ESTCP

FINAL REPORT

Improved Longevity and Selectivity of PFAS Groundwater Treatment Using Sub-Micron Powdered Activated Carbon (SPAC) and Ceramic Membrane Filtration (CMF)

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December 2022

ESTCP Project ER19-5181

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
31/12/2022	ESTCP Final Report	9/30/2019 - 12/31/2023

4. TITLE AND SUBTITLE

Improved Longevity and Selectivity of PFAS Groundwater Treatment Using Sub-Micron Powdered Activated Carbon (SPAC) and Ceramic Membrane Filtration (CMF)

5a. CONTRACT NUMBER
19-C-0055

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Joseph Quinnan and Vivek Pulikkal: Arcadis

Terence Reid: Aqua-Aerobic Systems, Inc.

Chris Bellona: Colorado School of Mines

5d. PROJECT NUMBER
ER19-5181

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Arcadis U.S., Inc.
28550 Cabot Dr., Suite 500
Novi, MI 48377

8. PERFORMING ORGANIZATION REPORT NUMBER
ER19-5181

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Environmental Security Technology Certification Program
4800 Mark Center Drive, Suite 16F16
Alexandria, VA 22350-3605

10. SPONSOR/MONITOR'S ACRONYM(S)
ESTCP

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
ER19-5181

12. DISTRIBUTION/AVAILABILITY STATEMENT
DISTRIBUTION STATEMENT A. Approved for public release: distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
This project presents the results of the Environmental Security Technology Certification Program (ESTCP) demonstration conducted at Horsham Air Guard Station (AGS) and former Naval Air Station (NAS) at Willow Grove in Horsham, Pennsylvania: sub-micron powdered activated carbon (SPAC) coupled with ceramic membrane filtration (CMF) to remove per- and polyfluoroalkyl substances (PFAS). The objective of the project was to demonstrate and validate the application of the SPAC-CMF treatment approach to reduce the total life-cycle cost of treating PFAS-impacted groundwater.

15. SUBJECT TERMS
PFAS, PFAS Groundwater Treatment, Sub-Micron Powdered Activated Carbon, SPAC, Ceramic Membrane Filtration, CMF, PFAS-impacted matrices, PFAS-impacted waters, per- and polyfluoroalkyl sustances, AFFF, aqueous film-forming foam

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			Joseph Quinnan
UNCLASS	UNCLASS	UNCLASS	UNCLASS	365	**19b. TELEPHONE NUMBER** *(Include area code)* 248-789-4951

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Project: ER19-5181

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ACKNOWLEDGEMENTS

This demonstration project was successfully completed as a direct result of the critical contributions of many people from multiple organizations. Specific acknowledgement is extended to the following:

- Arcadis: Meredith Braverman, Jeff McDonough, Hoa Voscott
- Aqua-Aerobic Systems, Inc.: Joe Campanaro, Blake Hoffmann
- Colorado School of Mines: Andrew Safulko, Bahareh Tajdini
- Horsham Air Guard Station: Keith Freihoffer, Lee Depersia
- Willow Grove Naval Air Station: Jason Speicher

Thank you all for your efforts and support.

ABSTRACT

This Final Report presents the results of the Environmental Security Technology Certification Program (ESTCP) demonstration conducted at Horsham Air Guard Station (AGS) and former Naval Air Station (NAS) at Willow Grove in Horsham, Pennsylvania: sub-micron powdered activated carbon (SPAC) coupled with ceramic membrane filtration (CMF) to remove per- and polyfluoroalkyl substances (PFAS). The objective of the project was to demonstrate and validate the application of the SPAC-CMF treatment approach to reduce the total life-cycle cost of treating PFAS-impacted groundwater.

The approach focused on a combination of proven CMF and SPAC technologies into a new configuration specifically designed to treat water resources highly contaminated with PFAS (> 1 microgram per liter [µg/L]) with a prototypical system at a fidelity level that could be replicated at other U.S. Department of Defense (DoD) sites. This AquaPRS technology provides an alternative to granular activated carbon (GAC) and ion exchange (IX) systems based on treatment efficacy and cost performance using life cycle cost analyses (LCA). The SPAC-CMF system consisted of cloth media filters to remove particulates, a sorbent reactor in which SPAC is mixed with influent surface water, followed by a CMF filter to separate PFAS-sorbed SPAC from the water matrix to obtain PFAS-free water. The SPAC is recirculated back into the sorbent reactor to continue the treatment cycle. The first study conducted at Horsham AGS demonstrated and validated the SPAC-CMF treatment approach using a mobile pilot system, while the second study (conducted at the former NAS at Willow Grove) provided further optimization of cost, performance, and scalability. At Horsham AGS, 13 tests were conducted over 9 months using a dual-train pilot, with ten tests conducted with treatment systems in parallel and the remaining three conducted in series. At Willow Grove, 10 tests were conducted over a 6-month period.

The technology was validated by measuring the specific adsorption rate (SAR) of various PFASs on SPAC, followed by its comparison to GAC and IX. Costs of the three treatment systems were compared to estimate a payback period for the SPAC-CMF system compared to GAC and IX. At 10 percent breakthrough, the SAR of SPAC-CMF for the combined concentration of the United States Environmental Protection Agency's (USEPA's) Third Unregulated Contaminant Monitoring Rule (UCMR3) compounds was nearly 1,000 times higher compared to those treated with GAC. At 40 nanograms per liter (ng/L) breakthrough for combined UCMR3 compounds, a single-stage SPAC-CMF system at Horsham achieved 146 µg PFAS/g sorbent SAR, while a dual-stage SPAC-CMF system at Willow Grove achieved 2,128 µg PFAS/g sorbent. The SPAC-CMF system showed a payback period of 3 months compared to a comparable GAC system, while with an IX system, the payback period ranged from 24 to 36 months. The benefits of the SPAC-CMF system are its effective performance in the presence of co-contaminants, adaptability to changing conditions, limited downtime for sorbent replacement, resistance to biofouling, small footprint, and reduced disposal requirements. The reduced disposal requirements are due to the ability of the SPAC-CMF system to dewater the sorbent resulting in a waste generation of just 0.002 percent of the total volume of water treated. Based on the treatment efficacy and cost performance, the SPAC-CMF system is positioned as an alternative to GAC and IX systems.

EXECUTIVE SUMMARY

INTRODUCTION

The relatively high occurrence, solubility, and mobility of per- and polyfluoroalkyl substances (PFASs) has resulted in significant need for remediation technologies to remove PFAS from contaminated drinking water sources. Recent state regulatory requirements focus on a broader suite of PFAS compounds including short-chained perfluorobutanoic acid (PFBA) and perfluorobutane sulfonic acid (PFBS) and lower discharge limits. PFAS-contaminated groundwater is often characterized as having the presence of numerous perfluoroalkyl acids (PFAAs), natural organic matter (NOM) and other co-contaminants, challenging remediation efforts.

Granular activated carbon (GAC) treatment is currently the most common approach to removing PFASs from water, particularly for addressing perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA). However, GAC also has drawbacks such as weak sorbability of short-chain PFASs, poor regeneration, and non-selectivity between PFASs and other organic co-contaminants such as dissolved organic matter (DOM). Operating costs for GAC treatment are often relatively high due to rapid PFAS breakthrough and the need for frequent GAC regeneration/ treatment. Other technologies, such as nanofiltration (NF) and reverse osmosis (RO), can achieve high PFAS removal rates but generate highly concentrated brine discharges that require further treatment for final PFAS disposal. Regenerable ion exchange (IX) resins can be effective at removing select PFAS compounds but are associated with high capital costs and complicated flow schemes necessary to regenerate the resins. Single-use resins are more commonly applied, but are subject to scaling, biofouling, and sediment loading issues that often necessitate pre-treatment with GAC.

Sub-micron powder activated carbon (SPAC) is a novel carbon-based sorbent material with a mean particle size less than 1-micron (µm) and a high specific surface area compared to GAC. SPAC exhibits faster PFAS adsorption kinetics possibly due to this smaller particle size and increased quantity of macropores coupled with greater accessibility to the interior mesopores and micropores. This faster PFAS diffusion rate could translate to shorter contact time, resulting in a smaller footprint and lower cost. Previous laboratory studies showed that SPAC had a significantly higher sorption capacity (> 2,000 times) for certain PFASs compared to conventional GAC (Murray 2019). Preliminary bench testing at the demonstration sites' actual groundwater exhibited greater than 99.9 percent removal of combined PFAS compounds using SPAC, with feed concentrations exceeding 9,000 ng/L. However, pilot-scale studies are required to establish the scalability and effectiveness of this treatment.

The field application of SPAC coupled with ceramic membrane filtration (CMF) to remove PFAS is discussed in this report. The technical approach integrated a combination of proven CMF and SPAC technologies into a new configuration specifically designed to treat high-strength (> 1 microgram per liter [µg/L]) PFAS applications in a prototypical system at a fidelity level that could be replicated at other DoD sites. The AquaPRS technology is positioned to offer an alternative to GAC and IX systems based on treatment efficacy and cost performance using lifecycle cost analyses (LCA) to determine its applicability.

OBJECTIVES

The overarching goal of this demonstration was to exhibit and validate the application of the SPAC-CMF treatment approach to reduce the total life-cycle cost of treating PFAS-impacted groundwater. Specific objectives included:

1. Demonstrate SPAC's sorption capacity to remove key PFAS contaminants with specific goals to attain a 40 nanograms per liter (ng/L) treated effluent based on cumulative values of the six compounds outlined in the United States Environmental Protection Agency's (USEPA's) Third Unregulated Contaminant Monitoring Rule (UCMR 3).
2. Quantify the relative reductions of 21 other PFAS compounds per USEPA Method 537/DoD QSM 5.1
3. Use preliminary data screening and waste treatment (concentration) trials to develop operational protocols to optimize removal efficiencies and reduce bulk-carbon requirements by exceeding a 40 grams per liter (g/L) total suspended solids (TSS; dry solids basis) waste product.
4. Identify the presence of co-contaminants, specifically dissolved organic matter (DOM), and determine their influence on the technology's operation and performance.
5. Characterize the cross-flow CMF system operation to permit scale-up design for the technology's application at this and other DoD sites.
6. Employ systematic approaches to reduce carbon disposal through membrane concentrating.

TEST DESIGN

A schematic diagram of the treatment system is provided as **Figure ES1**. The treatment train starts with: (1) a cloth media filtration to remove sediment and other debris. Raw water is then pumped (2) to the sorbent reactor, (3) where PFAS is mixed and adsorbed to SPAC. A recycle pump (4) conveys the SPAC slurry to the separator (5) before being returned to the sorbent reactor (3). A filtrate stream is produced by the separator (5), which then flows to a short-detention time filtrate tank (6) before being discharged as final effluent. A back-pulse pump (7) draws filtered water to occasionally pressurize the filtrate side of the separator. The back-pulse effectively dislodges particulates from the separator surface, which is then swept by the SPAC slurry and returned to the sorption reactor (3).

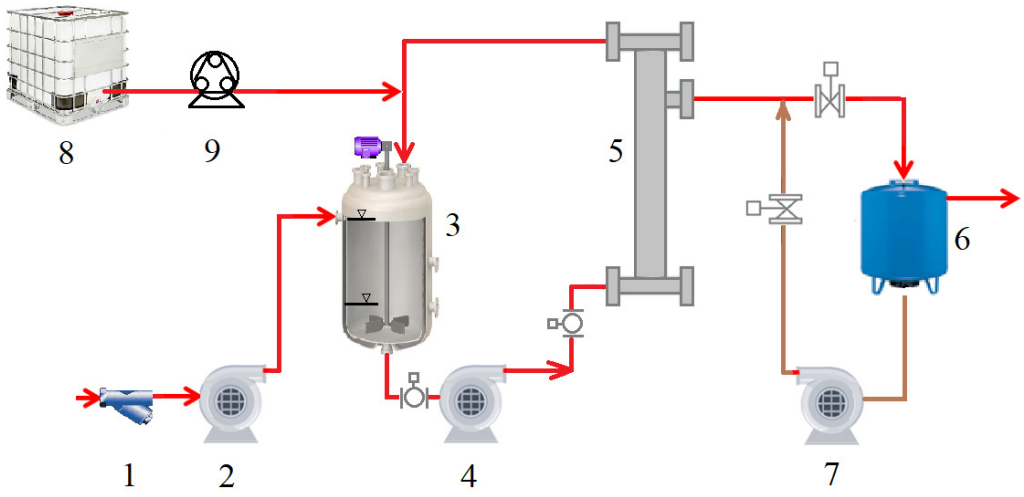


Figure ES1. Process Flow Diagram for SPAC-CMF Used at Horsham AGS and Willow Grove

The primary study demonstrated and validated the SPAC-CMF treatment approach using a mobile pilot system deployed at the DoD's Horsham Air Guard Station (Horsham AGS). Beginning in June 2020, a series of 13 tests was conducted over 9 months using the dual-train pilot. Ten tests (Test 1 through Test 10) were conducted with two treatment systems in parallel, enabling concurrent testing of different operating parameters whereas tests 11 through 13 were conducted with two treatment systems in series. Influent for all the tests was drawn from a combination of surface water and groundwater. Of the 13 tests, the results of six representative tests are used to illustrate findings that addressed the performance objectives. The test conditions of these six tests are described in **Table ES1**.

Table ES1. Test Conditions Evaluated at the Horsham AGS Pilot Study

Test Condition	Operating Mode	Hydraulic Detention Time (min)	Sorbent Mass (g)	Sorbent Density (g/L)	Flow Rate (L/min)
10A	1-Stage	20	200	10	1.0
10B	1-Stage	5	200	40	1.0
12A	1-Stage (lead)	7.5	200	40	0.67
12B	2-Stage (lag)	5	200	40	0.1
13A	2-Stage (lag)	5.4	200	40	0.93
13B	1-Stage (lead)	5	200	40	1

A second study was conducted at the Former Naval Air Station (NAS) Joint Reserve Base - Willow Grove site (Willow Grove NAS) upon the conclusion of the Horsham AGS testing. Beginning in May 2021, testing of a total of ten conditions were completed over a 6-month period ending in October 2021 on a slipstream taken from the influent to the existing 20-gallon-per-minute (gpm) on-site treatment system. The intent was to leverage lessons learned from the Horsham AGS and apply the technology in a series of treatment trials to: 1) develop optimal cost and performance data, 2) verify that the bench testing protocol is scalable to predict pilot test performance, and 3) compare the AquaPRS results with those from ongoing studies that evaluated polymeric adsorbents and IX resins.

Willow Grove NAS provided important performance data on a highly concentrated but stable groundwater without the influence of sediment or significant co-contaminants. The conditions used for the major tests at Willow Grove NAS are described in **Table ES2**.

Table ES2. Test Conditions Evaluated at the Willow Grove NAS Pilot Study

Test Condition	Operating Mode	Hydraulic Detention Time (min)	Sorbent Mass (g)	Sorbent Density (g/L)	Flow Rate (L/min)
3A	2-Stage (lead)	10	100	10	1.0
3B	2-Stage (lag)	10	100	10	0.9
5A	1-Stage	10	200	20	0.67
5B	1-Stage	10	200	20	0.67

RESULTS AND DISCUSSION

Comparison of SPAC-CMF System to GAC

Because site data for PFAS removal with the existing GAC system was not available, Colorado School of Mines (CSM) performed rapid small-scale column tests (RSSCTs) on the same water to determine a comparative specific adsorption rate (SAR) for GAC. The GAC RSSCT could not achieve the 70 ng/L Health Advisory Level (HAL) treatment objective for several of the key compounds; therefore, a 10 percent breakthrough threshold was used as a basis for comparison. The results are presented below in **Table ES3**. The SPAC-CMF SAR was more than 500 times higher than that of GAC for combined PFOA and PFOS and nearly 1,000 times higher to achieve 90 percent removal of UCMR3 contaminants. These data support the team's original proposal that referenced significantly higher adsorption rates for SPAC had been realized in previous studies. In a key study leading up to this project, CSM directly compared SPAC to GAC on aqueous film-forming foam- (AFFF-) impacted groundwater revealing an overall 480 times increase in adsorption of combined PFOS, PFOA, perfluorohexane sulfonate (PFHxS), perfluorohexanoic acid (PFHxA), perfluoroheptanoic acid (PFHpA), perfluoropentanoic acid (PFPeA), and PFBS (Murray et al. 2019).

Table ES3. Comparative SAR Performance for GAC and SPAC-CMF (data from Test 10A) to Reach 10% Breakthrough Threshold at Horsham AGS

TEST	PFOA + PFOS	UCMR3	ALL PFAS	PFOS	PFOA	PFHXS	PFHPA	PFBS
GAC	0.6	2.1	1.9	0.7	0.1	0.7	0.1	0.1
SPAC-CMF	>431	578	277	>543	31	124	4.7	4.0

Note:
1. SAR – units are µg PFAS removed per g sorbent.

Horsham AGS

The UCMR3 compound removal achieved by the single-stage SPAC-CMF system during Test 7A is illustrated on **Figure ES2**. The system effectively removed UCMR3 compounds and achieved SAR levels of approximately 130 µg removed per g sorbent at combined 40 ng/L limit for all UCMR3 compounds. The resulting media usage rate at this condition was 2,200 gallons per pound of sorbent. The system achieved an SAR more than 300 µg removed per g sorbent for the case in which the 2022 USEPA risk-based screening levels (RSL) were considered. This condition produced a media usage rate of more than 4,000 gallons per pound of sorbent. The system removed more than 99 percent of combined 8,000 ng/L PFOA, PFOS, PFHxS, perfluorononanoic acid (PFNA), PFHpA, and PFBS.

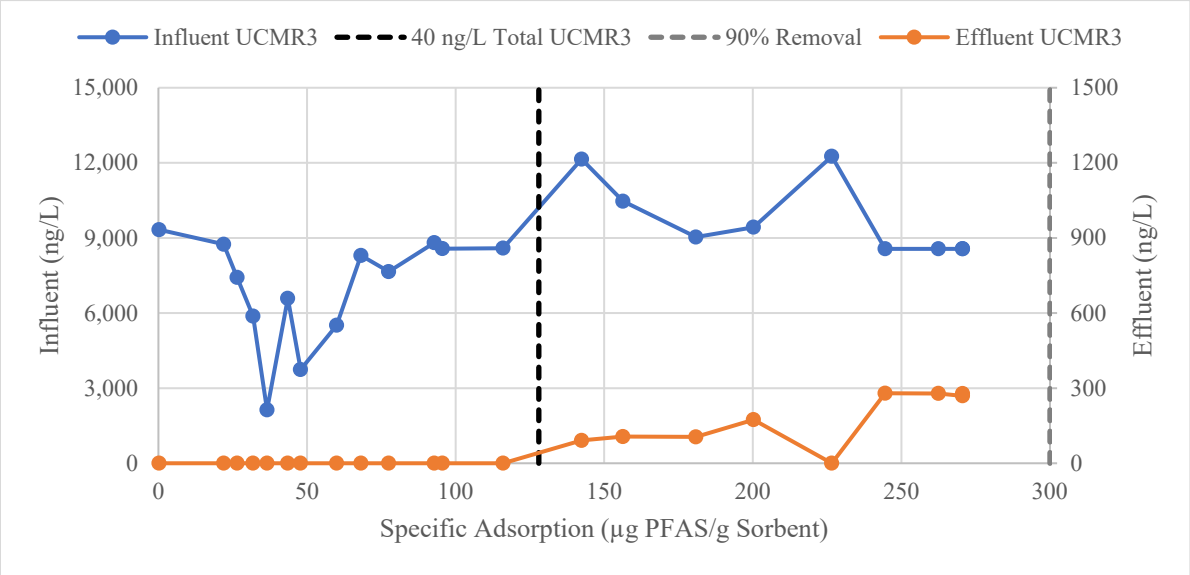
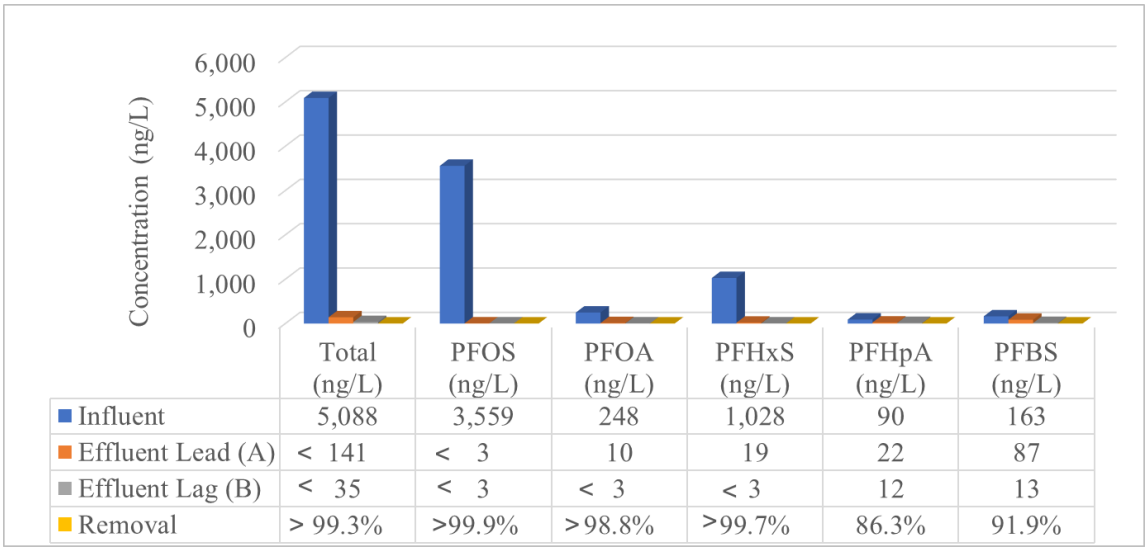


Figure ES2. UCMR3 Compound Removal with a 1-Stage SPAC-CMF System (Test 7A)

The removal of UCMR3 compounds using a two-stage lead-lag SPAC-CMF configuration during Test 12 is illustrated in Figure ES3. This configuration was important to evaluate, as typical PFAS treatment systems include two or more treatment systems in series, often with two different technologies used (e.g., GAC followed by IX). The series operation of the SPAC-CMF proved effective at reducing all UCMR3 compounds to desired levels within the defined replacement period. The lead unit (A) was able to meet the 40 ng/L UCMR3 level at a media usage rate of 3,000 gallons treated per pound of sorbent, but could utilize the lag unit (B) to increase the hydraulic capacity.



