.1	20411	10948	26548	14206	32182	17203	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	35	0.1	27396	14578	35431	18958	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	40	0.1	35578	19040	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	5	0.1	0	0	206	356	318	551	442	526	1143	665	1228	723	1304	749	1399	773	1544	829	1689	897	1891	996	2530	1358	3054	1632	3620	1934
Biochar	0.6	10	0.1	979	953	2361	1389	2557	1488	2808	1552	3250	1736	3792	2000	4544	2437	5070	2722	5755	3082	6500	3468	7265	3882	-1	-1	-1	-1	-1	-1
Biochar	0.6	15	0.1	3716	2187	4230	2335	4870	2601	5707	3009	7251	3893	8389	4496	9709	5181	10914	5832	12509	6699	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	20	0.1	5663	3125	6822	3624	8614	4596	10185	5467	12347	6598	14574	7788	16839	9017	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	25	0.1	8171	4363	10797	5761	13189	7076	15383	8221	19028	10184	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	30	0.1	11524	6077	15344	8236	18494	9884	21929	11719	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	35	0.1	15962	8556	20341	10893	24965	13329	29340	15713	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	40	0.1	20547	11029	26272	14019	32191	17248	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	5	0.1	0	0	0	0	0	0	221	382	268	464	807	432	940	537	1003	575	1080	612	1166	645	1264	686	1593	847	1990	1063	2355	1262
Biochar	0.5	10	0.1	443	767	551	954	1811	1024	2010	1154	2257	1264	2533	1375	2865	1533	3192	1697	3719	1981	4244	2271	4723	2533	6105	3260	-1	-1	-1	-1
Biochar	0.5	15	0.1	2432	1303	3023	1735	3379	1892	3808	2067	4548	2425	5386	2865	6337	3390	7093	3804	8094	4334	9166	4895	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	20	0.1	4042	2319	4697	2599	5497	2953	6407	3407	8036	4293	9469	5077	10895	5832	12232	6533	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	25	0.1	5660	3168	6885	3698	8342	4433	10006	5345	12331	6614	14395	7693	16782	8979	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	30	0.1	7666	4161	9645	5130	12024	6423	14238	7635	17381	9288	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	35	0.1	10050	5380	13117	6990	16228	8699	18966	10155	23452	12546	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	40	0.1	12905	6864	17112	9157	20803	11152	24555	13115	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	5	0.1	0	0	0	0	0	0	0	0	157	273	207	359	265	377	675	358	792	440	867	484	932	518	1136	618	1370	734	1607	857
Biochar	0.4	10	0.1	0	0	361	626	448	777	1349	716	1672	934	1866	1038	2075	1142	2273	1237	2584	1391	2898	1551	3223	1719	4276	2290	5216	2795	-1	-1
Biochar	0.4	15	0.1	624	1080	2024	1071	2500	1395	2803	1559	3266	1787	3761	2028	4327	2316	4839	2580	5636	3007	6417	3437	7131	3823	-1	-1	-1	-1	-1	-1
Biochar	0.4	20	0.1	2699	1427	3479	1943	4001	2210	4556	2479	5519	2960	6457	3443	7592	4052	8561	4586	9822	5266	11074	5929	-1	-1	-1	-1	-1	-1	-1	-1

Fipronil Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.4	25	0.1	4177	2330	5006	2765	5889	3193	6871	3685	8443	4499	10072	5387	11703	6275	13058	6997	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	30	0.1	5625	3129	6847	3726	8252	4427	9699	5173	12157	6503	14283	7659	16530	8851	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	35	0.1	7256	3993	9083	4888	11032	5888	13184	7036	16346	8764	19126	10242	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	40	0.1	9147	4978	11650	6236	14355	7651	17159	9192	21028	11269	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	151	262	177	307	241	323	586	308	675	364	856	467	1019	555	1186	642
Biochar	0.3	10	0.1	0	0	0	0	263	456	354	613	1027	528	1349	727	1554	846	1712	933	1928	1051	2149	1168	2377	1286	3065	1641	3797	2029	4519	2422
Biochar	0.3	15	0.1	0	0	530	919	1516	777	2022	1089	2455	1337	2811	1532	3206	1743	3565	1929	4080	2194	4597	2462	5137	2744	6792	3640	-1	-1	-1	-1
Biochar	0.3	20	0.1	706	1224	2328	1221	2963	1609	3423	1866	4095	2229	4753	2572	5486	2949	6130	3282	7097	3790	8092	4327	9057	4853	-1	-1	-1	-1	-1	-1
Biochar	0.3	25	0.1	2499	1280	3703	2011	4414	2406	5094	2773	6188	3342	7229	3878	8410	4493	9494	5072	11026	5906	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	30	0.1	4036	2174	5133	2798	6112	3327	7130	3858	8719	4678	10276	5490	12064	6451	13586	7280	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	35	0.1	5393	2934	6747	3676	8117	4398	9521	5120	11729	6268	13945	7456	16297	8737	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	40	0.1	6842	3729	8594	4671	10423	5616	12262	6567	15272	8161	18115	9708	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	122	211	151	262	174	301	596	315	756	404	897	482
Biochar	0.2	10	0.1	0	0	0	0	0	0	0	0	277	479	347	600	990	519	1189	628	1409	750	1607	860	1795	965	2323	1255	2842	1530	3355	1801
Biochar	0.2	15	0.1	0	0	0	0	410	711	518	898	1643	864	2032	1080	2392	1280	2689	1445	3094	1670	3482	1881	3869	2087	5040	2706	-1	-1	-1	-1
Biochar	0.2	20	0.1	0	0	598	1035	1681	896	2367	1250	3026	1615	3581	1925	4156	2244	4639	2506	5328	2873	6024	3240	6717	3606	-1	-1	-1	-1	-1	-1
Biochar	0.2	25	0.1	677	1172	2081	1112	3100	1641	3756	2005	4667	2512	5472	2956	6330	3416	7090	3818	8175	4391	9263	4964	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	30	0.1	1027	1780	3533	1865	4500	2402	5358	2880	6593	3562	7720	4166	8973	4827	10065	5403	11641	6235	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	35	0.1	3314	1735	4890	2602	6081	3265	7190	3881	8818	4760	10370	5580	12070	6476	13574	7271	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	40	0.1	4687	2474	6371	3409	7854	4235	9246	4995	11380	6128	13406	7197	15649	8381	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	103	140	243	420	231	576	305
Biochar	0.1	10	0.1	0	0	0	0	0	0	0	0	0	0	111	193	222	385	279	483	660	413	950	511	1149	609	1670	883	2128	1133	2548	1363
Biochar	0.1	15	0.1	0	0	0	0	0	0	153	266	374	647	568	811	1401	755	1716	909	2120	1118	2499	1321	2852	1513	3822	2044	4729	2539	-1	-1
Biochar	0.1	20	0.1	0	0	0	0	377	653	550	952	1655	915	2278	1207	2852	1504	3322	1756	3944	2095	4527	2414	5088	2721	6691	3595	-1	-1	-1	-1
Biochar	0.1	25	0.1	0	0	465	805	730	1264	2033	1128	3028	1600	3831	2021	4635	2458	5288	2815	6176	3301	7029	3767	7860	4220	-1	-1	-1	-1	-1	-1
Biochar	0.1	30	0.1	0	0	813	1409	2420	1346	3388	1795	4610	2433	5663	3005	6722	3584	7606	4068	8824	4733	10012	5379	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	35	0.1	724	1254	2034	1456	3769	2002	4880	2573	6426	3406	7752	4132	9123	4883	10280	5514	11896	6391	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	40	0.1	1069	1852	3671	1983	5207	2747	6570	3473	8454	4500	10107	5406	11838	6351	13317	7154	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	61	105	121	210	283	212
Biochar	0.05	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	117	202	204	354	273	473	554	426	1161	626	1632	862	2054	1085
Biochar	0.05	15	0.1	0	0	0	0	0	0	0	0	0	0	275	476	401	695	802	645	1349	762	1731	934	2094	1111	3078	1625	3968	2104	4794	2551
Biochar	0.05	20	0.1	0	0	0	0	0	0	214	370	472	818	1020	874	1821	1024	2295	1239	2935	1554	3529	1863	4091	2160	5656	3003	-1	-1	-1	-1
Biochar	0.05	25	0.1	0	0	0	0	337	584	579	1003	1654	1068	2540	1396	3359	1786	4031	2129	4925	2600	5772	3053	6582	3490	-1	-1	-1	-1	-1	-1
Biochar	0.05	30	0.1	0	0	285	493	688	1191	1139	1594	3053	1677	4129	2193	5213	2752	6099	3221	7302	3866	8447	4484	9552	5083	-1	-1	-1	-1	-1	-1
Biochar	0.05	35	0.1	0	0	671	1162	1087	1882	3056	1735	4619	2459	5984	3159	7356	3886	8497	4498	10051	5338	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	40	0.1	313	543	1034	1790	3089	1826	4488	2427	6414	3389	8082	4268	9790	5184	11214	5953	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.01	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	62
Biochar	0.01	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	66	114	246	427	706	498	1120	652
Biochar	0.01	15	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	87	150	240	416	364	631	520	809	1671	974	2561	1384	3392	1801
Biochar	0.01	20	0.1	0	0	0	0	0	0	0	0	0	0	91	158	325	563	479	829	1029	932	1658	1076	2210	1290	3775	2023	5232	2768	-1	-1
Biochar	0.01	25	0.1	0	0	0	0	0	0	0	0	221	383	487	844	757	1311	1696	1219	2567	1532	3411	1897	4220	2282	6516	3447	-1	-1	-1	-1
Biochar	0.01	30	0.1	0	0	0	0	0	0	0	0	581	1006	937	1623	2392	1576	3259	1909	4458	2446	5604	3004	6714	3566	-1	-1	-1	-1	-1	-1
Biochar	0.01	35	0.1	0	0	0	0	0	0	516	894	1022	1770	2687	1801	4032	2323	5168	2838	6724	3597	8221	4359	9670	5112	-1	-1	-1	-1	-1	-1
Biochar	0.01	40	0.1	0	0	0	0	465	806	904	1565	2637	1923	4273	2512	5974	3274	7397	3967	9358	4962	11246	5944	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	5	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	10	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	15	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	20	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	25	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Fipronil Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	1	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	5	0.4	1996	1012	2725	1436	3188	1664	3688	1866	4575	2373	5363	2774	6129	3158	6855	3559	7801	4044	8704	4513	9578	4978	-1	-1	-1	-1	-1	-1
Biochar	0.9	10	0.4	7471	3781	9623	4947	11761	6097	13787	7159	16662	8649	19228	9994	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	15	0.4	16346	8464	20796	10798	24985	12969	28950	15047	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	20	0.4	27882	14478	35263	18290	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	25	0.4	42013	21804	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	30	0.4	58547	30429	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	5	0.4	794	458	868	518	919	504	1020	522	1161	576	1503	792	1673	872	1830	937	2152	1114	2407	1247	2662	1370	3437	1777	4161	2156	4835	2511
Biochar	0.8	10	0.4	2057	1052	2574	1302	3255	1706	3681	1884	4615	2400	5344	2750	6193	3207	6892	3563	7868	4077	8808	4571	9706	5040	-1	-1	-1	-1	-1	-1
Biochar	0.8	15	0.4	4575	2409	5553	2842	6919	3598	8047	4141	9843	5089	11473	5946	13171	6833	14586	7574	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	20	0.4	7445	3810	9743	5048	11870	6148	13862	7167	16836	8725	19484	10118	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	25	0.4	11630	6048	14887	7711	18004	9320	20989	10876	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	30	0.4	16278	8379	20911	10812	25243	13081	29334	15233	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	35	0.4	21843	11313	27864	14437	33506	17393	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	40	0.4	28037	14498	35673	18512	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	5	0.4	136	235	165	285	542	313	582	342	619	347	689	357	748	381	823	413	1009	527	1133	592	1232	638	1608	833	1954	1009	2297	1190
Biochar	0.7	10	0.4	1173	689	1282	697	1459	747	1654	830	2175	1139	2472	1280	2865	1473	3224	1670	3686	1906	4152	2145	4611	2389	5909	3064	-1	-1	-1	-1
Biochar	0.7	15	0.4	2089	1083	2495	1252	3260	1707	3721	1926	4596	2372	5369	2778	6205	3206	6928	3590	7919	4101	8874	4601	9804	5091	-1	-1	-1	-1	-1	-1
Biochar	0.7	20	0.4	3345	1679	4579	2392	5442	2796	6482	3357	7905	4083	9253	4794	10662	5524	11848	6143	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	25	0.4	5476	2867	6824	3506	8413	4360	9853	5088	12054	6242	14044	7284	16124	8371	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	30	0.4	7516	3890	9773	5061	11848	6119	13928	7217	16960	8796	19676	10218	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	35	0.4	10085	5183	13045	6745	15891	8232	18589	9627	22559	11711	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	40	0.4	13098	6784	16807	8685	20389	10549	23820	12351	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	5	0.4	0	0	75	130	117	203	161	195	421	240	452	259	480	267	515	274	569	293	622	317	696	354	931	484	1125	581	1333	689
Biochar	0.6	10	0.4	368	340	869	500	942	530	1034	550	1197	614	1396	710	1673	870	1866	970	2119	1097	2393	1234	2674	1383	3455	1787	4205	2179	4913	2551
Biochar	0.6	15	0.4	1368	782	1557	828	1793	920	2101	1068	2669	1389	3089	1600	3574	1843	4017	2078	4605	2385	5188	2684	5762	2988	7390	3837	-1	-1	-1	-1
Biochar	0.6	20	0.4	2085	1109	2512	1281	3171	1642	3749	1949	4546	2347	5365	2775	6199	3210	6926	3583	7936	4115	8915	4623	9860	5120	-1	-1	-1	-1	-1	-1
Biochar	0.6	25	0.4	3009	1543	3975	2058	4855	2521	5664	2925	7005	3630	8177	4228	9468	4909	10542	5464	12044	6255	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	30	0.4	4242	2158	5648	2936	6809	3516	8072	4176	9874	5106	11560	5994	13323	6908	14814	7693	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	35	0.4	5876	3056	7489	3876	9189	4748	10802	5595	13240	6864	15429	7999	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	40	0.4	7564	3932	9672	4988	11851	6145	13916	7201	16999	8811	19782	10273	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	5	0.4	0	0	0	0	0	0	81	140	99	171	297	159	346	194	369	206	398	218	429	230	465	244	587	301	733	379	867	450
Biochar	0.5	10	0.4	162	281	203	351	667	371	740	414	831	450	933	488	1055	544	1175	603	1369	706	1562	811	1739	904	2247	1161	2754	1429	3236	1678
Biochar	0.5	15	0.4	895	479	1113	622	1244	674	1402	734	1674	860	1983	1021	2332	1210	2611	1357	2980	1543	3374	1744	3763	1952	4866	2524	5918	3074	-1	-1
Biochar	0.5	20	0.4	1487	832	1729	925	2024	1048	2358	1210	2958	1532	3485	1812	4011	2077	4502	2327	5188	2692	5841	3028	6493	3367	-1	-1	-1	-1	-1	-1
Biochar	0.5	25	0.4	2084	1129	2535	1313	3071	1576	3683	1907	4539	2359	5299	2739	6177	3202	6901	3581	7917	4104	8913	4629	9874	5128	-1	-1	-1	-1	-1	-1
Biochar	0.5	30	0.4	2822	1478	3550	1822	4426	2292	5241	2724	6398	3307	7545	3913	8725	4524	9751	5057	11164	5798	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	35	0.4	3700	1909	4829	2492	5973	3105	6982	3617	8632	4474	10101	5238	11694	6069	13032	6768	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	40	0.4	4751	2438	6299	3269	7658	3974	9038	4673	11121	5771	13018	6752	15025	7803	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	5	0.4	0	0	0	0	0	0	0	0	58	100	76	132	96	140	248	131	292	159	319	174	343	186	418	220	504	261	592	305
Biochar	0.4	10	0.4	0	0	132	229	165	285	496	263	615	336	687	372	764	408	837	441	951	495	1067	552	1187	612	1574	818	1920	997	2269	1177
Biochar	0.4	15	0.4	229	397	744	394	920	503	1032	558	1202	637	1384	722	1593	824	1781	918	2074	1074	2362	1228	2625	1365	3412	1769	4175	2170	4905	2551
Biochar	0.4	20	0.4	992	525	1280	698	1472	790	1677	884	2031	1054	2376	1225	2794	1447	3151	1639	3615	1880	4076	2114	4551	2360	5899	3065	-1	-1	-1	-1
Biochar	0.4	25	0.4	1536	840	1843	989	2168	1138	2529	1312	3107	1602	3707	1925	4307	2241	4806	2496	5543	2873	6268	3258	6963	3620	-1	-1	-1	-1	-1	-1
Biochar	0.4	30	0.4	2070	1121	2521	1329	3037	1576	3570	1841	4474	2324	5257	2735	6084	3156	6832	3543	7860	4087	8853	4600	9836	5117	-1	-1	-1	-1	-1	-1
Biochar	0.4	35	0.4	2671	1426	3343	1741	4061	2095	4852	2512	6016	3130	7040	3652	8199	4256	9173	4770	10524	5468	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	40	0.4	3367	1775	4288	2220	5283	2729	6315	3285	7740	4020	9116	4728	10576	5500	11811	6137	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	55	96	65	113	87	120	215	113	248	132	315	168	375	199	437	230
Biochar	0.3	10	0.4	0	0	0	0	96	167	130	225	378	196	496	264	572	305	630	335	710	377	791	418	875	460	1128	585	1397	725	1663	866
Biochar	0.3	15	0.4	0	0	195	337	558	289	744	395	903	481	1034	550	1180	624	1312	690	1501	783	1692	878	1891	979	2499	1302	3060	1593	3615	1881

Fipronil Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.3	20	0.4	259	449	856	448	1090	581	1259	671	1507	799	1749	920	2019	1053	2256	1171	2612	1353	2978	1547	3332	1736	4328	2252	5315	2771	-1	-1
Biochar	0.3	25	0.4	919	477	1362	726	1624	864	1874	994	2277	1195	2660	1384	3095	1603	3494	1812	4057	2113	4586	2391	5100	2655	6644	3464	-1	-1	-1	-1
Biochar	0.3	30	0.4	1484	789	1888	1005	2249	1193	2624	1380	3208	1669	3782	1959	4439	2307	4999	2605	5750	2997	6493	3378	7244	3770	-1	-1	-1	-1	-1	-1
Biochar	0.3	35	0.4	1983	1058	2483	1319	2987	1574	3503	1829	4316	2236	5131	2666	5997	3126	6708	3496	7722	4017	8739	4551	9718	5069	-1	-1	-1	-1	-1	-1
Biochar	0.3	40	0.4	2517	1341	3163	1673	3836	2007	4512	2343	5620	2916	6665	3474	7733	4030	8658	4505	9987	5202	11264	5875	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45	78	56	96	64	111	219	114	278	146	330	174
Biochar	0.2	10	0.4	0	0	0	0	0	0	0	0	102	176	127	221	364	190	437	228	518	271	591	310	660	348	855	451	1045	549	1235	645
Biochar	0.2	15	0.4	0	0	0	0	151	261	190	330	604	315	747	391	880	462	989	521	1138	601	1281	676	1423	749	1854	968	2292	1193	2727	1424
Biochar	0.2	20	0.4	0	0	220	380	619	332	870	454	1112	583	1317	694	1529	808	1706	901	1960	1031	2216	1161	2471	1291	3251	1694	4019	2102	4735	2476
Biochar	0.2	25	0.4	248	430	766	413	1140	595	1381	724	1716	905	2013	1063	2329	1227	2608	1369	3008	1572	3408	1776	3816	1987	5022	2626	-1	-1	-1	-1
Biochar	0.2	30	0.4	377	654	1299	678	1655	867	1970	1038	2425	1281	2840	1495	3301	1730	3703	1934	4282	2230	4873	2540	5458	2851	7112	3719	-1	-1	-1	-1
Biochar	0.2	35	0.4	1219	639	1798	941	2236	1177	2644	1397	3244	1709	3815	2000	4440	2318	4994	2601	5798	3023	6589	3443	7348	3844	-1	-1	-1	-1	-1	-1
Biochar	0.2	40	0.4	1723	899	2343	1230	2889	1526	3401	1796	4186	2198	4932	2576	5757	2998	6492	3384	7527	3934	8516	4455	9478	4956	-1	-1	-1	-1	-1	-1
Biochar	0.1	5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	38	52	89	155	85	212	111
Biochar	0.1	10	0.4	0	0	0	0	0	0	0	0	0	0	41	70	81	141	102	177	243	152	350	186	422	221	614	320	782	410	937	492
Biochar	0.1	15	0.4	0	0	0	0	0	0	56	97	137	238	207	299	515	275	631	330	779	405	919	478	1048	548	1405	739	1739	916	2060	1085
Biochar	0.1	20	0.4	0	0	0	0	138	239	202	350	609	335	837	438	1048	545	1221	636	1450	758	1664	873	1870	983	2460	1296	3036	1597	3596	1888
Biochar	0.1	25	0.4	0	0	170	295	268	464	748	413	1113	581	1408	732	1704	890	1944	1018	2270	1193	2584	1360	2890	1523	3791	1995	4677	2454	-1	-1
Biochar	0.1	30	0.4	0	0	299	517	890	493	1245	652	1695	881	2081	1087	2471	1296	2796	1470	3244	1708	3681	1940	4114	2167	5397	2833	-1	-1	-1	-1
Biochar	0.1	35	0.4	266	460	751	536	1385	728	1794	933	2362	1233	2849	1494	3354	1764	3779	1990	4374	2305	4962	2613	5547	2917	7276	3815	-1	-1	-1	-1
Biochar	0.1	40	0.4	393	680	1350	723	1914	996	2415	1258	3107	1628	3715	1953	4352	2292	4896	2580	5665	2983	6428	3380	7184	3772	-1	-1	-1	-1	-1	-1
Biochar	0.05	5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	39	44	77	105	78
Biochar	0.05	10	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43	74	75	130	100	174	205	156	427	227	600	313	755	393
Biochar	0.05	15	0.4	0	0	0	0	0	0	0	0	0	0	101	175	147	255	296	236	496	278	637	339	770	403	1131	589	1458	762	1762	923
Biochar	0.05	20	0.4	0	0	0	0	0	0	78	135	174	301	377	320	670	373	844	450	1079	564	1297	675	1504	783	2079	1087	2612	1372	3114	1640
Biochar	0.05	25	0.4	0	0	0	0	124	214	213	369	609	392	934	508	1235	648	1482	772	1810	942	2121	1106	2419	1264	3259	1712	4051	2133	4806	2535
Biochar	0.05	30	0.4	0	0	104	180	253	438	417	586	1122	610	1518	796	1916	998	2242	1167	2684	1400	3104	1624	3510	1840	4667	2457	5772	3044	-1	-1
Biochar	0.05	35	0.4	0	0	246	427	399	691	1124	633	1698	893	2200	1145	2704	1408	3123	1629	3694	1933	4242	2225	4773	2509	6301	3322	-1	-1	-1	-1
Biochar	0.05	40	0.4	114	198	380	657	1136	668	1650	882	2358	1229	2970	1547	3598	1878	4121	2156	4839	2539	5532	2908	6206	3267	-1	-1	-1	-1	-1	-1
Biochar	0.01	5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	23
Biochar	0.01	10	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	42	91	157	260	182	412	238
Biochar	0.01	15	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	55	88	153	134	232	190	298	615	355	942	503	1247	654
Biochar	0.01	20	0.4	0	0	0	0	0	0	0	0	0	0	33	58	119	207	176	305	379	342	610	393	813	470	1388	735	1924	1004	2427	1265
Biochar	0.01	25	0.4	0	0	0	0	0	0	0	0	81	141	179	310	278	482	624	446	944	558	1255	690	1552	829	2396	1251	3185	1660	3929	2051
Biochar	0.01	30	0.4	0	0	0	0	0	0	0	0	214	370	344	596	880	576	1199	696	1640	889	2061	1091	2469	1294	3626	1890	4714	2461	-1	-1
Biochar	0.01	35	0.4	0	0	0	0	0	0	190	328	375	650	989	658	1483	846	1901	1032	2473	1306	3023	1582	3555	1855	5071	2646	-1	-1	-1	-1
Biochar	0.01	40	0.4	0	0	0	0	171	296	332	575	970	704	1572	916	2197	1190	2720	1441	3441	1801	4134	2156	4806	2505	6724	3513	-1	-1	-1	-1
Biochar	1	5	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	10	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	15	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	20	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	25	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	30	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	5	1	1033	503	1410	722	1650	831	1908	931	2367	1186	2774	1388	3171	1578	3547	1780	4036	2022	4503	2255	4955	2487	6202	3128	-1	-1	-1	-1
Biochar	0.9	10	1	3865	1887	4979	2470	6085	3048	7133	3580	8620	4322	9947	4992	11316	5694	12438	6274	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	15	1	8456	4235	10759	5399	12926	6480	14976	7516	17905	9023	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	20	1	14425	7239	18241	9138	21776	10953	25011	12617	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	25	1	21735	10895	27310	13737	32309	16315	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	30	1	30287	15201	37723	19030	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Fipronil Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.9	35	1	39939	20097	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	40	1	50572	25514	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	5	1	411	232	450	259	476	251	528	260	601	287	778	397	866	436	947	468	1113	558	1245	624	1377	685	1778	888	2153	1077	2501	1254
Biochar	0.8	10	1	1065	524	1332	652	1684	853	1905	940	2388	1201	2765	1374	3204	1604	3566	1781	4070	2038	4557	2284	5021	2518	6316	3181	-1	-1	-1	-1
Biochar	0.8	15	1	2367	1208	2873	1418	3579	1801	4162	2070	5092	2543	5935	2972	6813	3415	7546	3785	8545	4295	9487	4779	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	20	1	3852	1901	5040	2524	6141	3075	7171	3583	8710	4360	10079	5056	11497	5780	12666	6380	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	25	1	6017	3027	7701	3857	9314	4660	10858	5436	13113	6585	15082	7591	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	30	1	8420	4188	10817	5405	13058	6538	15175	7612	18211	9166	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	35	1	11300	5657	14415	7216	17333	8691	20063	10085	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	40	1	14504	7247	18454	9253	22096	11100	25471	12831	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	5	1	70	121	85	148	281	158	302	172	321	173	356	178	387	190	426	206	522	264	586	296	638	319	832	417	1011	505	1188	595
Biochar	0.7	10	1	607	346	664	348	755	372	856	414	1125	571	1279	640	1482	736	1668	835	1907	953	2148	1073	2385	1195	3057	1531	3685	1850	4262	2145
Biochar	0.7	15	1	1081	540	1291	624	1686	855	1925	963	2378	1187	2777	1390	3210	1603	3584	1795	4096	2051	4591	2300	5072	2545	6410	3227	-1	-1	-1	-1
Biochar	0.7	20	1	1731	836	2369	1197	2815	1397	3353	1680	4090	2041	4787	2398	5516	2762	6129	3071	6977	3502	7785	3913	8555	4306	-1	-1	-1	-1	-1	-1
Biochar	0.7	25	1	2833	1437	3530	1752	4352	2181	5097	2544	6236	3121	7265	3642	8341	4185	9240	4640	10465	5266	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	30	1	3888	1944	5056	2533	6129	3060	7205	3609	8774	4398	10179	5108	11641	5851	12854	6471	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	35	1	5217	2591	6748	3373	8221	4118	9616	4814	11670	5854	13490	6780	15370	7741	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	40	1	6775	3395	8694	4344	10547	5274	12322	6174	14903	7484	17169	8643	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	5	1	0	0	39	67	61	105	83	101	218	121	234	130	249	133	267	137	294	146	322	158	360	177	482	242	582	290	689	345
Biochar	0.6	10	1	192	174	450	251	488	265	535	275	620	306	723	355	865	436	966	486	1096	549	1238	617	1383	692	1787	894	2175	1090	2542	1276
Biochar	0.6	15	1	708	392	806	413	928	459	1087	534	1381	696	1598	801	1849	922	2078	1040	2382	1193	2684	1343	2981	1495	3823	1919	4608	2318	-1	-1
Biochar	0.6	20	1	1079	553	1300	639	1641	822	1939	976	2352	1174	2775	1389	3207	1606	3583	1792	4105	2058	4611	2312	5101	2560	6481	3263	-1	-1	-1	-1
Biochar	0.6	25	1	1557	769	2056	1031	2512	1262	2930	1463	3624	1817	4230	2115	4898	2456	5453	2733	6230	3128	6975	3504	7690	3868	-1	-1	-1	-1	-1	-1
Biochar	0.6	30	1	2195	1078	2922	1470	3522	1758	4175	2090	5108	2554	5980	2999	6892	3455	7663	3847	8723	4386	9733	4900	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	35	1	3040	1531	3874	1939	4753	2376	5588	2799	6849	3434	7981	4001	9177	4607	10184	5120	11553	5818	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	40	1	3912	1969	5003	2495	6131	3075	7198	3602	8793	4406	10233	5137	11738	5902	12993	6541	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	5	1	0	0	0	0	0	0	42	72	51	88	154	81	179	98	191	104	206	109	222	115	241	122	304	150	379	190	448	226
Biochar	0.5	10	1	84	145	105	182	345	187	383	208	430	225	483	244	546	272	608	301	708	354	808	406	899	453	1162	581	1425	715	1674	840
Biochar	0.5	15	1	463	244	576	313	644	337	725	367	866	430	1026	511	1207	606	1351	680	1542	772	1745	873	1947	977	2517	1263	3061	1538	3573	1798
Biochar	0.5	20	1	769	418	895	462	1047	524	1220	605	1530	767	1803	908	2075	1039	2329	1165	2684	1348	3021	1515	3358	1685	4319	2172	5217	2628	-1	-1
Biochar	0.5	25	1	1078	565	1311	656	1589	788	1905	955	2348	1181	2741	1371	3195	1603	3570	1792	4095	2054	4610	2317	5107	2566	6523	3287	-1	-1	-1	-1
Biochar	0.5	30	1	1460	739	1837	911	2289	1148	2711	1365	3310	1655	3903	1959	4513	2264	5044	2531	5775	2901	6485	3261	7168	3607	-1	-1	-1	-1	-1	-1
Biochar	0.5	35	1	1914	954	2498	1247	3089	1556	3612	1810	4465	2240	5225	2622	6049	3037	6741	3387	7704	3876	8627	4342	9516	4797	-1	-1	-1	-1	-1	-1
Biochar	0.5	40	1	2458	1219	3258	1638	3961	1989	4675	2339	5753	2889	6733	3379	7772	3905	8655	4352	9863	4965	11021	5556	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	5	1	0	0	0	0	0	0	0	0	30	52	39	68	49	73	129	67	151	80	165	87	178	93	216	110	261	131	306	153
Biochar	0.4	10	1	0	0	68	119	85	148	257	134	318	169	355	187	395	204	433	221	492	248	552	276	614	306	814	410	993	499	1174	589
Biochar	0.4	15	1	118	205	385	200	476	253	534	280	622	319	716	362	824	413	921	460	1073	538	1222	616	1358	684	1765	886	2160	1087	2537	1278
Biochar	0.4	20	1	513	267	662	351	762	396	868	443	1051	527	1229	613	1445	725	1630	822	1870	942	2108	1059	2354	1182	3051	1535	3717	1874	4343	2192
Biochar	0.4	25	1	794	423	953	496	1121	570	1308	657	1607	802	1917	965	2228	1123	2486	1250	2867	1439	3242	1632	3601	1813	4648	2343	5631	2843	-1	-1
Biochar	0.4	30	1	1071	563	1304	665	1571	789	1847	921	2314	1165	2719	1370	3147	1580	3533	1775	4065	2047	4579	2303	5087	2562	6529	3295	-1	-1	-1	-1
Biochar	0.4	35	1	1382	715	1729	872	2100	1049	2510	1259	3112	1569	3641	1829	4241	2132	4744	2390	5443	2738	6130	3089	6791	3423	-1	-1	-1	-1	-1	-1
Biochar	0.4	40	1	1742	889	2218	1111	2732	1367	3266	1647	4003	2013	4715	2368	5470	2755	6109	3073	7008	3532	7870	3967	8709	4395	-1	-1	-1	-1	-1	-1
Biochar	0.3	5	1	0	0	0	0	0	0	0	0	0	0	0	0	29	50	34	58	45	62	112	57	129	67	163	84	194	100	226	115
Biochar	0.3	10	1	0	0	0	0	50	86	67	117	196	100	257	133	296	153	326	169	367	189	409	210	453	231	583	293	723	363	860	435
Biochar	0.3	15	1	0	0	101	174	288	148	384	200	467	242	535	276	610	313	679	346	777	393	875	440	978	491	1293	653	1582	799	1869	943
Biochar	0.3	20	1	134	232	442	228	563	293	651	337	779	401	905	462	1044	528	1167	587	1351	678	1540	776	1723	871	2239	1129	2749	1389	3228	1631
Biochar	0.3	25	1	475	245	704	366	840	434	969	499	1178	599	1376	694	1601	803	1807	909	2098	1060	2372	1199	2637	1331	3436	1737	4192	2118	4908	2485
Biochar	0.3	30	1	767	399	976	506	1163	599	1357	693	1659	837	1956	982	2296	1157	2585	1307	2974	1503	3358	1693	3746	1890	4851	2451	5901	2987	-1	-1
Biochar	0.3	35	1	1025	533	1284	662	1545	790	1812	917	2232	1121	2654	1337	3101	1568	3469	1753	3993	2013	4519	2282	5026	2541	6485	3282	-1	-1	-1	-1
Biochar	0.3	40	1	1301	674	1636	840	1984	1006	2334	1174	2906	1462	3447	1743	3999	2021	4478	2258	5165	2608	5825	2945	6469	3269	-1	-1	-1	-1	-1	-1
Biochar	0.2	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	40	29	50	33	57	114	58	144	73	171	88
Biochar	0.2	10	1	0	0	0	0	0	0	0	0	53	91	66	114	188	97	226	116	268	137	306	156	341	175	442	227	541	276	639	324

Fipronil Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.2	15	1	0	0	0	0	78	135	99	171	312	160	386	197	455	233	511	262	588	303	662	340	736	377	959	486	1185	599	1410	715
Biochar	0.2	20	1	0	0	114	197	320	171	450	230	575	294	681	350	790	406	882	453	1014	518	1146	583	1278	648	1681	851	2078	1055	2448	1242
Biochar	0.2	25	1	128	222	396	212	589	301	714	365	887	456	1041	535	1204	617	1349	688	1555	789	1762	891	1973	997	2597	1319	3182	1614	3751	1905
Biochar	0.2	30	1	195	338	671	343	855	438	1019	523	1254	645	1469	752	1707	869	1915	971	2214	1119	2520	1275	2822	1432	3678	1867	4509	2290	-1	-1
Biochar	0.2	35	1	630	326	929	475	1156	593	1367	703	1677	859	1973	1005	2296	1163	2582	1305	2998	1518	3407	1729	3799	1930	4940	2506	6034	3068	-1	-1
Biochar	0.2	40	1	890	456	1211	620	1493	768	1759	903	2165	1104	2550	1293	2977	1505	3357	1699	3892	1976	4403	2237	4901	2488	6368	3237	-1	-1	-1	-1
Biochar	0.1	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	19	27	46	80	43	110	56
Biochar	0.1	10	1	0	0	0	0	0	0	0	0	0	0	21	36	42	73	53	92	126	78	181	95	218	112	318	162	405	207	484	248
Biochar	0.1	15	1	0	0	0	0	0	0	29	50	71	123	107	155	266	140	326	167	403	205	475	242	542	277	726	373	899	462	1065	546
Biochar	0.1	20	1	0	0	0	0	71	124	104	181	315	171	433	222	542	276	631	322	749	383	860	440	967	496	1272	653	1569	804	1859	950
Biochar	0.1	25	1	0	0	88	152	139	240	387	212	575	294	728	370	880	449	1005	514	1173	602	1336	686	1494	767	1960	1004	2418	1234	2866	1462
Biochar	0.1	30	1	0	0	154	267	460	253	644	331	876	446	1076	549	1277	654	1445	741	1677	861	1903	977	2127	1091	2790	1425	3444	1757	4078	2085
Biochar	0.1	35	1	137	238	389	277	716	369	927	472	1221	623	1472	754	1733	890	1953	1003	2261	1161	2565	1316	2867	1468	3761	1919	4641	2372	-1	-1
Biochar	0.1	40	1	203	352	698	369	989	505	1248	636	1606	822	1920	985	2249	1156	2531	1300	2929	1502	3323	1701	3714	1898	4874	2488	5994	3068	-1	-1
Biochar	0.05	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	20	23	40	54	40
Biochar	0.05	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	38	39	67	52	90	106	81	221	116	310	158	390	199
Biochar	0.05	15	1	0	0	0	0	0	0	0	0	0	0	52	90	76	132	153	122	257	142	329	172	398	205	585	298	754	385	910	467
Biochar	0.05	20	1	0	0	0	0	0	0	40	70	90	155	195	165	346	190	436	229	558	286	671	342	777	396	1074	549	1350	693	1609	828
Biochar	0.05	25	1	0	0	0	0	64	111	110	191	315	202	483	258	638	329	766	391	936	477	1096	559	1250	639	1684	865	2093	1077	2483	1279
Biochar	0.05	30	1	0	0	54	93	131	226	215	303	580	311	785	404	990	505	1158	590	1387	708	1604	821	1814	930	2412	1241	2983	1536	3532	1818
Biochar	0.05	35	1	0	0	127	220	206	357	581	323	878	453	1137	580	1397	712	1614	824	1909	977	2192	1124	2466	1267	3256	1677	4018	2069	4751	2444
Biochar	0.05	40	1	59	102	196	340	587	342	853	448	1218	623	1535	783	1859	949	2129	1090	2500	1283	2858	1469	3207	1650	4217	2172	5196	2673	-1	-1
Biochar	0.01	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	12
Biochar	0.01	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	22	47	81	135	94	213	121
Biochar	0.01	15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	28	46	79	69	120	98	154	318	181	487	255	645	331
Biochar	0.01	20	1	0	0	0	0	0	0	0	0	0	0	17	30	62	107	91	158	197	176	316	201	420	240	717	373	994	509	1254	640
Biochar	0.01	25	1	0	0	0	0	0	0	0	0	42	73	93	160	144	249	323	230	488	286	649	352	802	421	1238	634	1646	840	2030	1038
Biochar	0.01	30	1	0	0	0	0	0	0	0	0	110	191	178	308	455	295	620	355	848	453	1065	554	1276	656	1874	957	2436	1245	2966	1519
Biochar	0.01	35	1	0	0	0	0	0	0	98	170	194	336	511	338	767	432	983	525	1278	663	1562	802	1837	939	2620	1339	3358	1720	4054	2081
Biochar	0.01	40	1	0	0	0	0	88	153	172	297	502	362	813	468	1136	606	1406	732	1778	913	2136	1092	2483	1268	3474	1777	4408	2261	-1	-1
Biochar	1	5	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	10	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	15	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	20	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	25	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	30	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	35	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	40	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	5	4	383	173	521	251	610	287	705	321	875	410	1026	480	1172	544	1311	615	1492	698	1664	778	1832	858	2293	1078	2697	1275	3048	1448
Biochar	0.9	10	4	1428	651	1841	852	2250	1052	2637	1237	3187	1491	3677	1722	4183	1963	4598	2163	5148	2429	5654	2676	6118	2905	7296	3503	-1	-1	-1	-1
Biochar	0.9	15	4	3126	1465	3977	1865	4778	2237	5536	2593	6619	3111	7540	3555	8461	4004	9192	4366	10131	4838	10958	5262	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	20	4	5332	2501	6742	3153	8050	3778	9245	4349	10908	5155	12278	5832	13606	6499	14630	7025	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	25	4	8035	3760	10095	4738	11943	5623	13602	6428	15853	7540	17645	8449	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	30	4	11195	5243	13944	6560	16358	7731	18482	8778	21292	10197	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	35	4	14763	6930	18228	8602	21209	10065	23779	11356	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	40	4	18693	8795	22886	10834	26422	12595	29408	14123	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	5	4	152	81	166	90	176	86	195	89	223	98	288	138	320	150	350	161	412	193	461	216	509	236	657	307	796	372	925	433
Biochar	0.8	10	4	394	180	493	225	623	295	704	324	883	415	1022	475	1184	554	1318	615	1505	704	1684	789	1856	869	2335	1097	2761	1302	3135	1485
Biochar	0.8	15	4	875	419	1062	489	1323	623	1539	715	1883	878	2194	1026	2519	1179	2789	1306	3159	1482	3507	1648	3835	1806	4714	2233	5455	2602	-1	-1
Biochar	0.8	20	4	1424	655	1863	872	2270	1063	2651	1237	3219	1505	3726	1745	4250	1994	4682	2200	5260	2478	5795	2738	6291	2980	-1	-1	-1	-1	-1	-1
Biochar	0.8	25	4	2224	1047	2847	1333	3443	1609	4013	1877	4847	2272	5575	2618	6318	2974	6923	3266	7720	3655	8445	4012	9104	4342	-1	-1	-1	-1	-1	-1

Fipronil Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.8	30	4	3113	1446	3998	1867	4827	2257	5609	2627	6732	3161	7698	3624	8672	4096	9453	4478	10467	4981	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	35	4	4177	1955	5328	2492	6407	3000	7416	3479	8846	4163	10060	4751	11265	5341	12220	5815	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	40	4	5361	2503	6821	3195	8167	3830	9415	4425	11164	5267	12627	5982	14061	6694	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	5	4	26	45	32	55	104	55	112	60	119	60	132	61	143	65	158	71	193	92	217	103	236	110	308	144	374	174	439	206
Biochar	0.7	10	4	224	120	246	119	280	128	317	142	416	198	473	221	548	254	617	289	705	329	794	371	882	413	1130	529	1362	639	1576	740
Biochar	0.7	15	4	400	186	478	215	623	296	712	333	879	411	1027	480	1187	554	1325	621	1514	708	1697	794	1875	879	2370	1113	2815	1327	3212	1519
Biochar	0.7	20	4	640	288	876	414	1041	482	1240	581	1512	705	1770	829	2039	954	2266	1061	2579	1209	2878	1351	3162	1486	3941	1860	4620	2191	-1	-1
Biochar	0.7	25	4	1047	498	1305	605	1609	754	1884	879	2305	1078	2686	1258	3083	1445	3416	1602	3868	1817	4296	2021	4698	2215	5777	2740	-1	-1	-1	-1
Biochar	0.7	30	4	1438	672	1869	876	2266	1057	2663	1248	3243	1519	3762	1764	4303	2020	4751	2233	5356	2522	5919	2794	6445	3049	-1	-1	-1	-1	-1	-1
Biochar	0.7	35	4	1929	896	2495	1166	3039	1424	3554	1663	4313	2022	4986	2340	5681	2671	6253	2944	7015	3312	7719	3654	8369	3974	-1	-1	-1	-1	-1	-1
Biochar	0.7	40	4	2504	1174	3214	1501	3898	1822	4555	2133	5509	2583	6346	2982	7203	3393	7902	3730	8826	4179	9671	4594	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	5	4	0	0	14	25	22	39	31	37	81	42	87	45	92	46	99	47	109	50	119	54	133	61	178	84	215	100	255	119
Biochar	0.6	10	4	72	64	166	88	180	92	198	95	229	106	267	122	320	151	357	168	405	190	458	213	511	240	661	309	804	377	940	441
Biochar	0.6	15	4	262	136	298	142	343	158	402	184	511	241	591	277	684	319	768	360	881	413	992	464	1102	517	1413	663	1703	800	1970	928
Biochar	0.6	20	4	399	191	481	220	607	285	717	338	869	406	1026	481	1186	555	1324	620	1518	712	1705	799	1885	885	2396	1127	2860	1348	3277	1550
Biochar	0.6	25	4	576	265	760	357	928	437	1083	506	1339	629	1563	731	1810	849	2016	945	2303	1081	2578	1211	2842	1336	3576	1686	4230	2002	4805	2283
Biochar	0.6	30	4	812	372	1080	509	1302	608	1543	723	1888	883	2210	1037	2547	1194	2832	1329	3224	1515	3598	1692	3954	1862	4928	2330	5777	2745	-1	-1
Biochar	0.6	35	4	1124	530	1432	671	1757	822	2066	968	2531	1188	2950	1383	3392	1592	3764	1769	4270	2009	4749	2237	5203	2455	6427	3049	-1	-1	-1	-1
Biochar	0.6	40	4	1446	682	1849	863	2266	1064	2661	1246	3250	1523	3782	1775	4339	2039	4802	2259	5430	2558	6021	2842	6576	3110	-1	-1	-1	-1	-1	-1
Biochar	0.5	5	4	0	0	0	0	0	0	15	27	19	33	57	29	66	34	71	36	76	38	82	40	89	42	112	52	140	66	166	78
Biochar	0.5	10	4	31	54	39	67	128	66	142	72	159	78	179	84	202	94	225	104	262	122	299	141	333	157	430	201	527	248	619	291
Biochar	0.5	15	4	171	86	213	109	238	117	268	127	320	149	379	177	446	210	499	236	570	267	645	302	720	338	930	437	1132	532	1321	622
Biochar	0.5	20	4	284	145	331	160	387	181	451	209	566	266	667	314	767	360	861	403	992	467	1117	524	1241	583	1596	751	1928	908	2234	1054
Biochar	0.5	25	4	399	195	485	226	587	272	704	331	868	409	1013	474	1181	555	1319	620	1514	711	1704	802	1888	887	2411	1136	2892	1365	3329	1575
Biochar	0.5	30	4	540	255	679	315	846	398	1002	473	1223	573	1442	678	1668	783	1864	876	2134	1004	2397	1128	2649	1247	3360	1586	4002	1894	4578	2173
Biochar	0.5	35	4	708	330	923	432	1142	539	1335	626	1650	776	1931	907	2236	1051	2491	1172	2847	1340	3188	1501	3517	1658	4429	2094	5242	2487	-1	-1
Biochar	0.5	40	4	909	421	1204	567	1464	689	1728	809	2126	1000	2488	1169	2872	1351	3199	1505	3645	1716	4073	1920	4482	2116	5607	2656	-1	-1	-1	-1
Biochar	0.4	5	4	0	0	0	0	0	0	0	0	11	19	15	25	18	27	48	24	56	28	61	30	66	32	80	38	97	45	113	53
Biochar	0.4	10	4	0	0	25	44	32	55	95	47	118	59	131	65	146	71	160	76	182	86	204	96	227	106	301	142	367	173	434	204
Biochar	0.4	15	4	44	76	142	71	176	88	197	97	230	111	265	125	305	143	341	159	397	186	452	214	502	237	652	307	798	376	938	442
Biochar	0.4	20	4	190	95	245	122	282	137	321	153	389	183	455	212	534	251	602	285	691	326	779	367	870	410	1128	531	1374	649	1605	758
Biochar	0.4	25	4	294	147	352	172	415	197	484	227	594	278	709	335	823	389	919	433	1059	499	1198	566	1331	628	1718	811	2081	984	2418	1145
Biochar	0.4	30	4	396	195	482	230	581	273	683	319	855	404	1005	475	1163	547	1306	615	1502	709	1692	798	1880	887	2413	1140	2908	1376	3362	1594
Biochar	0.4	35	4	511	248	639	302	776	363	928	436	1150	544	1346	634	1567	739	1753	828	2011	948	2265	1070	2510	1185	3205	1516	3843	1822	4422	2101
Biochar	0.4	40	4	644	308	820	385	1010	473	1207	571	1480	698	1742	821	2022	955	2258	1064	2590	1223	2908	1373	3218	1521	4088	1936	4878	2316	-1	-1
Biochar	0.3	5	4	0	0	0	0	0	0	0	0	0	0	0	0	11	18	13	22	17	23	41	20	48	23	60	29	72	35	84	40
Biochar	0.3	10	4	0	0	0	0	18	32	25	43	72	36	95	47	109	54	121	59	136	66	151	73	167	80	216	102	267	126	318	151
Biochar	0.3	15	4	0	0	37	65	107	53	142	70	173	84	198	96	226	109	251	120	287	136	324	153	361	170	478	227	585	277	691	327
Biochar	0.3	20	4	50	86	163	81	208	102	241	117	288	139	335	160	386	183	431	203	499	235	569	269	637	303	827	391	1016	482	1193	565
Biochar	0.3	25	4	176	88	260	128	310	151	358	173	435	208	509	241	592	279	668	315	775	368	876	416	975	462	1270	602	1549	734	1813	861
Biochar	0.3	30	4	283	140	361	176	430	208	502	240	613	290	723	340	848	402	955	454	1099	521	1241	587	1384	656	1793	850	2180	1035	2542	1208
Biochar	0.3	35	4	379	186	474	230	571	274	670	318	825	389	981	464	1146	545	1282	608	1476	698	1670	792	1857	881	2396	1138	2902	1379	3371	1604
Biochar	0.3	40	4	481	235	605	292	733	349	862	407	1074	507	1274	605	1478	701	1655	783	1908	905	2152	1021	2390	1133	3073	1459	3708	1764	4291	2045
Biochar	0.2	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	15	11	19	12	21	42	20	53	26	63	31
Biochar	0.2	10	4	0	0	0	0	0	0	0	0	19	34	24	42	70	35	84	41	99	48	113	55	126	61	163	79	200	96	236	113
Biochar	0.2	15	4	0	0	0	0	29	50	36	63	115	57	143	69	168	81	189	92	218	105	245	118	272	131	354	169	438	208	521	249
Biochar	0.2	20	4	0	0	42	73	118	62	166	81	213	103	252	122	292	142	326	158	375	180	424	203	472	225	621	296	768	367	905	432
Biochar	0.2	25	4	47	82	146	77	218	106	264	128	328	159	385	186	445	215	498	239	575	274	651	310	729	347	959	459	1175	561	1386	662
Biochar	0.2	30	4	72	125	248	121	316	153	376	183	463	225	543	262	631	302	707	338	818	389	931	443	1043	498	1359	649	1666	795	1955	934
Biochar	0.2	35	4	233	117	343	166	427	207	505	245	620	299	729	350	848	404	954	454	1107	528	1258	601	1403	671	1825	871	2229	1066	2609	1248
Biochar	0.2	40	4	329	161	447	217	552	268	650	315	800	384	942	450	1100	523	1240	591	1438	687	1627	778	1810	864	2352	1124	2863	1368	3343	1600
Biochar	0.1	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	7	10	17	30	16	41	20

Fipronil Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.1	10	4	0	0	0	0	0	0	0	0	0	0	8	13	16	27	20	34	47	29	67	34	81	40	117	57	149	72	179	87
Biochar	0.1	15	4	0	0	0	0	0	0	10	18	26	46	39	57	98	50	121	59	149	72	175	85	200	97	268	130	332	161	393	191
Biochar	0.1	20	4	0	0	0	0	26	46	39	67	116	62	160	79	200	97	233	113	277	134	318	154	357	174	470	228	580	281	687	331
Biochar	0.1	25	4	0	0	33	56	51	89	143	76	213	104	269	130	325	158	371	180	433	211	493	240	552	268	724	351	893	430	1058	509
Biochar	0.1	30	4	0	0	57	99	170	91	238	117	323	157	397	193	471	229	534	259	619	301	703	342	785	381	1030	497	1272	612	1506	727
Biochar	0.1	35	4	51	88	144	102	264	131	342	166	451	219	544	264	640	311	721	351	835	406	947	459	1059	512	1389	669	1714	827	2021	977
Biochar	0.1	40	4	75	130	258	132	365	178	461	224	593	288	709	345	830	404	934	454	1081	525	1227	594	1371	662	1800	867	2213	1069	2601	1256
Biochar	0.05	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	7	9	15	20	15
Biochar	0.05	10	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	14	14	25	19	33	39	30	82	41	115	56	144	70
Biochar	0.05	15	4	0	0	0	0	0	0	0	0	0	0	19	34	28	49	57	45	95	51	122	61	147	72	216	105	278	135	336	164
Biochar	0.05	20	4	0	0	0	0	0	0	15	26	33	58	73	61	128	68	161	81	206	101	248	121	287	139	397	193	498	243	594	290
Biochar	0.05	25	4	0	0	0	0	24	41	41	70	116	74	178	92	236	117	283	138	345	168	405	197	461	224	622	303	773	377	917	448
Biochar	0.05	30	4	0	0	20	34	48	84	80	112	214	111	290	143	366	178	428	208	512	249	592	288	669	326	890	435	1101	538	1304	636
Biochar	0.05	35	4	0	0	47	82	76	132	215	116	324	161	420	205	516	251	596	289	704	343	809	394	910	444	1202	587	1483	724	1754	854
Biochar	0.05	40	4	21	37	73	126	217	124	315	160	450	220	567	275	686	334	786	382	923	450	1055	515	1183	578	1556	760	1918	935	2265	1101
Biochar	0.01	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	4
Biochar	0.01	10	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	8	17	30	50	34	79	44
Biochar	0.01	15	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	11	17	29	26	44	36	57	118	65	180	91	238	117
Biochar	0.01	20	4	0	0	0	0	0	0	0	0	0	0	6	11	23	40	34	58	73	65	117	73	155	86	265	132	367	180	463	226
Biochar	0.01	25	4	0	0	0	0	0	0	0	0	16	27	34	59	53	92	119	84	180	103	240	126	296	150	457	224	607	296	749	365
Biochar	0.01	30	4	0	0	0	0	0	0	0	0	41	71	66	114	168	107	229	128	313	161	393	197	471	232	691	337	899	438	1094	534
Biochar	0.01	35	4	0	0	0	0	0	0	36	63	72	124	189	123	283	155	363	187	472	235	577	284	678	332	967	471	1239	605	1496	731
Biochar	0.01	40	4	0	0	0	0	33	57	63	110	185	133	300	169	419	216	519	260	656	323	788	385	916	447	1282	625	1626	795	1952	955
RAC	1	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	5	0.1	36449	11525	44977	7614	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	5	0.1	7341	6358	15695	6392	18039	6051	18705	5896	21103	5134	24559	4332	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	10	0.1	37705	11852	45172	9109	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	15	0.1	74745	13247	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	5	0.1	2392	4143	2508	4345	5053	4377	10168	3574	11914	3976	12761	3959	13548	3858	14756	3589	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	10	0.1	20507	7218	24673	7949	26556	7852	29665	7191	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	15	0.1	38683	11969	44725	10809	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	20	0.1	59939	14441	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Fipronil Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.7	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	5	0.1	0	0	1688	2924	1873	3244	3150	2944	6010	220	8014	2652	8973	2883	9635	2924	10356	2970	11164	2947	12225	2798	-1	-1	-1	-1	-1	-1
RAC	0.6	10	0.1	6362	5933	14329	3483	17303	5748	19343	5865	21631	5972	24523	5609	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	15	0.1	24270	8008	29120	8821	32416	8957	36894	8432	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	20	0.1	38968	11796	45078	11869	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	25	0.1	54373	15005	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	30	0.1	74452	16969	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	5	0.1	0	0	0	0	1168	2023	1427	2472	1573	2724	2988	2643	5500	880	6453	1845	7222	2177	7889	2280	8493	2365	-1	-1	-1	-1	-1	-1
RAC	0.5	10	0.1	2869	4970	4720	4833	6505	5687	12941	3694	15234	4494	17023	4739	18892	4940	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	15	0.1	9025	7986	19461	5545	22804	6728	25588	7122	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	20	0.1	26016	7402	31772	9172	36514	9803	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	25	0.1	38189	11256	45734	12274	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	30	0.1	51494	14318	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	35	0.1	66325	17399	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	5	0.1	0	0	0	0	0	0	0	0	1129	1956	1274	2207	2005	2092	2569	2308	4625	668	5543	1393	6094	1653	7542	1980	-1	-1	-1	-1
RAC	0.4	10	0.1	0	0	2374	4111	2705	4685	5144	4623	10429	2301	12202	3307	13739	3698	15100	3964	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	15	0.1	3841	6653	7723	6944	15560	3390	18323	4962	21679	5760	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	20	0.1	10307	9272	22235	5559	26387	7168	30255	7944	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	25	0.1	25965	5620	33023	8967	39049	10176	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	30	0.1	36767	9934	45471	11933	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	35	0.1	48003	12926	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	40	0.1	60739	15937	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	5	0.1	0	0	0	0	0	0	0	0	0	0	824	1428	1010	1749	1119	1938	1788	1893	2305	2119	3773	702	5505	1333	6631	1635	-1	-1
RAC	0.3	10	0.1	0	0	700	1212	1905	3299	2238	3877	4252	4015	7507	1426	9836	2208	11009	2664	12511	3085	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	15	0.1	2452	4247	3356	5813	6321	5988	11198	2176	15688	3697	18206	4485	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	20	0.1	4474	7749	9192	8465	18398	3773	22009	5325	26654	6575	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	25	0.1	10488	9970	22977	4701	28467	6953	33155	8178	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	30	0.1	21983	4646	33005	7975	39783	9811	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	35	0.1	33997	7482	43778	10792	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	40	0.1	43990	10622	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	673	1166	856	1482	996	1725	1125	1949	3319	965	4751	1056	5703	1295
RAC	0.2	10	0.1	0	0	0	0	0	0	1335	2312	1861	3223	2245	3888	4125	3965	6582	1965	8765	1926	10155	2276	11415	2592	-1	-1	-1	-1	-1	-1
RAC	0.2	15	0.1	0	0	1984	3436	2766	4791	3359	5817	6689	6325	12517	2742	15112	3385	17101	3884	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	20	0.1	2621	4540	3948	6839	7467	7444	12920	4102	19014	4229	22772	5174	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	25	0.1	4579	7931	9289	9284	18200	4309	23597	5245	29731	6791	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	30	0.1	6664	11543	18966	6487	28267	6280	34074	7741	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	35	0.1	14013	13591	30356	6664	38621	8746	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	40	0.1	24630	9253	40254	9025	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	417	722	601	1042	974	1687	1888	1947	3400	1172
RAC	0.1	10	0.1	0	0	0	0	0	0	0	0	0	0	1189	2060	1604	2778	1936	3353	3295	3598	4143	4166	6780	2348	-1	-1	-1	-1	-1	-1
RAC	0.1	15	0.1	0	0	0	0	0	0	1764	3055	2639	4572	4393	5224	6129	6182	10108	3529	13051	3481	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	20	0.1	0	0	1492	2583	2863	4958	3824	6624	7479	7735	13395	4716	17570	4651	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	25	0.1	0	0	3548	6146	5038	8727	9229	9575	18209	5724	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	30	0.1	3406	5899	5666	9813	11013	11442	19843	7106	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	35	0.1	5321	9216	11044	12348	21236	8970	30021	8064	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	40	0.1	7463	12926	16107	16279	31788	9076	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	563	975	892	1545	1552	1822

Fipronil Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.05	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	741	1283	1109	1921	1553	2690	1974	3419	3082	3633	6901	2925	-1	-1	-1	-1
RAC	0.05	15	0.1	0	0	0	0	0	0	0	0	1383	2395	2142	3710	2907	5034	4572	5421	6191	6530	10284	4386	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	20	0.1	0	0	0	0	0	0	2155	3732	3497	6056	6028	7192	8331	8764	13620	5846	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	25	0.1	0	0	0	0	2939	5091	4299	7446	8322	9413	14194	8073	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	30	0.1	0	0	3138	5435	5111	8853	8831	10687	17047	9705	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	35	0.1	1929	3341	5160	8937	8611	12550	14091	14927	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	40	0.1	4061	7034	7522	13029	14679	15956	26519	11685	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	447	774
RAC	0.01	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	497	860	876	1518	1922	3328	3729	4463	-1	-1
RAC	0.01	15	0.1	0	0	0	0	0	0	0	0	0	0	0	0	662	1146	1283	2222	2081	3605	2848	4933	4188	5760	-1	-1	-1	-1	-1	-1
RAC	0.01	20	0.1	0	0	0	0	0	0	0	0	0	0	1669	2891	2801	4851	3752	6499	6180	7965	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	25	0.1	0	0	0	0	0	0	0	0	2393	4145	4007	6940	5660	9803	9046	10909	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	30	0.1	0	0	0	0	0	0	2383	4127	4786	8290	7848	11382	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	35	0.1	0	0	0	0	2402	4160	4553	7885	7687	13313	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	40	0.1	0	0	835	1445	4417	7650	7158	12397	14170	17186	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0	0	0.4	30	0	40	0	50	0	60	0	75	0	90	0	106	0	120	0	140	0	160	0	180	0	240	0	300	0	360	0
RAC	1	10	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	15	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	20	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	25	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	5	0.4	13287	4008	16372	2357	20905	5212	23905	5370	28712	5932	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	10	0.4	48345	10738	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	15	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	20	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	25	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	5	0.4	2688	2331	5760	2355	6588	2150	6821	2058	7685	1707	8943	1358	10835	2582	11997	2895	13539	2700	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	10	0.4	13749	4136	16442	2938	20329	4187	24120	5807	28866	5727	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	15	0.4	27218	4156	36368	8735	43277	8582	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	20	0.4	48744	11678	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	25	0.4	72765	14457	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	5	0.4	852	1475	893	1546	1850	1603	3735	1327	4356	1426	4656	1387	4939	1325	5376	1198	6168	1034	7074	1423	7985	1878	-1	-1	-1	-1	-1	-1
RAC	0.7	10	0.4	7531	2679	9011	2822	9683	2719	10806	2399	13276	2329	16025	3768	18326	3935	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	15	0.4	14112	4191	16292	3603	19892	3483	24119	5671	29075	5991	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	20	0.4	21834	4810	28655	5813	35195	7932	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	25	0.4	33440	5888	44126	9937	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	30	0.4	48729	11454	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	35	0.4	64576	13922	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	5	0.4	0	0	601	1041	667	1154	1142	1053	2221	64	2939	976	3282	1036	3518	1031	3777	1028	4070	1001	4454	928	5885	1237	7211	1583	-1	-1
RAC	0.6	10	0.4	2305	2122	5270	1314	6334	2087	7062	2068	7887	2047	8935	1861	10392	1931	11797	2481	13618	3037	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	15	0.4	8900	2947	10632	3109	11819	3070	13443	2796	16683	3268	19822	4425	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	20	0.4	14227	4154	16432	4026	19772	3666	23703	4990	29145	6388	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Fipronil Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.6	25	0.4	19826	5140	24783	4597	30907	6734	36319	7966	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	30	0.4	27126	5625	35719	7528	43660	9574	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	35	0.4	36515	6779	48125	10723	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	40	0.4	47843	10095	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	5	0.4	0	0	0	0	416	721	508	880	560	969	1089	955	2024	327	2366	675	2642	783	2882	805	3100	821	3763	835	4615	918	5492	1164
RAC	0.5	10	0.4	1021	1768	1701	1718	2375	2065	4744	1352	5568	1600	6212	1645	6889	1682	7539	1673	8649	1732	9846	1989	11019	2336	-1	-1	-1	-1	-1	-1
RAC	0.5	15	0.4	3288	2885	7135	2030	8335	2396	9338	2472	10837	2531	12556	2551	14698	2964	16549	3508	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	20	0.4	9538	2708	11605	3234	13318	3357	15132	3355	18639	3712	22092	4684	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	25	0.4	13959	4006	16680	4204	19598	4197	23211	4623	28864	6215	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	30	0.4	18791	4968	22777	5048	27893	5556	33218	7044	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	35	0.4	24186	5928	30508	6113	37795	7925	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	40	0.4	30475	6750	39706	8035	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	5	0.4	0	0	0	0	0	0	0	0	402	696	454	786	723	743	936	831	1700	226	2030	501	2229	590	2753	685	3257	758	3780	819
RAC	0.4	10	0.4	0	0	844	1463	962	1667	1872	1665	3824	827	4463	1181	5019	1299	5512	1371	6186	1471	6860	1561	7579	1642	-1	-1	-1	-1	-1	-1
RAC	0.4	15	0.4	1366	2366	2811	2500	5706	1218	6702	1772	7916	2008	9039	2173	10247	2337	11377	2465	13134	2685	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	20	0.4	3752	3338	8145	1998	9644	2534	11044	2745	13123	3050	15181	3289	17681	3609	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	25	0.4	9522	2016	12069	3170	14251	3500	16341	3802	19804	4207	23402	4770	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	30	0.4	13450	3546	16597	4125	19624	4565	22806	4941	28245	5760	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	35	0.4	17538	4548	21746	5170	25979	5699	30726	6285	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	40	0.4	22171	5511	27575	6271	33551	6955	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	5	0.4	0	0	0	0	0	0	0	0	0	0	294	508	359	622	398	690	645	672	838	760	1386	213	2013	466	2422	565	2828	655
RAC	0.3	10	0.4	0	0	249	432	678	1174	796	1379	1543	1435	2759	433	3599	768	4024	931	4570	1072	5119	1190	5667	1313	7233	1620	-1	-1	-1	-1
RAC	0.3	15	0.4	872	1510	1194	2067	2293	2139	4115	661	5737	1291	6652	1561	7637	1776	8500	1969	9688	2231	10850	2430	12047	2586	-1	-1	-1	-1	-1	-1
RAC	0.3	20	0.4	1591	2756	3342	3036	6737	1293	8046	1859	9735	2272	11333	2625	13021	2996	14468	3241	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	25	0.4	3805	3561	8414	1610	10405	2426	12109	2827	14744	3413	17115	3900	19742	4268	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	30	0.4	8083	1425	12066	2785	14529	3392	16998	3937	20640	4700	24098	5175	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	35	0.4	12442	2597	15993	3750	19355	4484	22608	5206	27546	5971	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	40	0.4	16082	3711	20472	4759	24796	5731	28942	6484	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	240	415	305	528	354	614	400	693	1217	312	1736	353	2083	439
RAC	0.2	10	0.4	0	0	0	0	0	0	475	823	662	1147	799	1383	1496	1415	2414	637	3203	637	3710	766	4169	879	5472	1217	6724	1521	-1	-1
RAC	0.2	15	0.4	0	0	705	1222	984	1704	1195	2069	2429	2261	4576	898	5520	1138	6246	1316	7234	1568	8202	1823	9153	2063	-1	-1	-1	-1	-1	-1
RAC	0.2	20	0.4	932	1615	1404	2433	2704	2650	4740	1335	6947	1413	8317	1753	9722	2111	10926	2429	12610	2849	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	25	0.4	1629	2821	3363	3304	6664	1378	8622	1752	10859	2305	12842	2822	14970	3370	16776	3795	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	30	0.4	2371	4107	6961	2125	10328	2098	12445	2623	15476	3402	18265	4118	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	35	0.4	5080	4846	11096	2202	14106	2960	16811	3643	20850	4691	24515	5540	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	40	0.4	9046	3055	14705	3037	18322	3933	21778	4841	26925	6092	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	148	257	214	371	347	600	684	692	1241	389
RAC	0.1	10	0.4	0	0	0	0	0	0	0	0	0	0	423	733	571	988	689	1193	1189	1276	1501	1483	2475	780	3793	824	4911	1037	5925	1269
RAC	0.1	15	0.4	0	0	0	0	0	0	627	1086	939	1626	1580	1852	2220	2199	3690	1173	4761	1140	5673	1233	6532	1379	8890	1904	-1	-1	-1	-1
RAC	0.1	20	0.4	0	0	531	919	1018	1764	1360	2356	2706	2748	4890	1568	6410	1523	7542	1640	9058	1909	10480	2222	11833	2534	-1	-1	-1	-1	-1	-1
RAC	0.1	25	0.4	0	0	1262	2186	1792	3104	3340	3402	6644	1891	8655	1957	10600	2243	12199	2575	14350	3066	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	30	0.4	1212	2099	2016	3491	3984	4065	7245	2365	10417	2354	12968	2739	15555	3297	17689	3789	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	35	0.4	1893	3278	3981	4379	7760	3014	10952	2643	14685	3112	17930	3798	21239	4563	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	40	0.4	2655	4599	5835	5791	11597	2983	14912	3254	19502	4119	23506	5036	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200	347	317	550	559	646
RAC	0.05	10	0.4	0	0	0	0	0	0	0	0	0	0	0	0	264	457	395	684	553	957	702	1216	1110	1287	2514	989	3655	976	4679	1080
RAC	0.05	15	0.4	0	0	0	0	0	0	0	0	492	852	762	1320	1034	1791	1646	1921	2240	2318	3746	1483	4636	1438	7012	1619	-1	-1	-1	-1
RAC	0.05	20	0.4	0	0	0	0	0	0	767	1328	1244	2155	2170	2549	3015	3112	4961	1978	6523	1917	7957	1994	9320	2154	-1	-1	-1	-1	-1	-1
RAC	0.05	25	0.4	0	0	0	0	1046	1811	1529	2649	3003	3337	5176	2768	7415	2391	9024	2424	11196	2629	13234	2941	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	30	0.4	0	0	1117	1934	1819	3150	3177	3787	6216	3328	9136	2862	11741	2969	13892	3215	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	35	0.4	687	1190	1836	3180	3077	4455	5097	5299	10182	3350	13462	3441	16791	3834	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	40	0.4	1445	2504	2676	4636	5304	5661	9660	3960	14356	3868	18406	4267	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Fipronil Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.01	5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	159	276
RAC	0.01	10	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	177	307	312	540	684	1185	1344	1582	2383	1457
RAC	0.01	15	0.4	0	0	0	0	0	0	0	0	0	0	0	0	236	409	457	791	741	1283	1014	1756	1502	2043	3553	2183	5665	2170	-1	-1
RAC	0.01	20	0.4	0	0	0	0	0	0	0	0	0	0	594	1029	997	1727	1336	2313	2222	2823	3024	3420	4693	2907	-1	-1	-1	-1	-1	-1
RAC	0.01	25	0.4	0	0	0	0	0	0	0	0	852	1476	1426	2471	2015	3489	3260	3866	5356	3699	7408	3583	9330	3601	-1	-1	-1	-1	-1	-1
RAC	0.01	30	0.4	0	0	0	0	0	0	849	1470	1704	2951	2809	4040	4399	5014	6905	4351	9752	4292	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	35	0.4	0	0	0	0	855	1482	1621	2807	2736	4738	4985	5729	8622	5023	11302	4997	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	40	0.4	0	0	303	524	1573	2724	2548	4413	5106	6091	9030	5791	13078	5701	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0	0	1	30	0	40	0	50	0	60	0	75	0	90	0	106	0	120	0	140	0	160	0	180	0	240	0	300	0	360	0
RAC	1	10	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	15	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	20	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	25	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	30	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	5	1	6814	1981	8395	1054	10737	2563	12268	2602	14731	2832	17485	3496	19976	3935	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	10	1	24809	5197	31862	6764	38072	7368	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	15	1	53215	10593	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	20	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	25	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	30	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	5	1	1385	1204	2965	1208	3382	1077	3499	1019	3940	815	4587	615	5565	1263	6158	1410	6947	1287	7787	1505	8761	1801	-1	-1	-1	-1	-1	-1
RAC	0.8	10	1	7053	2047	8430	1365	10439	2018	12380	2828	14809	2718	17588	3613	20095	3922	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	15	1	13960	1885	18667	4254	22203	4074	26480	5437	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	20	1	25017	5687	31563	6134	38561	7582	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	25	1	37330	6861	48358	9503	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	30	1	53548	10974	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	35	1	70878	13835	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	5	1	430	745	451	781	953	827	1923	682	2237	719	2389	688	2533	649	2757	573	3164	477	3632	680	4100	914	5203	985	6392	1285	-1	-1
RAC	0.7	10	1	3878	1377	4626	1412	4967	1338	5542	1148	6810	1084	8227	1835	9404	1892	10432	1976	12032	2412	13551	2693	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	15	1	7242	2079	8355	1723	10204	1621	12382	2761	14919	2865	17484	3462	20257	4030	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	20	1	11197	2301	14709	2786	18062	3835	20973	3974	25858	5195	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	25	1	17154	2741	22646	4803	27258	5213	32228	6476	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	30	1	25015	5577	31623	5994	38755	7787	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	35	1	33138	6698	42592	8542	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	40	1	42383	8036	54839	10892	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	5	1	0	0	304	526	337	583	584	534	1148	41	1513	499	1686	523	1806	513	1938	505	2088	485	2285	442	3021	594	3701	762	4331	839
RAC	0.6	10	1	1180	1077	2716	679	3256	1059	3626	1029	4046	1000	4583	886	5331	905	6055	1192	6989	1467	7836	1572	8692	1684	-1	-1	-1	-1	-1	-1
RAC	0.6	15	1	4580	1506	5458	1548	6063	1500	6895	1331	8561	1549	10174	2139	11711	2355	13058	2530	14999	2972	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	20	1	7303	2069	8429	1953	10141	1718	12166	2398	14957	3076	17438	3379	20201	4011	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	25	1	10170	2509	12712	2152	15865	3250	18639	3836	22751	4410	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	30	1	13914	2676	18334	3618	22407	4611	26237	5084	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	35	1	18730	3177	24699	5179	29903	5817	35185	6973	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	40	1	24557	4852	31665	6345	38524	7550	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	5	1	0	0	0	0	210	364	257	444	283	489	560	489	1043	167	1217	344	1358	395	1480	401	1591	404	1931	401	2368	435	2819	558
RAC	0.5	10	1	516	893	868	867	1222	1060	2441	688	2860	801	3188	810	3534	817	3868	803	4437	821	5052	946	5655	1121	7341	1459	-1	-1	-1	-1
RAC	0.5	15	1	1690	1476	3671	1033	4282	1201	4793	1218	5560	1222	6442	1211	7542	1410	8493	1684	9790	2011	11022	2190	12232	2384	-1	-1	-1	-1	-1	-1

Fipronil Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.5	20	1	4907	1379	5959	1611	6833	1639	7763	1611	9563	1759	11338	2248	13179	2706	14709	2923	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	25	1	7170	2006	8558	2051	10054	2006	11908	2190	14813	2988	17389	3528	20082	3914	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	30	1	9644	2447	11685	2423	14311	2633	17048	3381	20993	4255	24526	4780	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	35	1	12409	2881	15651	2898	19396	3798	22939	4712	28067	5473	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	40	1	15634	3240	20373	3823	25107	5144	29526	5867	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	5	1	0	0	0	0	0	0	0	0	203	352	229	397	369	375	480	424	876	109	1044	252	1146	296	1413	336	1671	367	1939	392
RAC	0.4	10	1	0	0	427	739	486	842	962	849	1968	415	2294	592	2578	645	2829	673	3175	714	3520	752	3889	786	5099	979	6292	1282	-1	-1
RAC	0.4	15	1	690	1195	1444	1275	2936	611	3445	888	4065	991	4639	1057	5258	1126	5838	1180	6739	1277	7652	1469	8563	1721	-1	-1	-1	-1	-1	-1
RAC	0.4	20	1	1926	1702	4188	1005	4954	1263	5669	1348	6734	1475	7789	1575	9072	1716	10209	1960	11820	2396	13352	2700	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	25	1	4899	1010	6199	1579	7314	1712	8385	1838	10161	2009	12007	2269	14036	2803	15753	3209	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	30	1	6912	1778	8520	2025	10070	2207	11702	2366	14492	2740	17152	3447	19934	4036	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	35	1	9007	2258	11159	2509	13330	2733	15764	2989	19596	3904	23069	4677	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	40	1	11380	2704	14149	3021	17213	3312	20464	3931	25368	5167	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	5	1	0	0	0	0	0	0	0	0	0	0	148	257	181	314	201	348	329	339	430	387	714	95	1034	230	1244	277	1452	318
RAC	0.3	10	1	0	0	126	218	342	593	402	697	791	728	1421	193	1850	377	2068	459	2347	527	2628	581	2909	638	3712	779	4548	881	5405	1060
RAC	0.3	15	1	441	764	603	1045	1175	1085	2120	296	2948	636	3416	769	3921	868	4363	957	4972	1078	5568	1169	6182	1237	8124	1593	-1	-1	-1	-1
RAC	0.3	20	1	804	1392	1714	1543	3464	629	4134	917	4998	1114	5817	1275	6682	1447	7424	1559	8523	1683	9676	1866	10833	2125	-1	-1	-1	-1	-1	-1
RAC	0.3	25	1	1949	1805	4326	781	5345	1196	6217	1386	7567	1655	8783	1880	10130	2043	11371	2205	13183	2570	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	30	1	4165	647	6199	1374	7460	1663	8725	1913	10592	2266	12365	2476	14429	2784	16251	3188	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	35	1	6395	1273	8213	1844	9936	2181	11603	2516	14134	2860	16681	3219	19509	3854	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	40	1	8262	1830	10510	2325	12726	2774	14852	3118	18290	3547	21669	4251	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	121	210	154	267	179	310	202	350	626	147	892	169	1070	212
RAC	0.2	10	1	0	0	0	0	0	0	240	416	334	579	403	699	767	717	1242	302	1645	302	1905	368	2141	424	2810	590	3451	734	4057	849
RAC	0.2	15	1	0	0	357	618	497	861	603	1045	1246	1147	2351	423	2835	546	3207	635	3714	760	4211	884	4699	999	6093	1276	7479	1492	-1	-1
RAC	0.2	20	1	471	816	709	1228	1383	1339	2439	636	3568	675	4271	846	4992	1023	5610	1178	6473	1378	7306	1550	8120	1700	-1	-1	-1	-1	-1	-1
RAC	0.2	25	1	823	1425	1721	1670	3426	640	4428	836	5575	1114	6594	1368	7685	1632	8611	1833	9891	2080	11163	2288	12455	2484	-1	-1	-1	-1	-1	-1
RAC	0.2	30	1	1197	2074	3584	1019	5304	1002	6390	1266	7946	1650	9376	1994	10884	2310	12168	2548	14006	2837	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	35	1	2602	2454	5699	1042	7243	1427	8632	1765	10703	2272	12582	2673	14579	3037	16334	3309	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	40	1	4658	1474	7551	1457	9407	1903	11181	2348	13820	2942	16206	3394	18824	3805	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	75	130	108	187	175	303	350	349	637	187
RAC	0.1	10	1	0	0	0	0	0	0	0	0	0	0	214	370	288	499	348	603	607	643	768	749	1270	375	1947	388	2521	494	3042	609
RAC	0.1	15	1	0	0	0	0	0	0	317	549	474	821	804	933	1137	1111	1894	565	2443	539	2912	581	3353	653	4564	914	5686	1170	-1	-1
RAC	0.1	20	1	0	0	268	464	514	891	687	1190	1384	1387	2510	755	3289	720	3871	774	4650	906	5380	1062	6075	1216	8058	1669	-1	-1	-1	-1
RAC	0.1	25	1	0	0	638	1104	905	1568	1708	1717	3409	904	4441	923	5441	1061	6262	1227	7367	1470	8422	1709	9451	1945	-1	-1	-1	-1	-1	-1
RAC	0.1	30	1	612	1060	1018	1763	2037	2052	3719	1140	5345	1111	6657	1297	7986	1575	9081	1819	10588	2162	12058	2497	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	35	1	956	1656	2031	2207	3985	1467	5620	1251	7538	1472	9205	1813	10904	2192	12335	2520	14333	2974	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	40	1	1340	2322	2986	2926	5951	1416	7653	1534	10011	1962	12068	2417	14209	2906	16038	3322	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	101	175	160	278	285	325
RAC	0.05	10	1	0	0	0	0	0	0	0	0	0	0	0	0	133	231	199	345	279	483	355	614	566	648	1289	482	1875	465	2401	511
RAC	0.05	15	1	0	0	0	0	0	0	0	0	249	431	385	667	522	905	839	968	1145	1170	1920	724	2377	692	3598	766	4696	946	5710	1150
RAC	0.05	20	1	0	0	0	0	0	0	387	671	628	1088	1105	1284	1541	1570	2543	965	3345	919	4082	946	4782	1020	6710	1348	-1	-1	-1	-1
RAC	0.05	25	1	0	0	0	0	528	915	772	1338	1532	1681	2654	1366	3802	1153	4628	1155	5744	1245	6792	1393	7789	1569	-1	-1	-1	-1	-1	-1
RAC	0.05	30	1	0	0	564	977	918	1591	1618	1907	3188	1642	4684	1378	6023	1410	7128	1522	8612	1750	10021	2014	11377	2291	-1	-1	-1	-1	-1	-1
RAC	0.05	35	1	347	602	927	1606	1559	2246	2605	2673	5221	1618	6906	1635	8616	1815	10021	2036	11933	2398	13763	2777	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	40	1	730	1264	1351	2341	2709	2853	4952	1934	7363	1844	9444	2019	11551	2344	13303	2674	15700	3168	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	80	139
RAC	0.01	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	90	155	158	273	346	598	685	796	1220	723
RAC	0.01	15	1	0	0	0	0	0	0	0	0	0	0	0	0	119	207	231	400	374	648	512	887	763	1030	1818	1084	2903	1057	3919	1094
RAC	0.01	20	1	0	0	0	0	0	0	0	0	0	0	300	520	504	872	675	1168	1130	1422	1543	1723	2402	1443	4313	1414	6090	1530	-1	-1
RAC	0.01	25	1	0	0	0	0	0	0	0	0	430	746	720	1248	1017	1762	1661	1947	2741	1841	3793	1764	4781	1755	7583	1907	-1	-1	-1	-1
RAC	0.01	30	1	0	0	0	0	0	0	429	743	861	1491	1424	2037	2244	2525	3534	2161	4995	2105	6400	2112	7753	2176	-1	-1	-1	-1	-1	-1
RAC	0.01	35	1	0	0	0	0	432	749	819	1418	1382	2393	2543	2885	4413	2489	5789	2451	7695	2466	9520	2569	11287	2735	-1	-1	-1	-1	-1	-1