	Total (ng/L)	PFOS (ng/L)	PFOA (ng/L)	PFHxS (ng/L)	PFHpA (ng/L)	PFBS (ng/L)
Influent	5,088	3,559	248	1,028	90	163
Effluent Lead (A)	< 141	< 3	10	19	22	87
Effluent Lag (B)	< 35	< 3	< 3	< 3	12	13
Removal	> 99.3%	>99.9%	>98.8%	>99.7%	86.3%	91.9%

Figure ES3. UCMR3 Compound Removal with a Two-Stage SPAC-CMF (Test 12)

Willow Grove NAS

The pilot study conducted at Willow Grove NAS provided insights into the performance of the SPAC-CMF system for treating an AFFF-impacted groundwater matrix. Overall, the adsorption rates were an order of magnitude higher than they were for the Horsham AGS combined surface/ groundwater. The absence of a significant input of total organic carbon (TOC), particulates, and sediment resulted in more than 4,200 µg of PFAS removed per g of sorbent material while meeting the 70 ng/L effluent USEPA HAL target of combined PFOA and PFOS. The system treated over 12,000 gallons per pound of sorbent media at this effluent target. During a 2-week period of operation, the single-stage SPAC-CMF system approached SAR levels of 7,000 µg PFAS removed per g of sorbent material (more than 20,000 gallons per pound of sorbent) without approaching the 90 percent removal threshold (**Figure ES4**).

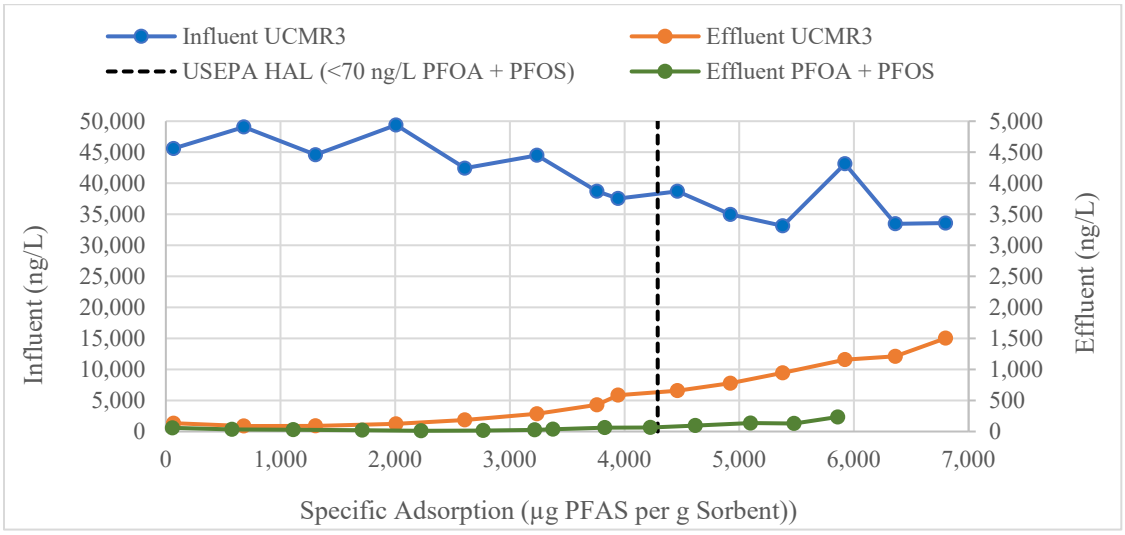
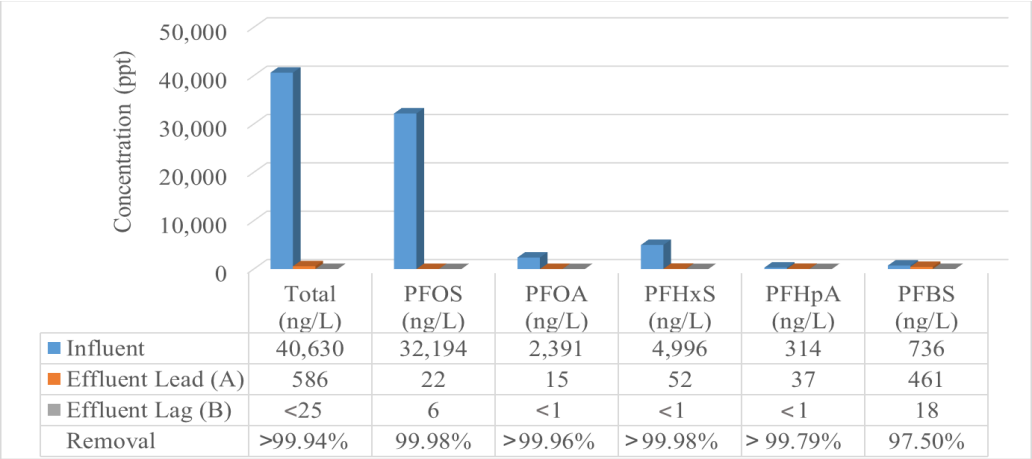


Figure ES4. UCMR3 Compound Removal with a 1-Stage SPAC-CMF System (Test 3A)

The second stage of the two-stage SPAC-CMF system effectively removed all PFASs, including short-chained compounds, during a 7-day SPAC replacement interval because the first stage was able to reduce majority of the PFAS load as shown in Figure ES5. While the first stage removed only 37 percent of the PFBS, the second stage was able to achieve 96 percent removal, resulting in a maximum concentration of 18 ng/L in the effluent within the targeted replacement interval.



	Total (ng/L)	PFOS (ng/L)	PFOA (ng/L)	PFHxS (ng/L)	PFHpA (ng/L)	PFBS (ng/L)
Influent	40,630	32,194	2,391	4,996	314	736
Effluent Lead (A)	586	22	15	52	37	461
Effluent Lag (B)	<25	6	<1	<1	<1	18
Removal	>99.94%	99.98%	>99.96%	>99.98%	> 99.79%	97.50%

Figure ES5. UCMR3 Removal with a Two-Stage SPAC-CMF System at Willow Grove (Test 3 A-B)

COST ASSESSMENT

Costs for SPAC-CMF systems and GAC were compared based on Horsham AGS application. The determined payback period is presented in **Figure ES6**. For evaluation purposes, SAR values for PFOS and PFOA of 4 and 2 µg per g of GAC were used, even though these values were not attained by the GAC in the rapid, small-scale column testing (RSSCT) performed on this waste. Similarly, the existing IX system could not be used for cost comparison due to the pre-treatment systems provided with it and the high empty bed contact time (EBCT) resultant from actual flows which were significantly below design values.

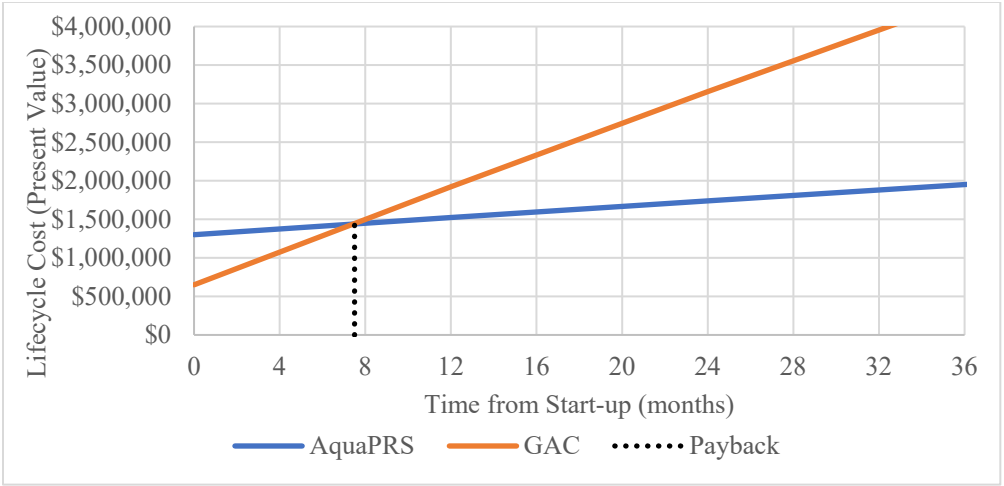


Figure ES6. Payback Period for SPAC-CMF versus GAC and IX at Horsham AGS

The AquaPRS system showed a higher capital equipment cost for the 100 gpm application, which was more than three times that of GAC and 60 percent more than the single-use IX. The non-discounted, 20-year life-cycle cost for GAC was more than 4.8 times that of the AquaPRS system. The savings in the AquaPRS operating costs result in its payback of less than 1 year when compared with GAC.

The economic evaluation for the Willow Grove NAS application used a lower 20 gpm flow rate. Similar to Horsham AGS, a direct comparison would prove challenging, as the existing treatment system includes IX, GAC, and zeolite filters. Hence, the highest performing, single-use IX performance data from the previous work of CSM were used (Ellis et al. 2022). The cost evaluation for regenerable resins was not included due to the significantly poorer performance exhibited in that study. Further, limited data on the production of brine and organic co-solvents during the regeneration process rendered such an evaluation difficult. Because GAC data was not available for Willow Grove NAS, and no RSSCT test was performed, it was not included in the cost analysis.

AquaPRS system compared similarly in CAPEX and OPEX when evaluated against the best performing IX single-use resin. The cost advantage in media replacement off-set the AquaPRS' slightly higher CAPEX and disposal costs in about 20 months resulting in a 10% cost savings over a 20-year period for the 20 gpm system.

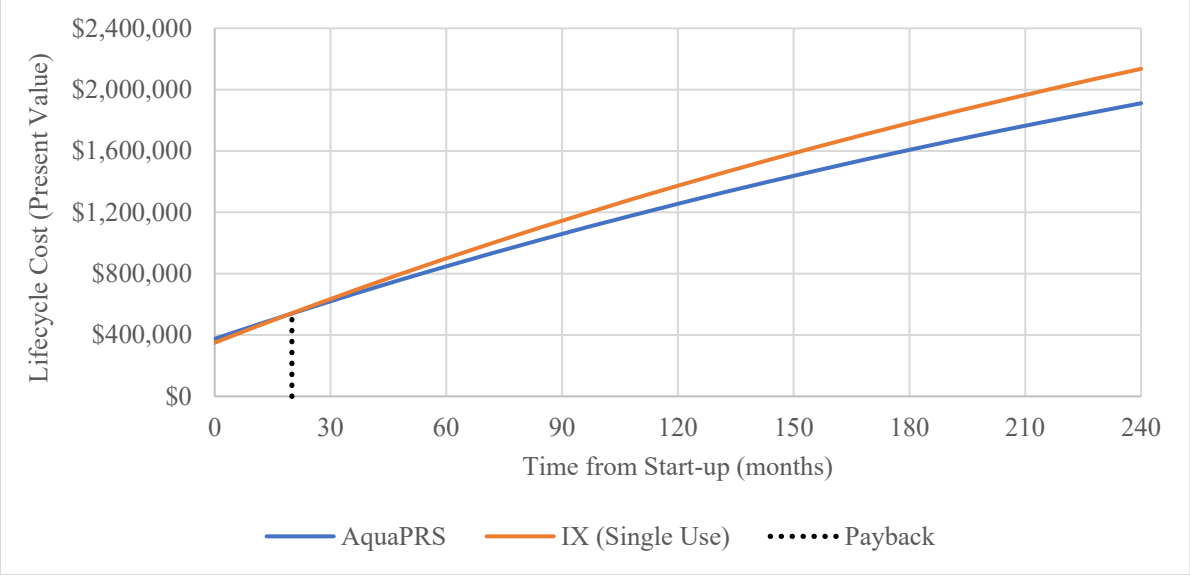


Figure ES7. Payback Period for SPAC-CMF versus IX Single-Use Resin at Willow Grove NAS

1.0 INTRODUCTION

1.1 BACKGROUND

This Final Report describes the field application of sub-micron powdered activated carbon (SPAC) coupled with ceramic membrane filtration (CMF) to remove per- and polyfluoroalkyl substances (PFASs) in support of the Environmental Security Technology Certification Program (ESTCP) Project ER19-B3-5181 (the Project). The technical approach to this Project integrated a combination of proven CMF and SPAC technologies into a new configuration that was specifically designed to treat water resources highly contaminated with PFAS (> 1 microgram per liter [µg/L]) with a prototypical system at a fidelity level that could be replicated at other U.S. Department of Defense (DoD) sites.

Proof-of-concept testing conceived by Arcadis and Aqua-Aerobic Systems, Inc. (AASI), and subsequently validated through lab testing conducted by AASI and the Colorado School of Mines (CSM), provided the basis for advancing the technology readiness level (TRL) to the field stage. A key consideration in the original proposal submission was to replicate lab-scale performance and deploy a production-level prototype in a relevant environment to yield valuable insight on system commissioning, operation, maintenance, and performance assessment. This study was anticipated to provide a long-term, critical measure necessary to assess the technology's readiness to present a viable alternative to existing approaches for PFAS removal. Specific approaches examined in this Project included using granular activated carbon (GAC) and ion exchange (IX) resins.

The primary study demonstrated and validated the SPAC-CMF treatment approach using a mobile pilot system deployed at the DoD's Horsham Air Guard Station (Horsham AGS) in Horsham, Pennsylvania. Beginning in June 2020, a series of 26 test conditions was conducted over 9 months using the dual-train pilot. This site presented several real-world challenges that forced responses to issues such as rapid and highly variable water quality conditions, hot/cold weather operations, limited site access due in part to the global pandemic, and the impact of co-contaminants. These challenges forced both confrontation and resolution that aided in addressing the technical risk. Horsham AGS offered comparative performance metrics based on evaluation of GAC on the same water source.

A second site was added upon the conclusion of the Horsham AGS testing. The mobile pilot system was decommissioned and redeployed at the Former Naval Air Station (NAS) Joint Reserve Base - Willow Grove in Horsham, Pennsylvania (Willow Grove NAS). Beginning in May 2021, ten test conditions were completed over a 6-month period ending in October 2021 on a slipstream taken from the influent to the existing 20-gallon-per-minute (gpm) on-site treatment system. Willow Grove NAS provided important performance data on a highly concentrated, but stable groundwater without the influence of sediment or significant co-contaminants. One new and important objective of this phase of the study was to directly compare the performance of the field system with a lab-scale model to determine if the technology offers an advantage for short-term but accurate rapid small-scale pilot testing (RSSPT). Additionally, this study provided a direct comparison of the SPAC-CMF performance with that of IX on the same water source to permit a life-cycle cost analysis (LCCA).

The validation study evaluated a comprehensive set of parameters to support stable operation that met performance objectives and addressed quality assurance and risk factors. The focus areas included the impact and performance of the pre-treatment system, the sorbent material (SPAC), the CMF system, waste minimization approaches, sampling and analyses methods, and control and operational settings. The result of the two-site, 15-month demonstration was a well-defined, pragmatic system that exceeded original expectations for performance and cost metrics when compared with IX and GAC system design.

This ESTCP program proved to be beneficial in establishing the system's operational readiness and commercial potential when compared directly with other existing, proven solutions. This technical report will serve as the basis for a subsequent Technology Transition Plan (TTP) geared towards introducing the technology to a broad range of users who may benefit from higher-level performance and/or reduced cost of ownership.

1.2 OBJECTIVES OF THE DEMONSTRATION

The purpose and scope of this demonstration were to exhibit and validate the application of the SPAC-CMF treatment approach to reduce the total life-cycle cost of treating PFAS-impacted groundwater. The objectives of this Project were to:

1. Demonstrate SPAC's sorption capacity to remove key PFAS contaminants with specific goals to attain a 40 ng/L treated effluent based on cumulative values of the six compounds outlined in the United States Environmental Protection Agency's (USEPA's) Third Unregulated Contaminant Monitoring Rule (UCMR 3).
2. Quantify the relative reductions of 21 other PFAS compounds as per USEPA Method 537/DoD QSM 5.1.
3. Use preliminary data screening and waste treatment (concentration) trials to develop operational protocols to optimize removal efficiencies and reduce bulk-carbon requirements by exceeding 40 grams per liter (g/L) total suspended solids (TSS; dry solids basis) waste product.
4. Identify the presence of co-contaminants (specifically, dissolved organic matter [DOM]), and determine their influence on the technology's operation and performance.
5. Characterize the cross-flow CMF system operation to permit scale-up design for the technology's application at this and other DoD sites.
6. Employ systematic approaches to reducing carbon disposal by using membranes to concentrate waste sorbent.

This Project leveraged previous laboratory investigations to direct site activities and validate design and operational protocols to characterize the technology's performance capabilities. Testing metrics were developed to quantify sorbent performance and effluent concentration targets for PFAS compounds and develop predictive models to establish replacement intervals. The demonstration elucidated equipment requirements, sorbent demands, and waste minimization methods to permit economic evaluations for this technology's application to other existing DoD sites.

This final report documents the methodology and results necessary to provide a framework for the SPAC-CMF's evaluation, design, and commercial implementation.

1.3 REGULATORY DRIVERS

GAC treatment is currently the most common approach to removing PFASs from water, particularly for addressing PFOS and PFOA in response to the May 2016 USEPA Drinking Water Health Advisory (epa.gov). Recent state regulatory requirements are focusing on a broader suite of PFAS compounds, including short-chained PFBA and PFBS, and lower discharge limits. The literature is also raising questions about the efficacy of GAC towards polyfluorinated compounds, which are precursors to regulated perfluoroalkyl acids (PFAAs). Other technologies, such as nanofiltration (NF) and reverse osmosis (RO), can achieve high PFAS removals but generate highly concentrated brine discharges that require further treatment for final PFAS disposal. Regenerable IX resins can effectively remove select PFAS compounds but are associated with high capital costs and complicated flow schemes necessary to regenerate the resins. Single-use resins are more commonly applied, but are subject to scaling, biofouling, and sediment loading issues that often necessitate pre-treatment with GAC.

Operating costs for GAC treatment are often relatively high due to rapid PFAS breakthrough and the need for frequent GAC regeneration/treatment. Previous laboratory studies showed that SPAC exhibits a significantly higher sorption capacity (> 2,000 times) for certain PFASs compared to conventional GAC (Murray 2019). Preliminary bench testing at the demonstration sites' actual groundwater exhibited greater than 99.9 percent removal of combined PFAS compounds using SPAC, with feed concentrations exceeding 9,000 ng/L. The SPAC's greater adsorption capacity for PFAS compounds, particularly short-chained constituents, offers a potentially significant advancement in carbon-based treatment technologies. The novel thickening process, coupled with the high specific adsorption rates, suggests that the SPAC-CMF concept will offer significant reductions in media use and disposal.

2.0 TECHNOLOGY DESCRIPTION

The technology employs a carbon-based sorbent media manufactured to a mean particle diameter (MPD) below 1 micron (µm). Compared to the MPDs of conventional powdered activated carbon (PAC) at ~40 µm, and both GAC and IX at ~300 to 1,600 µm, the SPAC offers an increased surface area per unit mass and a higher mesoporous volume, resulting in increased sorption kinetics. The smaller particle size improves effective sorption site utilization, thereby reducing demand while improving unit removal efficiencies. The technology is particularly effective at targeting chain-length-dependent compounds with high adsorption of four-, six-, and seven-carbon-chained PFAS compounds. The sub-micron MPD also permits suspension of the carbon medium to accelerate absorbance and improve predictive measures of media exhaustion.

SPAC is separated from the bulk liquid with CMF technology using a 0.1 µm nominal pore size barrier. The CMF's narrow pore size distribution results in high permeability and less pressure loss across each membrane unit when compared to polymeric membrane (PM) media. CMF was specifically selected for SPAC separation due to its mechanical, thermal, and chemical superiority over PMs, thereby permitting high suspended SPAC concentrations to maximize PFAS adsorption. A unique design and operational component of the system is the use of an internal back-pulse function to restore filterability. The back-pulse uses filtered water to dislodge solids from the filter surface and redirects it to the sorption reactor for treatment. The resulting SPAC-CMF operation generates no waste until the sorbent media is replaced. Unlike RO technologies, the more porous 0.1 µm microfiltration layer will not remove dissolved salts and relies on the carbon particles to remove the PFAS.

The system design accelerates PFAS adsorption while minimizing media disposal costs by conserving SPAC usage. The separator is operated using high surface velocities that exploit the scouring nature of the media to continually clean and restore filterability, eliminating the need to back-wash to waste. PFAS removal is facilitated using a sorption reactor that provides 5 to 60 minutes of contact time using a hydraulically generated mixing regime. Sorbent levels can be adjusted at any point during operation but are typically maintained between 1,000 and 50,000 milligrams per liter (mg/L) depending on the application.

2.1 SPAC-CMF SYSTEM OVERVIEW

The general process flow is illustrated in **Figure 1**. In applications that present a high input of suspended solids, such as those encountered at Outfall No. 9 on Horsham AGS, it is necessary to remove sediment and other debris with pre-treatment: (1) using cloth media filtration or cartridge filters. Raw water is then pumped (2) to the sorbent reactor (3), where PFAS is mixed and adsorbed to SPAC. A recycle pump (4) conveys the SPAC slurry to the separator (5) before being returned to the sorbent reactor (3). A filtrate stream is produced by the separator (5), which then flows to a short-detention time filtrate tank (6) before being discharged as final effluent. A back-pulse pump (7) draws filtered water to occasionally pressurize the filtrate side of the separator. The back-pulse effectively dislodges particulates from the separator surface, which is then swept by the SPAC slurry and returned to the sorption reactor (3).

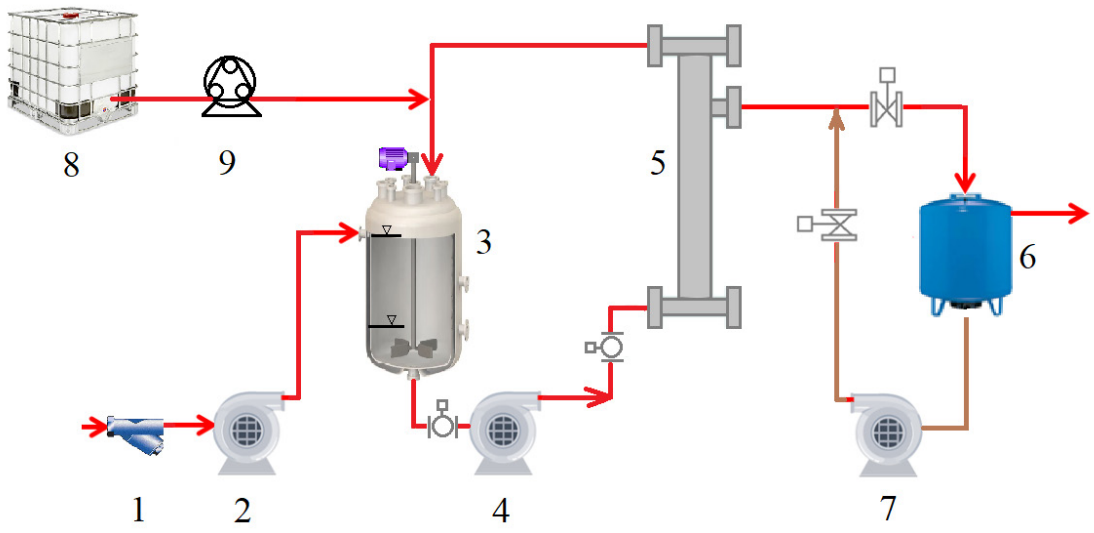


Figure 1. Process Flow Diagram for SPAC-CMF Used at Horsham AGS and Willow Grove

***Figure key**: 1. Influent strainer; 2. Feed pump; 3. Adsorption reactor; 4. Recycle pump; 5. Separator; 6. Effluent tank; 7. Back-pulse pump; 8. Sorbent supply; and 9. Sorbent dosing pump.*

Weekly or bi-weekly, the feed pump (2) will stop for a few minutes while filtrate production continues. This effectively concentrates the sorbent in the reactor (3) by reducing its water content. The concentrated sorbent is then removed from the reactor to offline storage, and a new supply of sorbent is drawn from a supply tank (8) to be introduced to the reactor (3) via a dosing pump (9). The feed pump (2) restarts operation, and the system is placed back online.

2.2 WASTE HANDLING

The robust design of the separation system offers a unique solution to media dewatering and waste minimization. Before replacement, the control system is pre-programmed to take the system off-line for approximately 30 minutes at the end of a treatment run. Treated water production continues from the system for a few minutes, allowing the media to concentrate within the reactor and reducing its volume up to 80 percent of the original operating volume. The system stops producing permeate once a specified minimum volume (maximum SPAC concentration) is reached. The used sorbent slurry is then pumped to an off-line thickening system for a further 75 to 80 percent volume reduction. A requisite amount of new sorbent material is then pumped into the sorption reactor, and the system is placed back on-line. The following steps are completed within the approximately 30-minute period:.

Table 1. Steps to Replace Sorbent Media

Step	Function	Approximate Time
Concentrate media	Stop feed flow, continue filtration	5-10 minutes
Remove spent media	Pump from reactor to off-line thickening system	5 minutes
Resume operation	Pump new media from stock supply, begin feed-flow	5-10 minutes

Due to the simple and automated process, the media replacement interval is intentionally kept short at a target of every 1 to 2 weeks. This short replacement interval is a key distinction from other adsorption technologies like GAC or IX, for which replacement intervals are intended to be long. In the time between replacements, the off-line thickening system further reduces the waste volume another 75 to 85 percent, with the water returned to the influent for treatment. Waste concentration trials performed as part of Task 3.0 of this study **(refer to Appendix A**) have shown that sorbent levels can be concentrated to 4 to 5 percent of the original working volume, which drastically reduces hauling and disposal costs.

The following example illustrates this operation for a 100 gpm feed flow:

1. Sorbent reactor = 500 gallons (1,900 L based on a 5-minute hydraulic detention time);
2. Working sorbent media concentration = 10 g/L;
3. Sorbent concentration after dewatering = 50 g/L;
4. Sorbent volume in reactor after concentrating = 100 gallons (379 L);
5. Spent sorbent concentration after off-line dewatering = 250 g/L; and
6. Spent sorbent volume remaining after off-line dewatering = 20 gallons (76 L).

Based on a 1-week replacement interval, the system will have treated more than 1,000,000 gallons of water, while producing only 20 gallons of waste (0.002 percent). The spent sorbent is then stored and inventoried for ultimate destructive treatment or disposal. Using the example described above, the 100 gpm system would be expected to generate just more than 1,000 gallons of spent media per year while having treated more than 50 million gallons of water. The spent media will comprise approximately 25 percent dry solids (250 g/L) and is generated in a slurry form for pumping and transport. Depending on the disposal mode, it can be further solidified, incinerated, landfilled in a Resource Conservation and Recovery Act (RCRA) Subtitle C landfill, or otherwise destroyed with suitable technologies.

2.3 TECHNOLOGY DEVELOPMENT

2.3.1 Literature Review - Comparison of GAC, SPAC, and IX for adsorption of PFAS

The relatively high occurrence, solubility, and mobility of PFASs has resulted in significant need for remediation technologies to remove PFAS from contaminated drinking water sources (i.e., groundwater, surface water). PFAS-contaminated groundwater is often characterized as containing numerous PFAAs, natural organic matter (NOM), and other co-contaminants, challenging remediation efforts (Dixit et al. 2020; Phong et al. 2020; Naidu et al. 2020). Due to the recalcitrance of PFASs to conventional treatment, recent research has explored advanced treatment technologies including oxidative and reductive destructive technologies, separation technologies such as sorption, and high-pressure membrane filtration. Many of these technologies are limited by their partial removal, high energy consumption, formation of short-chain PFAS intermediates, or lack of scalability (Crone et al. 2019; Vu and Wu 2022; Appleman et al. 2014; Rahman et al. 2014). Currently, the most effective methods for removal of PFASs from drinking water include use of high-pressure membranes (e.g., RO, NF) and sorption by activated carbon and IX resins (Crone et al. 2019). However, the high energy consumption and concentrate-management challenges associated with high-pressure membranes has made sorbent technologies a more feasible and adopted solution (Liu et al. 2021).

Sorbent technologies, such as GAC and anion exchange resins, have gained popularity due to their ease of operation and effectiveness at low PFAS concentrations (Rahman et al. 2014; Dudley 2012; Carter and Farrell 2010; Yu et al. 2009; Kothawala et al. 2017; Maimaiti et al. 2018).

GAC is the most popular among sorbents for PFAS removal, and its effectiveness has been well documented (Crone et al. 2019; Vu and Wu 2022; Belkouteb et al. 2020; Gagliano et al. 2020; Liu 2019; McCleaf et al. 2017; Park et al. 2020a; Rodowa et al. 2020; Xiao et al.2017). GAC sorbents mainly rely on hydrophobic interactions to remove PFAS from the water matrix (Gagliano et al. 2020; McCleaf et al. 2017; Zhang et al. 2019). The advantages of GAC are ease of operation, low unit media cost, and consistent PFAS and co-contaminant adsorption (Crone et al. 2019). However, GAC also has drawbacks: weak sorbability of short-chain PFASs, poor regeneration, and non-selectivity between PFASs and other organic co-contaminants such as dissolved organic matter (DOM; Carter and Farrell 2010; Gagliano et al. 2020; Senevirathna et al. 2010; Ochoa-Herrera and Sierra-Alvarez 2008).

IX resins have demonstrated superior adsorption capacity compared to GAC and rely on both hydrophobic interactions and IX for removal of PFAS from the water matrix (McCleaf et al. 2017; Laura Del Moral et al. 2020). IX resins have a neutral and hydrophobic backbone (polystyrene or polyacrylic beads [Crone et al. 2019]), which can attract the fluorinated carbon chain of PFASs, and positively charged surface sites that can exchange anions such as chloride with the negative head of PFASs (Vu and Wu 2022). Previous studies have reported effective sorption of PFAS by anion exchange resins (Dixit et al. 2020; McCleaf et al. 2017; Laura Del Moral et al. 2020; Boyer et al. 2021; Park et al. 2020b; Zaggia et al. 2016). Anion exchange resins have a smaller footprint, higher sorption capacity, and offer superior removal of anionic short-chain PFASs compared to GAC but have poor removal of neutral PFASs (Crone et al. 2019; Dudley 2012; Carter and Farrell 2010; Kothawala et al. 2017; McCleaf et al. 2017; Zhang et al. 2019; Zaggia et al. 2016). Both GAC and anion exchange resins offer better sorption of perfluorosulfonic acids (PFSAs) compared to perfluorocarboxylic acids (PFCAs). IX resins also exhibit limitations similar to those of GAC including rapid breakthrough of short-chain PFASs and reduced sorption of PFASs in presence of co-contaminants (Maimaiti et al. 2018; Gagliano et al. 2020; McCleaf et al. 2017; Laura Del Moral et al. 2020; Boyer et al. 2021; Zaggia et al. 2016; Ateia et al. 2019).

SPAC is a novel carbon-based sorbent material with a mean particle size less than 1µm and a high specific surface area compared to GAC (Murray et al. 2019). SPAC exhibits faster PFAS adsorption kinetics, possibly due to this smaller particle size and increased quantity of mesopores and macropores (Bonvin et al. 2016, Dudley 2012). This faster PFAS diffusion rate could translate to shorter contact time, resulting in a smaller footprint and lower cost.

The overall objective of this review is to introduce SPAC, discuss the mechanisms and factors that affect adsorption of PFASs, and compare the PFAS sorption capacities of SPAC and other conventional sorbents such as GAC and IX resins. SPAC being a novel sorbent, published available studies are limited compared to those studying established materials like GAC and IX resins.

2.3.1.1 Adsorption Mechanisms

Hydrophobic Interactions

Hydrophobic interactions are the main sorption mechanism for non-selective adsorbents such as activated carbon. The hydrophobic effect, or transfer of a hydrophobic solute from an aqueous matrix to a solid interface, results in a net reduction in system entropy. Hydrophobic interactions occur between the fluorinated carbon chain of PFASs and surface of the adsorbent. Polymerization of GAC has been shown to enhance surface hydrophobicity leading to improved sorption capacity. In a study that compared natural and polymerized activated carbon, the latter performed better owing to polymerization (Zhi and Liu 2015). It has been reported that for anion exchange resins, hydrophobicity determines the sorption rate and capacity for PFAS removal, and using a highly hydrophobic resin will improve PFAS removal efficiency (Maimaiti et al. 2018).

Surface Basicity (carbonaceous sorbents)

Surface basicity (the quantity and strength of basic sites on carbonaceous adsorbents like GAC) can improve sorption capacity when the target molecule is anionic. Because most PFASs found in contaminated water resources are anionic, improving surface basicity of GAC can enhance PFAS removal (Vu and Wu 2022). In a study that tested several carbonaceous sorbents, the sorption capacity was shown to be influenced more by surface basicity than hydrophobicity (Zhi and Liu 2015). Improving surface basicity was shown to enhance PFOS adsorption by multiwalled carbon nanotubes engineered with hydroxyl groups from 0.9 millimoles per gram (mmol/g) to 1.2 mmol/g (Deng et al. 2015a).

Anion Exchange

During anion exchange, anions such as chloride from the sorbent surface are exchanged for deprotonated PFASs. This mechanism is observed in IX resins; however, for PFAS adsorption, both hydrophobic interactions and anion exchange are utilized by IX resins (Vu and Wu 2022; Zaggia et al. 2016). For short-chain PFASs, which are relatively hydrophilic, anionic exchange will be the main mechanism in adsorptive removal by IX resins (Zaggia et al. 2016).

Other Mechanisms

Other mechanisms lending to PFAS removal by adsorption include micelle/hemi-micelle formation, bridging effects, hydrogen bonding, and bonding between fluoride on the adsorbent surface and fluoride on the PFAS molecule. At concentrations above a certain threshold, PFASs can form micelles by arranging their hydrophobic tails. This micelle formation can then promote multilayer adsorption on the sorbent surface, leading to enhanced sorption (Chen et al. 2017). The bridging effect is caused by divalent metallic cations like Ca^{2+} and Mg^{2+}, which attach to the negative charge on both carbon and PFAS, thus acting like a bridge between the sorbent and PFAS molecule (Vu and Wu 2022). Hydrogen bonding between fluorine atoms of PFASs and hydrogen atoms of sorbent might play an important role in adsorption for PFASs with high pK_a values (Vu and Wu 2022).

2.3.1.2 Factors that affect PFAS Removal Efficiency by Sorption

Natural Organic Matter

NOM can compete with PFAS for sorption sites, leading to lowered adsorption capacity for PFASs. Further, NOM can block the entryway to activated carbon pore structures, preventing PFASs from reaching sorption sites (Vu and Wu 2022). Complexation of PFASs with humic acid has been shown to reduce PFAS sorption. NOM adsorbed on the surfaces of sorbents can alter the surface charge of sorbents to a negative state, resulting in repulsion of anionic PFASs, thereby reducing sorption capacity. Moreover, highly hydrophobic organic matter can desorb PFASs from the sorbent surface. Hence, the presence of NOM generally has an adverse effect on PFAS sorption. Comparatively, IX resins are less affected by NOM than GAC. However, it was recently reported that up to 10 percent decline in PFCA and PFSA adsorption by an IX resin was observed compared to a DOM-free control (Boyer et al. 2021).

pH

pH affects the surface charge of the sorbent and also influences the species of contaminants present. When the pH of a solution is higher than the point of zero charge of an adsorbent, the surface charge of the adsorbent becomes negative, causing repulsion and less sorption of anionic PFASs (Vu and Wu 2022; Ahmadi et al. 2018). In a study conducted on PFOA and PFOS adsorption by bamboo-derived activated carbon, increasing pH from 3 to 10 decreased removal efficiency, with the steepest decline observed at 3 to 6 (Deng et al. 2015b). An IX resin (IRA67 [Dupont]) also demonstrated decreasing PFAS adsorption at elevated pH (Du et al. 2015). At low pH, the acidic functional groups on the adsorbent surface can become neutralized, leading to decline in electrostatic repulsion between sorbent surface anionic PFAS, thus improving sorption. Low pH can also improve the mobility of metal ions, causing a bridging effect that improves sorption of PFASs (Vu and Wu 2022).

Inorganic Ions

The presence of inorganic ions could improve anionic PFAS sorption on hydrophobic adsorbents by neutralizing their negative charge. This phenomenon mainly affects GAC (and potentially SPAC) and has less effect on IX resins. High ionic strength may also improve PFAS sorption to hydrophobic sorbents by reducing the solubility of PFASs, thereby promoting formation of micelles and hemi-micelles. Divalent cations (such as Ca^{2+}, Mg^{2+}, Fe^{2+}, and Mn^{2+}) can neutralize negative charge on the GAC surface, thereby enhancing adsorption of anionic PFASs. Conversely, in a study conducted on washing wastewater, addition of $MgCl_2$ and $CaCl_2$ significantly enhanced PFAS sorption due to the bridging effect (Du et al. 2015). However, in the case of anion exchange resins, high ionic strength can cause compression of the electric double layers, resulting in reduced anion exchange capacity (Vu and Wu 2022). Additionally, certain anions (such as sulfate) can compete with PFASs for anion exchange sites, thereby reducing efficiency of PFAS removal (Boyer et al. 2021).

In conclusion, SPAC is hypothesized to exhibit PFAS sorption higher than that of GAC due to its higher specific surface area and abundance of mesopores. These properties facilitate easier PFAS transportation to sorption sites and clogging of pores by NOM.

2.3.1.3 Comparison of Sorptive Capacities among GAC, SPAC, and IX Resin

Batch Studies

A large portion of comparative studies on different sorbents for PFAS removal have been conducted in batch systems (i.e., equilibrium isotherm experiments) due to ease of operation, smaller footprint, and low cost. While findings from these studies may not represent the real performance of large-scale flow-through adsorption systems, they allow comparison among different adsorbent types and can be used to assess the impact of PFAS properties and water quality constituents on adsorption.

Isotherm and batch studies carried out in solutions spiked with a single target PFAS showed PFOS removal better than that of PFOA, and PAC to have better sorption capacity than GAC (Ochoa-Herrera and Sierra-Alvarez 2008; Chen et al. 2017, Rattanaoudom et al. 2016; Wang et al. 2016). For instance, an isotherm study carried out using Calgon F400 (GAC) showed that, at an equilibrium aqueous phase concentration of 75 mg/L, the estimated PFOS and PFOA concentration adsorbed on the GAC was 225 mg/g-adsorbent and 70 mg/g-adsorbent, respectively (Ochoa-Herrera and Sierra-Alvarez 2008). Isotherm studies using PAC also observed similar results, with PFOS sorption exceeding that of PFOA at the same aqueous phase concentration (Rattanaoudom et al. 2016).

A batch adsorption study that tested PFOA and PFOS adsorption to GAC and PAC found similar results. In this study, separate 100 mg/L PFOS or PFOA solutions were tested, and the final PFOS and PFOA concentrations on the GAC were found to be 430 mg/g-adsorbent and 174 mg/g-adsorbent, respectively. Compared to GAC, PAC exhibited a higher sorption than both PFOS (538 mg/g-adsorbent) and PFOA (218 mg/g-adsorbent) (Chen et al. 2017). A batch study that investigated GAC adsorption found similar results, with PFOS adsorption at 250 mg/ g-adsorbent and PFOA sorption at 104 mg/g-adsorbent (Wang et al. 2016). The higher sorption observed for PFOS is due to the hydrophobicity from its longer perfluoroalkyl chain and sulfonic acid functional group (Maimaiti et al. 2018). The higher adsorption capacity of PAC can be attributed to its higher surface area, and larger availability of mesopores and macropores (Chen et al. 2017).

However, the adsorption capacity obtained in isotherm studies and batch studies discussed above are not representative of the adsorbent's performance in real groundwater samples or its field performance due to the high initial PFAS concentrations used in these studies and the absence of NOM and other PFASs that compete for sorption sites. The PFAS concentrations used in the isotherm and batch studies discussed above ranged from 4 to 415 mg/L, which is orders of magnitude higher than the PFAS concentration pertinent to natural water sources, in which the concentrations range from ng/L to low µg/L (Ochoa-Herrera and Sierra-Alvarez 2008; Chen et al. 2017, Rattanaoudom et al. 2012, Wang et al. 2016). Moreover, these tests were carried out in batch reactors in solutions spiked with a single target PFAS. Therefore, almost full saturation of sorption sites using the target PFAS could be achieved owing to high initial PFAS concentration and absence of other constituents in the water matrix that could compete with the target PFAS for sorption sites.

Anion exchange resin showed the highest sorption capacity among any evaluated sorbent during isotherm and single solute studies. In an isotherm study, IRA910 (IX resin) exhibited PFOS and PFOA sorption capacities at 1,750 mg/g-adsorbent and1450 mg/g-adsorbent, respectively.