Fipronil Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.01	40	1	0	0	153	266	794	1376	1287	2229	2601	3067	4621	2877	6699	2794	8444	2803	10834	2929	13137	3150	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0	0	4	30	0	40	0	50	0	60	0	75	0	90	0	106	0	120	0	140	0	160	0	180	0	240	0	300	0	360	0
RAC	1	10	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	15	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	20	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	25	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	30	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	35	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	40	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	5	4	2481	677	3057	293	3915	864	4470	857	5366	908	6372	1144	7279	1279	8135	1488	9258	1694	10320	1892	11377	2159	-1	-1	-1	-1	-1	-1
RAC	0.9	10	4	9039	1708	11614	2228	13870	2377	16359	2989	19790	3675	22838	4334	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	15	4	19392	3461	24673	4503	29675	5511	34384	6524	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	20	4	33076	6031	41803	7666	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	25	4	49896	9255	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	30	4	69531	13189	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	35	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	40	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	5	4	509	445	1085	437	1233	376	1274	349	1434	261	1671	177	2029	423	2244	469	2531	411	2837	483	3193	590	4086	736	4938	896	5737	1063
RAC	0.8	10	4	2568	701	3069	414	3807	658	4511	940	5394	862	6410	1184	7322	1270	8196	1476	9328	1674	10452	1918	11516	2134	-1	-1	-1	-1	-1	-1
RAC	0.8	15	4	5084	543	6801	1413	8087	1292	9650	1782	11678	2059	13604	2442	15629	2866	17305	3208	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	20	4	9116	1888	11499	1973	14051	2461	16483	2970	19981	3628	23116	4285	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	25	4	13597	2176	17621	3085	21394	3865	24909	4522	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	30	4	19515	3597	24864	4481	29957	5439	34802	6452	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	35	4	25825	4479	33038	5931	39758	7347	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	40	4	33337	6010	42331	7771	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	5	4	153	265	160	278	350	306	704	247	816	253	870	236	923	218	1004	185	1152	142	1324	219	1494	304	1895	315	2329	418	2722	479
RAC	0.7	10	4	1420	499	1686	491	1809	453	2018	370	2481	330	2998	609	3426	614	3801	632	4385	784	4938	876	5463	962	7009	1263	-1	-1	-1	-1
RAC	0.7	15	4	2638	713	3042	555	3717	493	4513	917	5435	921	6370	1121	7382	1311	8209	1445	9404	1690	10527	1898	11636	2139	-1	-1	-1	-1	-1	-1
RAC	0.7	20	4	4077	739	5362	897	6581	1257	7640	1271	9423	1691	10965	1931	12661	2277	14054	2533	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	25	4	6248	836	8251	1574	9930	1671	11744	2109	14296	2528	16664	3006	19136	3508	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	30	4	9117	1850	11520	1917	14122	2535	16504	2906	20123	3629	23352	4294	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	35	4	12073	2176	15520	2777	18830	3311	22075	3966	26773	4902	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	40	4	15440	2570	19983	3542	24213	4319	28255	5093	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	5	4	0	0	108	187	120	207	213	192	422	24	553	179	615	184	658	177	706	171	760	160	832	141	1101	192	1349	248	1578	270
RAC	0.6	10	4	430	387	995	247	1189	376	1321	355	1473	334	1669	282	1942	280	2207	386	2547	480	2855	509	3167	542	4110	732	4993	892	5830	1055
RAC	0.6	15	4	1674	541	1989	534	2208	501	2511	424	3119	490	3707	701	4267	763	4758	814	5465	962	6172	1099	6830	1204	8768	1588	-1	-1	-1	-1
RAC	0.6	20	4	2662	713	3069	644	3694	530	4434	777	5450	1001	6353	1087	7361	1299	8239	1467	9411	1664	10586	1904	11700	2118	-1	-1	-1	-1	-1	-1
RAC	0.6	25	4	3704	839	4629	664	5782	1062	6791	1249	8289	1419	9733	1736	11225	1979	12516	2236	14291	2584	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	30	4	5067	852	6682	1172	8164	1501	9559	1636	11754	2097	13703	2416	15821	2845	17577	3183	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	35	4	6822	981	9000	1694	10895	1874	12820	2258	15698	2769	18323	3292	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	40	4	8950	1572	11537	2054	14036	2436	16554	2947	20184	3607	23473	4250	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	5	4	0	0	0	0	75	130	91	158	101	174	205	178	382	60	445	123	496	139	540	138	580	137	703	130	863	137	1027	180
RAC	0.5	10	4	183	318	315	309	449	388	892	245	1043	279	1162	274	1287	270	1409	260	1616	259	1841	301	2061	362	2675	472	3268	574	3845	683
RAC	0.5	15	4	619	537	1342	368	1562	418	1746	412	2025	400	2346	384	2748	448	3095	544	3567	654	4016	708	4457	767	5782	1028	7028	1265	-1	-1
RAC	0.5	20	4	1794	491	2173	555	2489	546	2827	521	3484	555	4131	726	4802	880	5359	945	6146	1062	6944	1235	7714	1371	-1	-1	-1	-1	-1	-1
RAC	0.5	25	4	2615	699	3117	684	3662	644	4338	691	5398	969	6336	1145	7317	1260	8188	1439	9413	1675	10573	1879	11726	2111	-1	-1	-1	-1	-1	-1
RAC	0.5	30	4	3514	829	4256	784	5213	831	6212	1093	7649	1381	8936	1539	10371	1844	11585	2059	13249	2364	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	35	4	4519	953	5700	915	7067	1223	8358	1532	10226	1762	12004	2131	13882	2465	15466	2760	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	40	4	5694	1048	7422	1216	9148	1672	10758	1897	13197	2322	15466	2749	17833	3186	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	5	4	0	0	0	0	0	0	0	0	72	125	82	141	134	133	176	154	321	35	382	88	418	103	515	113	609	120	707	126
RAC	0.4	10	4	0	0	152	263	173	299	352	308	719	144	837	206	940	221	1031	226	1157	236	1282	245	1417	253	1858	313	2293	416	2696	473

Fipronil Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.4	15	4	245	425	528	462	1073	212	1257	309	1482	336	1690	350	1915	367	2127	380	2455	405	2788	469	3120	557	4053	710	4960	882	5825	1042
RAC	0.4	20	4	704	617	1530	351	1807	436	2066	453	2453	483	2838	507	3305	545	3719	626	4307	777	4865	875	5406	948	7014	1254	-1	-1	-1	-1
RAC	0.4	25	4	1791	351	2261	545	2665	573	3054	602	3701	644	4374	721	5114	906	5740	1041	6592	1162	7432	1297	8271	1470	-1	-1	-1	-1	-1	-1
RAC	0.4	30	4	2523	619	3105	681	3668	723	4263	762	5279	871	6250	1115	7263	1308	8115	1423	9324	1638	10527	1882	11681	2090	-1	-1	-1	-1	-1	-1
RAC	0.4	35	4	3284	775	4065	828	4855	882	5742	949	7140	1261	8406	1516	9730	1700	10882	1912	12515	2239	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	40	4	4147	909	5154	984	6270	1055	7455	1256	9243	1677	10829	1899	12548	2208	14044	2511	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	5	4	0	0	0	0	0	0	0	0	0	0	53	91	65	112	72	124	119	121	157	140	262	27	377	78	454	93	529	105
RAC	0.3	10	4	0	0	45	78	122	211	143	248	288	261	520	55	675	127	754	156	856	178	958	194	1060	211	1352	253	1657	281	1969	340
RAC	0.3	15	4	157	272	215	372	428	389	776	85	1076	215	1246	260	1429	290	1590	316	1812	353	2029	379	2252	397	2960	511	3648	659	4295	760
RAC	0.3	20	4	286	495	626	557	1265	207	1508	311	1822	374	2120	421	2435	473	2705	505	3105	539	3525	595	3947	682	5160	926	6309	1117	-1	-1
RAC	0.3	25	4	710	647	1580	257	1950	405	2267	465	2757	545	3200	613	3690	657	4142	703	4803	823	5450	971	6081	1098	7887	1397	-1	-1	-1	-1
RAC	0.3	30	4	1525	193	2261	466	2720	558	3180	632	3859	738	4504	795	5256	888	5920	1023	6846	1231	7740	1390	8607	1523	-1	-1	-1	-1	-1	-1
RAC	0.3	35	4	2334	426	2995	622	3621	722	4227	823	5149	920	6077	1026	7108	1240	7987	1437	9200	1648	10376	1833	11541	2055	-1	-1	-1	-1	-1	-1
RAC	0.3	40	4	3014	620	3831	775	4637	910	5410	1011	6663	1131	7894	1364	9209	1658	10321	1853	11859	2095	13379	2388	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43	75	55	95	64	110	72	125	229	47	325	54	390	69
RAC	0.2	10	4	0	0	0	0	0	0	85	148	119	206	144	249	279	257	454	97	600	95	695	118	781	138	1024	194	1258	240	1478	275
RAC	0.2	15	4	0	0	127	220	177	306	215	372	454	412	858	131	1034	176	1169	207	1354	249	1535	291	1712	327	2220	413	2725	479	3234	564
RAC	0.2	20	4	168	290	252	437	503	478	892	207	1301	215	1557	275	1820	336	2045	387	2359	451	2662	505	2959	551	3860	672	4772	848	5641	1024
RAC	0.2	25	4	293	507	625	596	1251	195	1615	267	2033	364	2404	450	2801	535	3138	598	3604	675	4067	738	4538	798	5964	1060	7332	1330	-1	-1
RAC	0.2	30	4	426	738	1311	336	1934	319	2330	412	2897	542	3417	654	3966	753	4433	826	5103	914	5786	1007	6475	1129	8474	1538	-1	-1	-1	-1
RAC	0.2	35	4	947	878	2079	326	2641	463	3147	579	3901	746	4584	871	5312	983	5951	1066	6882	1196	7817	1371	8735	1566	-1	-1	-1	-1	-1	-1
RAC	0.2	40	4	1704	493	2753	469	3430	623	4076	772	5036	960	5904	1100	6858	1225	7709	1342	8931	1566	10127	1821	11294	2050	-1	-1	-1	-1	-1	-1
RAC	0.1	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	46	39	67	62	108	127	124	232	61
RAC	0.1	10	4	0	0	0	0	0	0	0	0	0	0	76	132	103	178	124	214	220	228	280	267	463	123	709	121	919	157	1109	196
RAC	0.1	15	4	0	0	0	0	0	0	113	195	169	292	290	331	413	396	690	186	890	170	1061	181	1222	205	1663	294	2072	380	2463	459
RAC	0.1	20	4	0	0	95	165	183	317	244	423	503	494	915	248	1198	227	1410	241	1695	286	1961	339	2214	392	2937	543	3632	679	4295	795
RAC	0.1	25	4	0	0	227	393	322	558	620	611	1242	292	1618	289	1983	333	2282	389	2685	473	3070	554	3445	632	4535	848	5582	1029	-1	-1
RAC	0.1	30	4	218	377	362	627	739	730	1355	376	1947	348	2426	407	2910	503	3310	586	3859	702	4394	813	4920	918	6445	1193	-1	-1	-1	-1
RAC	0.1	35	4	340	589	735	782	1453	493	2047	395	2747	461	3355	578	3974	707	4496	818	5224	968	5936	1109	6634	1239	8670	1576	-1	-1	-1	-1
RAC	0.1	40	4	477	826	1085	1043	2167	451	2788	479	3649	623	4398	779	5179	943	5845	1081	6777	1266	7687	1435	8579	1588	-1	-1	-1	-1	-1	-1
RAC	0.05	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	62	57	99	103	115
RAC	0.05	10	4	0	0	0	0	0	0	0	0	0	0	0	0	47	82	71	123	99	172	126	219	204	230	469	162	683	149	875	161
RAC	0.05	15	4	0	0	0	0	0	0	0	0	88	153	137	237	186	322	303	343	416	416	699	244	865	227	1311	241	1711	299	2081	368
RAC	0.05	20	4	0	0	0	0	0	0	138	239	223	387	399	455	560	558	925	325	1217	299	1486	301	1742	321	2445	428	3094	553	3703	676
RAC	0.05	25	4	0	0	0	0	188	325	275	476	554	596	966	470	1383	380	1685	371	2092	392	2474	439	2838	496	3861	690	4820	883	5733	1066
RAC	0.05	30	4	0	0	201	348	327	566	583	675	1160	565	1705	452	2193	449	2596	479	3137	552	3651	639	4146	733	5550	1013	6885	1281	-1	-1
RAC	0.05	35	4	124	214	330	571	558	797	945	950	1899	534	2514	521	3138	571	3651	642	4348	762	5015	890	5660	1018	7511	1391	-1	-1	-1	-1
RAC	0.05	40	4	260	450	481	833	982	1013	1801	653	2680	592	3440	636	4208	739	4847	849	5721	1015	6562	1182	7379	1347	-1	-1	-1	-1	-1	-1
RAC	0.01	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	50
RAC	0.01	10	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	55	56	97	123	213	248	282	443	250
RAC	0.01	15	4	0	0	0	0	0	0	0	0	0	0	0	0	43	74	82	142	133	231	182	316	274	365	660	375	1056	355	1426	357
RAC	0.01	20	4	0	0	0	0	0	0	0	0	0	0	107	185	179	310	240	416	407	503	558	610	872	500	1569	469	2217	492	2825	549
RAC	0.01	25	4	0	0	0	0	0	0	0	0	153	265	256	444	362	627	600	689	995	641	1378	603	1738	589	2760	613	3715	709	4614	839
RAC	0.01	30	4	0	0	0	0	0	0	153	264	306	530	510	722	811	895	1282	750	1815	715	2328	701	2821	709	4221	822	5535	1006	-1	-1
RAC	0.01	35	4	0	0	0	0	154	266	291	504	491	851	919	1022	1602	860	2104	833	2799	817	3464	834	4109	875	5941	1095	7663	1376	-1	-1
RAC	0.01	40	4	0	0	55	95	283	489	458	793	939	1086	1677	999	2434	948	3071	932	3942	951	4782	1007	5595	1090	7910	1428	-1	-1	-1	-1
RAC	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Imidacloprid Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																													
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	1	5	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	5	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	5	0.1	40116	22866	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	5	0.1	23167	6518	23089	7165	28393	15863	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	5	0.1	12140	11225	17706	5531	18134	5730	18976	6780	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	10	0.1	38293	13722	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	5	0.1	4272	7399	5887	10196	13987	5066	14852	5084	16024	5880	17722	7569	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	10	0.1	29910	10234	33070	12622	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	15	0.1	53718	22999	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	5	0.1	0	0	3488	6042	4749	8225	8904	8020	12601	4845	13755	5402	15065	6188	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	10	0.1	17881	16112	26019	10006	29227	11798	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	15	0.1	41535	16304	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Imidacloprid Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																													
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.4	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	5	0.1	0	0	0	0	0	0	3663	6345	7229	6717	10361	4635	11751	5138	12858	5638	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	10	0.1	7325	12687	17574	10556	22527	9850	25738	11279	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	15	0.1	31110	13939	38624	16931	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	20	0.1	51507	22582	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	5	0.1	0	0	0	0	0	0	0	0	2708	4690	3475	6019	6600	6255	9150	4758	10782	5384	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	10	0.1	0	0	5958	10319	12109	11682	18241	9487	23133	11372	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	15	0.1	10335	17900	27258	14201	34436	16950	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	20	0.1	36189	18896	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	25	0.1	57101	28133	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	2008	3478	2632	4559	4952	5125	7315	4816	8840	5343	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	10	0.1	0	0	0	0	2792	4835	5195	8999	11313	11355	17550	10625	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	15	0.1	0	0	7688	13317	16663	16757	26123	15850	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	20	0.1	10106	17504	28285	19031	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	25	0.1	27161	27396	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	30	0.1	51031	31179	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1756	3042	2479	4294	4362	4831	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	10	0.1	0	0	0	0	0	0	0	0	4199	7274	8515	9529	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	15	0.1	0	0	0	0	6101	10567	12425	14112	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	20	0.1	0	0	9353	16199	21350	22419	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	25	0.1	9709	16816	26310	27677	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	30	0.1	17650	30570	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	35	0.1	44513	34442	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.01	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2053	3557	-1	-1	-1	-1	-1	-1
Biochar	0.01	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	2421	4193	3972	6879	7975	9675	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.01	15	0.1	0	0	0	0	0	0	0	0	4585	7941	8334	14435	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.01	20	0.1	0	0	0	0	0	0	7426	12862	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.01	25	0.1	0	0	0	0	10370	17961	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.01	30	0.1	0	0	10413	18036	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.01	35	0.1	5087	8810	19559	33877	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.01	40	0.1	12976	22474	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	5	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	10	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	15	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	20	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	25	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Imidacloprid Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																													
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	1	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	5	0.4	43207	21637	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	10	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	15	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	20	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	25	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	5	0.4	12832	7325	15764	8161	20451	9325	22152	10999	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	10	0.4	44733	22229	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	15	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	20	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	25	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	5	0.4	7358	2104	7374	2293	9080	5097	9909	5783	13271	5760	15281	7382	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	10	0.4	20019	11653	28309	12765	33125	16512	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	15	0.4	46437	22483	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	20	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	25	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	5	0.4	3846	3596	5611	1802	5773	1844	6055	2183	7381	3976	8503	4612	10227	4825	11448	5293	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	10	0.4	12208	4419	15412	8546	19322	9693	23001	10639	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	15	0.4	25850	13992	34663	16050	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	20	0.4	46430	21513	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	25	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	5	0.4	1364	2362	1893	3279	4421	1664	4717	1647	5102	1897	5650	2445	6474	3281	7244	3856	8424	4293	9582	4578	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	10	0.4	9487	3314	10527	4074	12379	5999	14541	7739	18151	8889	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	15	0.4	17116	7434	21895	11655	27166	13329	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	20	0.4	29302	15592	38656	18485	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	25	0.4	45551	22355	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	5	0.4	0	0	1115	1931	1526	2644	2823	2563	3999	1572	4373	1746	4793	2000	5184	2246	5856	2739	6644	3382	7366	3840	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	10	0.4	5661	5142	8256	3240	9291	3812	10392	4506	12599	6198	14757	7691	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	15	0.4	13193	5278	15629	6788	18837	9252	22175	11557	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	20	0.4	20887	9076	26721	13593	32734	16786	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	25	0.4	31515	15475	40980	21014	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	30	0.4	44578	23218	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	5	0.4	0	0	0	0	0	0	1177	2038	2294	2152	3286	1506	3734	1662	4087	1822	4562	2027	5027	2229	5503	2479	7090	3585	-1	-1	-1	-1	-1	-1
Biochar	0.3	10	0.4	2346	4064	5507	3493	7148	3189	8175	3645	9637	4274	11011	4960	12656	6074	14183	7169	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	15	0.4	9850	4543	12268	5477	14396	6393	16525	7450	20149	9947	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Imidacloprid Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.3	20	0.4	16359	7301	20134	8943	24063	11252	28382	14340	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	25	0.4	24009	10671	30092	14076	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	30	0.4	33090	14940	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	35	0.4	44007	21023	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	5	0.4	0	0	0	0	0	0	0	0	869	1506	1117	1935	2096	2006	2905	1542	3426	1740	3894	1917	4339	2077	5544	2576	-1	-1	-1	-1
Biochar	0.2	10	0.4	0	0	1909	3307	3840	3746	5785	3076	7348	3673	8659	4148	9992	4668	11074	5145	12589	5885	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	15	0.4	3319	5749	8642	4612	10937	5479	12964	6218	15808	7360	18293	8530	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	20	0.4	11473	6132	15468	7633	18948	8917	22093	10270	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	25	0.4	18136	9095	23646	11134	28528	13265	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	30	0.4	25768	12380	33052	15371	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	35	0.4	34422	16110	43835	20508	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	40	0.4	43955	20436	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	645	1117	846	1465	1575	1648	2322	1561	2811	1726	4091	2201	5209	2647	-1	-1
Biochar	0.1	10	0.4	0	0	0	0	888	1538	1667	2888	3594	3646	5576	3432	6979	3953	8140	4383	9660	4978	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	15	0.4	0	0	2469	4277	5294	5383	8299	5125	11297	6239	13881	7222	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	20	0.4	3245	5621	8960	6182	12753	7458	16116	8699	20715	10532	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	25	0.4	8631	8800	15838	9280	21036	11207	25659	13057	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	30	0.4	16209	10083	23931	12946	30673	15615	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	35	0.4	23399	13417	33137	17114	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	40	0.4	31588	17110	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	565	978	797	1380	1389	1555	2837	1892	4004	2348	-1	-1
Biochar	0.05	10	0.4	0	0	0	0	0	0	0	0	1348	2335	2709	3067	4449	3313	5612	3755	7200	4376	8670	4959	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	15	0.4	0	0	0	0	1960	3394	3955	4544	7467	5264	10130	6299	12812	7355	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	20	0.4	0	0	3004	5203	6789	7208	10986	7402	15766	9279	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	25	0.4	3118	5401	8369	8898	14597	9582	19438	11474	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	30	0.4	5669	9820	16132	10945	23155	13691	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	35	0.4	14120	11167	24186	14847	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	40	0.4	21065	14372	33331	19196	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.01	5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	660	1143	1590	1831	2735	2132
Biochar	0.01	10	0.4	0	0	0	0	0	0	0	0	0	0	0	0	777	1345	1276	2209	2543	3114	4025	3617	5398	4225	-1	-1	-1	-1	-1	-1
Biochar	0.01	15	0.4	0	0	0	0	0	0	0	0	1473	2552	2677	4636	5797	5325	7966	6269	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.01	20	0.4	0	0	0	0	0	0	2386	4132	6009	6998	10448	8267	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.01	25	0.4	0	0	0	0	3331	5769	7276	8523	14225	10841	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.01	30	0.4	0	0	3347	5797	8537	10051	15168	12137	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.01	35	0.4	1626	2817	6281	10879	16234	13473	24310	17020	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.01	40	0.4	4169	7220	13054	14840	24863	18160	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	5	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	10	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	15	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	20	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	25	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	30	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	5	1	20434	10190	27475	13028	33912	16010	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	10	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	15	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	20	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	25	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	30	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Imidacloprid Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																													
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.9	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	5	1	6066	3446	7445	3800	9635	4406	10463	5187	13371	6418	15332	7460	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	10	1	21132	10486	28183	13227	34125	16562	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	15	1	46709	22746	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	20	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	25	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	30	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	5	1	3465	983	3484	1068	4292	2401	4689	2722	6250	2723	7209	3483	8193	4055	9293	4519	10645	5098	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	10	1	9475	5487	13345	6030	15638	7782	18688	9087	22763	10986	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	15	1	21906	10601	28182	13702	34116	16462	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	20	1	37784	18367	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	25	1	57349	27692	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	30	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	5	1	1803	1698	2638	849	2722	862	2859	1024	3487	1874	4018	2168	4821	2273	5399	2496	6195	3034	6883	3379	7726	3779	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	10	1	5766	2074	7284	4030	9124	4544	10849	5017	13179	6483	15502	7583	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	15	1	12211	6571	16346	7564	19746	9714	23327	11410	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	20	1	21899	10141	27827	13663	34454	16659	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	25	1	33156	16312	43186	20883	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	30	1	47109	23044	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	5	1	643	1113	896	1552	2075	791	2221	775	2406	891	2666	1151	3057	1547	3420	1817	3976	2019	4520	2155	5078	2417	6505	3196	-1	-1	-1	-1	-1	-1
Biochar	0.5	10	1	4468	1560	4966	1916	5844	2829	6866	3646	8564	4184	10181	4846	11735	5754	13036	6405	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	15	1	8074	3497	10336	5487	12816	6270	15309	7288	18611	9166	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	20	1	13837	7343	18237	8700	22470	10908	26176	12863	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	25	1	21492	10519	28149	13667	34056	16701	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	30	1	30852	14701	39419	19371	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	35	1	41199	20174	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	40	1	52761	25928	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	5	1	0	0	526	911	722	1251	1324	1209	1882	742	2060	822	2259	942	2444	1059	2762	1292	3134	1595	3476	1810	4601	2210	5660	2768	-1	-1	-1
Biochar	0.4	10	1	2657	2427	3887	1529	4378	1796	4900	2124	5943	2925	6964	3626	8168	4090	9213	4427	10660	5166	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	15	1	6212	2482	7366	3196	8883	4363	10463	5446	13074	6395	15479	7462	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	20	1	9849	4277	12606	6412	15448	7899	18473	8882	22822	11164	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	25	1	14863	7299	19337	9888	24037	11515	28415	13897	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	30	1	21036	10942	27779	13363	34134	16693	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	35	1	28515	14336	37510	18183	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	40	1	37129	17871	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	5	1	0	0	0	0	0	0	557	964	1076	1016	1545	714	1758	784	1924	859	2148	956	2368	1052	2593	1170	3343	1692	4127	2093	-1	-1	-1
Biochar	0.3	10	1	1111	1925	2571	1678	3364	1507	3850	1720	4539	2016	5187	2342	5965	2869	6687	3384	7724	3963	8794	4387	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	15	1	4628	2148	5775	2580	6778	3013	7783	3515	9498	4695	11197	5758	13113	6554	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	20	1	7704	3443	9484	4218	11340	5313	13383	6767	16606	8418	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	25	1	11306	5031	14179	6645	17379	8877	20653	10477	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	30	1	15588	7047	20083	10149	24790	12574	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	35	1	20739	9929	27070	13882	33596	16418	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	40	1	26789	13531	35216	17583	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	5	1	0	0	0	0	0	0	0	0	411	712	528	915	984	948	1366	730	1613	822	1833	905	2042	981	2610	1216	3149	1489	3711	1830		
Biochar	0.2	10	1	0	0	904	1566	1804	1772	2721	1457	3459	1735	4076	1958	4703	2205	5213	2430	5928	2780	6663	3189	7430	3664	-1	-1	-1	-1	-1	-1		

Imidacloprid Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.2	15	1	1569	2717	4063	2182	5148	2585	6101	2933	7439	3474	8612	4027	9929	4746	11134	5490	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	20	1	5397	2904	7282	3603	8918	4210	10400	4850	12623	5975	14834	7312	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	25	1	8537	4293	11127	5255	13428	6264	15684	7423	19352	9638	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	30	1	12129	5839	15558	7256	18804	8900	22214	10949	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	35	1	16196	7607	20636	9686	25216	12339	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	40	1	20687	9652	26507	12698	32652	16435	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	5	1	0	0	0	0	0	0	0	0	0	0	0	0	305	528	400	693	740	781	1092	741	1323	817	1925	1040	2451	1250	2930	1453
Biochar	0.1	10	1	0	0	0	0	420	727	789	1367	1689	1726	2625	1625	3285	1869	3831	2072	4545	2353	5214	2632	5854	2904	-1	-1	-1	-1	-1	-1
Biochar	0.1	15	1	0	0	1167	2021	2486	2546	3906	2423	5316	2947	6530	3412	7745	3914	8754	4344	10129	4946	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	20	1	1535	2659	4211	2935	6004	3525	7585	4110	9747	4975	11638	5776	13591	6633	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	25	1	4054	4164	7455	4386	9897	5295	12072	6168	15166	7487	17909	8705	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	30	1	7631	4767	11262	6114	14434	7376	17352	8613	21550	10473	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	35	1	11011	6341	15589	8088	19631	9784	23395	11428	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	40	1	14863	8086	20427	10324	25461	12490	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	267	463	377	653	653	737	1336	895	1884	1111	2377	1314
Biochar	0.05	10	1	0	0	0	0	0	0	0	0	638	1105	1275	1453	2094	1571	2643	1777	3389	2070	4080	2345	4736	2620	6563	3405	-1	-1	-1	-1
Biochar	0.05	15	1	0	0	0	0	926	1604	1859	2152	3514	2491	4768	2978	6028	3478	7063	3910	8467	4508	9805	5089	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	20	1	0	0	1421	2462	3192	3412	5173	3502	7419	4388	9364	5189	11358	6038	13022	6760	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	25	1	1475	2554	3933	4212	6872	4532	9146	5426	12310	6743	15108	7938	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	30	1	2681	4644	7596	5176	10896	6473	13888	7706	18154	9536	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	35	1	6632	5303	11381	7022	15544	8707	19392	10343	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	40	1	9915	6803	15682	9079	20832	11246	25631	13319	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.01	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	312	541	748	868	1288	1009
Biochar	0.01	10	1	0	0	0	0	0	0	0	0	0	0	0	0	368	637	604	1046	1198	1476	1895	1715	2542	2001	4369	2807	-1	-1	-1	-1
Biochar	0.01	15	1	0	0	0	0	0	0	0	0	696	1206	1266	2192	2728	2524	3750	2968	5145	3579	6490	4177	7790	4758	-1	-1	-1	-1	-1	-1
Biochar	0.01	20	1	0	0	0	0	0	0	1129	1955	2829	3315	4920	3914	6900	4784	8570	5526	10870	6554	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.01	25	1	0	0	0	0	1576	2729	3424	4038	6697	5132	9500	6360	12417	7664	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.01	30	1	0	0	1583	2741	4019	4760	7143	5744	11362	7613	15205	9324	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.01	35	1	766	1328	2970	5144	7643	6381	11441	8059	16962	10531	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.01	40	1	1972	3415	6142	7029	11703	8597	16491	10718	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	5	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	10	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	15	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	20	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	25	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	30	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	35	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	40	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	5	4	6617	3247	8875	4167	10947	5104	12799	6016	15445	7162	17811	8144	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	10	4	25891	12190	32677	15027	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	15	4	54224	24786	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	20	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	25	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	30	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	35	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	40	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	5	4	1963	1099	2405	1192	3105	1408	3383	1656	4315	2042	4951	2378	5754	2709	6406	3027	7317	3422	8180	3793	9004	4141	-1	-1	-1	-1	-1	-1
Biochar	0.8	10	4	6832	3348	9091	4224	11022	5258	12884	6088	15620	7260	18075	8312	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	15	4	15085	7251	19434	9183	23419	10887	27212	12513	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	20	4	26056	12310	33135	15364	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	25	4	39380	18304	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Imidacloprid Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.8	30	4	55031	25299	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	35	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	40	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	5	4	1116	305	1127	332	1389	767	1519	869	2013	869	2327	1112	2647	1290	3000	1437	3436	1625	3864	1853	4294	2026	5502	2571	-1	-1	-1	-1
Biochar	0.7	10	4	3070	1751	4302	1925	5052	2481	6034	2890	7349	3502	8619	4067	9920	4667	11034	5155	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	15	4	7072	3386	9099	4359	11014	5248	12974	6122	15781	7394	18302	8486	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	20	4	12198	5841	15641	7503	18986	8962	22184	10363	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	25	4	18514	8825	23808	11238	28751	13380	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	30	4	26222	12373	33452	15626	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	35	4	34961	16460	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	40	4	44837	20943	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	5	4	574	547	848	268	878	269	924	322	1128	599	1299	690	1555	723	1742	795	1999	968	2222	1077	2495	1202	3225	1542	3930	1853	4589	2144
Biochar	0.6	10	4	1864	653	2356	1287	2946	1438	3500	1599	4254	2067	5005	2412	5805	2758	6464	3092	7418	3501	8322	3921	9210	4304	-1	-1	-1	-1	-1	-1
Biochar	0.6	15	4	3948	2091	5273	2412	6374	3099	7532	3630	9218	4387	10801	5118	12438	5863	13836	6466	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	20	4	7064	3232	8984	4354	11119	5303	12991	6213	15886	7493	18478	8635	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	25	4	10702	5201	13937	6648	16893	8080	19798	9337	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	30	4	15208	7330	19580	9366	23802	11227	27805	12996	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	35	4	20430	9714	26231	12380	31725	14848	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	40	4	26232	12550	33648	15854	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	5	4	207	358	290	501	665	253	715	244	776	281	861	366	988	494	1105	579	1284	643	1459	686	1638	770	2100	1018	2594	1238	3035	1450
Biochar	0.5	10	4	1438	493	1603	606	1888	902	2218	1163	2764	1331	3284	1544	3786	1836	4208	2041	4881	2343	5489	2614	6090	2909	-1	-1	-1	-1	-1	-1
Biochar	0.5	15	4	2608	1112	3339	1751	4136	1996	4938	2323	6006	2924	7083	3411	8202	3907	9146	4369	10484	4945	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	20	4	4470	2342	5884	2767	7247	3481	8448	4098	10476	5001	12211	5833	14110	6652	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	25	4	6936	3346	9079	4361	10993	5317	13050	6231	15937	7600	18582	8755	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	30	4	9950	4684	12722	6172	15684	7489	18365	8774	22433	10570	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	35	4	13290	6440	17225	8270	20916	9990	24574	11592	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	40	4	17031	8262	22149	10554	26954	12772	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	5	4	0	0	169	293	233	404	422	389	605	236	664	261	728	299	788	337	891	412	1012	509	1122	578	1484	704	1825	883	2137	1035
Biochar	0.4	10	4	847	780	1251	486	1411	570	1580	676	1917	934	2248	1157	2636	1301	2971	1410	3437	1648	3862	1878	4286	2076	5575	2657	-1	-1	-1	-1
Biochar	0.4	15	4	2001	788	2376	1017	2866	1393	3378	1739	4218	2035	4991	2381	5767	2804	6435	3116	7445	3570	8369	3988	9286	4424	-1	-1	-1	-1	-1	-1
Biochar	0.4	20	4	3176	1360	4067	2047	4986	2515	5958	2829	7359	3562	8587	4159	10020	4801	11166	5321	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	25	4	4795	2329	6242	3149	7751	3670	9163	4434	11223	5421	13213	6309	15239	7264	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	30	4	6790	3493	8959	4257	11007	5327	12904	6250	15946	7613	18606	8865	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	35	4	9202	4561	12095	5802	14684	7125	17423	8355	21288	10149	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	40	4	11975	5693	15538	7554	19040	9162	22392	10674	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	5	4	0	0	0	0	0	0	180	311	343	328	496	229	565	250	620	274	692	304	763	335	835	373	1078	540	1331	667	1585	761
Biochar	0.3	10	4	359	621	815	551	1082	482	1239	548	1462	642	1671	747	1923	916	2157	1081	2492	1264	2836	1398	3176	1526	4138	2008	5067	2434	-1	-1
Biochar	0.3	15	4	1485	691	1859	823	2183	960	2507	1121	3063	1501	3612	1838	4229	2088	4765	2290	5510	2652	6207	3013	6892	3334	-1	-1	-1	-1	-1	-1
Biochar	0.3	20	4	2479	1097	3054	1343	3654	1696	4315	2162	5357	2683	6355	3054	7413	3570	8278	4018	9504	4587	10759	5149	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	25	4	3640	1602	4569	2121	5605	2835	6662	3339	8302	3977	9778	4733	11298	5472	12673	6089	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	30	4	5021	2248	6476	3243	7996	4009	9536	4584	11795	5711	13791	6673	16051	7685	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	35	4	6684	3172	8732	4429	10832	5231	12866	6192	15768	7640	18568	8896	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	40	4	8639	4324	11358	5602	14053	6740	16569	8043	20390	9797	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	5	4	0	0	0	0	0	0	0	0	133	230	171	296	314	306	439	235	519	263	590	289	657	313	840	388	1014	476	1195	585
Biochar	0.2	10	4	0	0	292	506	576	572	874	469	1113	555	1311	626	1513	704	1677	776	1908	888	2146	1019	2393	1171	3140	1567	3885	1873	4590	2213
Biochar	0.2	15	4	507	878	1304	702	1656	827	1963	937	2393	1110	2772	1286	3197	1517	3587	1755	4146	2082	4707	2350	5271	2579	6896	3325	-1	-1	-1	-1
Biochar	0.2	20	4	1732	934	2342	1152	2868	1344	3346	1549	4064	1909	4778	2338	5574	2800	6273	3131	7271	3536	8245	3966	9190	4432	-1	-1	-1	-1	-1	-1
Biochar	0.2	25	4	2746	1373	3579	1678	4321	2000	5049	2371	6234	3081	7366	3699	8620	4232	9697	4678	11193	5393	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	30	4	3901	1866	5005	2318	6053	2844	7154	3501	8879	4459	10524	5151	12284	5910	13774	6643	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	35	4	5209	2430	6642	3094	8121	3946	9646	4841	12007	5903	14198	6833	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	40	4	6655	3083	8535	4059	10520	5253	12514	6246	15572	7514	18351	8850	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	5	4	0	0	0	0	0	0	0	0	0	0	0	0	98	171	129	224	237	253	350	239	426	263	619	333	788	400	942	465

Imidacloprid Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.1	10	4	0	0	0	0	135	234	255	442	540	558	844	523	1057	599	1232	664	1461	754	1677	842	1882	929	2460	1185	3012	1448	3556	1732
Biochar	0.1	15	4	0	0	377	653	795	823	1255	780	1709	945	2099	1093	2490	1253	2814	1390	3256	1582	3682	1774	4098	1968	5336	2600	-1	-1	-1	-1
Biochar	0.1	20	4	496	858	1349	950	1931	1132	2438	1317	3134	1593	3741	1847	4369	2121	4899	2360	5637	2707	6368	3072	7105	3462	-1	-1	-1	-1	-1	-1
Biochar	0.1	25	4	1296	1346	2397	1408	3181	1697	3881	1974	4875	2395	5758	2784	6689	3213	7490	3603	8638	4198	9789	4812	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	30	4	2452	1535	3620	1960	4640	2362	5578	2756	6928	3349	8149	3915	9467	4567	10628	5179	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	35	4	3540	2035	5011	2591	6311	3130	7521	3655	9294	4467	10931	5271	12737	6224	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	40	4	4778	2592	6567	3304	8185	3995	9711	4680	11984	5767	14131	6887	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	86	149	122	211	209	239	430	288	606	357	764	421
Biochar	0.05	10	4	0	0	0	0	0	0	0	0	206	357	408	471	672	508	850	572	1089	665	1312	753	1523	840	2110	1091	2653	1329	3161	1557
Biochar	0.05	15	4	0	0	0	0	299	518	596	697	1130	803	1533	957	1938	1117	2270	1254	2722	1445	3152	1630	3565	1811	4738	2334	-1	-1	-1	-1
Biochar	0.05	20	4	0	0	459	795	1021	1104	1663	1128	2385	1410	3010	1664	3651	1935	4185	2165	4917	2486	5620	2798	6302	3104	-1	-1	-1	-1	-1	-1
Biochar	0.05	25	4	476	825	1258	1362	2209	1458	2940	1743	3957	2162	4856	2543	5787	2948	6569	3293	7646	3775	8687	4246	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	30	4	866	1500	2441	1668	3502	2080	4464	2472	5834	3055	7055	3586	8329	4150	9404	4633	10890	5308	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	35	4	2124	1719	3658	2257	4996	2794	6232	3315	8008	4085	9598	4787	11265	5537	12677	6179	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	40	4	3187	2192	5040	2916	6696	3605	8238	4266	10468	5248	12474	6146	14586	7105	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.01	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	101	175	240	281	414	326
Biochar	0.01	10	4	0	0	0	0	0	0	0	0	0	0	0	0	119	206	195	338	384	478	609	555	817	645	1405	903	1954	1147	2472	1379
Biochar	0.01	15	4	0	0	0	0	0	0	0	0	225	390	409	708	876	817	1206	957	1654	1153	2086	1344	2504	1530	3695	2062	4816	2567	-1	-1
Biochar	0.01	20	4	0	0	0	0	0	0	365	632	907	1073	1581	1263	2217	1541	2754	1778	3493	2106	4207	2425	4899	2735	6876	3626	-1	-1	-1	-1
Biochar	0.01	25	4	0	0	0	0	509	881	1097	1307	2152	1655	3053	2048	3990	2464	4783	2816	5876	3306	6932	3781	7958	4244	-1	-1	-1	-1	-1	-1
Biochar	0.01	30	4	0	0	511	886	1288	1541	2296	1854	3652	2451	4886	2998	6176	3574	7267	4063	8774	4741	10232	5399	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.01	35	4	246	427	959	1661	2456	2060	3677	2597	5451	3386	7067	4104	8758	4863	10190	5508	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.01	40	4	637	1104	1968	2275	3761	2771	5300	3449	7542	4451	9583	5364	11724	6328	13536	7146	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	5	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	5	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	5	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	5	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Imidacloprid Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																													
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.7	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	5	0.1	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	5	0.1	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	5	0.1	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	5	0.1	0	0	0	0	0	0	0	0	11130	19278	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	10	0.1	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	10	0.1	0	0	0	0	12607	21836	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	15	0.1	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	10	0.1	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	15	0.1	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	20	0.1	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Imidacloprid Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.05	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1
RAC	0.05	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	15	0.1	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	20	0.1	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	25	0.1	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	30	0.1	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1
RAC	0.01	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	15	0.1	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	20	0.1	0	0	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	25	0.1	0	0	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	30	0.1	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	35	0.1	0	0	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	40	0.1	0	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	5	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	10	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	15	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	20	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	25	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	5	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	10	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	15	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	20	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	25	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	5	0.4	48279	21436	48135	20160	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	10	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	15	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	20	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	25	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	5	0.4	19143	19471	34061	14544	33525	14353	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	10	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	15	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	20	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	25	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	5	0.4	0	0	14176	14541	25542	10176	26237	10875	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	10	0.4	52836	21861	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	15	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Imidacloprid Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																													
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.6	20	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	25	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	5	0.4	0	0	0	0	10626	11133	17897	6358	21316	8473	22310	8940	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	10	0.4	35952	12774	43453	17348	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	15	0.4	67515	27026	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	20	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	25	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	5	0.4	0	0	0	0	0	0	5302	9183	9367	9659	17130	6495	18686	7243	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	10	0.4	10614	18383	29902	10832	36422	14045	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	15	0.4	51658	19544	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	20	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	25	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	5	0.4	0	0	0	0	0	0	0	0	3403	5895	7206	7580	12733	4750	14848	5589	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	10	0.4	0	0	8702	15072	15861	16480	29699	11169	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	15	0.4	21610	22759	44555	16749	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	20	0.4	59403	22325	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	25	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	3396	5882	5889	6270	10322	4257	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	10	0.4	0	0	0	0	3849	6668	11733	12501	23860	9174	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	15	0.4	0	0	17514	18680	35416	13627	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	20	0.4	23238	24816	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	25	0.4	58524	22562	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	30	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3960	4493	5178	5573	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	10	0.4	0	0	0	0	0	0	0	0	4925	8531	10266	11054	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	15	0.4	0	0	0	0	7121	12334	15258	16436	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	20	0.4	0	0	14563	17605	30823	18064	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	25	0.4	11208	19414	30135	32222	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	30	0.4	29676	32042	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	35	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	40	0.4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4889	5340	-1	-1	-1	-1	-1	-1
RAC	0.05	10	0.4	0	0	0	0	0	0	0	0	0	0	0	0	6938	7888	9652	10546	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	15	0.4	0	0	0	0	0	0	0	0	12308	13593	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	20	0.4	0	0	0	0	8299	14374	18805	20566	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	25	0.4	0	0	10114	17518	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	30	0.4	0	0	27475	30085	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	35	0.4	16159	27988	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Imidacloprid Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.05	40	0.4	35659	39128	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	5	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1489	2579	-1	-1
RAC	0.01	10	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4924	6013	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	15	0.4	0	0	0	0	0	0	0	0	0	0	0	0	5496	9519	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	20	0.4	0	0	0	0	0	0	0	0	5320	9215	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	25	0.4	0	0	0	0	0	0	6144	10641	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	30	0.4	0	0	0	0	6862	11885	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	35	0.4	0	0	0	0	22362	25753	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	40	0.4	0	0	12928	22392	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	5	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	10	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	15	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	20	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	25	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	30	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	5	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	10	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	15	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	20	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	25	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	30	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	5	1	22721	9820	22746	9040	31142	11133	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	10	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	15	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	20	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	25	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	30	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	5	1	8887	8983	15971	6695	15762	6565	15966	6383	21005	7994	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	10	1	32171	12839	43909	15643	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	15	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	20	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	25	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	30	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	5	1	0	0	6557	6705	11939	4687	12295	5000	12639	5062	13367	5179	16109	6229	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	10	1	24716	10041	25658	10168	30405	12264	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	15	1	40576	15717	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	20	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	25	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	30	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	5	1	0	0	0	0	4891	5133	8329	2886	9970	3896	10448	4098	11022	4274	11697	4475	13236	5001	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	10	1	16683	5790	20304	7965	21649	8436	23465	8976	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

Imidacloprid Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																													
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.5	15	1	31601	12399	35341	13525	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	20	1	47291	18095	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	25	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	30	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	5	1	0	0	0	0	0	0	2441	4228	4347	4453	8000	2975	8735	3320	9277	3533	10063	3820	10888	4099	11773	4395	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	10	1	4865	8427	13892	4902	16999	6434	18582	7076	21062	7965	23580	8804	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	15	1	24106	8962	27952	10651	31532	11931	35442	13236	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	20	1	37347	14228	43793	16496	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	25	1	52748	19959	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	30	1	71259	26610	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	5	1	0	0	0	0	0	0	0	0	1563	2707	3335	3494	5935	2147	6934	2546	7820	2910	8624	3221	9386	3502	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	10	1	0	0	3994	6917	7353	7582	13851	5083	16525	6165	18769	7004	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	15	1	9977	10478	20795	7635	24692	9216	28173	10518	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	20	1	27720	10173	34520	12901	40471	15090	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	25	1	41169	15364	50603	18867	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	30	1	56390	21053	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	5	1	0	0	0	0	0	0	0	0	0	0	0	0	1565	2710	2729	2889	4810	1919	6043	2246	6896	2570	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	10	1	0	0	0	0	1748	3028	5421	5750	11120	4144	13750	5125	16221	6015	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	15	1	0	0	8096	8600	16519	6162	20589	7676	25826	9555	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	20	1	10741	11430	23948	8906	30551	11372	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	25	1	27294	10193	38116	14189	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	30	1	40891	15238	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	35	1	55787	20730	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1824	2073	2406	2567	5771	2284	-1	-1	-1	-1	-1	-1
RAC	0.1	10	1	0	0	0	0	0	0	0	0	2262	3918	4762	5085	9216	3831	11464	4544	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	15	1	0	0	0	0	3275	5672	7080	7567	15476	6250	20306	7800	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	20	1	0	0	6640	8140	14329	8229	22657	8999	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	25	1	5154	8926	14006	14832	29993	11786	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	30	1	13768	14745	33574	13352	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	35	1	30052	12944	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	40	1	44214	17638	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2273	2458	5115	2214	-1	-1	-1	-1
RAC	0.05	10	1	0	0	0	0	0	0	0	0	0	0	0	0	3198	3630	4482	4851	8753	4021	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	15	1	0	0	0	0	0	0	0	0	5707	6257	11825	5735	16816	7044	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	20	1	0	0	0	0	3822	6619	8735	9467	20050	8735	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	25	1	0	0	4657	8066	11849	12790	24632	10780	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	30	1	0	0	12760	13841	29283	12847	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	35	1	7444	12893	28901	13585	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	40	1	16558	18010	43542	18379	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	687	1190	1884	2116		
RAC	0.01	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2265	2770	3698	4158	-1	-1	-1	-1	-1	-1		
RAC	0.01	15	1	0	0	0	0	0	0	0	0	0	0	0	0	2533	4387	5425	6106	11046	6413	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
RAC	0.01	20	1	0	0	0	0	0	0	0	0	2450	4243	7072	7970	14904	8571	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
RAC	0.01	25	1	0	0	0	0	0	0	2827	4897	10058	11249	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
RAC	0.01	30	1	0	0	0	0	3156	5466	10136	11449	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		

Imidacloprid Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.01	35	1	0	0	0	0	10369	11851	23901	14552	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	40	1	0	0	5959	10321	18411	20414	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	5	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	10	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	15	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	20	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	25	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	30	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	35	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	40	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	5	4	24196	8851	29946	8838	38668	13204	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	10	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	15	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	20	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	25	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	30	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	35	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	40	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	5	4	7332	2938	7386	2590	9955	3201	12152	4081	14855	5152	16390	4975	19998	6700	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	10	4	24581	8306	31052	9838	37887	12722	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	15	4	49872	15159	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	20	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	25	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	30	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	35	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	40	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	5	4	2825	2793	5126	2014	5081	1953	5165	1858	6715	2313	7588	2274	9195	3138	10265	3464	11581	3670	13092	4212	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	10	4	10420	3742	14061	4484	17695	5945	20636	6960	24796	7873	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	15	4	23124	6928	31112	10482	37160	11796	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	20	4	41696	14040	53016	17079	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	25	4	62468	19845	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	30	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	35	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	40	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	5	4	0	0	2071	2082	3815	1407	3944	1497	4069	1495	4315	1494	5173	1777	5740	1808	6807	2198	7642	2528	8449	2790	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	10	4	7942	3015	8276	2990	9803	3476	11532	3632	14642	4832	16951	5597	19697	6366	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	15	4	13098	4527	17376	5470	21934	7235	25506	8421	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	20	4	23274	7331	30884	10221	37696	12375	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	25	4	36822	12151	47252	15509	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	30	4	51496	17005	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	35	4	69309	22453	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	40	4	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	5	4	0	0	0	0	1529	1592	2645	841	3189	1165	3350	1217	3541	1256	3763	1299	4257	1429	4843	1578	5461	1768	7141	2355	-1	-1	-1	-1
RAC	0.5	10	4	5312	1690	6510	2383	6956	2494	7553	2609	9170	3026	10951	3546	12815	4146	14309	4720	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	15	4	10134	3679	11368	3925	13723	4529	16467	5332	20393	6650	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	20	4	15213	5256	19537	6367	24429	7888	28728	9478	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	25	4	23007	7594	30604	9883	37385	12418	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	30	4	33186	10754	43258	14273	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	35	4	44953	14547	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	40	4	57889	19107	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	5	4	0	0	0	0	0	0	757	1311	1378	1383	2552	883	2793	986	2969	1045	3224	1123	3491	1197	3780	1273	4954	1637	6139	2006	-1	-1

Imidacloprid Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.4	10	4	1512	2619	4425	1431	5439	1916	5952	2096	6754	2335	7574	2552	8749	2926	9920	3280	11474	3720	13079	4310	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	15	4	7691	2657	8945	3149	10105	3494	11379	3834	14053	4699	16636	5391	19522	6429	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	20	4	11954	4213	14043	4819	16568	5533	19890	6579	24762	8096	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	25	4	16903	5848	20741	6925	25866	8476	30818	10072	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	30	4	22877	7715	29908	9896	37018	12100	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	35	4	30533	10208	40374	13100	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	40	4	39969	13235	52604	17348	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	5	4	0	0	0	0	0	0	0	0	483	836	1052	1084	1888	624	2212	749	2497	858	2754	950	2998	1031	3687	1260	4430	1493	5281	1754
RAC	0.3	10	4	0	0	1242	2151	2338	2356	4424	1499	5281	1820	5999	2064	6739	2308	7376	2522	8335	2829	9423	3156	10586	3516	-1	-1	-1	-1	-1	-1
RAC	0.3	15	4	3146	3248	6634	2245	7885	2716	9000	3097	10603	3628	12131	4128	14051	4709	15881	5275	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	20	4	8845	2997	11026	3805	12937	4439	14762	5050	17827	6011	21179	7037	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	25	4	13146	4531	16173	5548	19035	6504	22175	7480	27708	9176	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	30	4	18013	6206	22156	7580	26618	8981	31779	10563	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	35	4	23454	8041	29220	9927	36060	12010	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	40	4	29551	10115	37734	12653	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	5	4	0	0	0	0	0	0	0	0	0	0	0	0	486	841	862	896	1530	559	1928	655	2200	751	2906	991	3526	1214	4084	1403
RAC	0.2	10	4	0	0	0	0	539	934	1715	1785	3550	1206	4390	1500	5175	1767	5803	1979	6647	2283	7431	2559	8177	2809	-1	-1	-1	-1	-1	-1
RAC	0.2	15	4	0	0	2557	2665	5265	1790	6568	2243	8235	2808	9650	3307	11078	3816	12255	4210	13940	4771	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	20	4	3389	3543	7640	2597	9744	3336	11572	3949	14130	4867	16327	5611	18726	6409	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	25	4	8697	2962	12154	4161	14985	5118	17556	6047	21190	7274	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	30	4	13045	4460	17306	5907	21046	7251	24450	8405	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	35	4	17785	6088	23121	7946	27850	9585	32437	11110	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	40	4	22999	7857	29543	10191	35525	12186	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	570	643	764	795	1839	665	2500	863	3095	1066
RAC	0.1	10	4	0	0	0	0	0	0	0	0	703	1218	1513	1577	2940	1117	3656	1324	4553	1588	5394	1858	6184	2130	8307	2864	-1	-1	-1	-1
RAC	0.1	15	4	0	0	0	0	1015	1759	2248	2343	4933	1819	6471	2275	7997	2755	9245	3185	10879	3742	12432	4286	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	20	4	0	0	2046	2536	4555	2475	7222	2622	9931	3434	12287	4235	14609	5027	16539	5703	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	25	4	1597	2766	4457	4594	9557	3435	12286	4250	16102	5548	19345	6662	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	30	4	4366	4570	10701	3892	14682	5082	18312	6313	23282	8019	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	35	4	9570	3781	15564	5449	20619	7110	25119	8648	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	40	4	14086	5137	21074	7273	27209	9375	32776	11310	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	723	761	1629	648	2232	809
RAC	0.05	10	4	0	0	0	0	0	0	0	0	0	0	0	0	1007	1126	1426	1503	2790	1181	3642	1392	4445	1613	6652	2317	-1	-1	-1	-1
RAC	0.05	15	4	0	0	0	0	0	0	0	0	1809	1936	3765	1691	5356	2059	6621	2405	8346	2944	9935	3461	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	20	4	0	0	0	0	1187	2055	2775	2930	6386	2559	8768	3189	11216	3955	13189	4597	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	25	4	0	0	1445	2503	3768	3958	7844	3159	11706	4212	15110	5294	18540	6441	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	30	4	0	0	4053	4286	9326	3767	12975	4730	18159	6363	22665	7872	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	35	4	2309	3999	9201	3995	14339	5289	19070	6742	25617	8905	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	40	4	5257	5574	13863	5378	20184	7195	25927	9050	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	213	370	598	654
RAC	0.01	10	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	709	860	1174	1286	3406	1518	5395	2053	-1	-1
RAC	0.01	15	4	0	0	0	0	0	0	0	0	0	0	0	0	787	1363	1722	1887	3512	1920	5043	2258	6565	2642	-1	-1	-1	-1	-1	-1
RAC	0.01	20	4	0	0	0	0	0	0	0	0	760	1317	2244	2463	4740	2564	6638	2987	9323	3675	11878	4435	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	25	4	0	0	0	0	0	0	877	1519	3193	3476	6929	3403	10304	4231	13153	5027	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	30	4	0	0	0	0	979	1695	3215	3540	8276	4074	12736	5168	17364	6509	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	35	4	0	0	0	0	3281	3661	7597	4369	13951	5797	19775	7445	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	40	4	0	0	1850	3205	5845	6309	12609	5783	20685	7933	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

PFOA Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	1	5	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	10	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	15	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	20	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	25	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	30	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	35	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	40	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	5	0.01	394	346	951	439	956	497	923	483	1003	304	1100	258	1332	443	1573	639	1727	579	1914	625	2188	688	2780	880	3389	1119	3973	1346
Biochar	0.9	10	0.01	1856	968	2047	548	2494	738	3166	1275	3652	1193	4395	1386	5017	1729	5575	1766	6469	2152	7181	2412	7974	2701	-1	-1	-1	-1	-1	-1
Biochar	0.9	15	0.01	3377	801	4780	1910	5476	1789	6622	2098	8024	2537	9400	3214	10727	3600	11983	4058	13662	4684	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	20	0.01	6416	2541	7750	2532	9640	3394	11212	3562	13705	4532	16005	5419	18379	6296	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	25	0.01	9215	3009	12087	4255	14589	4885	17091	5650	20792	6998	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	30	0.01	13419	4298	16913	5387	20553	6796	24095	8158	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	35	0.01	17704	6111	22917	7604	27599	9353	32081	10996	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	40	0.01	22678	7244	29132	9795	35279	12018	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	5	0.01	0	0	0	0	0	0	88	152	384	111	483	227	486	244	481	243	477	232	524	162	550	143	779	302	918	305	1070	338
Biochar	0.8	10	0.01	177	307	910	363	977	483	964	486	976	432	1103	286	1313	381	1561	606	1773	605	1932	626	2149	678	2806	916	3429	1149	4007	1348
Biochar	0.8	15	0.01	1462	690	1451	732	1465	650	1661	430	2144	710	2611	912	2888	938	3230	1019	3771	1282	4215	1376	4688	1550	6027	2029	-1	-1	-1	-1
Biochar	0.8	20	0.01	1941	980	2117	647	2511	672	3141	1223	3711	1230	4315	1362	5074	1725	5628	1837	6471	2165	7267	2407	8044	2707	-1	-1	-1	-1	-1	-1
Biochar	0.8	25	0.01	2461	1080	3150	844	4090	1602	4628	1534	5692	1813	6670	2236	7696	2527	8602	2882	9818	3296	11023	3723	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	30	0.01	3355	867	4739	1849	5565	1845	6499	2050	8056	2697	9411	3113	10865	3601	12089	4069	13783	4665	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	35	0.01	4633	1339	6270	2136	7387	2352	8854	3010	10762	3526	12587	4176	14502	4876	16093	5446	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	40	0.01	6355	2483	7826	2535	9737	3266	11319	3692	13878	4647	16149	5436	18555	6280	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	5	0.01	0	0	0	0	0	0	0	0	0	0	56	97	145	132	247	69	320	141	329	156	332	160	345	146	406	108	496	156
Biochar	0.7	10	0.01	0	0	0	0	118	204	500	138	656	304	664	319	669	315	691	292	773	218	878	237	997	314	1305	433	1586	515	1879	619
Biochar	0.7	15	0.01	169	294	760	211	984	456	999	480	1019	466	1140	335	1311	353	1498	473	1777	637	1961	650	2161	689	2826	932	3441	1129	4039	1342
Biochar	0.7	20	0.01	1026	285	1327	630	1339	640	1389	586	1644	437	2001	633	2391	852	2617	868	2979	950	3390	1116	3771	1244	4862	1617	5909	1981	-1	-1
Biochar	0.7	25	0.01	1649	764	1678	801	1818	635	2048	545	2674	931	3128	1073	3552	1134	3977	1292	4606	1516	5167	1708	5743	1884	7390	2478	-1	-1	-1	-1
Biochar	0.7	30	0.01	2011	968	2094	879	2463	655	3014	955	3775	1293	4337	1382	5063	1666	5666	1869	6488	2125	7302	2430	8106	2694	-1	-1	-1	-1	-1	-1
Biochar	0.7	35	0.01	2367	1117	2733	771	3398	1021	4171	1493	4969	1589	5858	1926	6786	2246	7576	2481	8686	2898	9758	3241	10815	3637	-1	-1	-1	-1	-1	-1
Biochar	0.7	40	0.01	2805	1172	3555	966	4578	1672	5260	1743	6418	2087	7568	2497	8739	2858	9749	3244	11158	3707	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	62	43	75	116	108	216	73	254	115	265	117	287	104
Biochar	0.6	10	0.01	0	0	0	0	0	0	72	124	210	188	433	146	492	215	508	229	522	235	539	233	576	208	735	210	930	321	1086	355
Biochar	0.6	15	0.01	0	0	108	187	312	279	651	220	755	337	779	352	809	350	866	313	966	282	1103	315	1259	405	1633	533	1987	644	2352	773
Biochar	0.6	20	0.01	144	250	466	435	964	405	1019	461	1066	473	1156	418	1300	377	1473	421	1748	584	1969	677	2178	711	2818	914	3448	1135	4052	1339
Biochar	0.6	25	0.01	524	469	1207	506	1285	583	1330	590	1498	494	1724	487	2057	647	2332	805	2660	879	2981	960	3316	1075	4313	1420	5264	1749	-1	-1
Biochar	0.6	30	0.01	1313	446	1534	694	1599	709	1739	628	2083	588	2526	813	2943	1013	3273	1069	3737	1208	4231	1372	4720	1552	6095	2015	-1	-1	-1	-1
Biochar	0.6	35	0.01	1734	754	1842	829	1988	768	2266	662	2871	896	3409	1176	3921	1269	4363	1411	5037	1636	5691	1875	6309	2069	8148	2706	-1	-1	-1	-1
Biochar	0.6	40	0.01	2052	928	2177	938	2500	762	2959	847	3760	1298	4370	1427	5032	1628	5648	1832	6507	2144	7317	2396	8133	2690	-1	-1	-1	-1	-1	-1
Biochar	0.5	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	43	33	57	164	47	202	84	215	91
Biochar	0.5	10	0.01	0	0	0	0	0	0	0	0	0	0	66	114	177	162	327	93	391	157	414	174	431	181	490	184	583	178	697	210
Biochar	0.5	15	0.01	0	0	0	0	0	0	99	171	286	268	574	224	621	261	648	273	687	279	736	276	800	267	1048	316	1301	434	1530	497
Biochar	0.5	20	0.01	0	0	98	170	301	262	656	187	813	338	865	364	920	373	982	368	1099	354	1241	368	1398	422	1842	612	2243	719	2651	861
Biochar	0.5	25	0.01	0	0	377	329	890	303	1013	420	1101	461	1184	466	1316	447	1459	446	1699	507	1942	625	2170	724	2805	899	3450	1123	4053	1329
Biochar	0.5	30	0.01	198	344	986	281	1218	505	1299	547	1428	561	1603	535	1853	551	2099	634	2443	804	2765	919	3069	998	3987	1295	4875	1599	-1	-1
Biochar	0.5	35	0.01	614	558	1377	554	1503	634	1608	654	1841	629	2143	639	2526	777	2852	938	3289	1089	3698	1194	4106	1319	5351	1753	6530	2151	-1	-1
Biochar	0.5	40	0.01	1318	374	1668	701	1803	745	1971	738	2352	719	2802	847	3290	1086	3691	1227	4228	1365	4761	1532	5319	1728	6889	2255	-1	-1	-1	-1
Biochar	0.4	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	46	78	73	160	58
Biochar	0.4	10	0.01	0	0	0	0	0	0	0	0	0	0	0	0	39	68	53	93	144	130	273	74	320	115	379	145	431	159	487	171
Biochar	0.4	15	0.01	0	0	0	0	0	0	0	0	74	128	198	175	403	105	480	173	530	203	569	218	607	229	732	257	891	272	1061	325
Biochar	0.4	20	0.01	0	0	0	0	0	0	107	185	315	292	640	231	710	273	759	291	827	310	898	328	977	342	1262	382	1573	505	1861	607

PFOA Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.4	25	0.01	0	0	0	0	138	239	392	364	829	308	917	353	1002	379	1078	399	1196	424	1335	436	1485	454	1967	631	2418	784	2845	911
Biochar	0.4	30	0.01	0	0	160	278	470	436	960	346	1106	426	1216	459	1343	490	1466	514	1674	528	1894	573	2127	653	2797	913	3422	1095	4042	1311
Biochar	0.4	35	0.01	112	194	503	455	1093	382	1239	476	1403	532	1558	570	1753	604	1954	617	2255	682	2574	801	2887	942	3751	1201	4603	1491	5421	1770
Biochar	0.4	40	0.01	214	371	1091	292	1378	524	1522	583	1734	641	1957	685	2253	707	2527	765	2942	915	3349	1097	3731	1218	4840	1557	5944	1936	-1	-1
Biochar	0.3	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	35	57	50
Biochar	0.3	10	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	56	44	77	113	101	276	89	332	113	379	131
Biochar	0.3	15	0.01	0	0	0	0	0	0	0	0	0	0	0	0	66	114	170	151	340	80	415	134	459	155	570	197	673	235	776	261
Biochar	0.3	20	0.01	0	0	0	0	0	0	0	0	82	141	226	200	464	114	553	179	630	215	697	239	760	262	943	328	1136	364	1347	409
Biochar	0.3	25	0.01	0	0	0	0	0	0	101	175	309	279	642	191	754	254	830	284	930	320	1027	357	1122	392	1420	455	1756	535	2094	664
Biochar	0.3	30	0.01	0	0	0	0	121	210	337	299	775	232	918	311	1040	357	1140	393	1278	446	1415	491	1556	523	2025	615	2518	799	2979	961
Biochar	0.3	35	0.01	0	0	108	188	354	307	789	182	1053	355	1205	413	1360	470	1491	520	1678	580	1872	619	2080	651	2749	856	3393	1096	4001	1275
Biochar	0.3	40	0.01	0	0	177	306	533	489	1105	356	1334	456	1520	524	1716	599	1887	655	2139	708	2412	750	2699	820	3568	1148	4382	1400	5166	1656
Biochar	0.2	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biochar	0.2	10	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	93	82	219	53	274	78
Biochar	0.2	15	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	53	92	139	122	227	72	412	117	515	158	608	195
Biochar	0.2	20	0.01	0	0	0	0	0	0	0	0	0	0	0	0	72	124	185	162	377	70	479	128	549	156	730	228	889	290	1035	341
Biochar	0.2	25	0.01	0	0	0	0	0	0	0	0	64	110	97	168	280	252	545	132	665	187	765	226	858	263	1111	363	1341	441	1569	504
Biochar	0.2	30	0.01	0	0	0	0	0	0	0	0	117	202	418	192	711	188	822	234	963	289	1094	342	1217	391	1554	511	1887	605	2233	686
Biochar	0.2	35	0.01	0	0	0	0	0	0	123	213	388	349	819	214	990	285	1123	337	1300	409	1465	474	1620	531	2069	673	2541	785	3025	927
Biochar	0.2	40	0.01	0	0	0	0	128	221	365	319	876	212	1095	312	1294	389	1457	455	1674	541	1876	615	2071	682	2668	842	3303	1009	3931	1231
Biochar	0.1	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biochar	0.1	10	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	49	85	75
Biochar	0.1	15	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	52	128	112	306	55	404	93
Biochar	0.1	20	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46	80	63	109	170	149	453	91	621	156	770	213
Biochar	0.1	25	0.01	0	0	0	0	0	0	0	0	0	0	0	0	37	64	69	120	197	172	388	49	508	92	775	195	1008	283	1216	358
Biochar	0.1	30	0.01	0	0	0	0	0	0	0	0	0	0	57	99	93	161	253	222	531	79	677	136	806	186	1155	320	1461	430	1741	529
Biochar	0.1	35	0.01	0	0	0	0	0	0	0	0	0	0	106	184	315	277	618	91	815	168	988	235	1151	298	1588	460	1980	600	2345	724
Biochar	0.1	40	0.01	0	0	0	0	0	0	0	0	111	192	335	294	719	110	900	181	1128	268	1340	350	1538	426	2074	619	2565	789	3027	944
Biochar	0.05	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biochar	0.05	10	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	32
Biochar	0.05	15	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	48	101	87	235	21
Biochar	0.05	20	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	63	161	140	397	54	550	108
Biochar	0.05	25	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38	65	63	109	166	144	496	67	735	152	949	230
Biochar	0.05	30	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	54	93	85	147	239	208	466	42	825	162	1140	277	1425	376
Biochar	0.05	35	0.01	0	0	0	0	0	0	0	0	0	0	0	0	70	122	99	171	293	255	594	61	760	117	1210	280	1610	420	1978	547
Biochar	0.05	40	0.01	0	0	0	0	0	0	0	0	0	0	70	122	115	199	317	275	677	69	892	142	1096	215	1647	413	2145	586	2604	741
Biochar	0.01	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biochar	0.01	10	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biochar	0.01	15	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	29
Biochar	0.01	20	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38	67	130	113
Biochar	0.01	25	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	48	83	186	161	440	36
Biochar	0.01	30	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	56	194	169	528	43	809	104
Biochar	0.01	35	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	48	83	79	137	500	60	890	105	1257	220
Biochar	0.01	40	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	54	94	95	164	255	223	825	71	1319	214	1781	363
Biochar	0	0	0.1	30	0	40	0	50	0	60	0	75	0	90	0	106	0	120	0	140	0	160	0	180	0	240	0	300	0	360	0
Biochar	1	5	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

PFOA Filter Performance Table Page 3

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	1	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	5	0.1	64	58	157	78	156	84	149	80	159	52	176	46	215	78	256	111	277	100	308	109	353	122	446	153	545	195	641	235
Biochar	0.9	10	0.1	300	161	324	93	399	132	515	222	587	207	709	247	809	301	895	308	1043	379	1155	420	1285	472	1635	610	1950	739	2237	862
Biochar	0.9	15	0.1	540	144	776	333	879	310	1068	374	1290	445	1517	564	1725	625	1931	709	2203	819	2455	917	2696	1012	3365	1297	3948	1556	4449	1791
Biochar	0.9	20	0.1	1042	443	1246	440	1555	594	1799	620	2204	790	2579	947	2963	1100	3278	1225	3707	1399	4111	1567	4490	1731	5503	2185	6349	2589	-1	-1
Biochar	0.9	25	0.1	1480	522	1950	745	2348	853	2749	985	3345	1218	3882	1434	4436	1662	4892	1854	5502	2114	6066	2361	6589	2598	7940	3238	-1	-1	-1	-1
Biochar	0.9	30	0.1	2167	768	2714	938	3305	1185	3882	1426	4688	1732	5412	2033	6149	2343	6748	2601	7542	2952	8266	3281	8929	3594	-1	-1	-1	-1	-1	-1
Biochar	0.9	35	0.1	2854	1064	3694	1337	4450	1640	5172	1922	6209	2325	7129	2713	8057	3113	8806	3446	9784	3894	10664	4311	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	40	0.1	3639	1260	4687	1706	5683	2099	6594	2464	7890	2991	9014	3474	10138	3971	11036	4381	12194	4930	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	5	0.1	0	0	0	0	0	0	13	23	65	22	79	40	79	41	78	41	77	39	84	28	88	24	127	54	148	53	172	59
Biochar	0.8	10	0.1	26	46	151	67	160	83	156	82	157	71	175	49	211	68	255	108	286	106	311	109	345	118	452	160	553	201	646	236
Biochar	0.8	15	0.1	240	120	235	123	236	107	264	74	347	126	421	160	464	163	519	178	609	226	679	241	755	272	971	355	1175	433	1364	509
Biochar	0.8	20	0.1	314	164	337	110	403	122	513	217	596	214	693	237	819	303	906	321	1043	380	1170	422	1296	473	1655	613	1983	745	2283	871
Biochar	0.8	25	0.1	396	179	505	153	665	281	743	267	916	319	1075	392	1239	442	1387	505	1581	576	1776	651	1961	723	2480	932	2950	1130	3367	1312
Biochar	0.8	30	0.1	532	149	773	328	894	321	1044	357	1298	472	1516	546	1750	631	1947	711	2220	814	2486	921	2737	1022	3433	1311	4048	1578	4585	1823
Biochar	0.8	35	0.1	742	239	1009	374	1187	409	1428	529	1732	617	2027	731	2336	853	2592	951	2950	1094	3291	1232	3614	1364	4496	1741	5259	2084	-1	-1
Biochar	0.8	40	0.1	1036	439	1258	441	1572	578	1822	646	2237	814	2601	950	2988	1096	3319	1230	3764	1409	4184	1582	4582	1749	5653	2219	-1	-1	-1	-1
Biochar	0.7	5	0.1	0	0	0	0	0	0	0	0	0	0	8	15	24	22	42	14	53	25	54	27	54	27	56	24	65	19	80	28
Biochar	0.7	10	0.1	0	0	0	0	18	31	85	28	107	53	108	54	108	53	111	49	123	38	141	42	161	56	210	76	256	90	303	109
Biochar	0.7	15	0.1	25	44	129	42	161	79	162	82	164	78	182	58	210	63	242	84	288	112	316	114	348	121	456	164	554	198	651	235
Biochar	0.7	20	0.1	174	58	216	108	217	108	224	98	262	76	323	112	387	150	421	152	479	166	547	196	608	219	783	284	952	347	1111	408
Biochar	0.7	25	0.1	270	133	271	135	291	109	327	95	435	167	504	188	571	199	641	226	743	267	833	299	925	330	1190	433	1441	531	1673	623
Biochar	0.7	30	0.1	326	164	337	147	393	114	486	169	609	226	698	242	816	293	913	329	1045	373	1177	426	1306	472	1671	613	2012	750	2323	878
Biochar	0.7	35	0.1	382	187	435	133	545	180	675	262	799	278	945	338	1094	394	1220	435	1400	508	1572	568	1743	637	2219	823	2657	1002	3052	1170
Biochar	0.7	40	0.1	451	196	570	172	743	295	847	305	1034	366	1220	439	1408	501	1571	569	1797	649	2020	739	2230	819	2828	1060	3368	1285	3851	1494
Biochar	0.6	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	9	7	11	19	18	36	14	42	20	43	20	46	18
Biochar	0.6	10	0.1	0	0	0	0	0	0	10	18	34	32	72	28	81	38	83	40	85	40	87	39	93	36	118	37	151	57	175	62
Biochar	0.6	15	0.1	0	0	16	27	51	47	109	42	123	59	127	60	131	59	139	54	155	49	177	56	204	72	263	94	320	113	379	136
Biochar	0.6	20	0.1	21	36	76	73	159	72	166	79	173	80	186	72	208	66	236	75	283	104	318	119	351	125	454	161	556	200	653	235
Biochar	0.6	25	0.1	85	79	198	91	209	100	215	100	240	85	276	86	332	115	377	142	429	155	480	169	534	189	695	250	849	307	993	360
Biochar	0.6	30	0.1	218	86	250	120	259	120	279	108	334	103	409	145	476	178	528	188	602	212	682	241	761	273	982	354	1194	433	1393	511
Biochar	0.6	35	0.1	284	133	298	141	320	131	362	115	463	159	551	206	632	223	703	248	812	288	918	330	1017	363	1313	475	1591	583	1850	687
Biochar	0.6	40	0.1	334	160	351	159	400	132	475	150	608	229	704	251	811	286	910	322	1049	378	1179	421	1311	472	1685	615	2036	753	2358	883
Biochar	0.5	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	6	5	9	28	9	33	15	35	16
Biochar	0.5	10	0.1	0	0	0	0	0	0	0	0	0	0	10	17	29	27	55	19	64	28	68	30	70	31	79	32	94	31	112	37
Biochar	0.5	15	0.1	0	0	0	0	0	0	15	26	46	45	94	41	101	46	105	47	111	48	119	47	129	46	169	56	210	77	247	88
Biochar	0.5	20	0.1	0	0	15	25	49	44	110	38	133	59	140	63	149	64	159	63	177	62	200	65	225	75	298	108	362	127	428	152
Biochar	0.5	25	0.1	0	0	61	55	147	58	166	74	179	79	191	80	212	77	235	78	273	90	314	111	351	128	452	159	557	198	654	234
Biochar	0.5	30	0.1	30	51	165	57	199	89	211	95	231	96	258	93	298	97	338	112	395	142	447	162	495	176	643	228	786	282	923	333
Biochar	0.5	35	0.1	99	93	225	99	244	110	260	112	296	109	344	113	407	138	461	166	531	192	596	211	662	232	863	309	1053	379	1233	447
Biochar	0.5	40	0.1	220	76	271	122	292	128	318	127	378	126	451	150	532	192	596	217	682	241	767	270	858	305	1111	397	1354	490	1582	579
Biochar	0.4	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	7	13	12	26	11
Biochar	0.4	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	6	10	8	14	23	22	46	15	53	21	62	26	70	28	79	30
Biochar	0.4	15	0.1	0	0	0	0	0	0	0	0	11	19	32	29	67	22	79	32	86	36	93	38	99	40	119	45	144	48	171	58
Biochar	0.4	20	0.1	0	0	0	0	0	0	16	28	51	49	105	42	116	48	123	51	134	54	145	57	158	60	203	68	254	90	301	108
Biochar	0.4	25	0.1	0	0	0	0	21	36	63	61	136	56	149	62	163	66	175	70	193	74	215	77	239	80	318	112	391	139	459	161
Biochar	0.4	30	0.1	0	0	24	42	76	73	158	63	180	75	197	80	217	86	237	90	270	93	305	101	343	116	452	162	552	194	652	232
Biochar	0.4	35	0.1	16	27	81	76	180	71	202	84	228	93	252	99	283	106	315	109	363	121	415	142	467	167	605	213	743	263	875	313
Biochar	0.4	40	0.1	32	55	182	59	225	93	247	102	281	112	316	120	363	125	407	135	474	162	541	195	603	216	781	275	959	343	1126	403
Biochar	0.3	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	5	9	8
Biochar	0.3	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	8	7	12	18	17	45	17	54	20	62	23
Biochar	0.3	15	0.1	0	0	0	0	0	0	0	0	0	0	0	0	10	17	28	25	57	17	68	25	75	28	93	35	109	42	126	46