However, the kinetics of PFOS adsorption were slow due to its susceptibility to formation of micelles and hemi-micelles, causing pore blockage and hindrance to intraparticle diffusion (Maimaiti et al. 2018). Another batch study that compared 14 commercially available sorbents for their removal efficiency of 75 different PFASs from a diluted aqueous film-forming foam (AFFF) mixture found anion exchange resin to exhibit significantly better sorption of PFASs compared to GAC, cation exchange resins, and non-ionic resins regardless of the predicted charge of PFASs (Fang et al. 2021).

Continuous Flow Studies

A column study conducted in PFAS-spiked municipal drinking water with an average dissolved organic carbon of 1.8 mg/L found IX resin (Purolite A600) to have a better average PFAS removal efficiency of 66 percent at 10 percent column breakthrough compared to GAC (Fitrasorb 400) with 62 percent efficiency (McCleaf et al. 2017). Increased removal was observed with increasing perfluoroalkyl chain length due to a proportionate improvement of hydrophobicity (McCleaf et al. 2017). In the case of isomers, linear chain PFASs were found to be more easily removed compared to their branched isomers. Additionally, sulfonates exhibited better removal than carboxylates of the same perfluoroalkyl chain length. A 20 percent breakthrough for perfluoro-n-butyric acid (PFBA) was observed at 5,000 bed volumes (BVs), while for PFOA and perfluorobutane sulfonate (PFBS) at 20,000 BVs and perfluorooctane sulfonate (PFOS) at more than 60,000 BVs (McCleaf et al. 2017). It was also observed that PFBA started desorbing at 18,000 BVs, while perfluorohexanoic acid (PFHxA) and PFOA began at 54,000 and 60,000 BVs, respectively. A similar column study conducted in PFAS-spiked drinking water compared the effect of different empty bed contact times (EBCTs) on PFAS removal concluded that full-scale treatment systems should have longer EBCTs to delay short-chain PFAA breakthrough. A cost analysis performed in the same study found IX resin to be more cost-effective than GAC due to the former's higher sorption capacity and held true even when using cheaper GAC or requiring fewer changeouts (Murray et al. 2021).

A study comparing GAC and SPAC conducted on PFAS-contaminated groundwater in a continuous flow-through system found SPAC to have more than 480 times the sorptive capacity of GAC. Using a sum of PFAS concentrations, SPAC achieved a sorptive capacity of 2.99 mg/g-adsorbent, with a PFOS sorption capacity of more than 2.6 mg/g-adsorbent (Murray et al. 2019).

2.3.2 Pilot-scale Studies

The sorption capacities achieved in batch studies do not accurately reflect the field conditions, in which the sorption capacities have been observed to be much lower. Pilot-scale studies comparing PFAS sorption performance of different adsorbents are limited. A pilot-scale study compared the performance of four different GACs (F400, GAC400, F600, and GCN1240) for the removal of ten different PFASs from impacted groundwater. At 5 percent breakthrough, F400 exhibited the highest sorption capacity for PFOA and PFOS at 0.75 and 2.5 µg/g-adsorbent, respectively (Liu et al. 2019). However, a pilot study conducted on treatment of PFAS-contaminated groundwater compared F400 and Sorbix A3F (resin) observed the resin to offer more than four times the sorption capacity for total PFAS than F400 before reaching breakthrough at the USEPA Health Advisory Level (HAL) of 70 ng/L for a combined concentration of PFOA and PFOS (Woodard et al. 2017). At the same EBCT of 5 minutes, Sorbix A3F resin treated six times more BVs than F400 before PFOS reached 70 ng/L and four times more BVs before PFOA reached 70 ng/L. This demonstrates the superiority of IX resin in terms of sorption capacity over GAC.

A pilot-scale GAC (Calgon DSR-A) study conducted on AFFF-contaminated groundwater at a military fire-fighting training site observed improved removal of longer-chain PFASs and linear isomers similar to the column studies discussed earlier (McCleaf et al. 2017; Rodowa et al. 2020). For PFASs with the same perfluoroalkyl chain lengths, PFCAs broke through initially followed by PFSAs, fluorotelomer sulfonates, and perfluoroalkyl sulfonamides, probably due to the improved electrostatic interactions in the latter ones (Rodowa et al. 2020; Murray et al. 2021). At a flowrate of 8 L/min, the first PFAS to breakthrough was PFBA at 3,900 BVs, while perfluorooctanoic acid (PFOA) and PFOS broke through at 8,500 and 14,900 BVs, respectively (Rodowa et al. 2020). Similar observations relating to PFAS selectivity were reported in a pilot-scale study conducted by Orange County Water District, in which 14 different sorbents (including GAC, IX resin, and novel sorbents) were studied for PFAS removal from contaminated groundwater (Pannu 2021). The study found FLUORO-SORB 200, a novel sorbent, to exhibit the latest initial PFOA breakthrough (2 ng/L).

2.3.3 AquaPRS™ Sorbent Technology

AASI initially tested, verified, and promoted PFAS removal capabilities with their Ceramic Membrane Separator Technology using SPAC with a mean particle size of approximately 1µm. SPAC was chosen based on previous use in removing taste and odor compounds (Geosmin and methyl-isoborneol [MIB]) with AASI's separations technology. SPAC has shown faster adsorption kinetics with improved micro-pollutant removals of various constituents over PAC and GAC (Matsui et al. 2013).

Before the start of the ESTCP Project, AASI's development efforts had advanced what was a variation of commercially available SPAC and engineered a differentiated sorbent offering capable of improved adsorption kinetics and pollutant removals versus the originally referenced SPAC. These formulated enhancements allow for targeted removals specific to site contaminants (type and concentration) and site remediation effluent requirements. One key objective was to address scaleup and manufacturability within the U.S. to support projected customer demands. AASI evaluated and tested different manufacturing methods resulting in a ten-fold reduction in the time to produce the desired sorbent material. The resulting end product met production goals for projected demand and future site requirements. In an ongoing effort to validate these methods, SPAC performance was evaluated in Test 5 of the Willow Grove NAS study to compare the original and revised manufacturing processes. The results, described later in this document, indicated similar to slightly better performance for the SPAC developed under the new production method.

To differentiate these media types, the new offering, referenced as "sorbent" in general text, has specific product identification variants under the parent product name "AquaPR Sorbent." The variants are identified by specific formulation numbers, such as "AquaPR-206™" for the original SPAC and "AquaPR-312™" for the media, which was produced using improved manufacturing methods. The modified CMF system that processes the sorbent is now referenced as the AASI PFAS Removal System, "AquaPRS™."

For clarity, all testing completed at Horsham AGS and Willow Grove NAS used AquaPR-206, except for test 'WG-Test 5B,' which used AquaPR-312.

2.4 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

The AquaPRS technology is positioned to offer an alternative to GAC and IX systems based on treatment efficacy and cost performance using LCCA to determine its applicability. It is recognized that some applications may be better suited for GAC or IX depending on the water quality characteristics, effluent targets, and PFAS content in the waste. Additional testing and comparisons across a broader range of PFAS concentrations; geochemical and co-contaminant conditions; and treatment applications including industrial pre-treatment, groundwater remediation, and drinking water will improve our understanding of its best application.

Identification of the following advantages of this technology are based on our previous experience and the findings of this test program:

1. ***Effective performance in the presence of co-contaminants*** – The Horsham AGS surface water testing showed that this technology removes PFAS compounds effectively despite the presence of total organic carbon (TOC) and sediment. Related work at the Brackish Groundwater National Desalination Research Facility indicated similarly good performance in the presence of chlorides.
2. ***Adaptive to changing conditions*** – The sorbent slurry exhibited viability when operated with a wide range of concentrations from 0.5 g/L to more than 40 g/L to combat variable water quality conditions. If PFAS levels increase or decrease, sorbent concentration can be adjusted to fit the need without changing detention time.
3. ***Scheduled sorbent replacement*** – Use of a slurry-based sorbent permits quick and automated replacement (weekly or bi-weekly, planned). Routine replacements result in continual sorbent renewal and high performance.
4. ***Limited downtime for sorbent replacement –*** The time to concentrate, remove, and replace sorbent is limited to about 30 minutes per replacement interval (every 1 to 2 weeks), resulting in >99 percent on-line, processing time.
5. ***Resistant to biofouling and scaling*** – Frequent sorbent replacement limits or avoids biofouling and scale build-up, which hinder other technologies targeting long replacement intervals.
6. ***Reduced disposal requirements*** – Demonstrated adsorption rates of 200 to 2,000 times higher than GAC significantly reduces the volume of spent sorbent material. Thickened, spent slurry material is easily pumped to storage and transport vessels for disposal at a small fraction of the overall mass and volume.
7. ***Simple but accurate small-scale pilot testing*** – Planned, short-term replacement intervals permit short (1- to 2-week) trials with limited waste volumes (~1 m^3) to accurately simulate full-scale operations. The 100 mL/minute pilot units use production-level sorbent, separations materials, and control strategies to demonstrate performance.
8. ***Membrane quality effluent*** – The 0.1 µm separation device produces filtrate that is free of PFAS and suspended solids, with turbidities typically well below 0.05 nephelometric turbidity unit (NTU). The technology is ideal for first-stage treatment ahead of secondary systems (such as second-stage AquaPRS, RO, NF, or IX systems).

9. ***Small footprint*** – Rapid PFAS adsorption has been demonstrated with detention times of 5 minutes. Higher PFAS levels can be addressed by raising the sorbent concentration in lieu of increasing detention times.
10. ***Media options*** – The system design permits the use of different sorbent formulations to address specific contaminants or if future conditions change.
11. ***No waste during operation*** – Back-pulsing (cleaning of the separation layer) uses particulate-free filtrate to dislodge foulants, which are returned to the sorption reactor. No waste streams are generated between media replacements, and the system is not subject to clogging of underdrains.
12. ***Remote monitoring and control*** – Programmable logic controller- (PLC-) based controls offer remote access, data acquisition, alarm notifications, and system control. Video monitoring is a simple and inexpensive add-on.
13. ***TOC removal*** – The carbon-derived sorbent material will remove pollutants additional to PFAS to improve disposal and other treatment options.
14. ***No odor generation*** – The system is not prone to biofouling and avoids the need for aerating to prevent hydrogen sulfide development.

Disadvantages of this technology include:

1. ***New technology for PFAS removal –*** The perception of added risk is associated with early adoption of any new technology. Widespread application and knowledge of SPAC-CMF for PFAS removal has not been established compared to GAC and IX. Additional work is needed to demonstrate this technology's effectiveness across a wide range of water qualities.
2. ***Reduced cost-effectiveness in low-strength water*** – The benefits associated with the use of membranes and controls render it less cost-effective on high-quality waters in which the combined PFAS concentrations are below 500 to 1,000 ng/L. Where GAC may offer suitable performance with extended periods between replacements, the payback period needed to offset the initial capital expenditure (CAPEX) may favor simpler approaches despite lower PFAS adsorption capacities.

3.0 PERFORMANCE OBJECTIVES

The six objectives identified in **Section 1.2** were addressed using the technology described in **Section 2.0** at both sites. Performance objectives, data requirements, and success criteria are outlined in **Table 2** below. PFAS treatment and longevity, as required to meet 40 ng/L UCMR3 compounds, are presented in **Section 6.3** for Horsham AGS and **6.4** for Willow Grove NAS. While both single- and two-stage systems were able to meet the treatment threshold, the two-stage arrangement achieved the longevity needed for the targeted sorbent replacement interval. Minimization of retentate waste was demonstrated throughout the program, as test results provided in **Appendices E and F** were obtained without wasting between sorbent replacements. Waste minimization through spent sorbent concentration exceeded the 40 g/L target, with final concentrations reaching 240 g/L. The success criteria and implications are discussed in **Section 3,** with more details provided in **Appendix A**. The influence from co-contaminants introduced from sediment loadings is discussed in **Section 6.3.1** and graphically illustrated in **Figure 11**. Specific adsorption rates used to quantify differences between surface and groundwater are identified in **Table 11** (surface water) and **Table 17** (groundwater).

Subsequent to the literature review for GAC and IX performance, comparative small-scale test results for these adsorbents were obtained on water from both sites for direct comparison to SPAC. These results were then used to determine scalability of the SPAC-CMF system through LCCAs presented in **Section 8.3**. Disposal requirements were found to be significantly lower than those associated with GAC due to the higher unit adsorption and volumetric reductions derived from waste concentrating methods. Disposal requirements were similar to those associated with single-use resin estimates but did not present a determining factor in the cost analysis shown in **Tables 21** and **22**.

Table 2. Performance Objectives

Performance Objective	Data Requirements	Success Criteria	Criteria Achieved	
Quantitative Performance Objectives			**Horsham AGS**	**Willow Grove NAS**
PFAS treatment longevity and selectivity	PFAS concentrations breakthrough curves (based on USEPA Method 537/DoD QSM 5.1), sorption rates, and selectivity	<40 ng/L UCMR3 PFAS compounds	**YES** – With dual-stage treatment and 12.5-minute (total) detention time. **NOTE** – Single-stage treatment was able to meet the objective for a limited duration due to PFBS exceeding 40 ng/L.	**YES** – With dual-stage treatment and SAR levels of 2,128 µg/g. **NOTE** – Performance sustained beyond the 1-week sorbent replacement target.
Minimization of retentate waste	Evaluation of retentate wasting volume as percentage of treatment flow	Optimization of retentate wasting volume through operation in pilot	**YES** – Zero wasting conducted between sorbent replacements. **YES** – Back-pulse return to sorbent reactor maintained 93% average net filtrate yield.	**YES** – Zero wasting conducted between sorbent replacements. **YES** – Back-pulse return to sorbent reactor maintained 96% average net filtrate yield.
Minimization of waste through concentration methods	SPAC dewatering using CMF system to determine dry solids concentration	Waste product > 40 g/L TSS (dry weight basis)	**YES** – SPAC concentration from membrane thickening greater than 80 g/L.	N/A – minimization trials conducted at Horsham and applied at Willow Grove NAS.
Influence of co-contaminants on operation and performance	Demonstrate effective PFAS removal and SARs in presence of elevated contaminant concentrations	SARs match or exceed values for GAC and IX on same water.	**YES** – After suitable pre-treatment for sediment removal in place. Inlet TOC values from 1.5 to 5.0 mg/L and turbidity of 1 to 5 NTU.	N/A – No significant co-contaminants found in Willow Grove NAS feed.
Characterize the cross-flow CMF system operation to permit scale-up	1) Simulate full-scale design conditions. 2) Validate whether test lab-scale unit performance to match field deployed system.	1) Continuous operation past expected sorbent replacement period. 2) Specific adsorption rates within 20% on same water.	**YES (1)** – Full range of detention times (5 to 60 min.) and sorbent levels (2 to 40 g/L) at targeted hydraulic loading rates (100 to 150 L/m^2-hr) completed. Evaluated back-pulse intervals from 10 to 60 minutes and full-scale SPAC replacement intervals.	**YES (2) –** Test 1A and lab tests had similar (< 20%) SARs for PFOA, PFBS compounds at same (20 min.) detention time. **NOTE: Direct** comparison for all tests and all compounds was not possible, as breakthrough was not reached.
Reduce carbon disposal through membrane concentration	Measure TSS per SM 2540D	Demonstrate final concentration exceeding 100 g/L.	**YES** – Side-stream dewatering increased spent SPAC to greater than 240 g/L.	N/A – minimization trials conducted at Horsham and applied at Willow Grove NAS.

Notes:
N/A = not applicable
SAR = specific absorption rate

3.1 EFFLUENT PERFORMANCE OBJECTIVES (HORSHAM AGS)

A 40 ng/L combined UCMR3 objective was identified as the project goal during the proposal phase despite the site selection having been unknown at the time. Site factors that could affect the ability to meet this objective included waste strength, PFAS composition, TOC, sediment, metals, and other organic and inorganic co-contaminants. During the Project, the team evaluated several other performance metrics to determine the SPAC-CMF's viability as an alternative treatment technology. These objectives and summary results are as follows:

10 Percent Breakthrough

Metric: Effluent concentration (Ce) to influent (Co) exceeding 0.10. This metric was used to compare SPAC-CMF with GAC, as GAC was unable to reach the more restrictive effluent limits.

Result: Single-stage treatment often approached 100 percent PFOS, PFOA (combined) removal and more than 90 percent of UCMR3 compounds. Dual-stage treatment was not necessary to meet this criterion.

USEPA HAL (2016)

Metric: < 70 ng/L combined PFOA and PFOS

Result: Single-stage treatment was successful at meeting the 70 ng/L target in most of the test runs with high specific adsorption rates. Dual-stage treatment was highly effective at meeting this objective, and all tests were completed without reaching a breakthrough condition.

UCMR3 Objective

Metric: < 40 ng/L combined PFOS, PFOA, perfluorononanoic acid (PFNA), perfluorohexanesulfonic acid (PFHxS), perfluoroheptanoic acid (PFHpA), and PFBS

Result: Single-stage treatment with SPAC-CMF was able to reach this effluent target in multiple tests. However, PFBS breakthrough resulted in short sorbent replacement intervals (2 to 5 days). Dual-stage treatment provided reliable performance and satisfactory loading capacities.

USEPA Risk-Based Screening Level (2022)

Metric: < 6 ng/L PFOA, PFNA; < 4 ng/L PFOS; < 39 ng/L PFHxS; < 601 ng/L PFBS

Result: Single-stage treatment was also able to meet this requirement in multiple tests, with runs extending past the minimum sorbent replacement interval. Dual-stage treatment provided reliable performance and improved loading capacities.

3.2 EFFLUENT PERFORMANCE OBJECTIVES (WILLOW GROVE NAS)

The Willow Grove NAS groundwater was known to contain PFAS levels that were four to five times higher than those present in the Horsham AGS surface water. However, the water at Willow Grove NAS was free of sediment, exhibited low (< 1 mg/L) TOC, and was not subject to significant variability in PFAS levels. The team maintained the same objectives for Willow Grove NAS that were in place for the Horsham AGS study.

10 Percent Breakthrough

Metric: Effluent concentration (Ce) to influent (Co) exceeding 0.10.

Result: Single-stage treatment achieved SAR levels greater than 5,800 µg/g for combined PFOA and PFOS and greater than 6,800 µg/g for combined UCMR3 compounds. Dual-stage treatment was not necessary for this objective.

USEPA HAL (2016)

Metric: < 70 ng/L combined PFOA and PFOS

Result: Single-stage treatment met this objective from influent levels of 25,000 to 30,000 ng/L. Dual-stage treatment was not necessary for this objective.

UCMR3 Objective

Metric: < 40 ng/L combined PFOS, PFOA, PFNA, PFHxS, PFHpA, PFBS

Result: Single-stage treatment with SPAC-CMF was not able to sustain the 40 ng/L combined effluent level, primarily due to PFBS breakthrough. Nevertheless, the SPAC-CMF system did demonstrate high removal rates (95 to 99 percent) from 35,000 to 40,000 ng/L for periods exceeding 2 weeks. Dual-stage treatment achieved the 40 ng/L combined effluent UCMR3 compounds from an influent of 40,000 ng/L for a period exceeding the 1-week target replacement interval.

USEPA Risk Screening Level (2022)

Metric: < 6 ng/L PFOA, PFNA; < 4 ng/L PFOS; < 39 ng/L PFHxS; < 601 ng/L PFBS

Result: Single-stage treatment was able to reach these levels but approached breakthrough near the targeted replacement interval. Dual-stage treatment easily met this requirement.

4.0 DEMONSTRATION SITES

4.1 HORSHAM AGS

Horsham AGS (Horsham AGS) is located approximately 18 miles north of Philadelphia in Horsham Township, Montgomery County, Pennsylvania. The approximately 207 acres that comprise Horsham AGS include properties formerly occupied by the Air Force Reserve and Navy. Horsham AGS is located immediately northwest of and adjacent to the formal Naval Air Station/Joint Reserve Base (NAS/JRB) Willow Grove (Willow Grove NAS). In 1942, the U.S. Government purchased the property known as Pitcairn Field for use as an anti-submarine warfare center by the Navy. Following World War II, the facility was designated a Naval Air Reserve Training Center. Training and operation support were highest during the Korean conflict, Vietnam conflict, and Gulf War. In 1994, the Naval installation was designated NASJRB Willow Grove. Willow Grove Air Reserve Station continued to be managed under the U.S. Air Force (USAF) authority; however, Air Force Reserve was deactivated in 2007 as a result of the Base Realignment and Closure (BRAC) program. The Air National Guard became responsible for the USAF land, with the official transfer completed in 2011 and renaming of the property to Horsham AGS (Leidos 2019).

4.1.1 Site Geology and Hydrogeology

The land surface at Horsham AGS is highest on the northern, eastern, and southern property margins at elevations in the range of 300 to 310 feet above mean sea level (AMSL). Within the confines of Horsham AGS, slopes steepen and converge toward the stormwater basin (265 ft AMSL) near the northwest-central property boundary. Land at the northern boundary of Horsham AGS slopes gently to the north-northwest toward Park Creek, located approximately 0.5 mile from Horsham AGS. Park Creek flows northeast and discharges to Little Neshaminy Creek. The eastern portion of Horsham AGS gently slopes toward an unnamed tributary roughly 0.3 mile from the boundary. The unnamed tributary flows northward to Little Neshaminy Creek, which is approximately 1 mile to the north of Horsham AGS. The Little Neshaminy Creek flows northeast and is the lowest regional drainage point in relation to Horsham AGS.