PFOA Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.3	20	0.1	0	0	0	0	0	0	0	0	12	21	37	33	77	24	91	33	103	39	113	43	124	47	153	58	184	64	217	73
Biochar	0.3	25	0.1	0	0	0	0	0	0	15	26	50	46	106	37	123	46	135	51	151	57	167	63	182	69	229	81	283	95	338	118
Biochar	0.3	30	0.1	0	0	0	0	18	31	55	50	127	44	150	56	169	64	185	70	207	79	229	87	252	92	326	110	407	142	482	171
Biochar	0.3	35	0.1	0	0	16	27	57	51	131	38	172	64	196	74	221	84	242	92	272	103	303	109	336	116	444	153	549	195	646	227
Biochar	0.3	40	0.1	0	0	27	46	86	81	181	66	217	82	247	93	278	106	306	116	346	125	389	133	435	146	577	204	708	249	834	294
Biochar	0.2	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biochar	0.2	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	14	36	11	45	15
Biochar	0.2	15	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	14	23	20	39	11	67	22	84	29	99	36
Biochar	0.2	20	0.1	0	0	0	0	0	0	0	0	0	0	0	0	11	19	30	27	63	15	78	24	90	29	119	42	145	52	168	61
Biochar	0.2	25	0.1	0	0	0	0	0	0	0	0	10	17	15	25	45	42	90	26	108	35	125	42	140	48	181	66	218	79	254	90
Biochar	0.2	30	0.1	0	0	0	0	0	0	0	0	18	31	73	26	116	36	134	44	157	53	178	62	198	71	252	92	306	108	361	123
Biochar	0.2	35	0.1	0	0	0	0	0	0	19	32	62	58	134	41	161	53	183	62	211	75	238	86	263	96	335	121	411	141	489	166
Biochar	0.2	40	0.1	0	0	0	0	19	33	59	53	144	42	178	58	211	72	237	83	272	98	305	111	336	122	432	151	534	181	636	221
Biochar	0.1	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biochar	0.1	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	7	14	12
Biochar	0.1	15	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	8	21	18	50	12	66	18
Biochar	0.1	20	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	12	10	17	27	24	74	18	101	30	126	40
Biochar	0.1	25	0.1	0	0	0	0	0	0	0	0	0	0	0	0	6	10	11	18	32	28	64	11	83	19	126	37	164	53	198	66
Biochar	0.1	30	0.1	0	0	0	0	0	0	0	0	0	0	9	15	14	24	41	36	87	18	110	28	131	36	188	60	238	80	283	97
Biochar	0.1	35	0.1	0	0	0	0	0	0	0	0	0	0	16	28	51	45	101	21	133	34	161	46	188	57	258	86	322	111	381	133
Biochar	0.1	40	0.1	0	0	0	0	0	0	0	0	17	29	54	48	118	25	147	37	184	52	218	67	250	80	337	114	417	145	492	172
Biochar	0.05	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biochar	0.05	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	5
Biochar	0.05	15	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	7	16	14	39	6
Biochar	0.05	20	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	10	26	23	65	12	90	22
Biochar	0.05	25	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	10	10	17	27	23	81	15	120	31	155	45
Biochar	0.05	30	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	14	13	22	38	34	76	11	134	33	186	54	232	72
Biochar	0.05	35	0.1	0	0	0	0	0	0	0	0	0	0	0	0	11	18	15	26	47	42	97	15	124	26	197	55	262	80	322	103
Biochar	0.05	40	0.1	0	0	0	0	0	0	0	0	0	0	11	18	17	30	51	45	110	18	145	31	179	44	268	79	349	111	424	139
Biochar	0.01	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biochar	0.01	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biochar	0.01	15	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	5
Biochar	0.01	20	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	10	21	18
Biochar	0.01	25	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	13	30	26	72	9
Biochar	0.01	30	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	9	31	27	86	11	132	24
Biochar	0.01	35	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	13	12	21	82	10	145	25	205	47
Biochar	0.01	40	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	14	14	25	41	35	135	19	215	46	291	74
Biochar	0	0	1	30	0	40	0	50	0	60	0	75	0	90	0	106	0	120	0	140	0	160	0	180	0	240	0	300	0	360	0
Biochar	1	5	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	10	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	15	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	20	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	25	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	30	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	5	1	5	9	26	12	26	12	25	11	26	8	28	8	35	13	41	18	44	16	49	18	56	20	71	25	87	32	102	38
Biochar	0.9	10	1	50	23	52	15	64	22	82	36	93	34	113	41	129	49	142	50	166	62	183	68	204	77	259	100	309	120	355	140
Biochar	0.9	15	1	86	25	124	54	140	50	170	62	205	73	241	92	273	102	307	116	350	134	390	150	428	165	534	211	626	252	706	290
Biochar	0.9	20	1	166	72	198	72	247	97	285	101	350	129	409	155	470	180	520	200	588	228	652	255	712	281	873	354	1007	419	1117	475
Biochar	0.9	25	1	235	85	310	121	372	139	436	161	530	198	615	234	703	271	776	302	872	344	962	383	1045	421	1259	524	1430	612	1563	685
Biochar	0.9	30	1	345	127	430	153	524	193	616	233	743	282	858	331	975	381	1070	423	1196	479	1311	532	1416	582	1679	715	1879	824	2029	912

PFOA Filter Performance Table Page 5

BC Material	C/Co	BC Vol%	Inf [µg/L]	Empty Bed Contact Time [minutes]																											
				30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.9	35	1	453	173	586	219	706	268	821	314	984	379	1130	441	1277	506	1396	560	1551	631	1691	698	1816	760	2122	922	2344	1050	2501	1150
Biochar	0.9	40	1	576	206	743	278	901	342	1046	402	1251	487	1429	565	1608	645	1750	710	1933	798	2096	879	2240	954	2581	1142	2817	1286	2973	1394
Biochar	0.8	5	1	0	0	0	0	0	0	0	0	11	3	13	6	13	6	13	6	13	6	13	5	14	4	21	9	24	9	28	10
Biochar	0.8	10	1	0	0	25	10	26	12	26	12	26	11	28	8	34	12	41	18	46	17	50	18	55	19	72	26	88	33	103	38
Biochar	0.8	15	1	39	18	39	18	39	16	42	12	56	21	67	26	74	27	82	29	97	37	108	39	120	44	154	58	187	71	217	83
Biochar	0.8	20	1	52	24	53	19	64	21	82	36	95	35	110	39	130	50	144	53	166	62	186	69	206	77	263	100	315	121	362	142
Biochar	0.8	25	1	65	27	81	26	107	45	118	43	146	52	171	64	197	72	220	83	251	94	282	106	311	118	393	152	468	184	534	213
Biochar	0.8	30	1	85	24	124	54	142	52	166	59	206	77	241	89	278	103	309	116	352	133	395	150	434	167	545	213	642	256	727	296
Biochar	0.8	35	1	118	40	160	61	188	67	227	86	275	101	322	120	371	139	411	155	468	178	522	201	573	222	713	283	834	338	937	388
Biochar	0.8	40	1	166	72	200	72	250	95	289	106	355	133	413	155	474	179	527	201	597	230	664	258	727	285	897	360	1041	428	1162	488
Biochar	0.7	5	1	0	0	0	0	0	0	0	0	0	0	0	0	4	4	7	2	9	4	9	4	9	4	9	4	11	3	13	5
Biochar	0.7	10	1	0	0	0	0	0	0	14	4	18	8	18	8	18	8	18	7	20	6	23	7	26	9	34	12	41	15	48	18
Biochar	0.7	15	1	0	0	21	6	26	12	26	13	27	12	29	9	34	11	39	14	46	18	50	19	55	20	73	27	88	32	104	39
Biochar	0.7	20	1	28	9	35	16	35	17	36	15	42	13	52	18	62	24	67	25	76	27	87	32	97	36	125	46	151	57	176	67
Biochar	0.7	25	1	44	20	44	21	46	18	52	16	70	27	80	31	91	33	102	37	118	44	132	49	147	54	189	71	229	87	266	102
Biochar	0.7	30	1	53	26	55	22	63	19	78	28	97	37	111	40	130	48	145	54	166	61	187	70	208	77	265	100	319	122	369	143
Biochar	0.7	35	1	62	30	69	22	87	30	108	43	127	46	150	55	174	65	194	71	222	83	250	93	277	104	352	134	422	163	484	190
Biochar	0.7	40	1	73	30	91	29	119	48	135	50	164	60	194	72	224	82	249	93	285	106	321	121	354	134	449	173	534	209	611	243
Biochar	0.6	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	3	6	2	7	3	7	3	8	3
Biochar	0.6	10	1	0	0	0	0	0	0	0	0	5	5	12	4	13	6	14	6	14	6	14	6	15	6	19	6	24	9	28	10
Biochar	0.6	15	1	0	0	0	0	8	7	18	7	20	9	21	9	21	9	23	9	25	8	28	9	33	12	42	15	51	19	61	22
Biochar	0.6	20	1	0	0	12	12	26	12	27	13	28	12	30	11	33	11	38	12	45	17	51	19	56	20	72	26	89	33	104	38
Biochar	0.6	25	1	13	12	32	14	34	16	35	15	38	14	44	14	53	19	60	23	68	25	76	28	85	31	111	41	135	50	158	59
Biochar	0.6	30	1	35	14	40	19	42	18	45	17	53	17	65	24	76	29	84	31	96	35	108	39	121	45	156	58	190	71	221	84
Biochar	0.6	35	1	46	21	49	22	51	21	58	19	74	26	88	34	101	37	112	41	129	47	146	54	162	59	209	78	253	95	294	112
Biochar	0.6	40	1	54	26	57	25	64	22	76	25	97	37	112	41	129	47	145	53	167	62	187	69	208	77	268	101	323	123	374	144
Biochar	0.5	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	5	2	6	2	6	2
Biochar	0.5	10	1	0	0	0	0	0	0	0	0	0	0	0	0	5	4	9	3	10	5	11	5	12	5	13	5	15	5	18	6
Biochar	0.5	15	1	0	0	0	0	0	0	0	0	7	7	15	7	17	7	17	7	18	8	19	8	21	8	27	9	34	13	39	14
Biochar	0.5	20	1	0	0	0	0	7	6	18	6	21	10	23	10	24	10	26	10	28	10	32	11	36	12	48	18	58	21	68	25
Biochar	0.5	25	1	0	0	9	8	24	10	27	12	29	13	31	13	34	13	38	13	44	15	50	18	56	21	72	26	89	32	104	38
Biochar	0.5	30	1	0	0	27	10	32	15	34	15	37	15	41	15	48	16	54	19	63	23	71	27	79	29	102	37	125	46	147	55
Biochar	0.5	35	1	16	15	36	16	40	17	42	18	47	18	55	19	65	23	74	27	85	32	95	35	105	38	137	51	167	62	196	73
Biochar	0.5	40	1	36	13	44	20	47	21	51	21	60	21	72	25	85	31	95	36	109	40	122	44	136	50	177	65	215	80	251	95
Biochar	0.4	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	2	5	2
Biochar	0.4	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	4	4	8	3	9	3	10	4	11	4	13	5
Biochar	0.4	15	1	0	0	0	0	0	0	0	0	0	0	5	5	11	4	13	5	14	6	15	6	16	6	19	7	23	8	27	10
Biochar	0.4	20	1	0	0	0	0	0	0	3	4	8	8	17	7	19	8	20	8	22	9	23	9	25	10	33	11	41	15	48	18
Biochar	0.4	25	1	0	0	0	0	3	6	10	10	22	9	24	10	26	11	28	11	31	12	35	13	38	13	51	18	62	23	73	27
Biochar	0.4	30	1	0	0	4	7	12	12	25	10	29	12	32	13	35	14	38	15	43	15	49	17	55	19	72	27	88	32	104	38
Biochar	0.4	35	1	0	0	13	12	29	12	33	14	37	15	41	16	45	17	50	18	58	20	66	23	74	27	96	35	118	43	139	51
Biochar	0.4	40	1	5	9	29	10	36	15	40	17	45	18	51	20	58	20	65	22	76	27	86	32	96	35	124	45	153	56	179	66
Biochar	0.3	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	1
Biochar	0.3	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	3	8	3	9	3	10	4
Biochar	0.3	15	1	0	0	0	0	0	0	0	0	0	0	0	0	2	3	4	4	9	3	11	4	12	5	15	6	18	7	20	8
Biochar	0.3	20	1	0	0	0	0	0	0	0	0	2	3	6	5	13	4	15	6	17	6	18	7	20	8	25	9	29	11	35	12
Biochar	0.3	25	1	0	0	0	0	0	0	0	0	8	8	17	6	20	8	22	8	24	9	27	10	29	11	37	13	45	16	54	20
Biochar	0.3	30	1	0	0	0	0	0	0	9	8	21	7	24	9	27	11	30	12	33	13	37	14	40	15	52	18	65	23	77	28
Biochar	0.3	35	1	0	0	0	0	9	8	21	7	28	11	32	12	36	14	39	15	44	17	48	18	54	19	71	25	88	32	103	37
Biochar	0.3	40	1	0	0	4	7	14	13	29	11	35	14	40	15	45	17	49	19	55	20	62	22	69	24	92	34	113	41	133	48
Biochar	0.2	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biochar	0.2	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	6	2	7	2

PFOA Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.2	15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	4	3	6	2	11	4	14	5	16	6
Biochar	0.2	20	1	0	0	0	0	0	0	0	0	0	0	0	0	2	3	5	4	10	3	13	4	15	5	19	7	23	9	27	10
Biochar	0.2	25	1	0	0	0	0	0	0	0	0	0	0	2	4	7	7	15	5	18	6	20	7	23	8	29	11	35	13	41	15
Biochar	0.2	30	1	0	0	0	0	0	0	0	0	3	5	12	4	19	6	22	7	25	9	29	10	32	12	40	15	49	18	58	20
Biochar	0.2	35	1	0	0	0	0	0	0	3	5	10	10	22	7	26	9	29	10	34	12	38	14	42	16	54	20	66	23	78	28
Biochar	0.2	40	1	0	0	0	0	3	5	9	8	23	7	29	10	34	12	38	14	44	16	49	18	54	20	69	25	85	30	101	37
Biochar	0.1	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biochar	0.1	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	2
Biochar	0.1	15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	8	2	11	3
Biochar	0.1	20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	3	5	4	12	3	16	5	20	7
Biochar	0.1	25	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	5	5	11	2	14	3	20	6	26	9	32	11
Biochar	0.1	30	1	0	0	0	0	0	0	0	0	0	0	0	0	2	4	7	6	14	3	18	5	21	6	30	10	38	13	45	16
Biochar	0.1	35	1	0	0	0	0	0	0	0	0	0	0	2	4	8	7	16	4	21	6	26	8	30	10	42	14	52	19	61	22
Biochar	0.1	40	1	0	0	0	0	0	0	0	0	3	4	9	8	19	5	24	6	30	9	35	11	40	14	54	19	67	24	79	29
Biochar	0.05	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biochar	0.05	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Biochar	0.05	15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	3	2	6	1
Biochar	0.05	20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	4	4	11	2	15	4
Biochar	0.05	25	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	4	4	13	3	19	5	25	8
Biochar	0.05	30	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	4	6	6	12	2	22	6	30	9	37	12
Biochar	0.05	35	1	0	0	0	0	0	0	0	0	0	0	0	0	2	3	2	4	8	7	16	3	20	5	32	9	42	14	52	17
Biochar	0.05	40	1	0	0	0	0	0	0	0	0	0	0	2	3	3	5	8	7	18	3	23	6	29	8	43	14	56	19	68	23
Biochar	0.01	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biochar	0.01	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biochar	0.01	15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Biochar	0.01	20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	4	3
Biochar	0.01	25	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	5	4	12	2
Biochar	0.01	30	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	5	4	14	2	21	5
Biochar	0.01	35	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	3	13	2	24	5	33	8
Biochar	0.01	40	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	4	7	6	22	4	35	8	47	13
RAC	0	0	0.01	30	0	40	0	50	0	60	0	75	0	90	0	106	0	120	0	140	0	160	0	180	0	240	0	300	0	360	0
RAC	1	5	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	10	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	15	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	20	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	25	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	30	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	35	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	40	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	5	0.01	5569	772	5959	911	8474	1282	9325	1367	11443	1826	13265	1989	15457	2390	17125	2599	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	10	0.01	18822	2762	24657	3729	29233	4616	34438	5232	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	15	0.01	40347	6066	51940	7897	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	20	0.01	69637	10599	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	25	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	30	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	35	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	40	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	5	0.01	240	415	2685	400	2826	401	2851	401	2954	425	3381	561	4362	665	4739	699	5195	795	5990	944	6695	1008	8615	1312	-1	-1	-1	-1
RAC	0.8	10	0.01	5744	806	6091	899	8203	1316	9523	1405	11214	1783	13438	2024	15361	2390	17278	2632	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	15	0.01	10334	1728	14351	2117	16806	2671	20227	3047	24640	3800	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	20	0.01	19226	2836	24290	3818	29322	4503	34747	5292	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	25	0.01	28281	4500	36770	5649	45054	6866	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

PFOA Filter Performance Table Page 7

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.8	30	0.01	40878	6155	52405	7979	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	35	0.01	54148	8420	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	40	0.01	70253	10695	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	5	0.01	0	0	0	0	426	738	1690	262	1886	272	1939	277	1996	286	2075	304	2315	367	2808	449	3168	477	3927	613	4872	744	5706	880
RAC	0.7	10	0.01	3408	527	3828	549	3963	566	4168	610	5149	852	6356	956	7096	1072	7876	1230	9191	1409	10314	1579	11454	1768	-1	-1	-1	-1	-1	-1
RAC	0.7	15	0.01	5872	838	6279	920	7708	1276	9564	1438	11223	1724	13354	2061	15418	2359	17211	2656	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	20	0.01	8408	1233	11377	1814	13727	2055	15836	2473	19704	3008	22988	3547	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	25	0.01	12969	2148	17203	2577	20684	3237	24557	3749	30046	4634	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	30	0.01	19311	2901	23881	3728	29531	4506	34603	5339	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	35	0.01	25011	3772	32525	4983	39414	6075	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	40	0.01	32008	4998	41731	6389	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	5	0.01	0	0	0	0	0	0	0	0	934	206	1300	198	1413	207	1467	213	1531	222	1604	235	1703	256	2310	360	2804	426	3267	505
RAC	0.6	10	0.01	0	0	2268	385	2772	409	2944	426	3151	459	3416	514	3973	637	4631	721	5321	807	5916	905	6556	1015	8574	1313	-1	-1	-1	-1
RAC	0.6	15	0.01	3932	598	4429	642	4722	689	5138	774	6485	1035	7766	1179	8842	1352	9849	1524	11420	1764	12876	1972	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	20	0.01	5925	859	6469	951	7481	1175	9304	1449	11326	1724	13153	2036	15384	2374	17188	2633	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	25	0.01	7912	1156	9374	1473	12146	1868	14113	2148	17195	2668	20334	3119	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	30	0.01	10361	1561	14019	2181	16967	2581	19789	3062	24554	3764	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	35	0.01	13932	2226	18792	2849	22538	3479	26784	4136	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	40	0.01	18773	2920	23898	3657	29250	4535	34531	5288	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	831	151	1011	157	1123	167	1193	175	1252	184	1452	220	1766	278	2136	330
RAC	0.5	10	0.01	0	0	0	0	1242	373	2026	314	2335	344	2510	369	2705	403	2908	441	3296	515	3793	595	4285	663	5523	849	6805	1053	-1	-1
RAC	0.5	15	0.01	0	0	3045	472	3496	515	3771	555	4215	633	4787	743	5658	889	6435	995	7408	1134	8292	1275	9225	1434	-1	-1	-1	-1	-1	-1
RAC	0.5	20	0.01	4069	631	4801	706	5275	782	5835	885	7134	1123	8591	1329	9968	1526	11066	1701	12750	1982	14474	2228	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	25	0.01	5846	864	6603	979	7516	1149	8880	1398	11235	1732	13112	2008	15129	2350	17048	2637	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	30	0.01	7584	1116	8780	1331	10673	1680	12916	1997	15828	2423	18496	2874	21616	3328	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	35	0.01	9498	1412	11623	1815	14670	2275	17353	2656	21136	3280	25017	3853	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	40	0.01	11744	1781	15293	2399	19030	2919	22211	3414	27480	4248	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	667	123	835	130	923	139	1097	164	1263	192	1447	223
RAC	0.4	10	0.01	0	0	0	0	0	0	0	0	1551	252	1847	278	2045	305	2197	329	2413	365	2646	404	2901	448	3822	599	4740	728	5558	860
RAC	0.4	15	0.01	0	0	0	0	2310	377	2772	418	3191	477	3539	534	3953	604	4354	672	5001	782	5736	898	6462	999	8356	1294	-1	-1	-1	-1
RAC	0.4	20	0.01	0	0	3346	522	3960	592	4401	659	5084	773	5810	897	6735	1054	7652	1199	8918	1374	10039	1545	11145	1725	-1	-1	-1	-1	-1	-1
RAC	0.4	25	0.01	3846	632	4952	741	5636	846	6329	963	7558	1172	8944	1404	10586	1640	11865	1823	13586	2100	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	30	0.01	5559	838	6611	989	7602	1156	8726	1347	10799	1694	12941	2000	14989	2306	16730	2590	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	35	0.01	7148	1065	8475	1280	9955	1533	11697	1828	14774	2289	17349	2668	20070	3112	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	40	0.01	8829	1321	10627	1625	12773	1989	15335	2401	19104	2935	22323	3455	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	505	105	801	123	958	146	1100	168
RAC	0.3	10	0.01	0	0	0	0	0	0	0	0	0	0	1004	210	1414	223	1602	245	1817	276	2013	306	2204	337	2763	426	3366	528	4039	631
RAC	0.3	15	0.01	0	0	0	0	0	0	1496	317	2273	351	2648	402	3004	457	3305	505	3727	572	4145	639	4578	712	6071	948	7513	1159	-1	-1
RAC	0.3	20	0.01	0	0	0	0	2603	426	3202	490	3849	585	4406	674	5007	769	5527	852	6307	984	7178	1127	8094	1264	-1	-1	-1	-1	-1	-1
RAC	0.3	25	0.01	0	0	3245	534	4143	632	4786	728	5711	874	6558	1009	7505	1165	8414	1319	9832	1538	11225	1740	12522	1932	-1	-1	-1	-1	-1	-1
RAC	0.3	30	0.01	2929	641	4799	734	5744	873	6608	1010	7909	1216	9157	1423	10699	1679	12141	1895	14106	2180	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	35	0.01	4862	769	6351	963	7541	1151	8694	1333	10474	1624	12363	1940	14598	2274	16456	2543	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	40	0.01	6394	978	8043	1224	9562	1466	11052	1704	13534	2121	16187	2527	18974	2931	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	407	89	649	103	796	124
RAC	0.2	10	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	806	178	1177	191	1401	219	1593	247	2111	325	2568	396	3001	465
RAC	0.2	15	0.01	0	0	0	0	0	0	0	0	352	609	1659	276	2082	327	2387	371	2788	431	3163	488	3514	541	4508	699	5520	863	-1	-1
RAC	0.2	20	0.01	0	0	0	0	0	0	1576	361	2596	412	3178	494	3748	579	4213	650	4832	744	5422	837	6007	931	7829	1227	-1	-1	-1	-1
RAC	0.2	25	0.01	0	0	0	0	2298	435	3217	511	4160	645	4953	765	5751	886	6406	988	7321	1134	8242	1283	9191	1438	-1	-1	-1	-1	-1	-1
RAC	0.2	30	0.01	0	0	2307	547	3855	611	4753	738	5970	921	7011	1079	8079	1247	9000	1395	10335	1612	11734	1839	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	35	0.01	0	0	4064	661	5372	834	6474	1000	8011	1233	9341	1441	10776	1672	12051	1879	13964	2190	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	40	0.01	2995	743	5544	869	7042	1089	8394	1294	10279	1584	11986	1858	13888	2166	15632	2450	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	383	74

PFOA Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.1	10	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	165	286	763	148	1341	218	1812	285	2224	346
RAC	0.1	15	0.01	0	0	0	0	0	0	0	0	0	0	0	0	206	357	1135	221	1612	271	2004	326	2370	378	3338	519	4196	648	4989	770
RAC	0.1	20	0.01	0	0	0	0	0	0	0	0	0	0	1501	295	2177	365	2663	433	3307	525	3896	609	4442	690	5950	919	7349	1136	-1	-1
RAC	0.1	25	0.01	0	0	0	0	0	0	0	0	2115	385	2997	494	3828	613	4498	708	5375	836	6193	959	6974	1077	9176	1418	-1	-1	-1	-1
RAC	0.1	30	0.01	0	0	0	0	0	0	2212	440	3610	594	4701	750	5776	904	6639	1031	7800	1206	8902	1374	9964	1538	-1	-1	-1	-1	-1	-1
RAC	0.1	35	0.01	0	0	0	0	2271	512	3697	621	5294	847	6650	1041	7986	1239	9086	1405	10581	1633	12017	1856	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	40	0.01	0	0	364	631	3826	660	5256	854	7191	1131	8820	1370	10469	1619	11839	1827	13720	2118	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RAC	0.05	10	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	712	139	1198	204	1629	265
RAC	0.05	15	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	220	381	1058	208	1438	255	2440	398	3316	524	4113	641
RAC	0.05	20	0.01	0	0	0	0	0	0	0	0	0	0	0	0	315	546	1398	276	2063	361	2672	448	3242	528	4778	751	6165	955	-1	-1
RAC	0.05	25	0.01	0	0	0	0	0	0	0	0	0	0	1310	331	2266	407	2949	504	3864	634	4706	754	5499	870	7692	1192	-1	-1	-1	-1
RAC	0.05	30	0.01	0	0	0	0	0	0	0	0	1576	397	2823	503	3928	660	4829	787	6017	958	7133	1121	8194	1276	-1	-1	-1	-1	-1	-1
RAC	0.05	35	0.01	0	0	0	0	0	0	414	717	3090	557	4484	756	5876	952	6999	1114	8512	1336	9941	1545	11310	1748	-1	-1	-1	-1	-1	-1
RAC	0.05	40	0.01	0	0	0	0	0	0	2691	540	4687	801	6393	1042	8079	1285	9466	1488	11340	1762	13124	2027	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RAC	0.01	10	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	524	121
RAC	0.01	15	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	778	180	1630	300	2424	415
RAC	0.01	20	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	170	295	1022	238	2521	450	3908	652	5205	843
RAC	0.01	25	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1078	283	1896	381	2675	494	4864	812	6898	1111	-1	-1
RAC	0.01	30	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1485	352	2628	509	3732	667	4788	820	7776	1259	-1	-1	-1	-1
RAC	0.01	35	0.01	0	0	0	0	0	0	0	0	0	0	0	0	1960	435	3038	589	4534	803	5958	1011	7334	1213	-1	-1	-1	-1	-1	-1
RAC	0.01	40	0.01	0	0	0	0	0	0	0	0	1917	462	3541	683	4912	879	6777	1150	8570	1413	10300	1668	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0	0	0.1	30	0	40	0	50	0	60	0	75	0	90	0	106	0	120	0	140	0	160	0	180	0	240	0	300	0	360	0
RAC	1	5	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	5	0.1	1130	131	1214	158	1699	238	1882	244	2305	334	2675	358	3114	435	3453	470	3969	542	4446	613	4918	672	6256	850	7476	1008	-1	-1
RAC	0.9	10	0.1	3799	492	4956	682	5900	833	6943	946	8481	1161	9872	1350	11329	1545	12546	1704	14196	1920	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	15	0.1	8137	1093	10472	1427	12717	1741	14864	2032	17995	2448	20741	2808	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	20	0.1	14039	1916	18015	2484	21741	2961	25233	3428	30245	4079	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	25	0.1	21387	2930	27268	3713	32682	4436	37711	5086	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	30	0.1	30066	4113	38062	5171	45353	6117	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	35	0.1	39978	5452	50281	6799	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	40	0.1	51032	6933	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	5	0.1	45	77	537	75	570	71	577	69	600	73	686	100	875	123	954	126	1050	142	1207	172	1348	183	1735	238	2112	291	2470	339
RAC	0.8	10	0.1	1162	140	1238	155	1645	246	1917	254	2265	321	2705	368	3098	432	3480	478	3979	550	4476	614	4959	681	6329	863	7592	1028	-1	-1
RAC	0.8	15	0.1	2095	310	2889	382	3395	481	4072	553	4965	689	5790	799	6692	919	7452	1024	8499	1164	9506	1297	10472	1424	-1	-1	-1	-1	-1	-1
RAC	0.8	20	0.1	3870	512	4892	696	5914	813	6998	961	8545	1175	9954	1367	11442	1566	12692	1732	14398	1955	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	25	0.1	5713	811	7417	1020	9077	1244	10652	1465	12975	1778	15060	2055	17233	2343	19041	2579	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	30	0.1	8229	1118	10555	1448	12811	1762	14986	2058	18187	2482	21022	2858	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	35	0.1	10923	1522	14093	1947	17096	2349	19958	2732	24118	3279	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	40	0.1	14151	1941	18130	2489	21926	3001	25525	3482	30712	4160	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	5	0.1	0	0	0	0	84	146	336	51	379	49	392	49	404	50	421	53	470	65	564	83	637	87	793	111	981	135	1150	160
RAC	0.7	10	0.1	678	102	770	98	801	99	846	106	1039	155	1277	175	1431	193	1589	222	1851	256	2078	286	2309	320	2988	413	3635	500	4242	581
RAC	0.7	15	0.1	1185	147	1273	160	1556	232	1922	263	2265	310	2689	375	3106	428	3469	481	3990	550	4488	621	4980	685	6380	874	7681	1046	-1	-1
RAC	0.7	20	0.1	1705	214	2285	336	2765	371	3195	447	3968	546	4633	643	5371	740	5992	829	6860	944	7702	1057	8514	1167	-1	-1	-1	-1	-1	-1

PFOA Filter Performance Table Page 9

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.7	25	0.1	2618	390	3466	465	4171	586	4945	681	6054	840	7081	977	8185	1126	9115	1254	10400	1426	11634	1590	12819	1745	-1	-1	-1	-1	-1	-1
RAC	0.7	30	0.1	3880	531	4819	673	5947	819	6974	968	8551	1180	9994	1375	11514	1580	12794	1753	14548	1985	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	35	0.1	5044	680	6549	907	7944	1101	9364	1290	11450	1575	13338	1831	15323	2097	16986	2318	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	40	0.1	6459	903	8408	1159	10269	1420	12046	1666	14704	2023	17088	2341	19578	2670	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	5	0.1	0	0	0	0	0	0	0	0	182	44	259	38	284	38	295	38	309	39	325	41	345	45	465	66	565	77	659	92
RAC	0.6	10	0.1	0	0	447	78	555	76	592	77	637	81	692	91	803	115	931	133	1071	147	1192	164	1322	184	1727	239	2114	293	2481	344
RAC	0.6	15	0.1	783	114	891	115	954	121	1041	136	1306	189	1562	215	1782	245	1985	276	2300	321	2593	359	2880	401	3731	517	4540	626	5300	728
RAC	0.6	20	0.1	1191	154	1308	167	1514	210	1870	266	2280	313	2651	369	3097	432	3461	479	3976	554	4485	621	4979	690	6406	882	7739	1060	-1	-1
RAC	0.6	25	0.1	1599	203	1898	262	2442	343	2842	390	3466	484	4093	568	4728	658	5298	735	6074	841	6838	944	7576	1045	9678	1325	-1	-1	-1	-1
RAC	0.6	30	0.1	2098	275	2818	401	3416	468	3989	555	4943	685	5778	804	6702	928	7480	1036	8567	1182	9620	1324	10635	1461	-1	-1	-1	-1	-1	-1
RAC	0.6	35	0.1	2816	401	3781	519	4543	631	5393	753	6610	919	7761	1074	8971	1242	10002	1380	11430	1573	12802	1757	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	40	0.1	3774	537	4815	663	5893	824	6953	962	8544	1185	9988	1384	11533	1592	12841	1768	14638	2008	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	163	31	201	30	225	31	240	32	252	33	293	39	357	50	430	60
RAC	0.5	10	0.1	0	0	0	0	239	80	403	61	468	63	505	66	546	72	588	79	666	93	764	108	862	121	1112	154	1370	192	1613	225
RAC	0.5	15	0.1	0	0	605	91	701	95	759	100	851	113	967	133	1140	162	1295	182	1490	207	1670	232	1858	261	2426	338	2972	413	3490	485
RAC	0.5	20	0.1	808	122	964	128	1063	140	1178	158	1439	204	1728	243	2005	279	2228	309	2568	361	2913	406	3236	451	4199	584	5118	709	5982	826
RAC	0.5	25	0.1	1173	158	1331	175	1519	205	1791	253	2260	317	2639	366	3048	427	3432	481	3948	550	4454	622	4959	690	6399	886	-1	-1	-1	-1
RAC	0.5	30	0.1	1526	201	1774	238	2153	304	2598	366	3185	442	3726	523	4350	607	4861	677	5593	780	6305	876	7001	973	8995	1241	-1	-1	-1	-1
RAC	0.5	35	0.1	1916	252	2348	327	2952	416	3491	485	4258	596	5034	703	5829	812	6528	911	7494	1042	8440	1171	9354	1295	-1	-1	-1	-1	-1	-1
RAC	0.5	40	0.1	2372	318	3081	437	3827	534	4472	621	5531	775	6489	904	7530	1050	8414	1169	9649	1339	10842	1501	12001	1656	-1	-1	-1	-1	-1	-1
RAC	0.4	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	131	26	166	25	185	26	221	30	254	35	292	40
RAC	0.4	10	0.1	0	0	0	0	0	0	0	0	307	50	369	52	410	56	441	60	486	66	533	73	585	81	769	109	953	133	1119	157
RAC	0.4	15	0.1	0	0	0	0	457	75	554	79	640	87	712	97	796	109	878	122	1008	142	1154	164	1299	183	1682	236	2074	291	2443	342
RAC	0.4	20	0.1	0	0	664	101	793	110	884	120	1023	140	1171	162	1357	191	1540	219	1792	252	2019	283	2243	315	2935	411	3594	504	4225	590
RAC	0.4	25	0.1	761	125	992	137	1133	154	1274	174	1524	212	1802	256	2128	301	2385	334	2734	383	3095	436	3459	486	4494	630	5488	766	6430	894
RAC	0.4	30	0.1	1110	158	1328	181	1531	209	1759	244	2175	309	2601	367	3014	422	3367	473	3891	548	4405	617	4899	686	6352	887	7732	1075	-1	-1
RAC	0.4	35	0.1	1433	197	1706	232	2006	278	2358	332	2970	420	3488	488	4039	568	4541	640	5237	734	5909	828	6580	921	8496	1182	-1	-1	-1	-1
RAC	0.4	40	0.1	1773	241	2140	294	2575	361	3086	439	3840	538	4492	631	5239	738	5876	824	6755	947	7629	1067	8473	1183	-1	-1	-1	-1	-1	-1
RAC	0.3	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	99	22	160	23	192	27	221	31
RAC	0.3	10	0.1	0	0	0	0	0	0	0	0	0	0	196	44	281	43	320	46	364	52	403	57	442	62	556	78	678	96	812	116
RAC	0.3	15	0.1	0	0	0	0	0	0	292	67	453	67	530	75	602	85	663	93	749	105	833	117	921	130	1220	174	1509	213	1778	252
RAC	0.3	20	0.1	0	0	0	0	515	85	639	93	771	109	884	124	1005	141	1111	156	1269	179	1444	206	1627	232	2133	301	2623	372	3101	437
RAC	0.3	25	0.1	0	0	642	106	827	119	958	135	1146	161	1318	185	1510	213	1694	241	1976	282	2254	320	2515	356	3278	464	4030	568	4746	668
RAC	0.3	30	0.1	570	136	957	139	1150	162	1325	186	1589	223	1843	260	2153	307	2440	348	2833	401	3199	452	3563	504	4660	657	5706	803	-1	-1
RAC	0.3	35	0.1	965	151	1271	180	1512	213	1746	245	2108	297	2488	355	2933	418	3305	468	3803	537	4300	609	4806	680	6252	881	7641	1072	-1	-1
RAC	0.3	40	0.1	1275	186	1611	227	1919	270	2222	312	2724	388	3253	464	3810	540	4266	603	4915	696	5574	789	6214	876	8064	1133	-1	-1	-1	-1
RAC	0.2	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	80	19	129	20	159	23
RAC	0.2	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	157	37	234	37	279	42	318	47	422	61	514	74	602	86
RAC	0.2	15	0.1	0	0	0	0	0	0	0	0	69	120	329	55	415	63	476	70	557	81	632	92	703	101	904	129	1109	159	1323	190
RAC	0.2	20	0.1	0	0	0	0	0	0	307	76	516	80	634	94	748	109	842	122	967	139	1086	155	1205	172	1573	226	1961	281	2325	332
RAC	0.2	25	0.1	0	0	0	0	452	89	640	99	830	122	990	144	1150	166	1283	184	1468	210	1654	237	1846	265	2450	352	3023	431	3570	509
RAC	0.2	30	0.1	0	0	449	115	766	118	948	140	1193	173	1403	202	1618	232	1805	258	2075	297	2357	339	2649	381	3492	499	4292	613	5075	722
RAC	0.2	35	0.1	0	0	806	130	1071	159	1293	189	1602	231	1871	268	2162	309	2420	347	2805	403	3203	461	3594	515	4695	670	5779	823	-1	-1
RAC	0.2	40	0.1	583	156	1104	167	1406	206	1678	243	2058	295	2404	344	2788	400	3140	451	3659	526	4168	597	4654	664	6076	867	7457	1059	-1	-1
RAC	0.1	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	76	15
RAC	0.1	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	57	151	30	267	42	361	55	443	66
RAC	0.1	15	0.1	0	0	0	0	0	0	0	0	0	0	0	0	41	71	224	45	321	53	399	63	472	73	665	99	837	123	996	145
RAC	0.1	20	0.1	0	0	0	0	0	0	0	0	0	0	296	60	433	71	530	83	658	101	776	117	885	132	1187	174	1468	214	1737	252
RAC	0.1	25	0.1	0	0	0	0	0	0	0	0	419	76	596	95	762	118	896	136	1071	159	1235	182	1391	204	1833	267	2258	328	2680	389
RAC	0.1	30	0.1	0	0	0	0	0	0	437	89	718	115	936	144	1150	173	1323	197	1555	229	1776	260	1989	290	2606	379	3220	468	3835	556
RAC	0.1	35	0.1	0	0	0	0	447	106	735	121	1054	163	1324	199	1591	236	1812	267	2111	309	2399	350	2681	390	3514	511	4360	632	5181	748
RAC	0.1	40	0.1	0	0	74	128	759	130	1046	165	1431	217	1757	261	2087	307	2362	346	2739	400	3106	452	3469	504	4564	663	5663	819	-1	-1