The Horsham AGS stormwater basin is a man-made, unlined structure at the head of an unnamed tributary to Park Creek. The basin receives stormwater runoff for Horsham AGS and Willow Grove NAS. Surface water outflow from the basin travels northwest along the unnamed tributary to Park Creek.

4.1.2 Previous PFAS Characterization

In 2015, the National Guard Bureau (NGB) conducted a preliminary assessment to identify potential PFAS sources at Horsham AGS. Based on these findings, NGB initiated a Facility Investigation for PFASs to evaluate the ten potential PFAS source areas, which included records review; sampling of soil, sediments, AFFF storage tanks, surface water, and groundwater; and completion of a hydrogeologic assessment (Leidos 2018 a.b). Based on the recommendations documented in the Facility Investigation, Horsham AGS initiated plans to treat surface water discharges at Outfall 9 (**Figure 2)** following completion of a stormwater and surface water study.

Figure 2. Horsham AGS Outfall No. 9

In response to elevated concentrations of PFAS detected in the surface water leaving Horsham AGS from Outfall 9, a temporary treatment system was installed and operated under a temporary discharge permit approved by the Pennsylvania Department of Environmental Protection (PADEP) on August 17, 2017. The treatment system relies on a weir to create a ponded water area in the concrete channel upstream of Outfall 9 and downstream of the stormwater basin. The treatment system receives water from four sources: (1) groundwater conveyed to the stormwater basin, (2) groundwater infiltrated into the old sewer lines, (3) stormwater conveyed to the stormwater basin, and (4) stormwater that infiltrates the old sewer line. The interim treatment system consisted of a four-stage process. Flow is routed through a sand filter, which may be backflushed as needed. The flow continues through a carbon/clay filter, then through a GAC unit and finally through a polishing resin. The system is designed to treat a maximum of 200 gpm, with baseflow from the stormwater basin of 40 to 60 gpm and sewer lift station of 10 to 20 gpm.

Influent PFAS data were obtained through ongoing testing with 16 bi-weekly measurements between August 2018 and April 2019. PADEP provided data in a transmittal letter in reference to the temporary discharge permit (PADEP 2019). PFOS concentrations ranged from non-detect (N.D.) to 6.6 µg/L, with an average of 2.6 µg/L. PFOA concentrations ranged from N.D. to 0.41 µg/L, with an average of 0.25 µg/L. This range of PFOS and PFOA concentrations was ideal to evaluate the performance of the SPAC-CMF system.

4.2 WILLOW GROVE NAS

Willow Grove NAS is located approximately 20 miles north of Philadelphia in Horsham Township, Pennsylvania. Approximately 1,000 of the 1,200 acres that comprise Willow Grove NAS are maintained by the DoD as an air station. The remaining 200 acres of the land in the northeastern section of Willow Grove NAS are occupied by Horsham AGS.

Originally a private airfield between 1919 and 1926, the Navy acquired a 516-acre parcel of the property in 1942. In January 1943, the airfield was commissioned as NAS Willow Grove. NAS Willow Grove became a Naval Air Reserve Training Station following World War II, with the primary purpose of providing support for aviation training operations and Navy reserve training. Over time, the DoD purchased additional land and supported other DoD tenants including the United States Marine Corps and the United States Army Reserve. NASJRB Willow Grove was officially disestablished on March 30, 2011, as a result of the BRAC program. BRAC Program Management Office (PMO) maintains caretaker status of Willow Grove NAS as of September 2011 (Tetra Tech 2019).

4.2.1 Site Geology and Hydrogeology

The land surface at Willow Grove NAS is flat, with the base runway as the highest local topographic feature. Willow Grove NAS lies in the Gettysburg-Newark Lowlands of the Piedmont Physiographic Province of Pennsylvania, which is underlain by the Stockton Formation, consisting of Triassic age sedimentary rocks. The subsurface lithology contains multiple layers of siltstone, siltstone/shale, and sandstone with direct communication between zones. Groundwater flow tends to the northwest in all three zones (Tetra Tech 2019).

Upstream from Willow Grove NAS lies Park Creek, a first- and second-order stream with a drainage area of approximately 10 square miles. Park Creek receives surface water discharge from Recreational Pond (on Willow Grove NAS), becoming a third-order stream as it passes the Site. Park Creek eventually joins Little Neshaminy Creek, becoming a larger, fourth-order stream. Pennypack Creek (first- and second-order stream) receives flow from an unnamed tributary that originates on Willow Grove NAS. There are several outfalls and ponding areas on site.

4.2.2 Previous PFAS Characterization

PFAS use at Willow Grove NAS was limited to AFFF for firefighting. PFAS-containing materials, including oils, lubricants, and paints, were stored on site (USEPA 2013). In 2014, the Navy conducted groundwater sampling for PFOS and PFOA at Willow Grove NAS and found concentrations of PFOS and PFOA above the USEPA Long-term HAL. In 2015, the Navy investigated surface water and sediment for PFOS and PFOA, finding detections of PFOS only in surface waters and sediment samples.

In 2019, the Navy completed a Remedial Investigation (RI) for PFAS in soil, groundwater, surface water, and sediment at Willow Grove NAS. The RI found PFOS and PFOA exceedances in the surface and subsurface soil, mainly around the hangars, and groundwater exceedances of PFOS and PFOA PHLs across the site. PFOS and PFOA were also detected in surface waters (Tetra Tech 2019).

4.2.3 Other Treatment Testing

In parallel with this effort, CSM operated a continuous-flow pilot system at Willow Grove to assess IX resin performance in treating aqueous film forming foam (AFFF)-impacted groundwater (ER18-C2-1063; project lead by PI Timothy Strathmann). This pilot was designed to test numerous resins in parallel as well as evaluating the efficacy of using multiple resins in series.

Five different resin formulations were tested from Purolite, Calgon, and Evoqua, including single use “PFAS-specific” resins. Design empty bed contact time (EBCT) for each vessel in the system enables comparisons of how increasing EBCT affects removal of PFAS both for a single resin as well as for different resin combinations. Results generated from this pilot, specifically breakthrough data and corresponding adsorptive capacity values (ug-PFAS/g-adsorbent) for the AER resins, will be used as a metric to compare results obtained through SPAC-CMF testing.

5.0 TEST DESIGN

5.1 CONCEPTUAL EXPERIMENTAL DESIGN

In these series of tests, the main objective was to evaluate the efficacy of the AquaPR-206 CMF treatment approach to reduce the total life-cycle cost of treating PFAS-impacted groundwater. To achieve this objective, several tests were conducted with varying key operational parameters and conditions to determine optimal system operating conditions and identify which conditions resulted in the most effective PFAS removals.

Table 3. Parameters and Conditions for Each Test

	Variables	Measurement Values
Primary Variables	Sorbent Reactor Concentration	2-40 g/L as carbon
	Sorbent Reactor Detention Time	5-60 minutes
	CMF Flux	100-150 L/m^2-hr
Secondary Variables	Membrane Cleaning: Acid Soak	0.05-1.0% Citric acid
	Membrane Cleaning: Hypochlorite Soak	0.05-0.3% as sodium hypochlorite
	Membrane Cleaning: Acid + Hypochlorite	Series soak with rinse between
	Configurational Flow Path: Parallel	Train A vs. Train B
	Configurational Flow Path: Series	Train A lead with Train B lag OR Train A lag with Train B lead
	Membrane Backwash Frequency	15- to 60-minute intervals

A simplified conceptual experimental design diagram is presented below as **Figure 3**. This figure shows the major treatment unit process steps such as adsorption and separation. Pre-treatment was applied to capture solids larger than 5 µm and to protect the CMF from premature fouling. This also helped to minimize premature sorbent exhaustion from co-contaminants.

Figure 3. Simplified Conceptual Experimental Design: Process Steps

Tests were set up and conducted first by preparing specific sorbent concentrations and volumes within the sorbent reactor. Sorbent concentrations varied per test to evaluate the optimal sorbent concentration necessary for efficient and cost-effective PFAS adsorption. Deionized water was added to the sorbent material within the reactors to make up the starting volume required to achieve the target concentration and detention time. The CMF-PFAS treatment system was started after establishing sorbent volumes and concentrations.

The first step in the treatment process was pre-treatment. Pre-treatment was achieved by pre-filtration, which was necessary due to poor surface water quality. The surface water was impacted by surface runoff, causing high TSS and turbidity conditions, especially during rainstorm or snow melt events. PFAS-contaminated raw water was pumped to the pre-treatment system, which comprised an automated (i.e., backwashable) 5 µm cloth media filter system followed by 5 µm pleated cartridge filters, used as backup for the cloth media filter.

The purpose of pre-treatment was twofold: (1) minimize potential co-contaminants from prematurely exhausting the sorbent material; and (2) prevent premature fouling of the CMF membrane.

Pre-filtered raw water then entered the SPAC-CMF system by filling the main system break tank. Water from the break tank was then pumped to each train's sorbent reactor, where PFAS-contaminated raw water was mixed with the sorbent in the bulk solution for a pre-set detention time. The sorption reactor with 5 to 60 minutes of contact time, in combination with cross-flow operation, permits suspended sorbent concentrations of 2 to 50 g/L to mix with incoming waste and facilitate PFAS adsorption. Sorbent reactor detention time varied per test to determine the time needed for complete adsorption. The bulk SPAC solution was pumped to the membrane through feed channels and returned to the sorption reactor. The CMF system was operated in cross-flow to benefit from high-velocity flow through the feed channels. High velocity creates a scouring effect from the sorbent material passing through the feed channels, which maintains permeability and reduces cleaning (backwash) requirements.

PFAS-free water is produced by permeation (via tangential pressure) through the membrane barrier separation process (pore size exclusion <0.1 µm). CMF effluent samples were collected for PFAS analysis by PACE lab using USEPA Method 537/DoD QSM 5.1, or, for samples analyzed by the CSM, a validated modified method of USEPA 537.1 was used. This method is characterized by whole-sample collection, preparation, and analysis of selected PFASs in unfiltered low-volume (3 to 7 milliliters [mL]) water samples. CSM's analytical method differs from USEPA 537.1, as it uses large-volume injection as opposed to solid-phase extraction (SPE), elution, and injection. To ensure the same results were achieved by USEPA 537.1, split samples from Horsham AGS Test 11 were sent to an ELAP certified lab (PACE Analytical) and CSM for confirmation analysis (refer to **Appendix D**). The results from the PACE lab analysis are included in **Appendix H**.

The CMF system described above was also used to re-concentrate the AquaPR-206 at the end of each run as the system approached breakthrough. Waste concentration trials have shown that carbon levels can be concentrated to 4 to 5 percent of the original working volumes to drastically reduce hauling and disposal costs.

5.2 TREATABILITY TESTING

Treatability studies were conducted at the AASI research and development (R&D) lab before field testing at Horsham AGS and Willow Grove NAS. The results from these tests informed the experimental design for larger-scale testing conducted at the two sites. These studies were conducted using an automated, bench- scale SPAC-CMF pilot treatment system identified as PT-3 (**Figure 4**). This unit is designed to function similar to the larger-scale field unit in order to yield consistent results (additional discussion is provided in **Section 10** of this document). The bench-scale unit includes an adsorption reactor and membrane separation process unit and is automated to function similar to full-scale systems. The adsorption reactor supports the same AquaPR-206 sorbent at design concentrations and detentions using a similar hydraulic regime. The separation process employs a single, production-level 30 mm diameter x 100 mm ceramic membrane.

Figure 4. Bench-scale Pilot Treatment (PT-3) Unit Front View on Left Picture and Backside on Right Picture, for Treatability Studies

5.3 DESIGN AND LAYOUT OF SYSTEM

The CMF-PFAS treatment test system as used at Horsham AGS included the following functional components: (1) AquaPR-206 media contained within a pair of 150 mm diameter x 2.4 m high columns; (2) the AASI CMF with a pair of 30 mm diameter by 1 m long ceramic membranes; (3) a pre-treatment system including 20 µm and 5 µm pre-filter cartridges and a 5 µm cloth media filter system. The CMF-PFAS treatment system is described in the subsections below. **Figure 5** shows the CMF-PFAS treatment system sorption reactor columns and membrane system as used for the series of tests conducted at Horsham AGS and Willow Grove NAS. The subsequent discussion details the components of the CMF-PFAS treatment system.

Figure 5. CMF-PFAS Removal System Sorption Reactor Columns (left) and CMF-PFAS Removal System Membranes (right)

Carbon-Based Adsorbent: The SPAC sorbent shares similarities with GAC with respect to PFAS removal. The SPAC provides an oleophilic surface that provides an attractive force to PFASs and other organic compounds, which are held within the internal macro-, micro- and mesopores within the sorbent particle. However, there are key differences that allow the SPAC-CMF system to achieve higher removal rates with a significantly lower adsorbent mass. The exceptionally small particle size of the SPAC permits greater penetration and access to the internal pores, thereby improving solute diffusion and adsorption kinetics. The small particle size limits the media density, as a packed bed of sub-micron media would prevent advection of the solutes due to a low hydraulic flux. In response, this technology arranges the sorbent media in a mixed suspension to facilitate exposure of the sorbent to the PFAS. The treated water is then separated from the slurry using a ceramic microfilter with a nominal pore size that is 10 percent of the sorbent's median particle size.

The Ceramic Membrane Filtration: The system is a fully automated, dual-train membrane system (**Figure 5**) with integrated AquaPR-206 adsorption reactor columns housed in a climate-controlled pilot container (**Figure 6**). The CMF pilot system includes a single skid-mounted unit with a footprint of approximately 6 ft (1.8 m) by 9 ft (2.7 m) and a height of 7 ft (2.1 m). The system comprises two identical filter trains (Trains A and B), which can be operated independently in single pass or in series for lead/lag configuration testing.

The membranes are operated in cross-flow filtration, whereby treated water is produced as filtrate and the AquaPR-206 sorbent media is returned to the upstream sorption reactor. High-velocity cross-flow and AquaPR-206 scouring effects on the membrane surface maintain high permeability and reduce cleaning (backwash) requirements. A sorption reactor column with 10 to 30 minutes of contact time, in combination with cross-flow operation, permits suspended AquaPR-206 concentrations of 1 to 50 g/L to mix with the incoming waste to facilitate PFAS adsorption. AquaPR-206 sorbent media is separated from the bulk liquid with CMF technology using a 0.1 µm nominal pore size barrier. A rapid backwash method increases recovery and reduces backwash waste to improve AquaPR-206 inventory control.

Pilot Container (PC) – A 40 ft (12.2 m) long, 8 ft (2.4 m) climate-controlled PC (**Figure 6)** housed the CMF-PFAS treatment system, including pre-treatment. **Table 4** lists the specifications of the CMF-PFAS treatment system:

Figure 6. Climate-controlled Pilot Container

Table 4. CMF-PFAS Treatment System Specifications Summary

System Summary	
Number of Trains	2
Membrane Material	Ceramic
Nominal Pore Size	0.1 µm
Size of element	30 mm (dia.) x 1.0 m (length)
Active membrane area per module	0.409 m^2 (4.4 ft^2)
Permeate flow (each train)	0.67 -1.0 L/min
Sorption Reactor Detention:	5 to 60 minutes
AquaPR-206 concentration	500 to 40,000 mg/L
AquaPR-206 size	0.8 to 1.0 µm

Pre-treatment System: The pre-treatment system was comprised of a floating pump with a submerged intake, 2.3 mm strainer, automated cloth media filter, and cartridge filters as backup. The pump was floated on the surface of the source water to minimize sediment intake. **Figure 7** shows the automated 5 µm cloth media filter system (AASI AquaBot 3 cloth media pilot system; AB3), which was used as the primary pre-filtration unit. Thereafter, effluent from the AB3 system routed through a 5 µm pleated cartridge filter before filling a break tank on the CMF system. On-line turbidimeters were provided with the AB3 system to assess the influent and effluent water quality. The cloth media filter material used in this study was also rated for a nominal 5 µm particle size.

Figure 7. AquaBot 3 System with Cloth Media (left) and Pleated Cartridge Filters (right)

5.3.1 Test System Layout

Test-specific experimental system design layouts are detailed below. **Figure 8** provides the parallel, single-pass test configuration flow diagram. Some of the tests were conducted in parallel (i.e., via two-train CMF system), single-pass operation. Single-pass refers to a single separation process as opposed to a lead/lag configuration using a dual-separation process (i.e., two membranes operated in series). **Table 5** describes the keyed process steps and componentry of the system illustrated on **Figure 8**.

Figure 9 displays the series flow path in lead/lag configuration. These series of tests evaluated PFAS removal performance from a dual-stage separation process. **Table 6** describes the keyed process steps and componentry of the system illustrated on **Figure 9**.

Parallel Flow Path (single pass) Tests flow diagram and process descriptions:

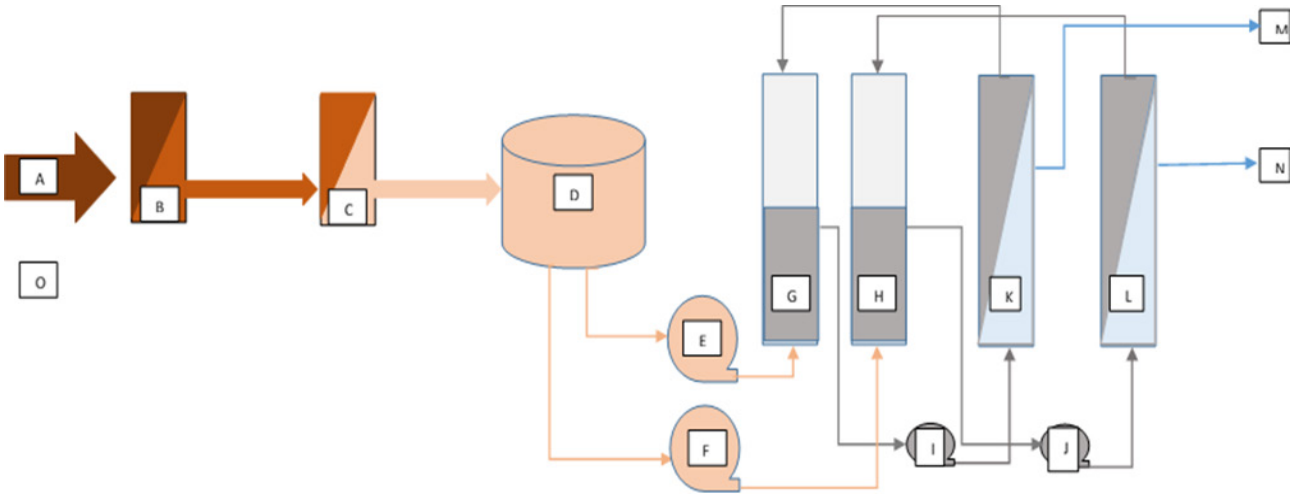


Figure 8. Parallel Flow Path (single-pass) Flow Diagram

Table 5. Parallel Testing (single-pass) Flow Diagram Process Descriptions

Key	Description	Notes
A	Raw feed water	Contaminated with 5,000 to 6,000 ng/L PFAS and sediment, resulting in turbidity values from 1 to more than 100 NTU.
B	20 µm pleated cartridge filter	Used as pre-treatment for solids removal > 20 µm particle size (changed to 5 µm for Willow Grove NAS tests).
C	5 µm cloth media filter	Used as pre-treatment for solids removal > 5 µm particle size. This was necessary at Horsham AGS (surface water with high TSS, especially during storm events) and not at Willow Grove NAS (groundwater with low TSS).
D	Raw water break tank	Collection tank for pre-filtered raw feed water.
E	Train A raw water feed pump	This pump supplied raw water to Train A sorbent reactor column.

Table 5. Parallel Testing (single-pass) Flow Diagram Process Descriptions (Continued)

Key	Description	Notes
F	Train B raw water feed pump	This pump supplied raw water to Train B sorbent reactor column.
G	Train A sorbent reactor column	The sorbent reactors contained the AquaPR-206 sorbent at varied concentrations per test to evaluate PFAS removals at difference concentrations. The volume of sorbent was also varied per test to evaluate PFAS removals at different detention times. The sorbent replacement interval was dictated by the PFAS loading and sorbent mass held in the reactors. Train A and B sorbent reactors were set up independently to evaluate different test parameters concurrently.
H	Train B sorbent reactor column	
I	Train A recycle loop pump	Recirculated the contents of each sorbent reactor through the feed channels of the membrane, returning to the reactor.
J	Train B recycle loop pump	
K	Train A CMF	The membrane served as a separation process whereby the PFAS-sorbent adsorbed material was separated from < 0.1 µm particulate sized, clean water.
L	Train B CMF	
M	Train A membrane permeate outlet and sample collection point	One liter of permeate from each train was collected daily using a dedicated auto-sampler. The samples were then collected in individual sample bottles and sent for analysis. This step was conducted in accordance with the sampling methods detailed in the demonstration plan.
N	Train B membrane permeate outlet and sample collection point	
O	Raw feed sample collection point	One liter of raw feed water was collected daily at this point 1.5 hours sooner than permeate samples due to total residence time in system downstream from this point and up to permeate sample point. This step was conducted in accordance with the sampling methods detailed in the plan.