PFOA Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.05	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RAC	0.05	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	142	28	239	40	324	51
RAC	0.05	15	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	44	76	210	42	287	50	486	77	660	100	819	123
RAC	0.05	20	0.1	0	0	0	0	0	0	0	0	0	0	0	0	63	109	278	55	411	70	532	87	645	102	951	144	1227	183	1483	219
RAC	0.05	25	0.1	0	0	0	0	0	0	0	0	0	0	259	68	452	80	588	98	769	122	937	145	1094	167	1531	228	1933	285	2310	339
RAC	0.05	30	0.1	0	0	0	0	0	0	0	0	311	81	562	98	782	128	961	152	1197	184	1419	215	1630	244	2222	328	2774	407	3298	483
RAC	0.05	35	0.1	0	0	0	0	0	0	83	144	615	110	893	146	1170	183	1393	214	1694	256	1978	296	2251	334	3021	444	3749	549	4446	650
RAC	0.05	40	0.1	0	0	0	0	0	0	534	108	934	155	1272	201	1608	247	1883	285	2256	337	2611	388	2954	436	3928	576	4858	711	5755	840
RAC	0.01	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RAC	0.01	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	105	24
RAC	0.01	15	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	156	36	326	59	484	81
RAC	0.01	20	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	60	204	48	504	88	780	126	1038	163
RAC	0.01	25	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	216	57	380	75	535	97	971	157	1376	214	1755	268
RAC	0.01	30	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	297	71	526	100	746	131	956	160	1551	243	2106	322	2627	396
RAC	0.01	35	0.1	0	0	0	0	0	0	0	0	0	0	0	0	392	87	608	116	906	157	1190	197	1464	235	2239	344	2964	447	3647	545
RAC	0.01	40	0.1	0	0	0	0	0	0	0	0	0	0	383	94	709	135	982	172	1354	224	1710	274	2054	322	3031	460	3948	591	4813	715
RAC	0	0	1	30	0	40	0	50	0	60	0	75	0	90	0	106	0	120	0	140	0	160	0	180	0	240	0	300	0	360	0
RAC	1	5	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	10	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	15	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	20	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	25	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	30	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	5	1	233	20	250	27	347	41	386	40	472	58	548	60	637	74	707	79	813	92	910	104	1007	114	1281	143	1531	170	1756	193
RAC	0.9	10	1	779	81	1014	116	1209	143	1422	160	1737	196	2021	228	2319	261	2569	288	2906	323	3225	356	3524	387	4320	465	4985	527	5531	575
RAC	0.9	15	1	1666	183	2144	241	2604	295	3043	344	3684	413	4246	473	4823	533	5295	581	5919	644	6489	699	7009	748	8316	865	-1	-1	-1	-1
RAC	0.9	20	1	2875	324	3688	421	4450	500	5166	578	6192	686	7073	776	7957	865	8663	933	9574	1019	10382	1092	11097	1154	-1	-1	-1	-1	-1	-1
RAC	0.9	25	1	4379	496	5582	627	6691	748	7720	856	9168	1004	10380	1123	11570	1237	12500	1322	13670	1425	14676	1509	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	30	1	6155	696	7792	873	9285	1029	10648	1169	12530	1356	14067	1501	15545	1636	16674	1734	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	35	1	8184	921	10294	1145	12190	1341	13896	1511	16209	1734	18053	1901	19787	2051	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	40	1	10447	1170	13058	1443	15370	1676	17418	1876	20148	2131	22269	2315	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	5	1	8	14	110	13	117	11	119	11	124	12	141	17	179	21	196	21	216	24	247	30	276	31	355	40	432	49	506	57
RAC	0.8	10	1	239	22	255	25	336	43	393	42	464	55	554	62	635	74	712	81	815	93	916	104	1015	115	1296	146	1554	173	1789	198
RAC	0.8	15	1	431	54	592	64	696	82	833	93	1016	117	1185	136	1370	156	1525	173	1740	197	1946	219	2144	240	2691	297	3174	346	3596	387
RAC	0.8	20	1	792	85	1001	120	1211	138	1432	163	1749	199	2038	232	2342	265	2598	293	2948	330	3278	365	3591	397	4433	482	5149	550	5750	605
RAC	0.8	25	1	1171	139	1519	173	1858	211	2180	248	2656	301	3083	347	3528	395	3898	435	4397	487	4863	534	5298	578	6440	688	7374	773	-1	-1
RAC	0.8	30	1	1684	189	2160	246	2622	299	3068	349	3723	420	4303	482	4903	545	5396	596	6053	663	6659	723	7217	777	8646	909	-1	-1	-1	-1
RAC	0.8	35	1	2237	259	2885	331	3500	398	4085	462	4937	554	5684	633	6446	711	7067	774	7886	855	8630	927	9308	990	-1	-1	-1	-1	-1	-1
RAC	0.8	40	1	2896	329	3711	422	4488	508	5225	588	6287	701	7208	797	8139	891	8890	966	9869	1060	10748	1142	11537	1213	-1	-1	-1	-1	-1	-1
RAC	0.7	5	1	0	0	0	0	17	29	69	9	78	8	81	8	83	8	87	9	97	11	116	14	130	15	163	19	201	23	236	27
RAC	0.7	10	1	138	18	158	16	165	16	174	17	213	27	261	30	293	32	326	38	379	44	426	49	473	54	612	70	744	85	868	98
RAC	0.7	15	1	243	24	262	26	319	40	393	45	464	52	551	64	636	73	710	82	817	93	919	105	1019	116	1306	148	1572	177	1816	202
RAC	0.7	20	1	351	35	467	58	566	62	655	76	812	93	949	109	1099	126	1227	141	1404	160	1577	179	1743	197	2210	248	2634	292	3013	330
RAC	0.7	25	1	537	68	710	78	854	100	1012	115	1239	143	1449	166	1675	191	1866	213	2129	241	2382	269	2624	295	3294	365	3887	425	4405	476
RAC	0.7	30	1	793	90	987	115	1217	139	1428	165	1750	200	2045	233	2357	268	2619	297	2978	335	3320	372	3645	406	4531	497	5297	572	5950	633
RAC	0.7	35	1	1033	114	1340	154	1626	187	1916	219	2343	267	2730	310	3136	355	3477	392	3940	441	4378	487	4791	529	5898	640	6834	729	-1	-1
RAC	0.7	40	1	1323	154	1721	197	2102	241	2466	283	3009	343	3498	396	4007	451	4432	496	5006	557	5543	612	6046	663	7376	793	-1	-1	-1	-1
RAC	0.6	5	1	0	0	0	0	0	0	0	0	37	9	53	7	58	6	61	6	64	6	67	7	71	7	95	11	116	13	135	16
RAC	0.6	10	1	0	0	91	14	114	13	121	13	131	13	142	15	165	20	191	23	219	25	244	28	271	31	354	41	433	50	508	58
RAC	0.6	15	1	160	20	183	19	196	20	214	23	268	33	320	37	365	41	407	47	471	55	531	61	590	68	764	88	929	106	1085	123

PFOA Filter Performance Table Page 11

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.6	20	1	244	25	269	27	311	36	383	46	467	53	543	63	634	74	708	81	814	94	918	105	1019	117	1311	149	1584	179	1836	206
RAC	0.6	25	1	328	33	390	45	499	59	582	66	710	82	838	97	968	112	1084	125	1243	143	1399	160	1551	177	1981	224	2377	267	2736	304
RAC	0.6	30	1	431	46	576	69	699	79	817	94	1011	117	1183	137	1372	158	1531	176	1753	201	1969	224	2177	247	2761	310	3290	366	3764	414
RAC	0.6	35	1	578	69	774	88	930	107	1104	128	1353	156	1588	183	1836	211	2047	234	2339	267	2620	297	2890	327	3641	406	4310	475	4900	534
RAC	0.6	40	1	772	92	986	112	1206	141	1423	163	1748	201	2044	235	2360	270	2628	300	2996	340	3347	378	3684	414	4610	511	5423	593	6128	661
RAC	0.5	5	1	0	0	0	0	0	0	0	0	0	0	0	0	33	6	41	5	46	5	49	5	52	5	60	7	73	9	88	10
RAC	0.5	10	1	0	0	0	0	48	16	82	11	96	11	104	11	112	12	121	13	137	16	157	19	177	21	228	26	280	33	330	38
RAC	0.5	15	1	0	0	123	16	143	16	156	17	175	19	199	23	234	28	265	31	305	35	342	39	381	44	497	57	608	70	714	82
RAC	0.5	20	1	165	22	197	21	218	23	242	26	295	35	354	42	410	47	456	53	526	62	596	69	662	77	859	99	1047	120	1224	140
RAC	0.5	25	1	240	27	273	29	312	34	367	43	462	54	540	62	624	73	702	82	808	94	911	106	1015	117	1309	151	1588	181	1847	210
RAC	0.5	30	1	313	33	364	40	441	52	531	63	652	75	763	89	890	103	995	115	1144	133	1290	149	1433	165	1840	211	2220	252	2570	290
RAC	0.5	35	1	393	42	481	56	604	71	714	83	872	102	1030	120	1193	138	1336	155	1533	177	1727	199	1914	220	2447	279	2938	331	3384	378
RAC	0.5	40	1	486	53	631	75	783	91	915	106	1132	132	1328	154	1541	179	1721	199	1974	228	2218	255	2455	281	3123	354	3732	418	4279	475
RAC	0.4	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	5	34	4	38	5	45	5	52	6	60	7
RAC	0.4	10	1	0	0	0	0	0	0	0	0	62	9	75	9	84	10	90	10	100	11	109	12	120	14	158	19	195	23	229	27
RAC	0.4	15	1	0	0	0	0	93	14	113	14	131	15	146	16	163	18	180	21	207	24	236	28	266	31	344	40	424	50	500	58
RAC	0.4	20	1	0	0	135	18	162	19	181	20	210	24	240	27	278	33	315	38	367	43	413	48	459	54	600	70	735	86	864	100
RAC	0.4	25	1	154	23	203	23	232	26	261	29	312	36	369	44	435	52	488	57	559	65	633	75	708	83	919	107	1123	130	1315	152
RAC	0.4	30	1	226	27	272	30	313	35	360	41	445	53	532	63	616	72	689	81	796	94	901	105	1002	117	1299	151	1581	183	1846	212
RAC	0.4	35	1	293	33	349	39	411	47	483	57	607	72	713	83	826	97	929	109	1071	125	1209	141	1346	157	1738	201	2107	242	2450	280
RAC	0.4	40	1	363	41	438	50	527	61	631	75	785	92	919	108	1071	126	1202	141	1382	161	1560	182	1733	201	2230	257	2694	308	3122	355
RAC	0.3	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	4	33	4	39	5	45	5
RAC	0.3	10	1	0	0	0	0	0	0	0	0	0	0	40	9	57	8	65	8	74	9	83	10	91	11	114	13	139	16	166	20
RAC	0.3	15	1	0	0	0	0	0	0	59	13	92	12	108	13	123	14	136	16	153	18	171	20	189	22	250	30	309	37	364	43
RAC	0.3	20	1	0	0	0	0	105	16	130	16	157	19	181	21	206	24	227	26	260	31	296	35	333	40	436	52	536	64	634	75
RAC	0.3	25	1	0	0	130	19	169	21	196	23	234	27	270	31	309	36	347	41	404	49	461	55	514	61	670	80	824	97	970	114
RAC	0.3	30	1	114	27	195	24	235	28	271	32	325	38	377	44	440	53	499	60	579	69	654	77	729	86	953	112	1167	137	1370	160
RAC	0.3	35	1	196	27	259	31	309	36	357	42	431	50	509	61	600	72	675	80	777	92	879	104	982	116	1278	151	1562	183	1830	213
RAC	0.3	40	1	260	33	329	39	392	46	454	53	557	66	665	80	779	93	872	103	1005	119	1139	135	1270	150	1648	193	2008	234	2345	272
RAC	0.2	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	4	27	4	33	4
RAC	0.2	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	7	48	7	57	7	65	8	86	11	105	13	123	15
RAC	0.2	15	1	0	0	0	0	0	0	0	0	14	24	67	10	85	11	97	12	114	14	129	16	144	17	185	22	227	27	271	33
RAC	0.2	20	1	0	0	0	0	0	0	62	15	105	14	129	16	153	19	172	21	198	24	222	27	246	30	322	39	401	48	475	57
RAC	0.2	25	1	0	0	0	0	91	17	130	18	169	21	202	25	235	29	262	32	300	36	338	41	377	45	501	61	617	74	729	87
RAC	0.2	30	1	0	0	90	23	156	21	193	25	243	30	286	35	331	40	369	44	424	51	482	58	541	66	713	86	877	105	1036	124
RAC	0.2	35	1	0	0	164	24	218	28	264	33	327	40	382	46	442	53	494	59	573	69	654	79	734	89	959	115	1180	141	1390	165
RAC	0.2	40	1	117	32	225	30	287	36	342	42	420	51	491	59	570	69	642	78	748	91	851	103	950	114	1241	149	1523	181	1791	213
RAC	0.1	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	3
RAC	0.1	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	11	31	6	54	8	74	10	90	12
RAC	0.1	15	1	0	0	0	0	0	0	0	0	0	0	0	0	8	14	46	9	65	10	81	11	96	13	136	17	171	21	203	25
RAC	0.1	20	1	0	0	0	0	0	0	0	0	0	0	60	11	88	13	108	15	134	18	158	21	180	23	242	30	299	37	354	44
RAC	0.1	25	1	0	0	0	0	0	0	0	0	85	14	121	17	155	21	182	24	218	28	251	32	283	36	374	46	461	57	547	67
RAC	0.1	30	1	0	0	0	0	0	0	88	17	146	21	190	26	234	31	269	35	317	40	362	45	405	50	531	66	657	81	782	96
RAC	0.1	35	1	0	0	0	0	90	21	149	22	214	29	269	35	324	41	369	47	430	54	489	61	546	68	717	88	889	109	1056	129
RAC	0.1	40	1	0	0	15	26	154	24	213	30	291	39	358	46	425	54	481	60	558	69	633	78	707	87	931	115	1155	142	1366	167
RAC	0.05	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RAC	0.05	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	5	49	7	66	9
RAC	0.05	15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	15	43	8	58	9	99	14	134	18	167	22
RAC	0.05	20	1	0	0	0	0	0	0	0	0	0	0	0	0	13	22	57	10	84	13	108	16	131	18	193	26	250	32	302	38
RAC	0.05	25	1	0	0	0	0	0	0	0	0	0	0	52	13	92	15	120	18	156	22	191	26	223	30	311	40	393	50	470	59
RAC	0.05	30	1	0	0	0	0	0	0	0	0	63	16	114	18	159	23	195	27	244	33	289	38	332	43	452	58	564	71	671	84
RAC	0.05	35	1	0	0	0	0	0	0	17	29	125	20	182	27	238	33	283	38	344	45	402	52	458	59	615	78	763	96	905	113

PFOA Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.05	40	1	0	0	0	0	0	0	108	21	190	28	259	36	327	44	383	51	459	60	531	68	601	77	799	101	989	124	1172	146
RAC	0.01	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RAC	0.01	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	5
RAC	0.01	15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	7	66	11	99	15
RAC	0.01	20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	12	42	9	103	16	159	23	211	29
RAC	0.01	25	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	44	11	77	14	109	18	198	29	280	38	357	48
RAC	0.01	30	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	14	107	19	152	24	195	29	315	44	428	57	534	70
RAC	0.01	35	1	0	0	0	0	0	0	0	0	0	0	0	0	80	17	124	22	184	29	242	36	298	42	455	62	602	80	741	97
RAC	0.01	40	1	0	0	0	0	0	0	0	0	0	0	78	18	144	25	200	32	275	41	348	49	418	58	616	82	802	105	977	126

PFOS Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																													
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	1	5	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	10	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	15	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	20	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	25	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	30	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	35	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	40	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	5	0.01	19460	7031	21284	9261	23584	2578	22598	1936	23170	691	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	10	0.01	45468	3858	51277	6209	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	15	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	20	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	25	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	30	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	35	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	40	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	5	0.01	0	0	2269	3929	2144	3713	2026	3510	10842	4373	10845	4188	12078	1374	11954	1066	11873	837	12579	385	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	10	0.01	11404	1494	21828	8835	24168	3412	23995	2125	24185	1328	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	15	0.01	32856	12548	36116	3180	36281	2000	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	20	0.01	48312	4256	51141	1774	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	25	0.01	60912	3292	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	30	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	35	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	40	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	5	0.01	0	0	0	0	0	0	1502	2601	1485	2572	1437	2490	6798	2231	7289	2658	7439	2627	8151	1294	8326	879	8775	411	-1	-1	-1	-1	-1	-1
Biochar	0.7	10	0.01	3038	5261	2954	5117	12166	3140	14635	5323	15271	4646	16697	1751	16995	1222	17592	816	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	15	0.01	4363	7558	22028	8004	22884	7007	25108	2620	25954	1560	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	20	0.01	29470	10717	32907	5110	33878	2782	35348	1630	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	25	0.01	38424	11586	42449	3468	45335	1544	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	30	0.01	50589	5232	53273	2427	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	35	0.01	60067	4357	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	40	0.01	71340	3234	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	5	0.01	0	0	0	0	0	0	0	0	983	1703	1121	1942	1131	1959	1131	1959	3864	415	5346	1638	5620	1789	6354	938	6841	489	-1	-1	-1	-1
Biochar	0.6	10	0.01	0	0	2165	3750	2277	3944	2276	3942	10124	2793	11267	3579	11786	3254	12735	1871	13381	1207	14064	782	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	15	0.01	3405	5898	3426	5934	15133	4141	16938	5373	18607	3625	19875	2007	21072	1198	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	20	0.01	4575	7924	21555	6589	23220	7018	25564	3746	27598	1942	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	25	0.01	25376	6947	29087	8771	32463	4134	34428	2436	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	30	0.01	34101	10783	38492	5605	41382	2922	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	35	0.01	41510	11599	47217	4218	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	40	0.01	51484	7447	56770	3130	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	808	1400	879	1523	914	1584	939	1627	964	1670	4556	1190	5013	1056	5528	666		
Biochar	0.5	10	0.01	0	0	0	0	1393	2413	1770	3065	1869	3237	1936	3353	8426	2040	9127	2378	9721	2309	10397	1830	11087	1326	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	15	0.01	0	0	2663	4612	2802	4853	2911	5041	13312	3423	14385	3549	15562	2787	16650	1990	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	20	0.01	3551	6151	3786	6558	15548	3115	18306	4768	20215	4216	22225	2658	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	25	0.01	4693	8128	19462	3881	23320	6015	25202	5276	28572	2885	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	30	0.01	5859	10148	27539	7150	30283	6331	33414	3984	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	35	0.01	29400	6947	34248	8092	38424	5054	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	40	0.01	36786	9518	41881	7315	47382	3666	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	640	1109	718	1244	760	1317	864	1496	3729	708	4156	774		
Biochar	0.4	10	0.01	0	0	0	0	0	0	0	0	1391	2410	1526	2643	1637	2835	1732	3000	7007	1214	7797	1497	8331	1548	9885	1264	-1	-1	-1	-1	-1	-1
Biochar	0.4	15	0.01	0	0	0	0	2081	3604	2293	3972	2534	4389	10003	1518	11659	2235	12507	2322	13584	2283	14836	1897	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	20	0.01	0	0	2889	5004	3198	5538	3469	6009	15018	2843	16687	3100	18222	3033	19791	2534	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

PFOS Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.4	25	0.01	3477	6023	4008	6941	11272	1833	18698	3526	21415	3890	23642	3595	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	30	0.01	4606	7978	5221	9042	22452	4227	25070	4644	28515	4310	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	35	0.01	5743	9946	24571	4207	28824	5397	31777	5323	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	40	0.01	6977	12085	31300	5966	35370	6169	39666	5064	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	490	849	658	1141	773	1339	2895	223
Biochar	0.3	10	0.01	0	0	0	0	0	0	0	0	0	0	982	1701	1203	2083	1320	2286	1472	2550	1623	2811	5802	445	7532	931	-1	-1	-1	-1
Biochar	0.3	15	0.01	0	0	0	0	0	0	1469	2545	1898	3288	2153	3728	2424	4198	8698	661	10227	1172	11299	1394	12292	1550	-1	-1	-1	-1	-1	-1
Biochar	0.3	20	0.01	0	0	0	0	2281	3950	2637	4568	3108	5384	11589	877	13740	1588	15067	1861	16833	2118	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	25	0.01	0	0	2857	4949	3399	5887	3870	6704	15396	1456	17975	2153	20217	2544	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	30	0.01	2910	5041	3963	6865	4646	8047	17360	1286	21673	2597	24594	3094	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	35	0.01	4178	7236	5157	8932	19175	960	23862	2720	28244	3544	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	40	0.01	5286	9156	6499	11257	26141	2812	30137	3698	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	384	664	536	928	651	1128
Biochar	0.2	10	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	766	1327	990	1714	1151	1993	1305	2261	4978	249	6521	278	-1	-1
Biochar	0.2	15	0.01	0	0	0	0	0	0	0	0	0	0	1416	2453	1713	2966	1956	3387	2300	3983	7455	379	8741	251	-1	-1	-1	-1	-1	-1
Biochar	0.2	20	0.01	0	0	0	0	0	0	1510	2615	2148	3720	2603	4508	3092	5355	9924	509	12121	401	13894	704	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	25	0.01	0	0	0	0	2086	3613	2669	4623	3415	5915	10315	1732	14235	386	16270	687	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	30	0.01	0	0	2241	3881	3199	5541	3899	6753	12508	2025	17441	497	20688	1026	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	35	0.01	0	0	3436	5951	4408	7634	5346	9259	19781	534	23891	1153	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.2	40	0.01	2944	5099	4570	7915	5802	10050	19696	1118	26113	1111	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	327	567
Biochar	0.1	10	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	655	1135	1100	1906	1508	2612	4663	775
Biochar	0.1	15	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	978	1693	1320	2286	1646	2850	1968	3410	6999	1164	-1	-1	-1	-1
Biochar	0.1	20	0.01	0	0	0	0	0	0	0	0	0	0	1293	2240	1780	3084	2186	3786	2752	4766	6806	2527	9310	1554	-1	-1	-1	-1	-1	-1
Biochar	0.1	25	0.01	0	0	0	0	0	0	0	0	1780	3083	2454	4250	3177	5503	3748	6491	11026	2085	13739	1567	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	30	0.01	0	0	0	0	0	0	1921	3327	2956	5119	3908	6768	9505	4270	13902	2343	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	35	0.01	0	0	0	0	2051	3552	3034	5254	4391	7605	8068	7529	17034	2571	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.1	40	0.01	0	0	0	0	3164	5479	4321	7485	5997	10387	18441	3151	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biochar	0.05	10	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	588	1018	983	1703	1351	2340
Biochar	0.05	15	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	875	1515	1169	2024	2025	3508	6008	1991	-1	-1
Biochar	0.05	20	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1156	2002	1679	2909	2211	3829	2691	4661	-1	-1	-1	-1	-1	-1
Biochar	0.05	25	0.01	0	0	0	0	0	0	0	0	0	0	1159	2007	1844	3194	2421	4194	3210	5561	3909	6771	9941	3324	-1	-1	-1	-1	-1	-1
Biochar	0.05	30	0.01	0	0	0	0	0	0	0	0	1393	2413	2297	3979	3251	5630	4012	6949	9595	4707	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	35	0.01	0	0	0	0	0	0	0	0	2516	4359	3706	6419	4882	8456	11100	5533	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.05	40	0.01	0	0	0	0	0	0	2245	3889	3851	6670	5316	9207	13157	6101	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.01	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biochar	0.01	10	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	422	730
Biochar	0.01	15	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	627	1086	1341	2322	2007	3476
Biochar	0.01	20	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	823	1426	2077	3597	-1	-1	-1	-1
Biochar	0.01	25	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	890	1541	1527	2645	2202	3814	-1	-1	-1	-1	-1	-1
Biochar	0.01	30	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1203	2084	2138	3702	3078	5332	3966	6869	-1	-1	-1	-1	-1	-1
Biochar	0.01	35	0.01	0	0	0	0	0	0	0	0	0	0	0	0	1576	2729	2470	4279	3742	6481	4949	8573	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.01	40	0.01	0	0	0	0	0	0	0	0	0	0	1560	2701	2886	4998	4055	7023	5630	9752	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0	0	0.1	30	0	40	0	50	0	60	0	75	0	90	0	106	0	120	0	140	0	160	0	180	0	240	0	300	0	360	0
Biochar	1	5	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

PFOS Filter Performance Table Page 3

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	1	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	5	0.1	2998	1203	3191	1457	3468	503	3310	382	3378	121	5234	951	5742	983	6000	575	6572	431	8138	1261	8624	917	-1	-1	-1	-1	-1	-1
Biochar	0.9	10	0.1	6662	769	7404	681	11235	2349	12048	1153	15689	2251	17301	1835	20640	2857	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	15	0.1	15996	3002	18137	1729	23514	3364	26027	2752	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	20	0.1	24273	2310	32893	5078	37782	4250	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	25	0.1	39597	5751	47459	5370	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	30	0.1	52524	5515	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	35	0.1	72789	10039	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	5	0.1	0	0	320	554	303	525	287	497	1636	706	1622	664	1779	267	1756	215	1738	173	1834	67	2130	74	3111	370	3582	326	4412	567
Biochar	0.8	10	0.1	1888	246	3283	1419	3566	644	3525	432	3537	287	4289	150	5852	1068	6237	741	6678	569	8073	1057	8854	1135	-1	-1	-1	-1	-1	-1
Biochar	0.8	15	0.1	4911	1995	5303	645	5303	432	6475	228	9115	1395	9826	882	12033	1554	13302	1704	14889	1668	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	20	0.1	7093	861	7446	245	11396	2089	12529	1477	14555	1366	17765	2274	20088	2303	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	25	0.1	8905	716	14290	2621	15938	1668	18119	1683	22877	2744	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	30	0.1	13237	506	18880	2210	21806	2034	26737	3415	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	35	0.1	20660	3776	23641	2005	30748	4038	34980	3939	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	40	0.1	25282	2934	32748	4317	38312	4140	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	5	0.1	0	0	0	0	0	0	211	366	209	363	203	352	1037	382	1099	435	1113	423	1205	237	1227	173	1285	97	1754	203	2103	302
Biochar	0.7	10	0.1	425	735	415	719	1885	592	2208	875	2279	756	2461	348	2496	263	2577	194	2929	105	3894	588	4219	606	5163	532	6464	787	-1	-1
Biochar	0.7	15	0.1	614	1063	3320	1314	3414	1139	3699	521	3806	349	4222	146	5816	872	6338	909	6962	703	7755	799	8865	1052	-1	-1	-1	-1	-1	-1
Biochar	0.7	20	0.1	4440	1757	4862	942	4980	580	5175	388	7147	867	8463	1214	9357	924	10355	1068	12234	1468	13657	1640	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	25	0.1	5733	1888	6241	727	6630	390	8877	1054	10881	1464	12220	1144	14536	1715	16210	1972	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	30	0.1	7455	1044	7801	580	10684	1275	12735	1823	14754	1383	17795	2112	20420	2456	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	35	0.1	8824	939	10389	380	14652	2157	16339	1644	20310	2392	23663	2856	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.7	40	0.1	10444	766	15751	2373	18098	2088	20825	2152	26142	3177	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	5	0.1	0	0	0	0	0	0	0	0	137	237	158	273	159	276	159	276	608	113	809	279	844	297	941	174	1007	108	1091	75
Biochar	0.6	10	0.1	0	0	302	523	319	553	320	554	1545	498	1693	596	1759	542	1886	349	1973	251	2068	187	2189	151	3144	387	3748	433	4342	452
Biochar	0.6	15	0.1	476	825	481	833	2309	740	2543	894	2761	641	2933	405	3098	284	3288	226	3883	326	4720	581	5176	655	6531	680	-1	-1	-1	-1
Biochar	0.6	20	0.1	643	1114	3261	1125	3471	1159	3783	696	4062	431	4390	302	5286	474	6301	775	7102	883	7917	856	8714	907	-1	-1	-1	-1	-1	-1
Biochar	0.6	25	0.1	3873	1243	4350	1452	4800	793	5069	542	5672	371	7351	846	8524	1081	9395	1085	10652	1102	12059	1344	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	30	0.1	5121	1796	5698	1046	6092	650	6605	454	8888	1028	10383	1313	11837	1286	13093	1363	15259	1769	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	35	0.1	6199	1931	6964	880	7598	550	9120	772	11930	1513	13715	1503	15690	1660	17815	2066	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.6	40	0.1	7619	1388	8343	745	9645	647	12657	1555	15145	1740	17483	1819	20572	2403	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	113	196	124	214	129	223	132	229	136	235	683	204	747	184	819	129
Biochar	0.5	10	0.1	0	0	0	0	192	333	248	429	262	454	272	471	1276	367	1370	410	1451	397	1545	329	1642	259	1928	162	2365	219	2893	317
Biochar	0.5	15	0.1	0	0	372	645	393	680	408	707	2004	597	2148	608	2312	500	2465	389	2682	273	2895	243	3162	270	4351	477	5300	599	6160	649
Biochar	0.5	20	0.1	497	861	531	920	2373	602	2745	820	3009	736	3290	519	3598	358	3863	324	4373	382	5113	506	5804	637	7444	786	-1	-1	-1	-1
Biochar	0.5	25	0.1	658	1139	2973	755	3493	1033	3753	922	4226	590	4653	414	5192	439	5926	549	7053	754	8018	963	8843	999	-1	-1	-1	-1	-1	-1
Biochar	0.5	30	0.1	822	1424	4132	1233	4509	1107	4947	779	5613	497	6340	541	7626	749	8718	956	10035	1205	11177	1180	12361	1303	-1	-1	-1	-1	-1	-1
Biochar	0.5	35	0.1	4458	1264	5112	1394	5695	967	6283	639	7260	612	8806	858	10485	1185	11715	1406	13265	1379	14942	1628	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.5	40	0.1	5517	1639	6221	1316	6995	809	7753	648	9557	886	11637	1275	13500	1610	14916	1573	17083	1860	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.4	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	90	155	101	175	107	185	121	210	559	131	620	140
Biochar	0.4	10	0.1	0	0	0	0	0	0	0	0	195	337	214	370	229	398	243	421	1057	235	1167	274	1243	281	1468	245	1728	180	1970	176
Biochar	0.4	15	0.1	0	0	0	0	291	504	321	556	355	615	1515	311	1744	408	1865	421	2021	418	2203	368	2405	296	2962	264	3622	328	4418	485
Biochar	0.4	20	0.1	0	0	405	701	448	777	486	843	2252	526	2488	562	2711	555	2938	491	3293	379	3623	353	3951	353	5213	514	6479	733	-1	-1
Biochar	0.4	25	0.1	485	840	561	972	1783	116	2806	655	3192	707	3515	670	3959	508	4325	452	4839	438	5367	471	6040	547	8102	917	-1	-1	-1	-1
Biochar	0.4	30	0.1	645	1117	732	1267	3369	785	3739	844	4240	804	4819	594	5415	531	5932	530	6736	592	7824	771	8861	973	-1	-1	-1	-1	-1	-1
Biochar	0.4	35	0.1	804	1393	3709	820	4303	983	4730	976	5536	723	6278	621	7082	627	7861	691	9352	948	10688	1192	11836	1331	-1	-1	-1	-1	-1	-1
Biochar	0.4	40	0.1	978	1694	4681	1089	5266	1123	5889	982	6961	722	7915	705	9071	797	10437	1026	12217	1361	13716	1534	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.3	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	69	119	93	160	108	188	435	57
Biochar	0.3	10	0.1	0	0	0	0	0	0	0	0	0	0	137	237	168	292	185	320	206	357	227	394	873	114	1122	188	1319	218	1529	217
Biochar	0.3	15	0.1	0	0	0	0	0	0	205	354	266	461	302	522	339	588	1308	170	1525	245	1682	281	1829	309	2298	325	2755	277	3169	275

PFOS Filter Performance Table Page 4

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.3	20	0.1	0	0	0	0	319	553	370	640	435	754	1742	225	2049	330	2243	375	2504	421	2777	443	3064	434	3859	361	4640	411	5575	545
Biochar	0.3	25	0.1	0	0	399	692	476	825	542	939	2307	335	2678	441	3009	508	3299	545	3740	549	4187	501	4593	462	5800	514	7291	733	-1	-1
Biochar	0.3	30	0.1	405	701	555	961	650	1127	2612	336	3229	531	3660	617	4145	664	4597	651	5226	578	5790	542	6353	551	8381	819	-1	-1	-1	-1
Biochar	0.3	35	0.1	584	1012	722	1250	2899	313	3561	571	4204	709	4800	774	5504	746	6098	674	6864	630	7640	663	8510	772	-1	-1	-1	-1	-1	-1
Biochar	0.3	40	0.1	740	1283	910	1576	3904	603	4486	746	5303	872	6129	866	7020	764	7721	722	8731	756	9879	902	11174	1091	-1	-1	-1	-1	-1	-1
Biochar	0.2	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	54	93	75	130	91	158
Biochar	0.2	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	107	185	139	240	161	280	183	317	745	26	969	85	1158	128
Biochar	0.2	15	0.1	0	0	0	0	0	0	0	0	0	0	198	344	240	416	274	475	322	557	1114	38	1300	89	1739	192	2143	283	2503	321
Biochar	0.2	20	0.1	0	0	0	0	0	0	211	365	301	522	365	632	433	749	1483	50	1802	136	2064	198	2317	256	3022	402	3668	426	4298	417
Biochar	0.2	25	0.1	0	0	0	0	292	505	374	648	478	828	1563	144	2119	135	2418	210	2817	301	3203	393	3569	470	4584	532	5574	525	6506	577
Biochar	0.2	30	0.1	0	0	313	541	448	776	546	946	1894	165	2595	176	3074	292	3472	382	4021	512	4530	602	5011	641	6458	627	7821	694	-1	-1
Biochar	0.2	35	0.1	0	0	481	833	617	1069	748	1295	2945	182	3551	333	4169	474	4689	597	5378	713	6033	751	6699	737	8592	767	-1	-1	-1	-1
Biochar	0.2	40	0.1	410	711	640	1109	812	1407	2945	94	3880	335	4624	507	5403	691	6035	800	6892	857	7762	839	8606	835	-1	-1	-1	-1	-1	-1
Biochar	0.1	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46	80
Biochar	0.1	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	92	159	154	267	211	366	691	77
Biochar	0.1	15	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	137	238	185	321	231	400	276	477	1037	115	1448	47	1830	93
Biochar	0.1	20	0.1	0	0	0	0	0	0	0	0	0	0	182	314	250	433	307	531	385	667	1023	294	1379	154	2104	67	2752	183	3322	284
Biochar	0.1	25	0.1	0	0	0	0	0	0	0	0	250	432	344	596	445	771	525	909	1635	214	2035	130	2407	79	3438	228	4332	387	5158	519
Biochar	0.1	30	0.1	0	0	0	0	0	0	269	466	414	718	547	947	1440	504	2060	232	2617	127	3147	99	3656	185	4985	426	6198	624	-1	-1
Biochar	0.1	35	0.1	0	0	0	0	287	497	425	737	615	1065	1327	877	2524	244	3049	148	3768	127	4447	251	5061	365	6768	658	-1	-1	-1	-1
Biochar	0.1	40	0.1	0	0	0	0	444	769	606	1049	839	1454	2732	314	3525	164	4184	131	5075	285	5876	432	6636	566	8768	903	-1	-1	-1	-1
Biochar	0.05	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biochar	0.05	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	83	143	138	239	189	328
Biochar	0.05	15	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	123	213	164	284	284	492	887	240	1259	166
Biochar	0.05	20	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	163	282	236	408	310	537	377	653	1350	286	2006	156	2601	83
Biochar	0.05	25	0.1	0	0	0	0	0	0	0	0	0	0	162	281	259	449	340	588	450	779	548	949	1468	400	2502	196	3430	103	4275	195
Biochar	0.05	30	0.1	0	0	0	0	0	0	0	0	195	339	323	559	456	789	562	974	1427	587	2013	430	2506	334	3899	124	5135	234	6273	404
Biochar	0.05	35	0.1	0	0	0	0	0	0	0	0	353	612	519	900	684	1185	1653	690	2438	483	3108	351	3766	225	5514	207	7108	439	-1	-1
Biochar	0.05	40	0.1	0	0	0	0	0	0	315	546	540	936	745	1290	1953	759	2666	576	3543	404	4398	242	5182	165	7353	387	-1	-1	-1	-1
Biochar	0.01	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biochar	0.01	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	59	103
Biochar	0.01	15	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	88	153	188	326	282	488
Biochar	0.01	20	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	116	201	292	505	456	791	1217	536
Biochar	0.01	25	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	125	217	215	372	309	536	568	984	1688	647	2531	516
Biochar	0.01	30	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	169	294	300	520	432	749	557	964	1815	804	3037	619	4176	462
Biochar	0.01	35	0.1	0	0	0	0	0	0	0	0	0	0	0	0	222	384	347	601	525	910	694	1202	972	1398	3065	793	4653	570	6148	381
Biochar	0.01	40	0.1	0	0	0	0	0	0	0	0	0	0	220	381	406	703	569	986	790	1368	1602	1220	2396	1072	4541	757	6547	491	-1	-1
Biochar	0	0	1	30	0	40	0	50	0	60	0	75	0	90	0	106	0	120	0	140	0	160	0	180	0	240	0	300	0	360	0
Biochar	1	5	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	10	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	15	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	20	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	25	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	30	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	1	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	5	1	449	190	470	219	504	83	480	62	488	21	772	160	839	158	872	99	950	75	1190	208	1255	156	1617	228	1961	303	2283	377
Biochar	0.9	10	1	966	125	1064	85	1646	374	1750	197	2300	382	2516	312	3017	480	3241	456	3774	612	4141	646	4581	756	5762	1066	6799	1374	-1	-1
Biochar	0.9	15	1	2356	499	2635	296	3446	571	3785	468	4735	747	5490	879	6184	957	6884	1135	7797	1371	8655	1602	9457	1834	-1	-1	-1	-1	-1	-1
Biochar	0.9	20	1	3526	396	4809	836	5482	698	6514	913	7925	1218	9194	1516	10481	1841	11556	2139	12959	2545	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	25	1	5803	973	6886	882	8374	1137	9884	1521	11922	1983	13757	2484	15584	3003	17053	3449	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	30	1	7638	937	9820	1370	11885	1828	13840	2280	16615	3007	18983	3684	21344	4421	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