Series Flow Path (lead/lag) Tests flow diagram with process descriptions:

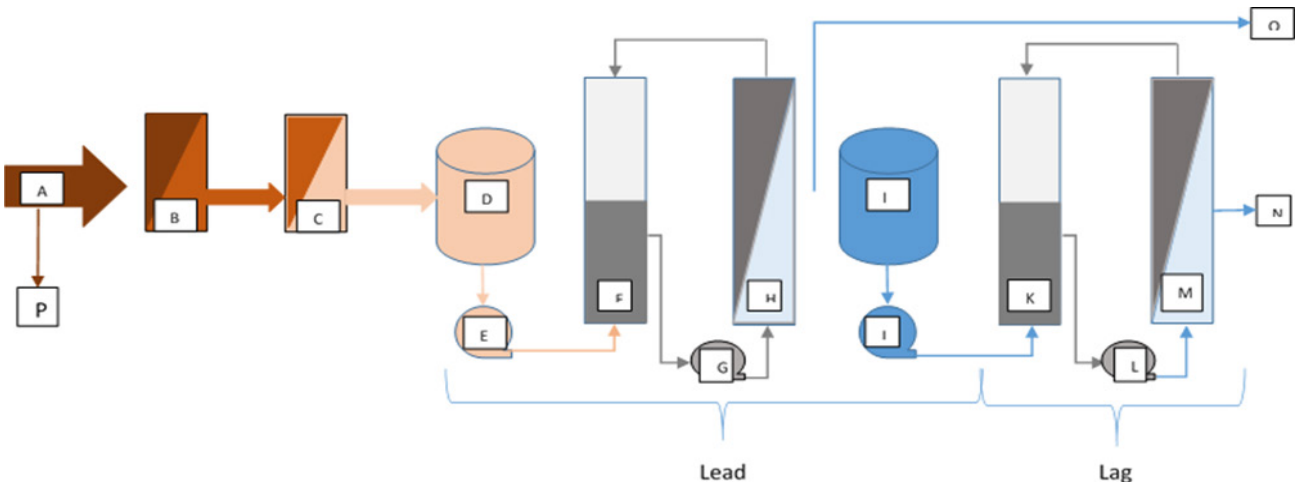


Figure 9. Series Flow Path (lead/lag) Flow Diagram

Table 6. Series (lead/lag) Testing Flow Diagram Process Descriptions

Key	Description	Notes
A	Raw feed water	Contaminated with 30,000 to 50,000 ng/L PFAS and sediment, resulting in turbidity values from 1 to more than 100 NTU.
B	20 µm pleated cartridge filter	Used as pre-treatment for solids removal >20 µm particle size (changed to 5 µm for Willow Grove NAS tests).
C	5 µm cloth media filter	Used as pre-treatment for solids removal > 5 µm particle size. This was necessary at Horsham AGS (surface water with high TSS, especially during storm events) and not at Willow Grove NAS (groundwater with low TSS).
D	Lead position raw water break tank	Lead position raw water collection tank. This water was used as influent feed to the lead position sorbent reactor.
E	Lead position raw water feed pump	This pump supplied raw water to the lead position sorbent reactor column.
F	Lead position sorbent reactor	The lead position sorbent reactor contained the AquaPR-206 sorbent at varied concentrations per test to evaluate PFAS removals at different concentrations. The volume of sorbent was also varied per test to evaluate PFAS removals at different detention times. The sorbent replacement interval was dictated by the PFAS loading and sorbent mass held in the reactors. Lead and lag sorbent reactors were set up independently to evaluate different test parameters concurrently.
G	Lead position sorbent recycle loop pump	Recirculated the contents of the lead position sorbent reactor through the feed channels of the lead position membrane, returning to the lead position sorbent reactor. One variable parameter evaluated here was the recirculation rate velocity through the membrane.
H	Lead position ceramic membrane filter (CMF)	The membrane served as a separation process whereby the PFAS-sorbent adsorbed material was separated by microfiltration (i.e., > 0.1 µm particulate size exclusion).
I	Lag position feed water break tank	Lead position membrane permeate collection tank. This water was used as influent feed to the lag position treatment unit.
J	Lag position feed water pump	This pump supplied influent feed from the lag position feed water break tank to the lag position sorbent reactor column.
K	Lag position sorbent reactor	The lag position sorbent reactor contained the AquaPR-206 sorbent at varied concentrations per test to evaluate PFAS removals at different concentrations. The volume of sorbent was also varied per test to evaluate PFAS removals at different detention times. Lead and lag sorbent reactors were set up independently to evaluate different test parameters concurrently.
L	Lag position sorbent recycle loop pump	Recirculated the contents of the lag position sorbent reactor through the feed channels of the lag position membrane, returning to the lag position sorbent reactor. One variable parameter evaluated here was the recirculation rate velocity through the membrane.
M	Lag position CMF	The membrane served as a separation process whereby the PFAS-sorbent adsorbed material was separated by microfiltration (i.e., > 0.1 µm particulate size exclusion).
N	Lag position membrane permeate outlet and sample collection point	One liter of lag position membrane permeate was collected using a dedicated auto-sampler daily. The samples were then collected in individual sample bottles and sent for analysis. This step was conducted in accordance with the sampling methods detailed in the plan.
O	Lead position membrane permeate outlet and sample collection point	One liter of lead position membrane permeate was collected using a dedicated auto-sampler daily. The samples were then collected in individual sample bottles and sent for analysis. This step was conducted in accordance with the sampling methods detailed in the plan.
P	Raw feed sample collection point	One liter of raw feed water was collected using a dedicated auto-sampler daily. The samples were then collected in individual sample bottles and sent for analysis. This step was conducted in accordance with the sampling methods detailed in the plan 1.5 hours sooner than permeate samples due to total residence time in system downstream from this point and up to permeate sample point.

6.0 FIELD TESTING RESULTS

6.1 SAMPLING METHODS

Field samples were collected closely following guidelines established in the demonstration plan.

Three sample point sources were identified for each test: (a) feed source, (b) Train A effluent, (c) Train B effluent. Each of these was routed to a dedicated ISCO model 3700 sequential auto-sampler unit, which collected 1 L of sample daily from each. Polypropylene bottles and polyethylene-lined caps were used for sample collection inside the Teledyne ISCO (ISCO) sampler units. The bottles were reused for each test but cleaned in between using 10 percent methanol solution and rinsed with distilled water. All samples were collected by the sampler using nitrile gloves, which were replaced after each sample point source.

At each test end, water samples collected in the ISCO sampler bottles were then transferred to sample containers provided by PACE lab and separately, CSM lab as split samples. PACE lab required 500 ml total volume (2 x 250 ml bottles) per sample analysis; whereas CSM lab required 50 ml (collected in 50 ml polypropylene centrifuge tubes) per sample analysis. Each bottle was labeled after sealing the bottle with a cap. Sample bottles were then kept in cold storage until shipment to lab. PACE lab samples were sent via a chilled cooler (i.e., using bagged ice). Samples sent to CSM lab were not chilled and were sent to the lab in sealed polyethylene bags.

The following precautions were taken to minimize contamination impacts from clothing and other items near the sample collection area:

1. Samples were not filtered upon collection to sample bottles for lab submission.
2. Effluent samples were collected first.
3. Sample bottle caps were held in a gloved hand before filling the bottle, then closed onto the bottle after filling.
4. After the sample bottle label was applied, the sample was kept in refrigerated storage (< 6 degrees Celsius) until shipment to the lab.

6.2 CSM ANALYTICAL LAB EVALUATION

CSM lab split a sample with detectable PFAS concentrations into two identical sets of three replicates. CSM analyzed one set of replicates was analyzed for PFAS following the procedures described in the Standard Operating Procedure (SOP; **Appendix B**). The remaining set of replicates was delivered to PACE, a third-party DoD Environmental Laboratory Accreditation Program- (ELAP-) accredited laboratory under chain-of-custody protocol for PFAS analysis. The resulting analytical reports were evaluated for statistically significant differences in reported PFAS concentrations in accordance with the provisions included in the Analytical White Paper (**Appendix C**).

A linear regression analysis was performed comparing the CSM and PACE data. The objective of the analysis was to evaluate whether the data conform to the following performance metrics: slope between 0.8 and 1.2, R^2>0.8, and average relative percent difference (RPD)≤30%.

The performance metrics are summarized in **Table 7.** The scatter plots from the regression analysis and more related discussion are available in **Appendix D**.

The R^2 values demonstrate that all UCMR3 PFASs met the performance metric. The R^2 values represent how well the model fits the two sets of lab data. Hence, results of the linear regression analysis indicate a strong linear relationship between the CSM and PACE data. However, slopes of three of the UCMR3 PFASs are less than 0.8, indicating a positive bias on the CSM data and a conservative estimate of effluent concentrations. Similarly, the average RPD of these three PFASs was slightly above 30 percent. The plausible reason for a positive bias on the CSM data and having an RPD above 30 percent for some of the PFASs might lie in the difference between the two labs in terms of sample preparation. While PACE used SPE, CSM used direct injection, which could have caused slight deviations in the performance metrics for some of the PFASs.

Table 7. Summary of Performance Metrics from the Linear Regression Analysis

Analyte	Slope	R^2	Average RPD
PFOS	0.58	0.965	40.4
PFOA	0.92	0.987	13.3
PFHxS	0.70	0.967	34.3
PFHpA	0.93	0.980	12.2
PFNA	ND	ND	ND
PFBS	0.55	0.84	36.0
PFBA	0.58	0.764	30.6
PFPeA	0.82	0.932	10.6
PFHxA	0.73	0.970	47.5
PFPeS	0.69	0.982	51.1
PFHpS	0.529	0.987	63.5
4:2 FTS	ND	ND	ND
6:2 FTS	0.60	0.994	41.2

Note:
PFASs listed in UCMR3 are bold
ND = non-detect

6.3 HORSHAM AGS

Testing began on June 24, 2020, with the initial design condition based on a combination of previous lab testing and a preliminary bench-top evaluation performed at AASI's lab on water from Horsham AGS. The first 2 months of testing were critical for understanding the challenges associated with variable water quality characteristics, identifying optimal system operating variables, and assessing the implications of sampling methods.

Influent was drawn from Outfall No. 9 (**Figure 10**), which comprises a combination of surface water and groundwater. Unlike a typical groundwater treatment application, surface waters are exposed to a much broader range of contaminants including dissolved and particulate organic matter, particulate matter (e.g., silt), surface water runoff, and any contaminants that may come in contact with the water. Further, surface water quality can be significantly and adversely impacted by local and regional weather events. The photo shows an example of the water quality treated by the SPAC-CMF system during testing. Wind, rainfall, and high flows in the outfall regularly mixed bottom sediments, which can dramatically impact PFAS removal performance in surface water compared to groundwater with much more consistent water quality.

Figure 10. Feed Conditions at Horsham AGS Outfall No 9

Thirteen tests were conducted at Site as summarized in **Table 8** and discussed in the following sub sections. Tests with gray highlight in **Table 8** are discussed in the body of this report, as their results illustrate findings that address the performance objectives; tests that are not highlighted were used to understand and optimize performance at Horsham AGS and are summarized in **Appendix E** for completeness.

Table 8. Test Conditions Evaluated at the Horsham AGS Pilot Study

Test	Operating Mode	Hydraulic Detention Time (min)	Sorbent Mass (g)	Sorbent Density (g/L)	Flow Rate (L/min)
1A	1-Stage	60	20	0.5	0.67
1B	1-Stage	60	10	0.25	0.67
2A	1-Stage	120	20	0.5	0.33
2B	1-Stage	120	10	0.25	0.33
3A	1-Stage	60	10	0.5	0.33
3B	1-Stage	60	20	0.5	0.67
4A	1-Stage	30	70	3.5	0.7
4B	1-Stage	15	35	3.5	0.7
5A	1-Stage	30	70	3.5	0.7
5B	1-Stage	30	40	2	0.7
6A	1-Stage	60	200	5	0.7
6B	1-Stage	40	200	5	1.0
7A	1-Stage	20	300	15	1.0
7B	1-Stage	5	75	15	1.0
8A	1-Stage	20	430	21.5	1.0
8B	1-Stage	5	430	86	1.0
9A	1-Stage	20	200	10	1.0
9B	1-Stage	5	200	40	1.0
10A	1-Stage	20	200	10	1.0
10B	1-Stage	5	200	40	1.0
11A	1-Stage (lead)	5	200	40	1.0
11B	2-Stage (lag)	7.5	200	40	0.7
12A	1-Stage (lead)	7.5	200	40	0.67
12B	2-Stage (lag)	5	200	40	0.1
13A	2-Stage (lag)	5.4	200	40	0.93
13B	1-Stage (lead)	5	200	40	1

Notes:
1. Tests 1 through 4 were completed using canister pre-filtration; Test 5 through 13 using AASI's fabric filter systems.
2. The highlighted rows indicate tests discussed in the following sections. All other tests are detailed in **Appendix E.**
3. Test 8 was terminated early, as test conditions did not support stable operation.

6.3.1 Tests 1 through 4

Tests numbered 1 through 4 were conducted during June and August of 2020, each test evaluating two different conditions (for six separate evaluations during this period).

These initial tests highlighted challenges that jeopardized the system's ability to effectively remove PFASs. Despite the lack of PFAS performance results, this 5-week period allowed the team to focus on advancing the pre-treatment system design to permit stable operation. A series of cartridge filters from 5 to 20 µm was effective at removing suspended particulate matter ahead of the PFAS treatment system (refer to **Sections 5.3** and **8.1** for more detail). However, these filters were prone to rapid plugging and required replacement within only a few hours.

After several attempts to add filtration capacity with secondary lines became impractical, the team installed an automatic-backwashing cloth media filtration system midway through Test 4.

On-line turbidimeters are provided with the cloth media filter to assess the influent and effluent water quality. The cloth media filter was effective at reducing turbidity, particularly during upset conditions when the water quality deteriorated (**Table 9**). The cloth media filter material is rated for a nominal 5µm particle size rejection and was able to reduce most (74 to 95 percent) of the turbidity during poor conditions and less (46 percent) under normal conditions, in which the water quality was deemed relatively good. No polymers or coagulants (or other chemicals) were used to achieve these reductions.

Table 9. Cloth Media Pre-Filtration Performance at Horsham AGS

	FILTER INFLUENT (NTU)	FILTER EFFLUENT (NTU)	REMOVAL (%)
AVERAGE	3.3	1.8	46%
MAXIMUM	25.4	6.6	74%
95%-TILE	8.2	2.9	65%
75%-TILE	5.4	2.5	54%
25%-TILE	1.7	1.2	28%

Testing concluded that the PCMF did not remove PFAS, but it was effective at removing the sediment. The data from Test 11 (shown on **Figure 11**) illustrates the variability of the feed conditions. While raw turbidities varied from 2 to 100 NTU, the automatic backwashing cloth media filter stabilized system feed turbidities to below 5 NTU and dramatically reduced sediment load to the PFAS treatment system.

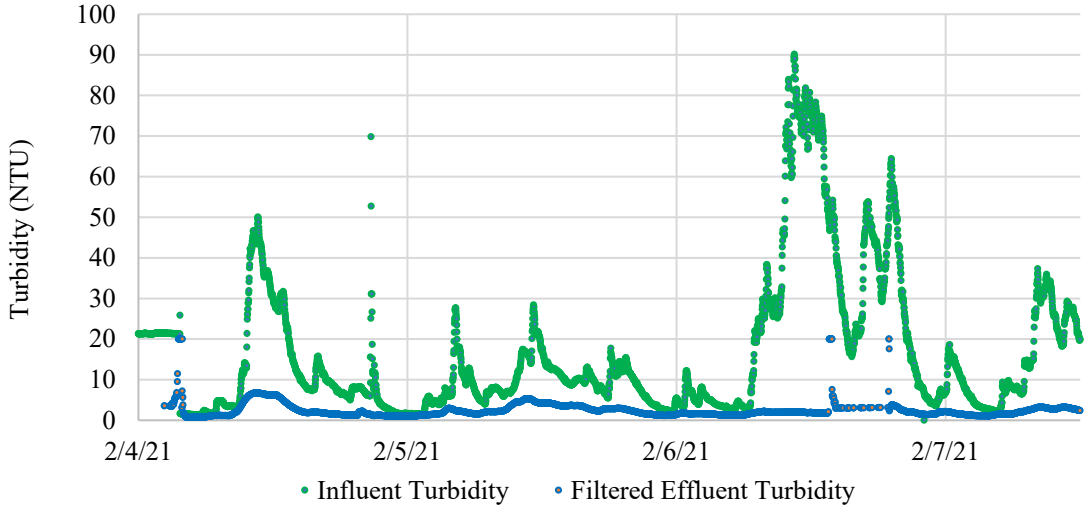


Figure 11. Influent and Effluent Turbidity Using Cloth Media Filtration at Horsham AGS (Test 11)

The team was interested in understanding what, if any, PFAS reductions could be expected from the cloth media filter. If the filter achieved significant removals, then PFAS could be consolidated into the cloth media filter backwash, which would be undesirable from a waste management perspective. In the absence of PFAS removal, the backwash PFAS levels would be similar to the source water conditions, alleviating backwash disposal issues. Results from PFAS sampling and analysis across the filter are shown in **Figure 12** below. As the filter media is rated for a 5 µm nominal particle rejection level; none of the PFAS were removed, and the backwash PFAS concentrations were expected to match those of the source water levels.

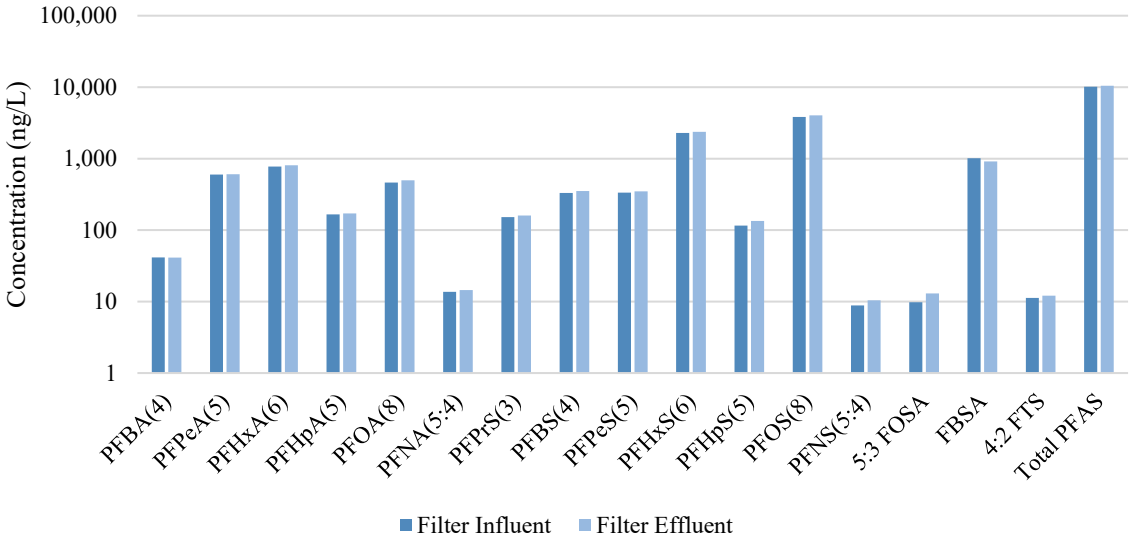


Figure 12. PFAS Concentration Measured in the Cloth Media Filter Influent and Effluent at Horsham AGS (Test 5)

The sediment removed from the outfall was combined with treated filtrate and returned to a location just downstream of the inlet pump in a manner consistent with the existing treatment system. As there were no additional chemicals used during normal operation, the only difference in the water quality between the system's overall intake and discharge back to the outfall was the removal of PFAS and some sediment retained within the treatment system.

All testing after Test 4 used the PCMF pre-treatment system and permitted the SPAC-CMF system to operate reliably for the remainder of the study (Tests 5 through 13). More detail on the PCMF system for surface water treatment is provided in **Section 9.1**.

6.3.2 Summary Conditions for Tests 5 – 13

With a reliable sediment removal system in place, the remainder of the Horsham AGS study was conducted without interruptions from deteriorated feed conditions, despite raw feed turbidities that occasionally exceeded 100 NTU. Nine tests were completed on each of Train A and B from September 2020 through March of 2021 for a total of 18 separate evaluations. **Table 8** illustrates the range of test conditions evaluated, highlighting several key performance variables. Additional operational settings were also evaluated including back-pulse intervals, run times, surface flow velocities, and sorption tank geometry and mixing regimes.

Source water sampling for PFAS was conducted to align with effluent sampling. As Trains A and B often had different operational periods, it was important to note the volumes treated at the time the feed samples were taken. Coordinating the sampling with cumulative volumes treated permitted accurate definition of system PFAS loading conditions for each train given variations in feed concentrations. **Table 10** provides a summary of all PFAS testing performed during the Horsham testing period. The UCMR3 compounds represented 72 percent of all PFAS compounds measured with PFOA and PFOS comprising 74 percent of the UCMR3 compounds.

Table 10. Horsham AGS Influent Composition for Tests 4 through 13

Statistics	Total Measured	UCMR3	PFOS	PFOA	PFNA	PFHxS	PFHpA	PFBS
Count	101	101	101	101	11	101	101	101
Maximum	18,213	12,259	10,032	602	14	2,399	203	395
Upper Quartile	11,943	8,743	6,138	456	14	1,750	144	297
Median	**10,510**	**7,597**	**5,103**	**381**	**11**	**1,603**	**133**	**269**
Mean	**9,842**	**7,109**	**4,880**	**367**	**12**	**1,498**	**123**	**240**
Lower Quartile	7,815	5,513	3,695	298	11	1,093	96	178
Minimum	2,108	1,641	1,237	79	7	262	1	20
Std. Dev.	3,171	2,307	1,773	117	2	508	40	82

Note:
1. Units reported as concentrations in ng/L.

6.3.3 System Performance Characterization

The use of a suspension to support the adsorbent media is a key difference of this technology from both GAC and IX. Whereas GAC and IX are packed into vessels at densities between 500 and 700 kilograms per cubic meter (kg/m^3), the SPAC is operated at a much lower concentration of 2 to 100 kg/m^3. The use of a slurry greatly simplifies the sorbent replacement process, reducing the time, labor, and volumes required to change out the media. Where GAC and IX seek to maximize the number of BVs between change-outs, this is not the goal of the SPAC-CMF system. On the contrary, the intent of this system is to regularly replace small quantities of media. By targeting short replacement intervals of 1 to 2 weeks, this technology avoids significant operational issues faced by both GAC and IX due to scaling, biofouling, and sediment loading when running long periods between change-outs.

While BVs are commonly used to compare GAC and IX, a mass-based metric has been used in this study. To compare the SPAC suspension with GAC and IX, the SAR has been applied to each sorbent media to allow a direct comparison. The SAR expression used in this study is:

$$SAR = (V_{BT} \times C_{PFAS}) / (Q_i \times EBCT \times r_s)$$

Where:

SAR = Specific adsorption rate (µg PFAS removed/g sorbent)

V_{BT} = Cumulative volume processed at the point the breakthrough threshold target is reached (L)

C_{PFAS} = Average PFAS concentration measured over the time to breakthrough (µg/L)

Q_i = Average flow rate treated during the operational period (L/min)

EBCT = Detention time provided in the sorbent reactor (min)

r_s = Density of sorbent held in suspension (g/L)

As each of these parameters is known for GAC, IX, and SPAC, it was considered to provide a better performance metric than the more common expression of BVs for this study. However, the two are analogous as the BV determination related as:

$$SAR = (BV \times C_{PFAS})/r_s$$

The use of the SAR over BV as a measure of performance addresses two issues:

1. BV to media exhaustion does not directly consider the source water PFAS concentration.
2. The SPAC-CMF system intentionally limits the BVs between media changes to optimize performance.

While the SAR provides an equitable comparison of the media's capacity to remove PFAS, the system's capital and operational costs will be addressed later in this report to provide the economic assessment of the SPAC-CMF technology.

6.3.4 Specific Adsorption Summaries for Lead Units over Tests 5 through 13 at Horsham AGS

An extensive dataset was generated and evaluated for each of the 13 separate tests for the technology to treat Horsham AGS raw water. Ten tests (Test 1 through Test 10) were conducted with two treatment systems in parallel, enabling concurrent testing of different operating parameters. In the case of two-stage or series operation (Tests 11 through 13), the influent to the lag reactors was low in PFAS compounds, and breakthrough was not reached. As such, SAR determination was not practical on those lag units, and the performance data (effluent PFAS) are presented later.

Table 11 provides the summary SAR data for each of the tests upon reaching the original 40 ng/L effluent concentration target. Current advisory levels and proposed regulations for PFAS discharges were considered in the evaluation and several performance metrics were used as a basis to define the technology's treatment capacity. The SAR values were determined using the following target concentrations < 40 ng/L: sum of UCMR3 list of six PFAS, < 70 ng/L: sum of PFOA + PFOS, or individual PFAS compounds. Operational settings for each test condition varied, with changes in detention time, sorbent concentration, surface flow velocities, and back-pulse intervals affecting performance.

Table 11. Specific Adsorption Rates (SARs) for Lead Test Units at Horsham AGS

TEST	UCMR3[1]	PFOA + PFOS[2]	PFOS[3]	PFOA[3]	PFHXS[3]	PFHPA[3]	PFBS[3]
4A	NA	105	118	10.1	45	2.6	1.7
4B	NA	NA	186	11.6	NA	0.7	0.9
5A	40	126	147	12.4	58	3.7	2.2
5B	217	300	340	29.2	87	4.7	1.6
6A	27	203	191	15.2	36	2.8	1.2
6B	1.2	196	204	15.4	27	3.0	0.2
7A	128	>214	>204	>10.3	>48	>3.2	3.3
7B	109	308	361	16.8	42	3.7	2.6
9A[5]	60	76	72	5.5	20	1.5	1.9
9B	65	184	220	13.8	47	3.4	2.9
10A	248	409	>400	34.0	96	8.2	6.1
10B	81	194	250	16.7	50	4.2	4.0
11A[6]	61	156	>145	>16	42	>4	3.0
12A	117	216	>202	>14	45	3.6	3.2
13B[6]	96	70	93	4.7	9.6	0.6	NA

Notes:
1. SAR – units are µg PFAS removed per g sorbent.
[1]SAR based on achieving 40 ng/L combined UCMR3 primary objective.
[2]SAR based on achieving USEPA HAL of 70 ng/L combined PFOS and PFOA.
[3]Individual PFAS SARs targeted at less than 70 ng/L.
[4]Test conditions that are not identified in the table were either lag reactors, in which the SAR could not be reached (11B, 12B, 13A), or were tests that were interrupted by untenable site conditions (1 through 4, 8).
[5]Test 9, Train A did not operate at the targeted sorbent level, resulting in lower than anticipated SAR.
[6]Test 11A used fresh sorbent in the lead position, whereas test 13B (also lead position) was conducted with previously "used" sorbent from Test 12B (lag position) to investigate potential sorbent conservation. This supports the difference in SAR value despite both tests having the same operating conditions.
>## Indicates that the test was terminated before breakthrough above target concentration, and SAR is greater than number summarized in Table 5.

A significant volume of data (PFAS lab data tables and performance graphs) was generated for each test including lab analysis and on-line operational performance variables. These data have been consolidated and provided in **Appendix E** for reference. One of the additional benefits of media replacement with short intervals is the ability to isolate a wide range of key design parameters within the 9-month study. This dataset allows for design optimization to refine projected capital and operational costs for benchmarking against other technologies.

6.3.5 Comparison to Granular Activated Carbon

The Horsham AGS surface water produced SAR results that were notably lower than results for the treatment of groundwater in previous testing by CSM (Murray et al. 2019) and Willow Grove NAS (this study, **Appendix F**). Site data for PFAS removal with the existing GAC system was not available. Further, the GAC was being used for pre-treatment ahead of a series of IX vessels.

To benchmark the SPAC-CMF system, CSM performed RSSCT on the same water to determine a comparative SAR for GAC. The GAC RSSCT could not achieve the 70 ng/L HAL treatment objective for several of the key compounds; therefore, a 10 percent breakthrough threshold was used as a basis for comparison. The results are presented below in **Table 12** with data provided in **Appendix G**.

Table 12. Comparative SAR Performance for GAC and SPAC-CMF (data from Test 10A) to Reach 10% Breakthrough Threshold at Horsham AGS

TEST	PFOA + PFOS	UCMR3	ALL PFAS	PFOS	PFOA	PFHXS	PFHPA	PFBS
GAC	0.6	2.1	1.9	0.7	0.1	0.7	0.1	0.1
SPAC-CMF	>431	578	277	>543	31	124	4.7	4.0

Note:
1. SAR units are µg PFAS removed/g sorbent

The difficulties of treating this water were confirmed with the relatively inferior performance of GAC on the same influent source. The SPAC-CMF SAR was more than 500 times higher than that for GAC for removing combined PFOA and PFOS and nearly 1,000 times higher to achieve 90 percent removal of UCMR3 contaminants. The GAC was unable to achieve the 70 ng/L target for PFOS and PFOA and for combined UCMR3 compounds. These data support that the team's original proposal, which referenced significantly higher adsorption rates for SPAC, had been realized in previous studies. In a key study leading up to this project, CSM directly compared SPAC to GAC on AFFF-impacted groundwater, revealing an overall 480 times increase in adsorption of combined PFOS, PFOA, PFHxS, PFHxA, PFHpA, PFPeA, and PFBS (Murray, et al. 2019).

IX performance of the existing treatment system was not available to draw a direct comparison with the SPAC-CMF technology.

6.3.6 Example Results for Single-Stage SPAC-CMF Treatment at the Horsham AGS Outfall No. 9

The system effectively removed UCMR3 compounds and was able to achieve the primary objective, which is a combined 40 ng/L effluent including PFOS, PFOA, PFNA, PFHxA, PFHpA and PFBS. The SAR maintained at this condition was approximately 130 µg removed per g sorbent and is shown on **Figure 13**. As the effluent target directly affects the sorbent's capacity, the SAR at 90% removal is 146 µg removed per g sorbent which may be considered or used to benchmark different technologies. Effluent targets that have evolved from the start of this study include the USEPA Regional Screening Level (RSL) proposed for tap water. The effluent PFBS level in this screening level is allowed to reach 601 ng/L, which is well above the levels discharged in the testing shown on **Figure 13**. In fact, this test realized an SAR exceeding 300 µg/g (total PFAS basis) without exceeding the USEPA RSL target concentrations

The 90 percent removal (10 percent breakthrough) target is also shown for reference, as this target is often used as a metric to benchmark technologies. In this case, the sorbent's capacity would be more than double that needed to reach 40 ng/L UCMR3. In fact, the SPAC-CMF system's removal did not fall below 95 percent during Test 10A's operational period.

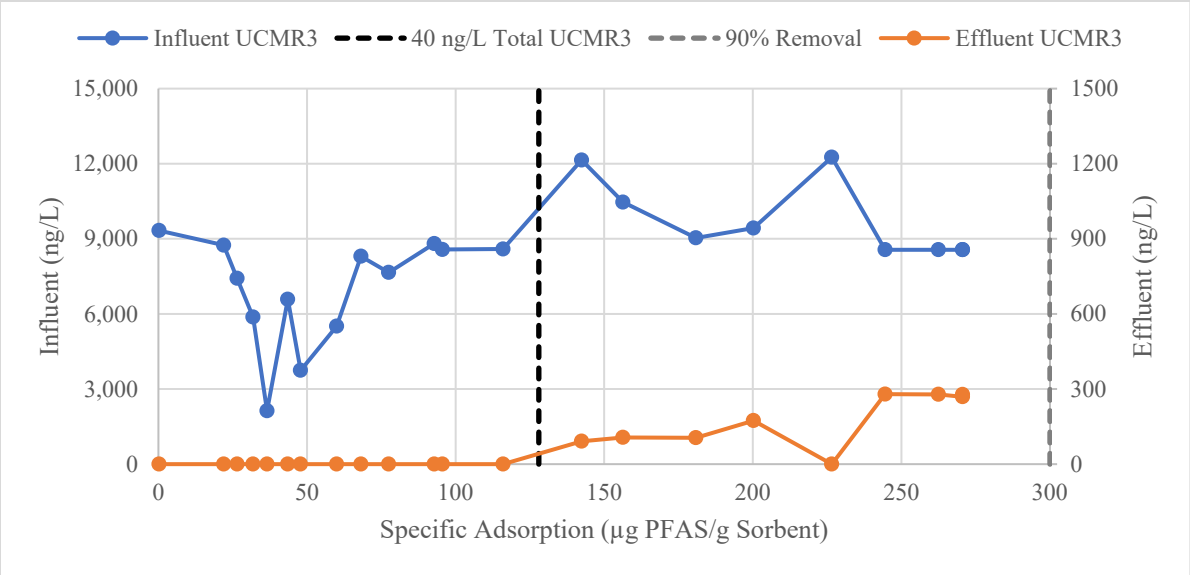


Figure 13. UCMR3 Compound Removal with a One-Stage SPAC-CMF System (Test 7A)

To address a range of effluent targets, the system's performance at the Horsham AGS was evaluated also on the basis of the USEPA HAL of 70 ng/L combined PFOA and PFOS. **Figure 14** illustrates the performance capabilities of a one-stage SPAC-CMF system to meet this discharge target. The system was effective at reducing the combined PFOA and PFOS concentration from approximately 6,000 ng/L to less than 70 ng/L at an SAR just higher than 400 µg removed per g of sorbent material.

The system's removal efficiency was not significantly affected by detention time, with comparable results produced between 5 and 20 minutes of detention. In addition, sorbent concentrations from 5 to 40 g/L produced similar results. The sorbent mass maintained in the reactor exhibited the greatest impact on performance.

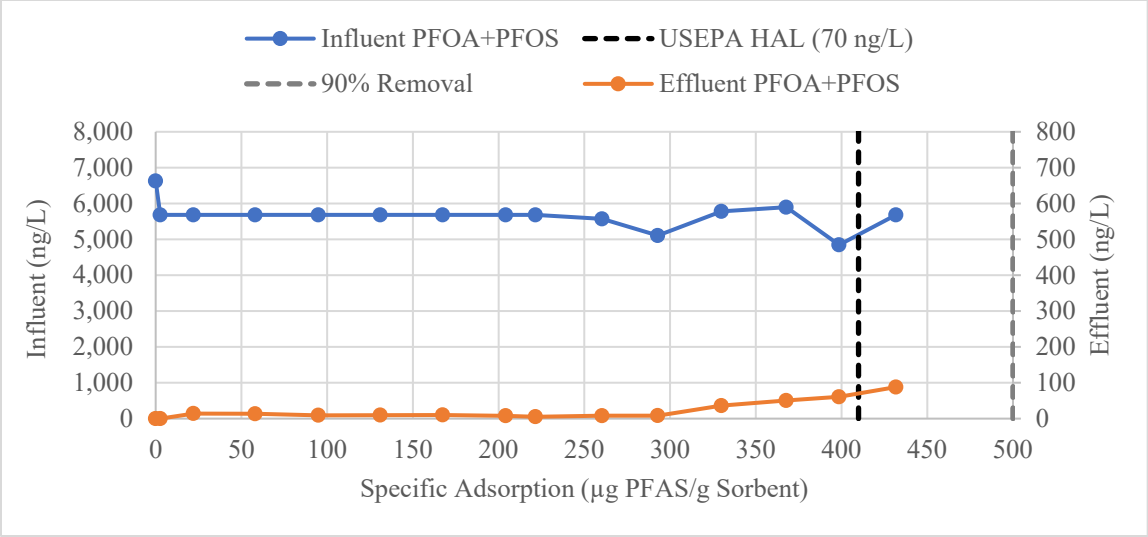


Figure 14. Combined PFOA and PFOS Removal with a 1-Stage SPAC-CMF System (Test 10A)

As a benchmark for treatment capacity, the one-stage SPAC-CMF system was able to meet the 70 ng/L USEPA HAL for PFOA and PFOS to nearly 9,000 gallons per pound of sorbent. **Figure 15** illustrates the system's performance based on cumulative volume treated. The media usage rate was primarily affected by the feed concentration and water quality conditions reflected in the suspended solids and turbidity. One design aspect that differentiates this technology from fixed-bed media types like IX and GAC is the ability to modify the sorbent concentration. For example, reactor 10A's effluent was below the 70 ng/L combined PFOA and PFOS target with a sorbent concentration of 10 g/L. Simply raising this sorbent concentration will enable the system to increase the hydraulic loading capacity.

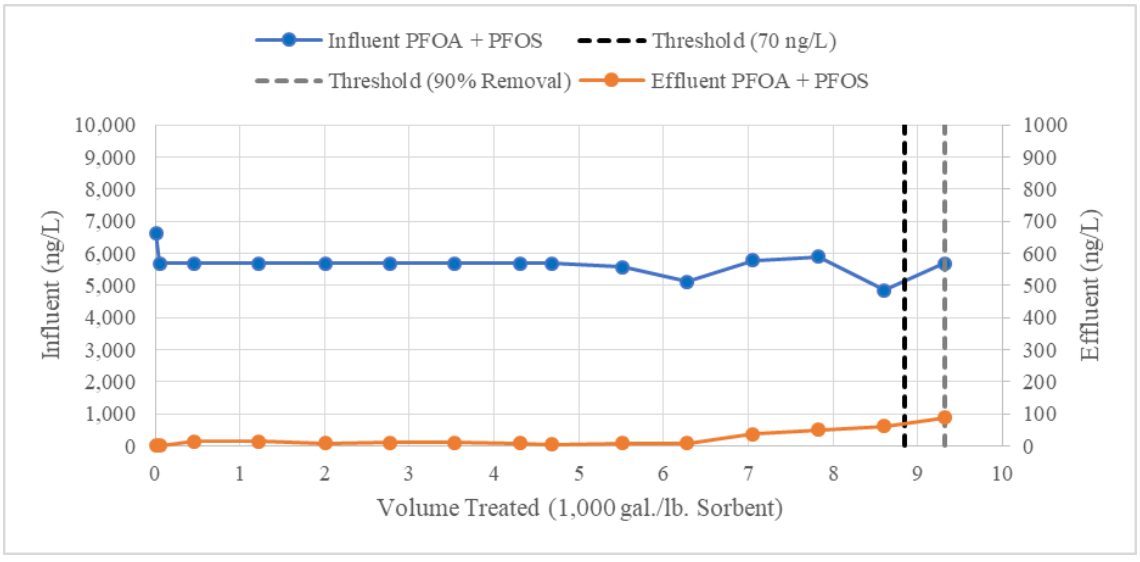


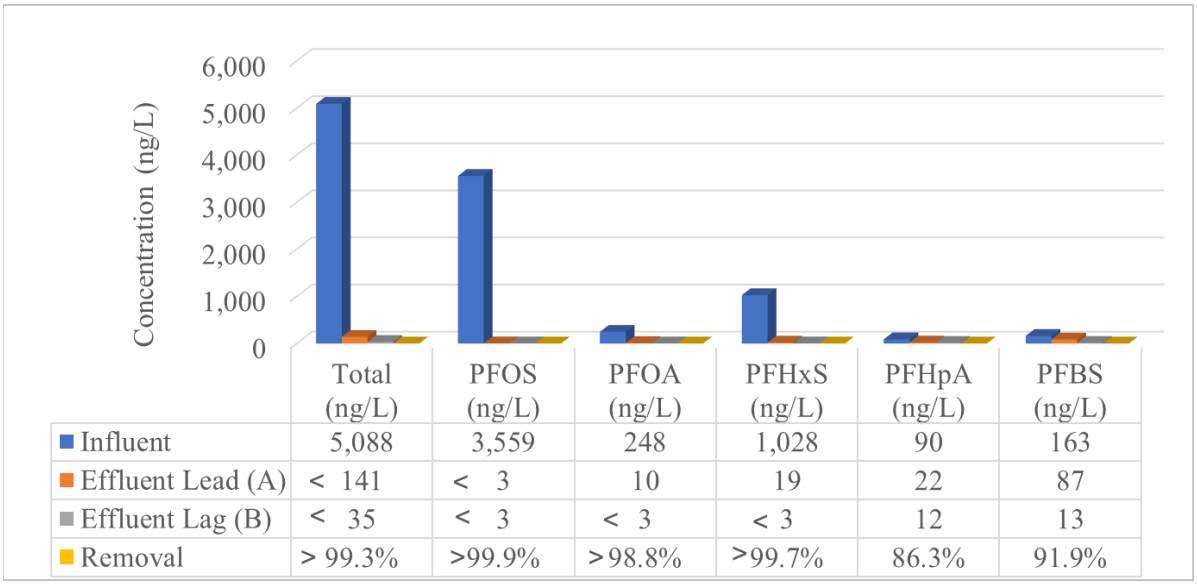
Figure 15. Media Use Rates for SPAC-CMF System at Horsham AGS (Test 10A)

6.3.7 Example Results for Two-Stage SPAC-CMF Treatment at the Horsham AGS Outfall No. 9

Most of the initial testing evaluated the SPAC-CMF technology in a one-stage operation, with focus on identifying the SAR at the targeted breakthrough threshold. The latter portion of testing was conducted in a two-stage (or series) configuration using a lead-lag arrangement in which the effluent from the first stage fed the second stage SPAC/CMF system. This was important to understand, as typical PFAS treatment systems include two or more treatment systems in series, often with two different technologies used (e.g., GAC followed by IX).

Another practical consideration was the longevity of the SPAC-CMF operational period before removal and replacement of the exhausted media. Unlike packed bed systems, the operational time between media replacements is not an important cost or operational measurement in the slurry-based SPAC-CMF system. As mentioned previously, the intent is to automatically replace the media weekly or bi-weekly.

The series operation of the SPAC-CMF proved to be quite effective at reducing all UCMR3 compound concentrations to desired levels within the defined replacement period. **Figure 16** illustrates the staged performance from Test 12 when the technology was used in series.