PFOS Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																													
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
Biochar	0.9	35	1	10639	1685	13357	2161	15887	2651	18303	3216	21818	4193	24764	5113	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.9	40	1	13157	1828	16808	2647	20250	3544	23235	4303	27500	5573	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Biochar	0.8	5	1	0	0	45	78	43	75	41	71	242	108	238	100	259	44	255	35	252	29	265	12	307	11	453	62	520	55	644	95		
Biochar	0.8	10	1	294	52	483	215	519	104	512	71	512	48	617	24	857	173	909	125	969	98	1180	179	1291	190	1656	245	1993	306	2313	369		
Biochar	0.8	15	1	720	300	770	106	768	71	932	37	1331	228	1427	151	1759	263	1940	285	2165	279	2487	367	2721	394	3479	555	4182	730	4808	895		
Biochar	0.8	20	1	1030	142	1076	43	1672	342	1825	249	2111	230	2591	380	2922	385	3320	490	3753	552	4223	660	4642	741	5861	1041	6955	1350	-1	-1		
Biochar	0.8	25	1	1289	118	2096	429	2319	284	2627	284	3333	460	3922	580	4475	649	5000	768	5671	897	6348	1061	6980	1218	8698	1688	-1	-1	-1	-1		
Biochar	0.8	30	1	1908	87	2750	373	3162	343	3899	571	4740	702	5463	792	6315	986	6977	1114	7909	1333	8804	1564	9651	1797	-1	-1	-1	-1	-1	-1		
Biochar	0.8	35	1	3024	611	3430	344	4486	675	5086	660	6262	909	7318	1140	8366	1362	9234	1556	10441	1865	11572	2182	12634	2499	-1	-1	-1	-1	-1	-1		
Biochar	0.8	40	1	3683	496	4789	731	5572	699	6676	985	8067	1241	9320	1488	10643	1800	11755	2088	13233	2496	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
Biochar	0.7	5	1	0	0	0	0	0	0	30	52	30	52	29	50	155	60	162	67	164	64	176	38	179	29	187	17	258	36	307	50		
Biochar	0.7	10	1	60	104	59	102	283	97	326	134	334	115	358	57	363	44	374	33	423	19	570	98	616	100	751	90	943	132	1093	148		
Biochar	0.7	15	1	87	151	490	201	500	173	538	85	552	59	610	26	852	146	925	150	1013	121	1128	136	1293	178	1644	223	2006	295	2347	367		
Biochar	0.7	20	1	655	270	709	152	724	97	750	67	1050	153	1236	201	1362	159	1506	181	1784	248	1991	276	2194	298	2825	418	3417	547	3959	675		
Biochar	0.7	25	1	840	287	907	120	960	69	1304	186	1587	243	1777	197	2119	290	2363	332	2680	360	3041	443	3347	491	4273	684	5129	891	5904	1098		
Biochar	0.7	30	1	1085	171	1131	100	1569	225	1859	301	2145	239	2594	357	2977	413	3297	447	3812	565	4244	628	4711	737	5955	1015	7100	1321	-1	-1		
Biochar	0.7	35	1	1281	157	1500	68	2140	356	2378	282	2961	404	3449	480	3956	548	4451	659	5050	758	5661	890	6243	1020	7853	1419	-1	-1	-1	-1		
Biochar	0.7	40	1	1515	133	2307	398	2637	352	3029	366	3811	535	4404	598	5129	760	5666	838	6473	1017	7234	1191	7947	1355	-1	-1	-1	-1	-1	-1		
Biochar	0.6	5	1	0	0	0	0	0	0	0	0	19	33	22	39	23	39	23	39	92	21	120	44	125	46	138	28	147	18	159	13		
Biochar	0.6	10	1	0	0	43	74	45	79	45	79	230	79	249	92	258	83	275	56	287	42	301	32	318	27	459	66	547	74	632	77		
Biochar	0.6	15	1	68	117	68	119	343	118	374	137	403	101	427	67	450	49	477	40	565	57	689	99	755	110	951	116	1186	166	1374	186		
Biochar	0.6	20	1	91	158	483	176	510	178	552	112	591	73	637	54	770	84	920	132	1036	148	1154	147	1269	155	1666	232	2026	292	2361	351		
Biochar	0.6	25	1	575	198	638	223	700	128	737	92	823	66	1074	146	1244	182	1370	184	1551	189	1756	227	1979	278	2534	365	3065	462	3569	572		
Biochar	0.6	30	1	754	277	831	168	886	110	958	81	1299	178	1515	220	1725	220	1906	233	2224	300	2502	349	2758	374	3551	528	4292	688	4975	850		
Biochar	0.6	35	1	909	296	1014	146	1103	97	1327	135	1740	254	1999	257	2284	282	2597	350	2968	410	3328	462	3710	542	4737	748	5689	965	-1	-1		
Biochar	0.6	40	1	1112	224	1213	130	1399	114	1848	265	2209	296	2545	311	2999	408	3340	465	3806	528	4300	631	4738	705	6043	991	7233	1287	-1	-1		
Biochar	0.5	5	1	0	0	0	0	0	0	0	0	0	0	0	0	16	28	18	30	18	32	19	33	19	34	101	32	110	29	120	21		
Biochar	0.5	10	1	0	0	0	0	27	46	35	61	37	65	39	67	189	58	202	64	213	62	226	52	240	42	281	29	344	38	422	55		
Biochar	0.5	15	1	0	0	53	91	56	97	58	101	295	94	315	95	338	79	360	63	391	47	421	43	460	47	635	82	773	102	897	111		
Biochar	0.5	20	1	70	122	75	131	353	99	404	128	441	116	480	85	524	62	562	57	636	67	745	88	847	110	1085	135	1332	177	1567	218		
Biochar	0.5	25	1	93	162	442	124	513	161	549	144	616	98	677	73	755	77	863	96	1028	130	1170	164	1290	171	1665	221	2031	280	2385	347		
Biochar	0.5	30	1	117	202	608	193	660	174	722	127	817	88	922	94	1111	130	1271	164	1465	205	1629	203	1800	223	2357	327	2868	418	3342	506		
Biochar	0.5	35	1	659	202	749	217	832	157	915	110	1056	107	1283	149	1529	203	1710	239	1933	237	2176	277	2445	330	3142	443	3815	574	4449	713		
Biochar	0.5	40	1	813	258	910	210	1020	138	1128	115	1392	155	1697	220	1971	274	2174	271	2488	317	2838	385	3144	437	4049	600	4892	773	5673	948		
Biochar	0.4	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	22	14	25	15	26	17	30	83	21	91	22		
Biochar	0.4	10	1	0	0	0	0	0	0	0	0	28	48	30	53	33	57	35	60	156	38	172	44	182	45	215	40	252	31	287	31		
Biochar	0.4	15	1	0	0	0	0	41	71	46	79	50	87	224	52	256	65	273	67	296	67	322	60	351	50	432	47	527	57	645	84		
Biochar	0.4	20	1	0	0	57	99	64	110	69	120	332	85	365	90	397	89	430	80	481	65	528	62	576	62	760	90	946	126	1104	138		
Biochar	0.4	25	1	69	119	80	138	271	16	413	105	468	113	514	108	578	86	631	79	705	78	781	83	879	96	1182	157	1431	178	1694	227		
Biochar	0.4	30	1	92	158	104	180	496	127	548	135	620	129	704	101	790	93	864	94	980	104	1141	135	1293	168	1659	208	2037	273	2392	334		
Biochar	0.4	35	1	114	198	547	134	631	156	693	156	808	122	916	109	1031	111	1144	121	1364	165	1560	205	1727	229	2223	289	2730	381	3192	460		
Biochar	0.4	40	1	139	240	688	175	772	180	861	160	1016	126	1153	125	1320	140	1522	179	1783	235	2002	264	2213	277	2886	395	3500	495	4103	619		
Biochar	0.3	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	17	13	23	15	27	64	10		
Biochar	0.3	10	1	0	0	0	0	0	0	0	0	0	0	19	34	24	41	26	46	29	51	32	56	129	20	164	31	193	36	224	36		
Biochar	0.3	15	1	0	0	0	0	0	0	29	50	38	65	43	74	48	83	193	30	224	41	246	46	268	51	336	55	402	49	462	49		
Biochar	0.3	20	1	0	0	0	0	45	78	52	91	62	107	257	40	301	55	329	62	367	69	407	73	449	73	563	64	676	73	813	96		
Biochar	0.3	25	1	0	0	57	98	68	117	77	133	339	58	392	73	441	84	483	90	548	92	612	86	671	82	845	91	1063	128	1264	165		
Biochar	0.3	30	1	57	99	79	136	92	160	385	60	473	88	536	102	607	110	673	109	764	101	845	97	926	99	1222	144	1519	198	1779	227		
Biochar	0.3	35	1	83	144	102	178	428	59	522	96	616	117	703	128	805	126	891	117	1001	113	1113	119	1240	136	1666	213	2029	261	2382	313		
Biochar	0.3	40	1	105	182	129	224	574	103	657	124	777	144	897	146	1026	134	1127	129	1272	136	1439	159	1629	192	2145	280	2609	336	3084	427		
Biochar	0.2	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	13	11	19	13	23		
Biochar	0.2	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	26	20	34	23	40	26	45	110	6	142	16	170	23		

PFOS Filter Performance Table Page 6

BC		BC	Inf	Empty Bed Contact Time [minutes]																													
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360			
Biochar	0.2	15	1	0	0	0	0	0	0	0	0	0	0	28	49	34	59	39	67	46	79	164	9	190	18	255	34	314	49	367	55		
Biochar	0.2	20	1	0	0	0	0	0	0	30	52	43	74	52	90	61	106	218	12	264	26	302	36	339	45	443	69	537	74	628	75		
Biochar	0.2	25	1	0	0	0	0	41	72	53	92	68	118	231	13	310	27	354	39	412	54	469	68	523	81	671	93	814	95	949	104		
Biochar	0.2	30	1	0	0	44	76	64	110	77	134	280	15	380	35	450	53	508	68	589	89	663	103	734	110	944	112	1141	126	1349	156		
Biochar	0.2	35	1	0	0	68	118	88	152	106	184	431	37	520	61	610	84	687	103	787	122	883	129	980	130	1254	139	1533	175	1837	227		
Biochar	0.2	40	1	58	100	91	157	115	199	433	23	568	63	677	90	792	120	884	137	1009	148	1135	148	1258	150	1611	179	2004	243	2383	308		
Biochar	0.1	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	11		
Biochar	0.1	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	23	22	38	30	52	101	9		
Biochar	0.1	15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	34	26	46	33	57	39	68	152	13	212	8	268	20		
Biochar	0.1	20	1	0	0	0	0	0	0	0	0	0	0	26	45	36	62	44	75	55	95	151	37	202	17	308	15	403	37	486	54		
Biochar	0.1	25	1	0	0	0	0	0	0	0	0	35	61	49	85	63	109	74	129	239	25	297	13	352	12	503	46	634	72	755	94		
Biochar	0.1	30	1	0	0	0	0	0	0	38	66	59	102	78	134	213	64	301	26	382	13	460	22	535	40	730	80	907	113	1073	139		
Biochar	0.1	35	1	0	0	0	0	41	71	60	105	87	151	200	114	368	26	445	15	551	29	651	52	741	71	991	121	1222	158	1443	182		
Biochar	0.1	40	1	0	0	0	0	63	109	86	149	119	206	399	35	515	17	612	29	743	60	860	84	971	107	1284	163	1579	201	1863	225		
Biochar	0.05	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Biochar	0.05	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	20	20	34	27	47		
Biochar	0.05	15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	30	23	40	40	70	129	31	184	19		
Biochar	0.05	20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	40	34	58	44	76	54	93	197	36	293	16	380	14		
Biochar	0.05	25	1	0	0	0	0	0	0	0	0	0	0	23	40	37	64	48	84	64	111	78	135	214	52	366	20	501	21	625	43		
Biochar	0.05	30	1	0	0	0	0	0	0	0	0	28	48	46	79	65	112	80	138	209	78	293	54	366	39	570	21	751	52	918	82		
Biochar	0.05	35	1	0	0	0	0	0	0	0	0	50	87	74	128	97	168	242	91	355	60	453	39	550	22	806	47	1040	90	1257	129		
Biochar	0.05	40	1	0	0	0	0	0	0	45	78	77	133	106	183	286	100	389	73	517	45	643	24	757	27	1076	83	1368	135	1640	182		
Biochar	0.01	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Biochar	0.01	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	15		
Biochar	0.01	15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	22	27	46	40	69		
Biochar	0.01	20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	29	41	72	65	112	177	72		
Biochar	0.01	25	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	31	31	53	44	76	81	140	245	87	369	64		
Biochar	0.01	30	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	42	43	74	61	106	79	137	263	109	443	77	610	51		
Biochar	0.01	35	1	0	0	0	0	0	0	0	0	0	0	0	0	32	55	49	85	75	129	98	171	142	195	446	102	679	65	898	37		
Biochar	0.01	40	1	0	0	0	0	0	0	0	0	0	0	31	54	58	100	81	140	112	194	233	168	348	145	662	91	956	49	1233	40		
RAC	0	0	0.01	30	0	40	0	50	0	60	0	75	0	90	0	106	0	120	0	140	0	160	0	180	0	240	0	300	0	360	0		
RAC	1	5	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
RAC	1	10	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
RAC	1	15	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
RAC	1	20	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
RAC	1	25	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
RAC	1	30	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
RAC	1	35	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
RAC	1	40	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
RAC	0.9	5	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
RAC	0.9	10	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
RAC	0.9	15	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
RAC	0.9	20	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
RAC	0.9	25	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
RAC	0.9	30	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
RAC	0.9	35	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
RAC	0.9	40	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
RAC	0.8	5	0.01	50483	30873	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
RAC	0.8	10	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
RAC	0.8	15	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
RAC	0.8	20	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
RAC	0.8	25	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		

PFOS Filter Performance Table

BC Material	C/Co	BC Vol%	Inf [µg/L]	Empty Bed Contact Time [minutes]																													
				30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.8	30	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	35	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	40	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	5	0.01	15997	18030	33900	19580	34191	20354	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	10	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	15	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	20	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	25	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	30	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	35	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	40	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	5	0.01	0	0	3068	5314	13988	17086	25707	14636	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	10	0.01	51749	29449	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	15	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	20	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	25	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	30	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	35	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	40	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	5	0.01	0	0	0	0	2304	3990	9651	11152	19703	10795	21294	11857	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	10	0.01	19394	22389	40985	22654	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	15	0.01	64390	35833	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	20	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	25	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	30	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	35	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	40	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	5	0.01	0	0	0	0	0	0	0	0	5299	5135	9028	10826	16934	9092	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	10	0.01	0	0	15704	18116	32436	17319	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	15	0.01	27210	32604	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	20	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	25	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	30	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	35	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	40	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	5	0.01	0	0	0	0	0	0	0	0	0	0	1419	2458	6489	7464	11155	6188	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	10	0.01	0	0	0	0	9903	10244	21970	12430	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	15	0.01	4260	7379	32299	18809	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	20	0.01	41848	25519	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	25	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	30	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	35	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	40	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1105	1913	5107	5735	9030	5086	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	10	0.01	0	0	0	0	0	0	2204	3817	11778	13570	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	15	0.01	0	0	3288	5695	17465	20098	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	20	0.01	4357	7546	25474	29556	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	25	0.01	28822	33098	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	30	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	35	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	40	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	678	1174	912	1580	-1	-1	-1	-1	-1	-1	-1	-1

PFOS Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.1	10	0.01	0	0	0	0	0	0	0	0	0	0	1808	3132	9199	10234	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	15	0.01	0	0	0	0	0	0	2685	4650	15601	17501	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	20	0.01	0	0	0	0	15144	16292	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	25	0.01	0	0	18577	19866	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	30	0.01	5223	9047	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	35	0.01	29827	32873	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	40	0.01	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	826	1431	-1	-1	-1	-1
RAC	0.05	10	0.01	0	0	0	0	0	0	0	0	0	0	1124	1946	1629	2822	8333	9011	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	15	0.01	0	0	0	0	0	0	0	0	2030	3516	11109	11886	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	20	0.01	0	0	0	0	0	0	3160	5474	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	25	0.01	0	0	0	0	4347	7529	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	30	0.01	0	0	4618	7998	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	35	0.01	0	0	27293	29372	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	40	0.01	5991	10377	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	5	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	618	1071
RAC	0.01	10	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1211	2098	-1	-1	-1	-1	-1	-1
RAC	0.01	15	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1769	3064	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	20	0.01	0	0	0	0	0	0	0	0	0	0	2294	3974	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	25	0.01	0	0	0	0	0	0	0	0	3362	5822	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	30	0.01	0	0	0	0	0	0	3271	5666	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	35	0.01	0	0	0	0	3240	5611	20202	20118	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	40	0.01	0	0	0	0	16816	15779	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0	0	0.1	30	0	40	0	50	0	60	0	75	0	90	0	106	0	120	0	140	0	160	0	180	0	240	0	300	0	360	0
RAC	1	5	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	5	0.1	18633	13185	24588	13623	29123	19023	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	10	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	15	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	5	0.1	7352	4888	6857	4590	7332	3579	9451	6381	12160	7771	13446	7809	15539	9798	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	10	0.1	19092	12911	25555	14638	30110	18893	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	15	0.1	40969	23886	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	20	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	25	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	5	0.1	2347	2928	4982	3199	4968	3245	4874	3190	5161	2764	6098	3653	7345	4657	8504	5281	9404	5559	10587	6391	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	10	0.1	9817	6426	10604	5553	13745	8923	17088	10611	20146	12036	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	15	0.1	18625	11249	25751	15985	30191	18030	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	20	0.1	34493	21404	42851	25875	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

PFOS Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.7	25	0.1	50753	30328	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	30	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	35	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	5	0.1	0	0	347	602	2029	2680	3763	2390	3850	2461	3896	2488	4056	2522	4435	2492	5319	3277	6280	3806	6969	4252	-1	-1	-1	-1	-1	-1
RAC	0.6	10	0.1	7574	4813	7749	4954	7979	5072	8913	5010	11581	7119	13980	8531	15913	9517	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	15	0.1	11804	7536	13431	7552	17332	10658	21032	12834	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	20	0.1	17992	10119	25388	15383	30469	18523	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	25	0.1	29121	17898	38196	23219	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	30	0.1	42440	25892	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	35	0.1	55976	33550	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	40	0.1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	5	0.1	0	0	0	0	257	446	1410	1787	2898	1799	3099	1938	3228	2015	3343	2082	3546	2190	3858	2294	4286	2532	5837	3536	-1	-1	-1	-1
RAC	0.5	10	0.1	2833	3591	5998	3740	6387	3992	6709	4179	7433	4493	8595	5078	10252	6109	11697	7086	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	15	0.1	9371	5859	10096	6287	11133	6734	12925	7636	16540	9945	19566	11911	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	20	0.1	13503	8407	15562	9256	19316	11447	23480	14223	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	25	0.1	18662	11282	24203	14342	30571	18575	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	30	0.1	26050	15392	35355	21411	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	35	0.1	35896	21354	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	40	0.1	47311	28650	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	5	0.1	0	0	0	0	0	0	0	0	790	871	1305	1697	2473	1513	2639	1614	2838	1729	3036	1842	3239	1972	3950	2350	4902	2927	-1	-1
RAC	0.4	10	0.1	0	0	2288	2894	4757	2907	5289	3236	5907	3590	6489	3951	7181	4406	7910	4707	9131	5389	10499	6298	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	15	0.1	3930	5109	7949	4863	8841	5372	9748	5935	11314	6885	13221	7759	15660	9391	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	20	0.1	10619	6494	12207	7402	13868	8494	15861	9443	19775	11810	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	25	0.1	14784	8980	17361	10631	20581	12096	24613	14694	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	30	0.1	19585	11914	23854	14206	29563	17645	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	35	0.1	25157	15414	32135	18957	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	40	0.1	31889	19002	42233	25323	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	5	0.1	0	0	0	0	0	0	0	0	0	162	280	941	1186	1662	1047	2105	1261	2335	1394	2546	1513	3139	1888	3677	2218	4236	2525
RAC	0.3	10	0.1	0	0	0	0	1457	1693	3280	2095	4471	2675	5094	3027	5738	3431	6279	3777	7007	4226	7711	4650	8492	5061	-1	-1	-1	-1	-1	-1
RAC	0.3	15	0.1	483	837	4836	3143	6676	3993	7643	4541	9032	5418	10248	6178	11516	6944	12741	7594	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	20	0.1	6294	4214	9345	5578	11004	6553	12565	7555	14792	8919	16992	10129	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	25	0.1	11127	6653	13758	8191	16179	9739	18412	11101	22164	13141	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	30	0.1	15290	9079	18855	11333	22101	13322	25502	15203	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	35	0.1	19963	11914	24559	14804	29037	17377	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	40	0.1	25150	15115	30909	18615	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	126	218	738	911	1342	855	1728	1011	2370	1389	2932	1733	3420	2022
RAC	0.2	10	0.1	0	0	0	0	0	0	251	434	1693	2132	3446	2018	4162	2421	4731	2773	5498	3248	6202	3663	6847	4047	-1	-1	-1	-1	-1	-1
RAC	0.2	15	0.1	0	0	374	648	2510	3158	5154	3017	6669	3889	7957	4695	9242	5459	10261	6065	11638	6903	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	20	0.1	497	861	3657	4627	7776	4529	9431	5524	11748	6942	13670	8078	15627	9269	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	25	0.1	4148	5209	9698	5647	12264	7203	14594	8623	17742	10495	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	30	0.1	10214	5977	14099	8251	17492	10333	20471	12093	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	35	0.1	14275	8294	19116	11283	23309	13760	27078	16055	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	40	0.1	18739	10961	24654	14554	29714	17598	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	74	129	104	181	1276	738	1884	1085	2420	1402
RAC	0.1	10	0.1	0	0	0	0	0	0	0	0	0	0	206	358	1315	1607	2530	1466	3368	1924	4121	2386	4833	2801	6714	3907	-1	-1	-1	-1
RAC	0.1	15	0.1	0	0	0	0	0	0	307	531	2225	2738	4732	2693	6100	3528	7224	4186	8694	5042	10048	5846	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	20	0.1	0	0	0	0	2179	2593	4962	2891	7476	4302	9597	5562	11683	6776	13366	7775	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	25	0.1	0	0	2673	3168	6757	3869	9238	5311	12672	7335	15555	9036	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	30	0.1	597	1034	7292	4272	11032	6337	14294	8281	18722	10875	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	35	0.1	4276	5186	11474	6537	16005	9274	20061	11625	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	40	0.1	9509	5624	16064	9279	21603	12501	26485	15400	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

PFOS Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.05	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	94	163	988	604	1559	893
RAC	0.05	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	126	218	186	322	1184	1412	2391	1364	3102	1777	5058	2898	-1	-1	-1	-1
RAC	0.05	15	0.1	0	0	0	0	0	0	0	0	232	402	1580	1867	3491	1996	4616	2643	6134	3515	7551	4326	8876	5101	-1	-1	-1	-1	-1	-1
RAC	0.05	20	0.1	0	0	0	0	0	0	362	626	3679	2447	6105	3494	8261	4731	10020	5739	12358	7106	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	25	0.1	0	0	0	0	496	858	3396	4073	8282	4753	11309	6468	14316	8223	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	30	0.1	0	0	527	914	4030	4832	9012	5150	13593	7771	17543	10078	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	35	0.1	0	0	3883	4611	9822	5596	13973	8007	19750	11338	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	40	0.1	683	1183	8947	5138	14551	8354	19670	11256	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	5	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	71	122
RAC	0.01	10	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	138	239	1935	1166	3614	2055	-1	-1
RAC	0.01	15	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	202	350	1333	1485	2849	1722	4121	2392	-1	-1	-1	-1	-1	-1
RAC	0.01	20	0.1	0	0	0	0	0	0	0	0	0	0	263	455	1807	2017	3729	2263	5978	3442	8175	4631	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	25	0.1	0	0	0	0	0	0	0	0	383	663	2750	3139	6350	3711	8766	4988	12114	6857	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	30	0.1	0	0	0	0	0	0	374	648	3280	3740	7935	4616	11889	6734	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	35	0.1	0	0	0	0	373	646	2841	3141	8505	4987	13464	7630	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.01	40	0.1	0	0	0	0	2377	2486	6888	4285	13736	7820	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0	0	1	30	0	40	0	50	0	60	0	75	0	90	0	106	0	120	0	140	0	160	0	180	0	240	0	300	0	360	0
RAC	1	5	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	10	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	15	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	20	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	25	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	30	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	1	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	5	1	2670	2017	3494	2075	4182	2865	5084	3205	6211	3931	7170	4590	8389	5379	9322	5987	10529	6778	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	10	1	10292	6511	13416	8691	16228	10408	18759	12048	22480	14467	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	15	1	21792	13954	28308	18180	33711	21694	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	20	1	37969	24386	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	25	1	56671	36472	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	30	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	35	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.9	40	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	5	1	1059	726	984	672	1032	553	1356	985	1753	1157	1917	1182	2227	1485	2574	1617	2920	1890	3281	2093	3654	2348	4683	3004	5627	3619	-1	-1
RAC	0.8	10	1	2738	1992	3644	2233	4317	2881	5176	3252	6209	3994	7334	4714	8416	5400	9390	6025	10692	6871	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	15	1	5842	3615	7804	4903	9309	5989	11041	7098	13443	8632	15580	10012	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	20	1	10460	6572	13303	8483	16123	10321	18882	12116	22765	14644	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	25	1	15654	10066	20220	12945	24396	15678	28382	18257	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	30	1	22325	14355	28474	18274	34134	21957	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	35	1	29684	19043	37863	24336	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.8	40	1	38171	24497	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	5	1	343	453	722	485	715	484	700	473	729	427	875	567	1053	711	1223	795	1346	841	1516	975	1692	1095	2201	1418	2689	1724	3132	2009
RAC	0.7	10	1	1408	951	1501	849	1968	1370	2457	1597	2884	1829	3397	2197	3955	2507	4413	2844	5042	3220	5696	3657	6288	4033	-1	-1	-1	-1	-1	-1
RAC	0.7	15	1	2672	1743	3703	2405	4322	2740	5114	3307	6294	4015	7336	4689	8517	5470	9449	6061	10782	6923	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	20	1	4961	3220	6133	3946	7572	4826	8873	5718	10881	6978	12622	8096	14507	9317	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	25	1	7264	4609	9494	6051	11521	7421	13561	8695	16484	10587	19100	12277	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	30	1	10340	6686	13380	8623	16308	10457	19001	12189	23068	14827	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	35	1	13937	8836	17853	11400	21653	13875	25309	16251	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.7	40	1	17935	11559	23049	14799	27869	17885	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	5	1	0	0	42	73	295	405	544	362	553	369	559	372	583	372	632	378	762	503	902	582	1000	645	1268	804	1559	997	1836	1177
RAC	0.6	10	1	1093	729	1112	742	1145	753	1269	760	1657	1090	2006	1294	2280	1444	2542	1613	2927	1891	3321	2112	3685	2362	4761	3056	5771	3705	-1	-1
RAC	0.6	15	1	1692	1125	1912	1145	2479	1632	3018	1946	3624	2282	4258	2755	4962	3155	5536	3549	6341	4054	7151	4589	7895	5059	-1	-1	-1	-1	-1	-1

PFOS Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																											
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.6	20	1	2561	1535	3645	2352	4374	2800	5107	3241	6306	4029	7393	4739	8538	5457	9546	6126	10880	6978	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	25	1	4166	2741	5482	3509	6648	4256	7856	5022	9628	6191	11274	7212	12978	8316	14469	9290	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	30	1	6090	3926	7697	4886	9445	6037	11125	7132	13615	8712	15840	10152	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	35	1	8023	5089	10350	6683	12695	8113	14877	9511	18153	11633	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.6	40	1	10312	6546	13428	8539	16301	10451	19183	12312	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	5	1	0	0	0	0	30	53	206	274	420	276	446	294	464	305	480	314	509	329	553	347	613	385	837	540	1022	649	1196	762
RAC	0.5	10	1	413	550	866	569	917	604	962	631	1065	677	1229	773	1467	936	1677	1083	1929	1239	2160	1367	2400	1529	3130	1993	3815	2444	4480	2873
RAC	0.5	15	1	1348	887	1447	949	1595	1014	1849	1162	2369	1521	2808	1811	3227	2043	3604	2297	4158	2672	4699	2992	5222	3345	6738	4321	-1	-1	-1	-1
RAC	0.5	20	1	1936	1269	2228	1398	2761	1754	3366	2173	4125	2620	4811	3067	5600	3597	6272	3994	7191	4614	8096	5175	8990	5766	-1	-1	-1	-1	-1	-1
RAC	0.5	25	1	2674	1700	3459	2197	4383	2835	5139	3265	6278	4020	7401	4728	8579	5489	9559	6124	10972	7033	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	30	1	3726	2344	5068	3272	6176	3924	7236	4613	8936	5708	10472	6709	12094	7732	13502	8660	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	35	1	5134	3273	6807	4370	8243	5240	9745	6263	11993	7668	14001	8952	16173	10373	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.5	40	1	6783	4378	8716	5517	10647	6848	12593	8020	15409	9870	18027	11562	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	5	1	0	0	0	0	0	0	0	0	117	139	189	256	357	232	380	246	408	264	436	281	465	300	566	357	702	448	848	544
RAC	0.4	10	1	0	0	333	442	688	446	761	493	847	547	931	601	1032	666	1133	714	1306	823	1503	965	1701	1091	2199	1395	2698	1730	3185	2029
RAC	0.4	15	1	569	770	1143	741	1268	819	1398	903	1625	1039	1891	1183	2242	1439	2554	1637	2936	1879	3301	2094	3676	2345	4788	3051	-1	-1	-1	-1
RAC	0.4	20	1	1527	990	1750	1129	1991	1287	2272	1433	2831	1808	3408	2185	3950	2526	4404	2793	5069	3241	5736	3673	6387	4071	-1	-1	-1	-1	-1	-1
RAC	0.4	25	1	2121	1370	2492	1611	2944	1842	3523	2249	4457	2859	5203	3308	6031	3841	6755	4332	7786	4963	8774	5613	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	30	1	2809	1814	3417	2156	4231	2701	5120	3283	6279	3992	7365	4698	8562	5484	9590	6112	10992	7043	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	35	1	3613	2332	4597	2895	5809	3724	6872	4398	8424	5363	9907	6348	11501	7333	12829	8221	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.4	40	1	4569	2884	6046	3880	7536	4835	8832	5603	10882	6978	12798	8156	14789	9477	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	5	1	0	0	0	0	0	0	0	0	0	0	20	34	137	181	243	163	304	194	336	214	366	233	451	290	528	338	608	384
RAC	0.3	10	1	0	0	0	0	214	264	480	326	643	411	731	466	824	527	902	579	1006	646	1107	707	1218	770	1615	1030	2009	1284	2361	1499
RAC	0.3	15	1	59	103	709	488	960	613	1097	698	1297	832	1471	946	1653	1057	1827	1156	2113	1335	2423	1545	2728	1743	3548	2254	4351	2781	-1	-1
RAC	0.3	20	1	926	652	1343	857	1580	1008	1804	1159	2123	1361	2437	1542	2845	1798	3232	2061	3768	2408	4257	2718	4732	3005	6154	3936	-1	-1	-1	-1
RAC	0.3	25	1	1601	1023	1975	1260	2323	1493	2642	1694	3176	2004	3779	2401	4465	2852	5024	3212	5767	3665	6511	4143	7253	4635	-1	-1	-1	-1	-1	-1
RAC	0.3	30	1	2195	1398	2707	1739	3171	2034	3657	2315	4560	2898	5458	3487	6352	4056	7099	4509	8172	5211	9233	5905	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	35	1	2866	1832	3525	2265	4166	2643	4934	3117	6227	3977	7349	4694	8513	5406	9536	6080	10978	7018	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.3	40	1	3611	2319	4436	2834	5376	3389	6467	4123	8083	5167	9469	6014	10994	7012	12313	7874	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	27	107	139	196	133	249	157	341	215	422	268	491	312
RAC	0.2	10	1	0	0	0	0	0	0	31	54	245	322	496	313	598	376	680	429	790	502	891	566	983	624	1242	792	1504	951	1788	1133
RAC	0.2	15	1	0	0	46	80	363	477	742	468	958	603	1144	726	1328	843	1473	936	1670	1064	1862	1187	2054	1307	2687	1702	3348	2130	3952	2516
RAC	0.2	20	1	61	106	528	697	1117	702	1355	856	1688	1073	1963	1247	2243	1429	2481	1581	2825	1795	3192	2016	3581	2269	4742	3019	5805	3689	-1	-1
RAC	0.2	25	1	600	788	1393	876	1762	1115	2097	1333	2547	1619	2941	1874	3366	2143	3755	2376	4351	2754	4967	3157	5576	3548	7255	4610	-1	-1	-1	-1
RAC	0.2	30	1	1471	929	2026	1279	2514	1597	2939	1867	3543	2259	4102	2611	4755	3004	5367	3401	6255	3978	7109	4525	7914	5039	-1	-1	-1	-1	-1	-1
RAC	0.2	35	1	2050	1288	2748	1745	3347	2125	3886	2475	4693	2989	5496	3472	6448	4090	7295	4639	8451	5381	9538	6069	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.2	40	1	2692	1699	3542	2249	4266	2714	4951	3155	6031	3816	7150	4531	8413	5351	9473	6030	10898	6935	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.1	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	15	13	23	184	116	271	170	348	219
RAC	0.1	10	1	0	0	0	0	0	0	0	0	0	0	26	45	189	243	364	231	484	302	592	373	695	437	965	607	1207	761	1429	902
RAC	0.1	15	1	0	0	0	0	0	0	39	67	320	413	679	423	877	551	1038	653	1249	784	1444	909	1629	1026	2145	1353	2624	1658	3080	1950
RAC	0.1	20	1	0	0	0	0	315	394	715	454	1074	673	1379	867	1679	1054	1921	1209	2248	1416	2558	1613	2855	1801	3702	2341	4521	2862	-1	-1
RAC	0.1	25	1	0	0	387	483	971	609	1327	831	1821	1144	2235	1405	2654	1671	3001	1891	3472	2190	3925	2478	4364	2757	5646	3575	-1	-1	-1	-1
RAC	0.1	30	1	74	129	1051	673	1584	992	2054	1292	2690	1692	3238	2039	3801	2397	4270	2694	4916	3105	5542	3504	6156	3897	-1	-1	-1	-1	-1	-1
RAC	0.1	35	1	617	786	1647	1026	2300	1448	2883	1810	3684	2320	4388	2766	5116	3228	5729	3617	6578	4160	7413	4694	8254	5222	-1	-1	-1	-1	-1	-1
RAC	0.1	40	1	1373	884	2308	1451	3104	1948	3806	2395	4801	3025	5678	3581	6595	4165	7373	4661	8465	5359	9565	6051	-1	-1	-1	-1	-1	-1	-1	-1
RAC	0.05	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	21	143	95	224	141
RAC	0.05	10	1	0	0	0	0	0	0	0	0	0	0	0	0	15	26	23	41	170	213	343	216	446	280	727	454	975	610	1203	754
RAC	0.05	15	1	0	0	0	0	0	0	0	0	29	51	227	282	501	316	663	416	881	552	1085	677	1275	798	1804	1130	2289	1437	2743	1723
RAC	0.05	20	1	0	0	0	0	0	0	46	79	533	380	876	551	1186	743	1440	899	1775	1111	2094	1311	2398	1503	3253	2043	4052	2547	4803	3021
RAC	0.05	25	1	0	0	0	0	62	108	486	614	1189	749	1624	1015	2056	1286	2412	1510	2896	1815	3356	2105	3800	2385	5057	3178	-1	-1	-1	-1
RAC	0.05	30	1	0	0	66	114	577	729	1293	813	1952	1219	2520	1577	3098	1940	3578	2243	4233	2656	4861	3052	5469	3436	7200	4529	-1	-1	-1	-1
RAC	0.05	35	1	0	0	557	697	1409	884	2007	1259	2837	1774	3562	2230	4306	2699	4928	3092	5780	3629	6601	4147	7396	4649	-1	-1	-1	-1	-1	-1

PFOS Filter Performance Table

BC		BC	Inf	Empty Bed Contact Time [minutes]																									
Material	C/Co	Vol%	[µg/L]	30		40		50		60		75		90		106		120		140		160		180		240		300		360	
RAC	0.05	40	1	86	149	1285	814	2090	1314	2826	1763	3844	2405	4745	2974	5677	3561	6457	4054	7532	4732	8569	5387	9576	6023	-1	-1	-1	-1	-1	-1
RAC	0.01	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	15
RAC	0.01	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	30	277	185	519	326	746	465
RAC	0.01	15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	44	190	224	408	273	591	380	1115	694	1605	998	2066	1287
RAC	0.01	20	1	0	0	0	0	0	0	0	0	0	0	33	57	257	304	534	358	857	546	1173	733	1476	919	2340	1456	3151	1965	3916	2445
RAC	0.01	25	1	0	0	0	0	0	0	0	0	48	83	392	474	910	590	1258	791	1739	1083	2201	1369	2648	1648	3925	2447	5127	3203	-1	-1
RAC	0.01	30	1	0	0	0	0	0	0	47	81	468	565	1137	734	1706	1066	2183	1359	2843	1768	3478	2164	4094	2550	5854	3656	-1	-1	-1	-1
RAC	0.01	35	1	0	0	0	0	47	81	404	475	1219	793	1932	1209	2672	1663	3299	2051	4161	2589	4994	3111	5802	3619	-1	-1	-1	-1	-1	-1
RAC	0.01	40	1	0	0	0	0	340	378	988	676	1971	1240	2871	1787	3807	2367	4596	2859	5686	3543	6740	4204	7764	4848	-1	-1	-1	-1	-1	-1

XI.3 TEMPEST

Please see the excel spreadsheet attached to this pdf.

ER18-1145: Prevention of Sediment Recontamination by Improved BMPs to Remove Organic and Metal Contaminants from Stormwater Runoff

Column Experiment Operation and Maintenance Manual

Version 2.0
4/29/2020

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Emergency Information

Emergency Contacts

Conrad Pritchard	(630) 433-1679	cpritc@stanford.edu
YeoMyoung Cho	(650) 804-6825	daybreak@stanford.edu

To report a major flood, broken pipe, or request janitorial clean up support: (650) 723-2281

Chemicals Present

Atrazine
Benzotriazole
Diuron
Fipronil
Imidacloprid
Mecoprop
TNT
DNAN
Permethrin
Bifenthrin
Fluorene
Anthracene
Fluroanthene
Pyrene
Benz[a]anthracene
Benzo[a]pyrene
PCB-52
PCB-77
PCB-101
PCB-118
PCB-126
PFAS
Copper II
Cadmium II
Nickel II
Lead II
Zinc II

Column and System Overview

System Design

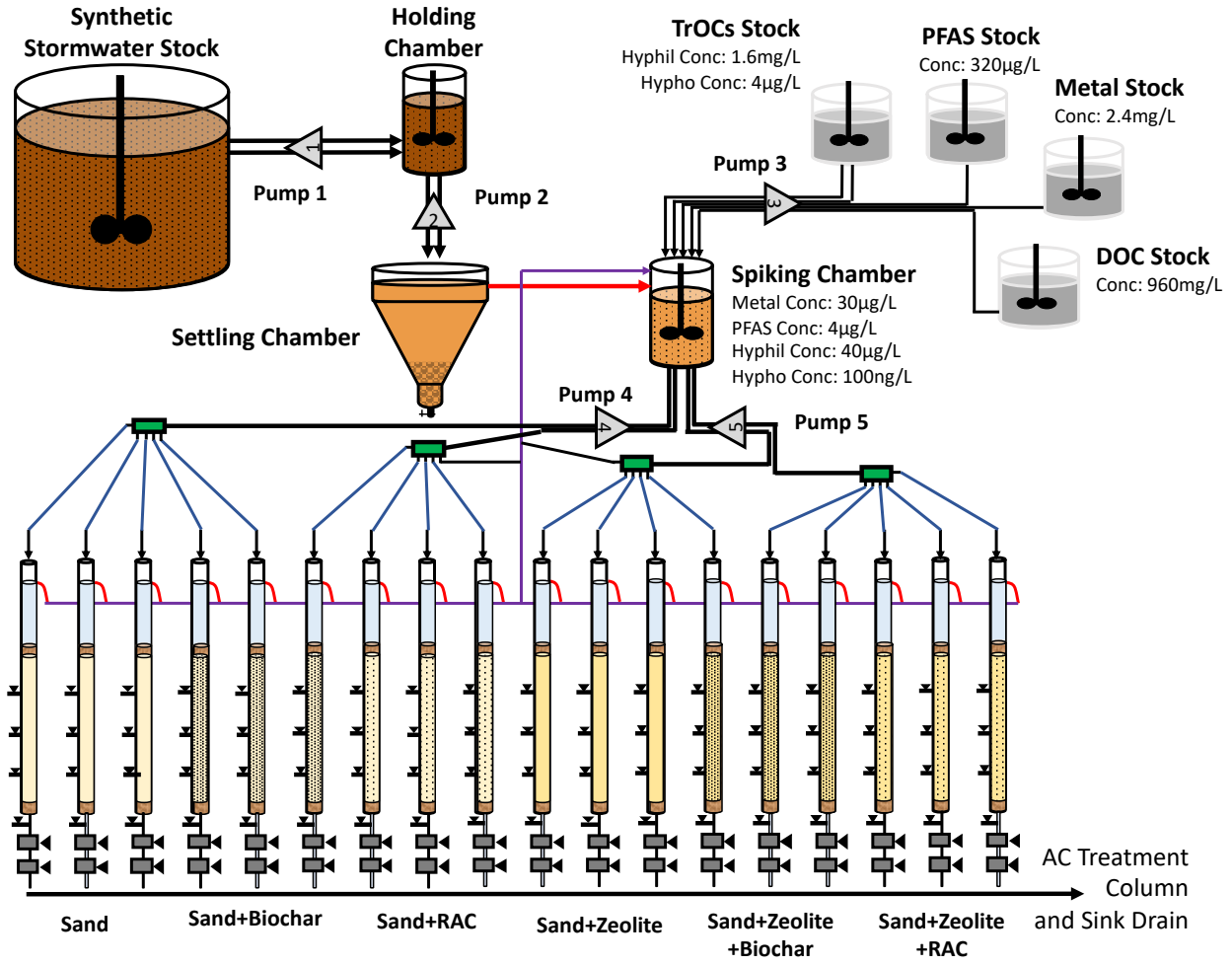

Figure 1.1 Diagram of the column system showing all pumps, tubing, and tanks. PTFE manifolds (green) are used to split flow from pumps 4 and 5 to the columns. The purple pipe returns flow from the column overflow ports back to the spiking chamber. Note that the two extra tubes from the manifold delivering flow directly into the purple pipe are used to sample influent.

Pumps

Five pumps are used in this system. Pumps 1, 2, and 3 are controlled by the Arduino and are programmed to turn on and off depending on the water level of the Mixing Chamber and Spiking Chamber. Replacement tubing for Pump 1, 2, 4, and 5 are Grainger, part #35U578. Replacing the tubing is necessary from time to time. Information on the pump model numbers and flow rates are found below in table 1.1. Information on the pump setting may be found in table 1.2.

Table 1.1 Pump Information and Flow Rates

Pump	Model	Supplier	System Column Flow Rate		
			20 cm/hr	40 cm/hr	60 cm/hr
Pump 1	4NA16	Grainger	445 mL/min	445 mL/min	445 mL/min
Pump 2	4NA16	Grainger	257 mL/min	257 mL/min	385 mL/min
Pump 3	EW-07528-30	Cole Parmer	3.4 mL/min	3.4 mL/min	5.1 mL/min
Pump 4	4NA16	Grainger	445 mL/min	445 mL/min	445 mL/min
Pump 5	4NA16	Grainger	445 mL/min	445 mL/min	445 mL/min

Table 1.2 Pump Setting

Pump	Pump Setting for Column Flow Rate		
	20 cm/hr	40 cm/hr	60 cm/hr
Pump 1	10	10	10
Pump 2	6	6	9
Pump 3	1.7	1.7	2.4
Pump 4	10	10	10
Pump 5	10	NA*	NA*

**Column experiments with flow rates of 40 and 60 cm/hr do not use pump 5.*

Tubing

Three sizes of PTFE tubing are used in the system, as seen above in figure 1.1. The lines in blue represent $^{1}/_{8}$ inch tubing, the lines in black represent $^{3}/_{16}$ inch tubing, and the lines in red represent ½ inch tubing. The total length of tubing connecting the spike tank to the columns is the same length for each column.

Table 1.3 Tubing used in system

Tubing Diameter Siz	Model #	Supplier
1/8 inch	5239K11	McMaster Carr
3/16 inch	5239K12	McMaster Carr
1/2 inch	5239K13	McMaster Carr

Mixers

Information on the three tank mixers used may be found below in table 1.4.

Table 1.4 Tank Mixers used in system

Tank	Model	Supplier	Approx. Mix Speed
Synthetic Stormwater Stock	32V128	Grainger	500 RPM
Mix Chamber	*	*	300 RPM
Spike Chamber	Uxcell 12V DC 200-250RPM Gear Motor		200 RPM

**Information not currently available*

Tanks

A variety of tanks are used in the system. Tank capacities may be found below in table 1.5

Table 1.5 Tanks used in system

Tank	Volume
Synthetic Stormwater Tank	300 gallons
Holding Chamber; Spiking Chamber; TrOCs Stock	25 L
Settling Chamber	30 gallons
PFAS Stock; Metals Stock; DOC Stock	18 L

Settling Chamber

The settling chamber consists of a cone-bottom cylindrical tank with two overflow ports. Sediment is removed by opening the vavle at the bottom of the cone. Influent enters the sedimentation basin from the top and is forced to the bottom by a 1 inch clear PVC pipe. The stormwater then outflows through an overflow port on the side wall. The designed retention time is 5.19 hours.

Column Design

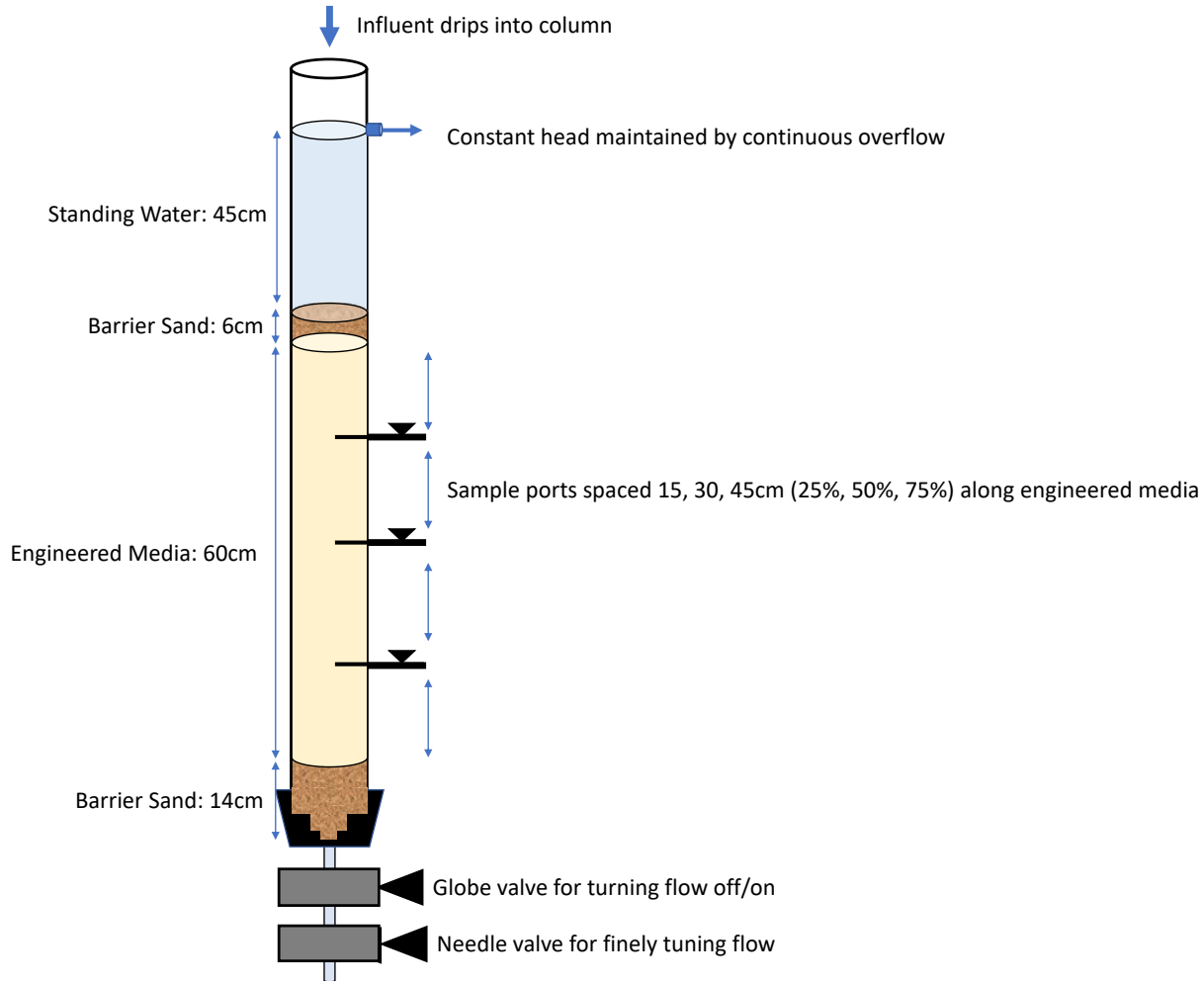

Figure 1.2 Diagram of each individual column showing the overflow port, sampling ports, and outlet controls.

Parts and Construction

Part used for the column construction may are found below in table 1.6. Columns were initially roughened using a metal wire drill head attachment.

Table 1.6 Parts used to construct columns

Part	Description	Material	Vendor	part number
Column*	3" x 8 ft. PVC Pipe, Pipe Schedule 40, Clear	PVC	Grainger	1AAZ9
Union	3" Socket x socket Union	PVC	Grainger	22FL18
Reducer	Bushing Adapter with Hex Body, 3 Socket Male x 1 NPT Female	PVC	McMaster Carr	4880K222
Reducer	Bushing Reducing Adapter, 1 NPT Male x 3/4 NPT Female	PVC	McMaster Carr	4880K349

Barbed Connector	High-Purity, Adapter for 1/4" Tube ID x 3/4 NPT Male	PVDF	McMaster Carr	53055K421
Tubing	Extreme-Temperature Teflon® PTFE Semi-Clear Tubing for Chemicals, 1/4" ID, 5/16" OD	PTFE	McMaster Carr	5239K13
Needle Valve	Precision Barbed Valve, for Food and Beverage 1/4" Connection Size	PVC	McMaster Carr	2883N11
Ball Valve	Plastic On/Off Valves with Barbed Fittings	PVC	McMaster Carr	4757K17

**Columns were cut in 4 ft sections*

Engineered Media

The engineered media consists of sand, biochar, regenerated activated carbon, zeolite, and barrier sand. Information about these materials may be found below in table 1.7.

Table 1.7 Engineered Media used in columns

Material	Packed Density		Source
Sand	1.8	g/mL	Cemex (#2/12 Lapis Lustre)
Biochar	0.10	g/mL	Biochar Supreme (Environmental Ultra - dry)
RAC	0.56	g/mL	Cabot Corporation (Norit GAC 830R M-2384)
zeolite	0.86	g/mL	BioGreen Technologies

Column Packing

The column procedure is as follows:

1. Sieve engineered media to mesh size 12-30 using a mechanical shaker.

2. Add stainless steel mesh to bottom of column to prevent media from falling out of the column.

3. Pour initial layer of barrier sand to the bottom of the column. Use a massager to vibrate the column to facilitate adequate settling and packing of the barrier sand.

4. Mix target dry masses of engineered media in a 5-gallon bucket by hand. Alternate pouring the engineered media mixture into the column in 1-2-inch lifts and using the massager to facilitate adequate settling and packing of the engineered media.

5. Pour the final layer of barrier sand to the top of the column in 1-2-inch lifts and use the massager to facilitate the settling of the barrier sand.

6. Saturate the column with carbon dioxide by purging the column with carbon dioxide in up flow configuration for two hours. Then saturate the column with DI water in up flow configuration.

Table 1.8 Engineered Media in Packed Columns

Engineered Media Mixture	Bottom Barrier Sand [g]	Sand		Zeolite		RAC		Biochar		Top Barrier Sand [g]
		Mass Added [g]	% (w/w)	Mass Added [g]	% (w/w)	Mass Added [g]	% (w/w)	Mass Added [g]	% (w/w)	
100% sand	883.2	4960.0	100%	--	--	--	--	--	--	417.5
70% sand 30% zeolite	865.7	3468.0	83%	704.2	17%	--	--	--	--	432.2
90% sand 10% RAC	863.5	4458.8	97%	--	--	153.0	3%	--	--	432.2
70% sand 30% biochar	864.3	3716.5	98%	--	--	--	--	90.2	2%	433.8
60% sand 10% RAC 30% zeolite	865.3	1982.3	72%	703.8	25%	--	--	84.3	3%	434.3
40% sand 30% biochar 30% zeolite	873.0	2972.8	44%	3677.0	54%	153.0	2%	--	--	434.2

Tracer Testing

Tracer testing is to be conducted at the beginning and conclusion of each column experiment using bromide as a conservative tracer and DI water.

1. Adjust the column flow rate to the desired flow rate.
2. Draw the water level in the column down to the top of the media.
3. Pump a 30s pulse of bromide solution into the column and then switch the DI water.
4. Flush the columns for 3 pore volumes, sampling with greater frequency near the expected breakthrough.
5. Check the flow rate of the column after the conclusion of the tracer tests.

DOC Concentrate

The procedure for preparing DOC concentrate is as follows:

1. Cut straw from a straw wattle (Home Depot, 25 ft) into 1-2 inch pieces.
2. Create a straw tea by soaking 50 grams straw per 1 L water in 5 gallon buckets for three days.

3. Remove the straw from the straw tea and filter the straw tea using a 400 mesh sieve into a 50 gallon barrel to homogenize all the individual straw teas. Mix the filtered DOC concentrate thoroughly.

4. Filter 10 mL of DOC concentrate using a 0.45 PES syringe filter and dilute by a factor of 20. Analyze using the DOC concentration using a TOC Analyzer.

5. Add DOC concentrate to 2L pyrex jars, autoclave, and store at 4 °C. Freeze the remaining DOC concentrate for future use.

Synthetic Stormwater Recipe

A table showing the recipe to make various amounts of synthetic stormwater is below:

Table 1.XX Synthetic Stormwater Stock Recipe (without DOC addition)

To Make	Add: NWSSB Sediment	CaCl2.2H2O	MgCl2.6H2O	NaHCO3	NaH2PO4.H2O	NaNO3	Na2SO4	NH4Cl
100 L	300 g	9.6 g	1.1 g	8.4 g	0.2 g	0.6 g	4.4 g	0.4 g
150 L	*450 g*	*14.4 g*	*1.6 g*	*12.6 g*	*0.3 g*	*0.9 g*	*6.6 g*	*0.6 g*
200 L	600 g	19.2 g	2.2 g	16.8 g	0.4 g	1.2 g	8.8 g	0.8 g
250 L	*750 g*	*24.0 g*	*2.7 g*	*21.0 g*	*0.6 g*	*1.5 g*	*11.0 g*	*1.0 g*
300 L	900 g	28.8 g	3.3 g	25.2 g	0.7 g	1.8 g	13.1 g	1.2 g
350 L	*1,050 g*	*33.6 g*	*3.8 g*	*29.4 g*	*0.8 g*	*2.1 g*	*15.3 g*	*1.3 g*
400 L	1,200 g	38.4 g	4.4 g	33.6 g	0.9 g	2.4 g	17.5 g	1.5 g
450 L	*1,350 g*	*43.2 g*	*4.9 g*	*37.8 g*	*1.0 g*	*2.8 g*	*19.7 g*	*1.7 g*
500 L	1,500 g	48.0 g	5.5 g	42.0 g	1.1 g	3.1 g	21.9 g	1.9 g
550 L	*1,650 g*	*52.8 g*	*6.0 g*	*46.2 g*	*1.2 g*	*3.4 g*	*24.1 g*	*2.1 g*
600 L	1,800 g	57.6 g	6.6 g	50.4 g	1.3 g	3.7 g	26.3 g	2.3 g
650 L	*1,950 g*	*62.4 g*	*7.1 g*	*54.6 g*	*1.4 g*	*4.0 g*	*28.5 g*	*2.5 g*
700 L	2,100 g	67.2 g	7.7 g	58.8 g	1.5 g	4.3 g	30.7 g	2.7 g
750 L	*2,250 g*	*72.0 g*	*8.2 g*	*63.0 g*	*1.7 g*	*4.6 g*	*32.9 g*	*2.9 g*
800 L	2,400 g	76.8 g	8.8 g	67.2 g	1.8 g	4.9 g	35.1 g	3.1 g
850 L	*2,550 g*	*81.6 g*	*9.3 g*	*71.4 g*	*1.9 g*	*5.2 g*	*37.3 g*	*3.3 g*
900 L	2,700 g	86.4 g	9.9 g	75.6 g	2.0 g	5.5 g	39.4 g	3.5 g
950 L	*2,850 g*	*91.2 g*	*10.4 g*	*79.8 g*	*2.1 g*	*5.8 g*	*41.6 g*	*3.7 g*
1000 L	3,000 g	96.0 g	11.0 g	84.0 g	2.2 g	6.1 g	43.8 g	3.9 g
1050 L	*3,150 g*	*100.8 g*	*11.5 g*	*88.2 g*	*2.3 g*	*6.4 g*	*46.0 g*	*4.0 g*
1100 L	3,300 g	105.6 g	12.1 g	92.4 g	2.4 g	6.7 g	48.2 g	4.2 g

To Make:	Add: NWSSB Sediment	CaCl2.2H2O	MgCl2.6H2O	NaHCO3	NaH2PO4.H2O	NaNO3	Na2SO4	NH4Cl
1 L	3 g	96.03 mg	10.98 mg	84.01 mg	2.21 mg	6.12 mg	43.83 mg	3.85 mg

Columns and System Maintenance

Daily System Check

The column system should be checked daily to ensure that the system is running normally. The initial check should only take a few minutes and entails:

1. Check to see if there is any water dripping down the columns or pooling below on the lab bench or on the floor. Walk around to make sure there is no water on the opposite side of the lab bench near the stock solutions, near the settling basin, under the pumps, or on the floor.

Note: If water is found, immediately contact Conrad and look to see where the water is coming from. If there is a significant spill of water such that you are not able to clean up the water alone with the wet vacuum, contact janitorial support at (650) 723-2281.

2. Check the pumps to make sure each pump is operating and there is flow in the line. Flow may be identified by the movement of suspended particles in the pump line. Occasionally, some of the pump lines may get clogged, and it will appear as if the pump head is operating, but there is no or minimal flow in the lines or air bubbles bounce back and forth without progressing in the line. From time to time, the tubing in the pump head will get worn out and need to be replaced. If something does not appear to be right, immediately contact Conrad.

Note: Pumps 1, 2, and 3 are controlled by the Arduino, and will turn on and off from time to time. This is normal. If pumps 3, 4, or 5 are not operating, there is an issue. Pumps 1 and 2 deliver flow from the stormwater tank to the mixing chamber and from the mixing chamber to the sedimentation basin while pump 3 delivers flow from the stock solutions to the spiking chamber. Pumps 4 and 5 deliver flow from the spiking chamber to the column. See diagram of pumps in figure 1.1.

3. Check to make sure all the tank mixers are operating. There are four total tank mixers: one in the 300 gallon stormwater tank, one in the 75 gallon stormwater tank, one in the mixing chamber, and one in the spiking chamber.

4. Check to make sure that the water level of the spiking and mixing chambers is above half full. Check to make sure that the water levels in the columns is at the overflow level.

5. **Always be sure to contact Conrad (630) 433-1679 if you have any questions or if you see anything that you think might not look quite right.**

Adjusting Column Flow Rates

Use the lab timer, mini balance, and clear plastic 20 mL vial to record the flow rates. Wear gloves and proper lab safety gear. Dispose of your gloves when finished.

1. Tare the mini balance with the plastic 20 mL vial.

2. Collect column effluent for 20 seconds and record the mass in the column flow rate document in the google drive. Note: the timer beeps at the conclusion of 20 seconds, despite the timer screen flashing 00:00 prematurely for a second before the timer beeps.

3. Repeat for each column. Be sure to empty the plastic 20 mL vial after each measurement, as the scale becomes less accurate with larger masses.

4. Adjust flow rate for columns with flow rates outside of the 19.7 cm/hr – 20.9 cm/hr (5.00 g/20s – 5.3 g/20s) window. Target values are 19.9 cm/hr – 20.5 cm/hr (5.05 g/20 s – 5.20 g/20s). Record new flow rate values in the column flow rate document in the google drive.

Cleaning Spike Chamber and System Tubing

The system pump tubing should be cleaned every 6 days. Biomass accumulates on the surface of the tubing with the potential to affect the water quality and contaminant concentrations, impact flow rates, and even prevent flow entirely by clogging the lines. Thus, periodic tubing cleaning is essential for keeping the system running smoothly.

1. Turn off pumps 2 and 3 to draw down the water level in the spike chamber. While the water level is going down, make sure that the replacement glass chamber is cleaned, disinfected, and ready to be swapped in. Remove the particle screen, mixer shaft and propeller (the Allen wrench is taped to the metal beam above), and water level sensor and protective pipe casing. Clean each of these items with DI water to remove any biofilms and disinfect with bleach.

2. Once the spike chamber is empty, turn off pump 4 and pump 5 to stop flow to the columns. Remove the pump tubing from the spiking chamber and dry with a paper towel. Remove the dirty glass chamber. Use a paper towel to clean the exterior and interior of the white overflow pipe. Set the clean glass chamber in place and reattach the (1) water level sensor and protective pipe casing, (2) particle screen, (3) attach the pipe delivering DOC and contaminant stock solution to the chamber with tape. Turn on pumps 2 and 3 to begin refilling the spiking chamber. Reattach the mixer shaft and propeller to the motor, and turn on the mixer once the water level has risen above the propeller.

Note: if pump 2 and pump 3 do not begin delivering flow to the spike chamber after reattaching the water level sensor and turning the pumps on, there may be an issue with the water level sensor. Connect the Arduino to a computer using the USB-cord to check the water level sensor output. If the output is significantly off or reading NaN, consider switching out the water level

sensor with a new one. If your computer has trouble recognizing the Arduino board, try (1) reattaching the USB cord to the computer, (2) closing your internet browser, (3) restarting your computer, (4) unplugging and replugging the USB cord into the Arduino itself. Be very careful not to jostle the Arduino when unplugging the USB cord, as you may accidently disconnect any of the wires.

3. Next, while the spiking chamber refills and while there is still standing synthetic stormwater above the engineered media in the columns, begin to clean the tubing. First detach the influent and effluent tubing from pump 4. Then detach the pump effluent tubing from the manifold, detach the manifold from the scaffolding, and detach each of the tubes from the manifold.

Note: It is critical that the tubing is cleaned before the water level drops below the top of the engineered media so that the columns remain fully saturated.

4. Use a coiled metal wire to clean the tubing by pushing the wire through the tubing, and then rotating the wire as you pull the wire out. Rotating the wire while extracting it from the tube will cause it to rub the inner walls of the tubing, helping to free the biofilm so it can be more easily removed. Rinse the tubing with bleach and then DI water until clean.

5. Clean the interior of the manifold with a bristled brush and rinse with cleach followed by DI water.

6. Reattach the tubing to the manifold. Then reattach the manifold to the scaffolding. Finally reattach the tubing the pump 4.

7. Repeat with the tubing by pump 5.

Note: in order to prevent the water level from falling below the top of the engineered media in the columns, it is recommended that you only clean 9 columns at a time and that you allow the pump to run for the other 9 columns.

Cleaning Biomass from Top of Columns

The barrier sand layer in the top of the column should be cleaned every 6 days to remove biomass growth. Accumulating biomass significantly impedes the flow through the column and may restrict and prevent flow through the sample ports if not cleaned properly. Therefore, regular cleaning of the barrier sand layer is critical to ensuring sample port and effluent flow rates remain stable.

Note: If flow ceases from a sample port, there is likely flow of air into the sample port due to lower-than-atmospheric pressure forming within the column as water is pulled out of the column due to the hydraulic head.

1. Use a tool (such as a long wire brush or flexible PVC tubing with a scrapping attachment) to agitate the top barrier sand layer and suspend the biomass growing at the surface of the column.

2. Pump the standing water from the top of the column and collect in a hazardous waste container, and allow the column to refill with fresh synthetic stormwater.

3. Repeat steps 1 and 2 until the barrier sand is visibly clean and flow from the top sample port is restored to normal. Be careful not to disturb the engineered media below the barrier sand.

Making Synthetic Stormwater Procedure

When making more synthetic stormwater, flip the blackout cloth and plastic back to access the tanks. **Do not adjust the 300 gallon tank mixer compressed air valve on the mixer or in the fume hood.** Contact Conrad first if something seems to be wrong (630-433-1679).

Note: In order to protect the tank mixers, the water level in the 300 gallon tank should never fall below 300 L and the water level in the 75 gallon tank should never fall below 60 L.

1. Read through the entire instructions before proceeding.

2. Switch influent tubing from the to-be-filled synthetic stormwater tank to the other synthetic stormwater tank. The two synthetic stormwater tanks include the 300 gallon tank on the floor and the 75 gallon tank on the bench, both of which have mixers and are covered with plastic and black-out cloth.

3. Determine amount of synthetic stormwater to make.

Note: ***Do not fill the 300 gallon tank above 11,019 L. Do not fill the 75 gallon tank above 300 L.*** *This is the tank's maximum capacity even though it looks like the water is not at the very top of the rim.*

4. Reference the Synthetic Stormwater Recipe table to determine the mass of salts to add. Use the balance to mass the salts into a carry tray. Bring the carry tray back into the column room.

5. Reference the Synthetic Stormwater Recipe table to determine the mass of NWSSB sediment to add. Sediment is kept next to the 300 gallon tank in orange buckets. Use the balance next to the orange bucket to mass the sediment into the cup kept on top of the orange bucket.

6. Reference the Synthetic Stormwater Recipe table to determine the amount of DI water to add to the tank. Set a timer on your phone to count the allotted time to spend filling the tank. Turn on the DI water by turning the handle four complete rotations (arrow points up for each rotation; flow rate = 7.6 L/min) and begin your timer.

7. Add the salts and NWSSB sediment to the synthetic stormwater tank.

8. Close the DI tap at the allotted time and wait at least five minutes before switching the tubing back to the newly-filled tank. Record the amount of stormwater made in the synthetic stormwater generation log.

Emptying Sedimentation Tank Procedure

1. Position sediment bucket onto the white tray and underneath the sedimentation tank.

2. Slowly twist the valve handle at the bottom of the sedimentation tank in the clockwise direction to open the valve.

3. Empty ~2-4 L of sediment slurry each day to prevent sediment accumulation.

4. Record volume and mass of sediment emptied in the Sedimentation Tank Maintenance log.

5. Empty sediment slurry into orange bucket next to 300 gallon tank labeled “Used Sediment”

6. Rinse out bucket with water into orange bucket labeled “Used Sediment”

Synthetic Stormwater Generation Log

Date/Time Finished	Person	Volume of SSW Made (L)		Notes
		300 gallon tank	75 gallon tank	

Sedimentation Tank Maintenance Log

Date/Time	Person	Sediment Slurry Removed		Notes
		Volume	Mass	

Preparing DOC Stock

Use orange bucket next to DOC stock solution labeled “DOC Stock Preparation Bucket” to prepare more DOC stock solution. Use balance next to 300 gallon tank.

1. Determine how much DOC stock solution to make. Note: the maximum capacity of the metals secondary stock bucket is 18 L.

2. Reference the concentration of DOC Concentrate for the current DOC concentrate batch to determine the amount of DOC concentrate and DI water to add. Add appropriate amounts of DOC Concentrate to the DOC stock bucket and DI water to DI water bucket using the balance.

3. Add the DOC concentrate and DI water to the DOC stock bucket and ensure the stir bar is still stirring the DOC stock at 300-400 rpm.

Preparing Metals Secondary Stock

Use orange bucket next to metals stock solution labeled “Metals Stock Solution Preparation” to prepare more metals secondary stock solution. Use balance next to 300 gallon tank. Metals Primary Stock solution consists of 5% Nitric Acid by volume. Use proper lab safety wear when making more metals secondary stock.

1. Determine how much metal secondary stock solution to make. Note: the maximum capacity of the metals secondary stock bucket is 18 L.

2. Fill the orange bucket next to the metals secondary stock labeled “For Making More Metals Stock” with the appropriate volume of DI Water. Use the balance next to the 300 gallon tank to determine the volume of water.

3. Add 2.4 mL of metals primary stock (1g/L) per liter of DI water to the orange bucket labeled “For Making More Metals Stock”. Metals primary stock solution is kept in the 3 C room. Use the 5mL Eppendorf pipette to add the metal primary stock solution. Note: metal primary stock solution consists of 5% Nitric Acid. Be very careful when handling the metals primary stock.

4. Add the newly made metals secondary stock to the metals secondary stock bucket on the stir plate.

Preparing PFAS Stock

Use orange bucket next to metals stock solution labeled “PFAS Stock Solution Preparation” to prepare more PFAS secondary stock solution. Use balance next to 300 gallon tank. PFAS Primary Stock solution consists of MTBE. MTBE is a volatile solvent that is hazardous if inhaled. Minimize the amount of time that PFAS primary stock is open and exposed to the air to

limit any potential exposure to MTBE. Use proper lab safety wear when making more PFAS secondary stock.

1. Determine how much PFAS secondary stock solution to make. Note: the maximum capacity of the PFAS secondary stock bucket is 18 L.

2. Fill the orange bucket next to the metals secondary stock labeled “For Making More PFAS Stock” with the appropriate volume of DI Water. Use the balance next to the 300 gallon tank to determine the volume of water.

3. Add 0.111 mL of PFAS primary stock (2.898 g PFOS/L) per liter of DI water to the orange bucket labeled “For Making More PFAS Stock”. PFAS primary stock solution is kept in the 3 C room. Use the 1mL or 5mL Eppendorf pipette to add the metal primary stock solution. Note: PFAS primary stock solution consists of the very volatile solvent MTBE. Be very careful when handling the PFAS primary stock and limit the amount of time that the primary stock is exposed to the atmosphere.

4. Add the newly made PFAS secondary stock to the PFAS secondary stock bucket on the stir plate.

Preparing Trace Organics Stock

Use the 5 L glass pyrex jars and sonicators on bench labeled “TrOCs Secondary Stock Solution Preparation”. Use balance next to 300 gallon tank. Trace Organic Primary Stock solutions consist of hexane and methanol. These are both volatile solvents that are hazardous if inhaled. Always work with the trace organic primary stocks in the fume hood to prevent exposure to volatile solvents. Use proper lab safety wear when making trace organics secondary stock.

1. Determine how much trace organics secondary stock solution to make. Note: the maximum capacity of the trace organics secondary stock bucket is 25 L. Make multiples of 5 L.

2. Add 5 mL of primary LC trace organics stock and 1 mL of primary GC trace organics stock to a secondary stock 5 L glass pyrex jar.

3. Place glass jar in the fume hood and allow the solvent to evaporate for 12 hours

4. Add 5 L of DI water to the glass pyrex jar.

5. Sonicate the 5 L glass jar for 1 hour 30 minutes to ensure the trace organic compounds are dissolved in the DI water.

6. Pour the trace organics secondary stock into the 25 L trace organics secondary stock jar on the stir plate next to the columns.

Stock Solution Preparation Log

Date/Time	Person	Stock Solution Made	Volume Used		Notes
			Contaminant	DI Water	
2/20 5:00 pm	Conrad	DOC	9x150L, 1x100 L DOC ice cubes	11.452 L	

Sampling

Contaminant Sampling Procedure

At the designated time points, sample column effluent, 25% (top sample port), 50% (middle sample port), and influent. Take a single sample at each column location for contaminant group and take three influent samples for each contaminant group. Samples should be frozen immediately at -20°C. When sampling from the sample ports, open the sample ports to achieve a steady slow drip (1 drip every 1-2 seconds; ~1-2 mL/min).

1. Label each vial with proper printed label. See below for which vials are to be used for each compound group. Do not label 1L amber glass jars for GC compounds – these are already labeled with tape and will require further processing before freezing.

2. Begin with the influent, effluent, then 25% (top sampling port), and finally 50% (middle sampling port). When sampling the sample ports, flush 5mL of stormwater in a plastic vial before collecting samples.

3. Collect samples as follows:

Metals: Use HDPE 20mL vials to collect 1 sample per sample location. Fill bottle to just below the neck to prevent the bottle from breaking as the ice expands while freezing.

LC Compounds: Use 20mL clear glass bottles to collect 1 sample per sample location. Fill bottle half way.

PFAS: Use 15mL Falcon tube to collect 1x 7mL sample per sample location.

GC Compounds: Use 1L glass amber bottles and long-neck glass funnels to collect 1L of sample from only the influent and effluent.

DOC and Nutrients: Use HDPE 20mL vials to collect 1 sample per sample location. Fill bottle to just below the neck to prevent the bottle from breaking as the ice expands while freezing.

Water Quality Parameters Sampling

Synthetic stormwater and column influent should be tested every 3 days for conductivity, DO, DOC, pH, TDS, turbidity, and TSS. Use the DO probe, multi-parameter probe, and turbidimeter.

1. Collect 3x 200mL of synthetic stormwater from the mixing and spiking chambers and column influent using 250 mL glass beakers to test for TSS. Dry 9 glass filters at 105°C for 1 hour and mass filters and record dry mass. Use filter apparatus and glass filters to filter the 9x 200mL samples and dry the glass filters at 105°C for 1 hour. Mass filters dry and record the original and final masses in the sampling log.

2. Measure turbidity of the synthetic stormwater in the mixing and spiking chambers and column influent. Record turbidity values in the sampling log. Remember to calibrate the turbidimeter once at the beginning of sampling during each sampling period.

3. Collect 100 mL of synthetic stormwater from the mixing and spiking chambers, column influent, and each column effluent in glass 150 mL beaker and test conductivity, pH, TDS, and temperature. The pH probe and conductivity probe should be calibrated daily. Record the parameter values in the log sheet.

4. Analyze the dissolved oxygen of the synthetic stormwater in the mixing and spiking chamber, column influent, and each column effluent. Use the flow-through cell for the column effluent to ensure that no oxygen in the atmosphere contaminants the sample. Ensure that the DO reading has stabilized for at least 30 seconds before recording the DO measurement. Record DO values (both as % saturation and as mg oxygen per litre), temperature, and pressure in the log shet.

Hydraulic Conductivity Sampling

Use the hydraulic conductivity apparatus strapped to the columns. Dispose of your gloves when finished. Note: <u>be very careful when handling the sample ports – these are very delicate!!</u>

1. Attach the manometer tubes to the top and bottom sampling ports. Be very careful when working with the sampling ports as it is very easy to snap the sampling port or to cause a leak.

2. Open the two sets of valves at each sampling port/manometer connection. The water level in both manometers should increase.

3. Wait for the water levels in each of the manometers to stabilize at equilibrium. This may take 10-30 minutes.

4. Record the difference in manometer heights for each column in the Hydraulic Conductivity document in the google drive. Measure the column flow rate by finding the mass of water flowing from each column over 20 seconds and record the value in the Hydraulic Conductivity document.

5. Close the two sets to valves at each manometer/sample port connection and gently unconnected the two valves from each other. Always keep one hand on the sample port to stabilize and prevent the sample port from becoming loose.

6. Drain each manometers.

7. Secure the manometers to the manometer apparatus so that the manometers do not interfere with the sample ports.