	Total (ng/L)	PFOS (ng/L)	PFOA (ng/L)	PFHxS (ng/L)	PFHpA (ng/L)	PFBS (ng/L)
Influent	5,088	3,559	248	1,028	90	163
Effluent Lead (A)	< 141	< 3	10	19	22	87
Effluent Lag (B)	< 35	< 3	< 3	< 3	12	13
Removal	> 99.3%	>99.9%	> 98.8%	>99.7%	86.3%	91.9%

Figure 16. UCMR3 Compound Removal with a Two-Stage SPAC-CMF System at Horsham AGS (Test 12)

The final three tests conducted at the Horsham AGS system were similarly effective at reducing all UCMR3 compound concentrations to the 40 ng/L (combined) target with detention times of 5 to 7.5 minutes based on the 7-day targeted replacement interval. Further, Tests 12 and 13 were conducted while replacing only half of the sorbent in the transition from Test 12 to Test 13. The operational modes for these tests are highlighted in **Table 13**.

Table 13. Series Operation of SPAC-CMF System at Horsham AGS

	Test 12	Test 13
Train A	Lead – New AquaPR-206 Sorbent	Lag – New AquaPR-206 Sorbent
Train B	Lag – New AquaPR-206 Sorbent	Lead – Kept existing AquaPR-206 Sorbent from the prior Test 12

6.4 WILLOW GROVE NAS

Upon completion of the site testing at the Horsham AGS station, the Arcadis, CSM, and AASI team developed a white paper and proposal to request additional funds to apply the AquaPRS technology at the Willow Grove NAS. This proposal took advantage of the site's proximity to the Horsham AGS site to limit mobilization and facilitate further demonstration of the technology's cost and performance attributes to treat PFAS in groundwater. The intent was to leverage lessons learned from the Horsham AGS study and apply the technology in a series of treatment trials to: 1) develop optimal cost and performance data, 2) verify that the bench-testing protocol is scalable to predict pilot test performance, and 3) compare the AquaPRS results with several ongoing studies that evaluated polymeric adsorbents (SERDP ER-18-C2-1300) and IX resins (SERDP ER18-C2-1063).

Results from testing completed to date at the Horsham AGS were critical to developing a baseline understanding of how this technology performs on PFAS-impacted combined groundwater/surface water. The presence of co-contaminants (namely TOC and sediment) has been shown to play a significant role in PFAS removal rates. However, previously referenced work by CSM on groundwater (Murray et al. 2019) suggested the removal rates will be significantly higher than can be realized with surface water. This additional study provided an opportunity to test representative AFFF-impacted groundwater, which does not contain sediments and suspended solids.

Influent samples were similarly aligned with effluent samples and marked based on total volume treated. PFAS concentrations for all test conditions are identified in **Table 14** and were 4 to 5 times higher than observed at the Horsham AGS site. However, UCMR3 compound comprised a higher fraction (84 percent) of the total PFAS measured. Similarly, combined PFOA and PFOS made up 85 percent of the UCMR3 compounds.

Table 14. Willow Grove Influent composition for Tests 1 through 5

Statistics	Total Measured	UCMR3	PFOS	PFOA	PFNA	PFHxS	PFHpA	PFBS
Count	63	63	63	63	NA	63	63	63
Maximum	58,426	49,392	39,429	3,300	NA	6,245	410	990
Upper Quartile	44,801	37,814	30,383	2,230	NA	4,733	301	836
Median	**39,840**	**33,469**	**26,000**	**1,937**	**NA**	**4,244**	**276**	**719**
Mean	**40,859**	**34,291**	**27,191**	**2,090**	**NA**	**3,987**	**289**	**734**
Lower Quartile	35,623	29,796	23,000	1,788	NA	3,623	252	645
Minimum	31,690	25,616	19,175	1,633	NA	2,092	232	489
Std. Dev.	6,283	5,636	4,948	427	NA	1,081	47	123

Note:
1. Units reported as concentrations in ng/L.

6.4.1 Bench Optimization

After the Horsham AGS testing, a key objective of the Willow Grove NAS testing was to develop a predictive tool to estimate the system's adsorptive capacity and validate it against field testing results. The team obtained approximately 40 L of untreated groundwater from the Willow Grove NAS site and sent it to AASI's lab in Rockford, IL for bench-scale testing. Unlike typical RSSCT simulations performed with GAC, the AquaPRS bench testing was performed with unmodified sorbent and processed through an actual production-level ceramic membrane. The lab-scale, 0.04 m^2 ceramic membrane offered the same cross-flow channel dimensions and separation layer (pore size) as provided in the 25 m^2 full-scale elements. These data were used to guide the testing efforts to reach optimal performance and minimize time in the field. A limitation of the short-term, bench-scale testing is its inability to demonstrate steady-state performance over several weeks. However, it provided a useful tool to help identify adsorbent doses, detention times, and hydraulic loading rates before deploying the pilot system on site.

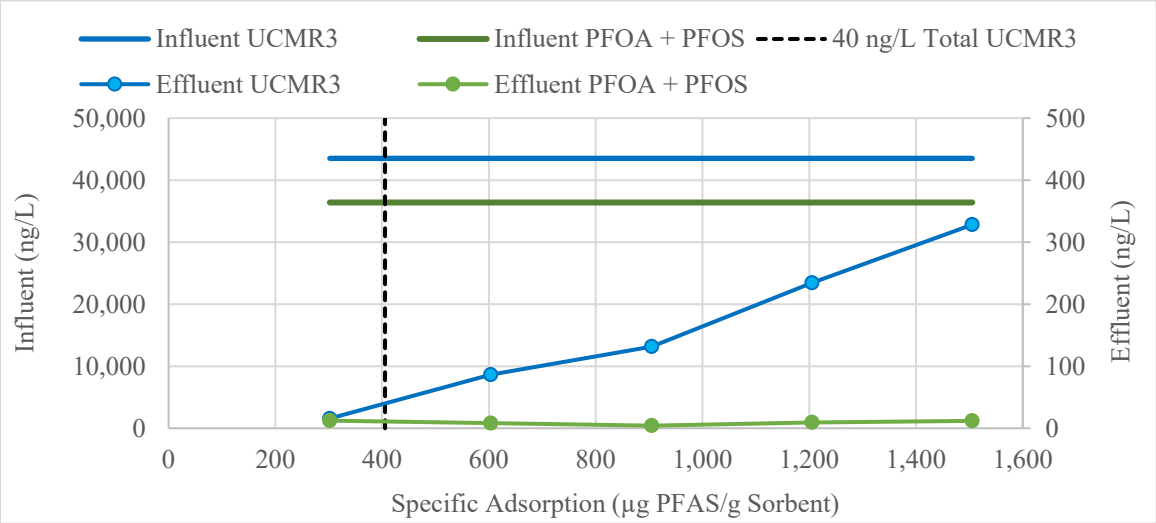


Figure 17. Preliminary Test Results for UCMR3 Compounds at Willow Grove NAS (Bench Test Prior to Test 1)

As shown in **Figure 17**, the bench testing indicated that an SAR exceeding 1,500 µg PFAS per g sorbent could be realized while maintaining greater than 99 percent removal. Apart from PFBS, concentrations of the remaining UCMR3 analytes (PFOS, PFOA, PFNA, PFHpA, and PFHxS) were collectively less than 40 ng/L at this loading condition. Despite being higher than 40 ng/L, PFBS concentrations remained well below the USEPA's RSL of 601 ng/L. The SAR at the point the combined UCMR3 compound concentrations were below 40 ng/L (including PFBS) was 405 µg PFAS per g sorbent.

Table 15 reports the SAR values observed in the bench testing, with the values for most compounds reflecting a minimum SAR to achieve 70 ng/L for that constituent or sum, as in the case of PFOA+PFOS, and the UCMR3 list of six PFAS. The sample volume was limited to 40 L, and the breakthrough threshold for five of the six compounds was not reached. However, these data did provide a reasonable starting point for the initial field studies and helped to identify the sorbent mass needed to achieve the objectives.

Table 15. Bench Study Predictive SAR Results at Willow Grove NAS

(values in µg PFAS removed per g sorbent)

TEST	PFOA + PFOS	UCMR3	PFOS	PFOA	PFHXS	PFHPA	PFBS
Bench	>1,264	534	>1,146	>118	>198	>13	13

6.4.2 Summary Conditions for Field Testing at Willow Grove NAS

The consistent water quality produced at the Willow Grove NAS site provided for smooth startup and operation over a series of five tests, with ten separate test conditions. **Table 16** summarizes the tests performed from May 28 to October 12, 2021.

Table 16. Test Conditions Evaluated at the Willow Grove NAS Pilot Study

Test Condition	Operating Mode	Hydraulic Detention Time (min)	Sorbent Mass (g)	Sorbent Density (g/L)	Flow Rate (L/min)
1A	1-Stage	20	200	10	1.0
1B	1-Stage	10	200	20	1.0
2A	1-Stage	8	200	25	1.0
2B	1-Stage	16	200	12.5	1.0
3A	2-Stage (lead)	10	100	10	1.0
3B	2-Stage (lag)	10	100	10	0.9
4A	2-Stage (lag)	10	100	10	0.9
4B	2-Stage (lead)	10	100	10	1.0
5A	1-Stage	10	200	20	0.67
5B	1-Stage	10	200	20	0.67

Note:
1. The highlighted rows indicate the tests discussed in the following sections. All other tests are detailed in **Appendix F**.

6.4.3 Specific Adsorption Summaries for Lead Units at Willow Grove NAS

The primary objective of this testing was to identify the difference in SAR for this groundwater. Overall, the adsorption rates were an order of magnitude higher for the Willow Grove NAS groundwater than they were for the Horsham AGS combined surface/groundwater. **Table 17** shows the SAR values at the point at which concentrations in the combined effluent were below 70 ng/L. Attainment of 70 ng/L of all six UCMR3 compounds through a single-stage system proved challenging for all but one of the tests due primarily to PFBS. However, it should be noted that the influent concentrations were typically 30,000 to 40,000 ng/L (with some samples approaching 50,000 ng/L). Furthermore, the field results matched closely with those from the initial bench trial, suggesting that the lab methodology offers a reasonable approach to predicting field performance.

Table 17. SARs for One-Stage Treatment to Reach < 70 ng/L at Willow Grove NAS

TEST	PFOA + PFOS	UCMR3	PFOS	PFOA	PFHXS	PFHPA	PFBS
1A	648	NA	1,807	118	165	14.8	11.7
1B	837	NA	1,755	199	183	23.8	11.6
2A	NA	NA	NA	19	NA	NA	NA
2B	1,231	NA	1,682	88	130	9.1	6.8
3A	4,289	NA	>5,459	317	524	38	30
4B	1,890	NA	3,174	153	228	19.8	NA
5A	1,154	NA	>1,555	81	107	10.3	6.0
5B	1,616	404	>1,547	>95	>121	>12.7	12.7

Note:
NA = 70 ng/L not attained.

Single-stage treatment offers insight into the sorbent capacity required to meet the targeted effluent objectives. However, practical implementation of this technology to reduce PFAS concentrations from 40,000 ng/L to less than 70 ng/L would use two systems in series depending on discharge permit requirements. Such an approach is more consistent with industry standards, in which multiple GAC or IX (or a mix of the two) would be used to increase treatment reliability and longevity. In such a case, a secondary set of breakthrough criteria was developed for first-stage treatment systems in which the effluent target is based on 90 percent removal of each component. By allowing a higher effluent quality, the team was interested in understanding the system's added capacity. **Table 18** shows the SAR values determined for the first-stage (lead) test units at the point at which the PFAS components realized >90 percent removal. In the case of PFHpA, the 90 percent removal objective required an effluent with concentrations below 25 to 30 ng/L due to the lower inlet concentrations, which was more difficult to achieve than the nominal 70 ng/L target.

Table 18. SARs for One-Stage Treatment to Achieve 90% Removal at Willow Grove NAS

TEST	PFOA + PFOS	UCMR3	PFOS	PFOA	PFHXS	PFHPA	PFBS
1A	3,400	3,500	>4,800	198	333	12.1	11.7
1B	3,700	2,840	>4,122	208	370	23.8	12.6
2A	1,437	690	1,519	29	73	9	NA
2B	>2,400	2,248	>2,300	111	261	7	7
3A	>5,860	>6,800	>5,460	>400	>838	28.2	34.7
4B	>5,000	5,389	>4,650	246	513	12.7	NA
5A	>1,650	>1,802	>1,555	>95	>120	7.4	3.6
5B	>1,642	>1,806	>1,547	>95	>121	9.2	12.7

Note:
Values expressed in µg PFAS removed per g sorbent.

Using a 10 percent breakthrough threshold (90 percent removal) resulted in significantly higher SAR values, which are particularly useful in designing series-operated systems. In most cases, the breakthrough threshold was not actually encountered before the end of the testing, which ran beyond 3 weeks for some of the tests. These results suggest a two- to three-times safety factor in the standard operating condition, in which weekly sorbent replacement is planned.

6.4.4 Single-Stage PFAS Treatment with the AquaPRS System

Specific adsorptive capacities were higher in the treatment of groundwater compared to previous testing on surface water at Horsham AGS. The absence of TOC, particulates, and sediment resulted in more than 4,200 µg of PFAS removed per g of sorbent material while meeting the 70 ng/L USEPA HAL effluent target of combined PFOA and PFOS. During a 2-week operation mark, the single-stage SPAC-CMF system approached SAR levels of 7,000 µg PFAS removed per g of sorbent material with removal efficiencies significantly higher than the 90 percent removal threshold (**Figure 18**).

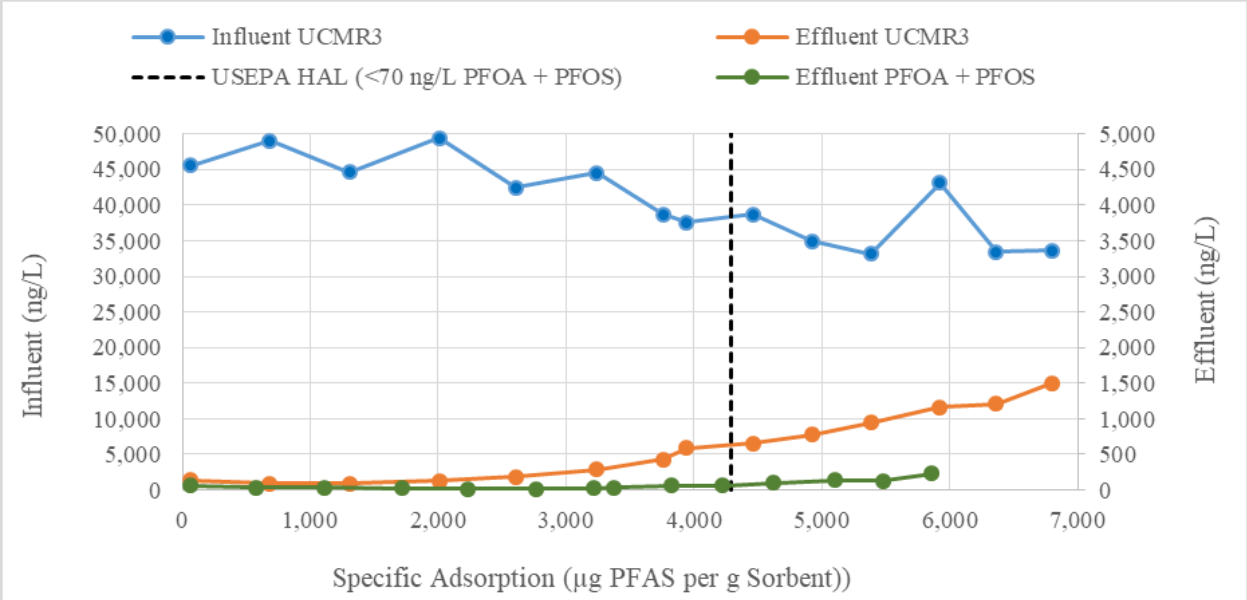


Figure 18. UCMR3 Compound Removal with a One-Stage SPAC-CMF System at Willow Grove NAS (Test 3A)

A challenge with comparing a slurry-based system against a packed-bed technology (such as GAC or IX) is what metric to use. Media use (MU) expressions were used to relate the hydraulic loading capacity with the mass of sorbent material (volume treated per unit mass of sorbent). **Figure 19** illustrates that the single-stage AquaPRS system was able to treat about 12,000 gallons of water per pound (100 m^3/kg) of sorbent material while keeping the effluent concentrations of combined PFOA and PFOS below 70 ng/L.

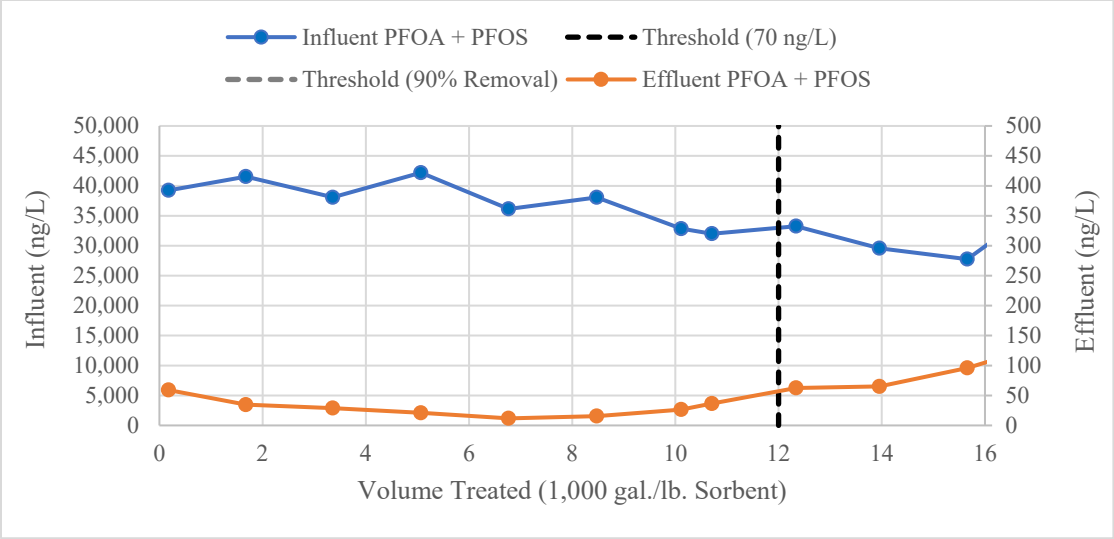
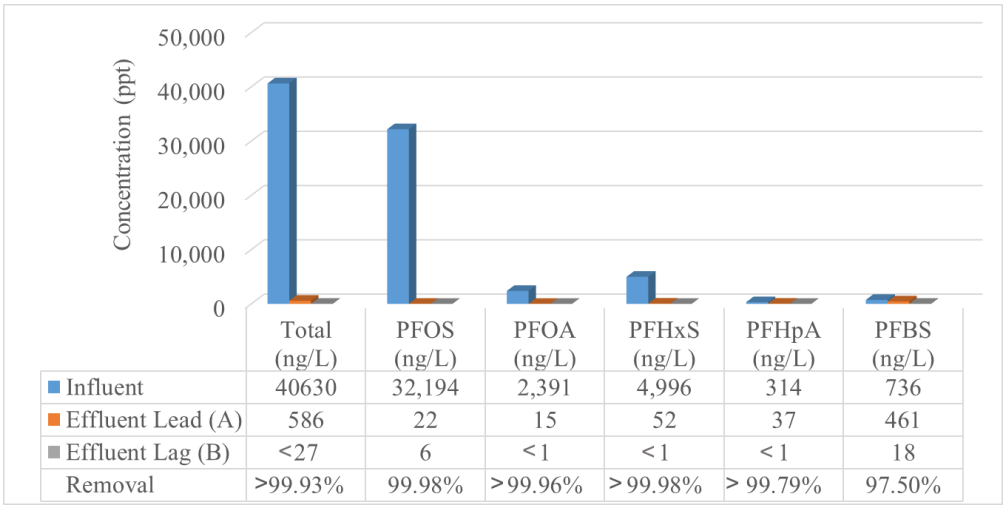


Figure 19. Media Use Rates for SPAC-CMF System at Willow Grove NAS (Test 3A)

6.4.5 Two-Stage (series) PFAS Treatment with the AquaPRS System

The first stage in the AquaPRS treatment is responsible for the majority of the overall PFAS removal, but also removes TOC with higher molecular weights and particulates from the raw water. The resulting filtrate is exceptionally clean and ideally conditioned for second-stage adsorption of shorter-chained constituents (i.e., C4 and C6 PFAS). As discussed earlier, the AquaPRS removed all the UCMR3 compounds effectively, but smaller-chained compounds like PFBS were more difficult to adsorb. **Figure 20** illustrates that, with most of the PFAS removed in the first stage, the second stage removes the small-chained compounds more efficiently. These data show the performance at the end of a 7-day replacement interval (where spent SPAC is removed and fresh material is added). It shows that the first stage removed only 37 percent of the PFBS, whereas the second stage process removed 96 percent.



	Total (ng/L)	PFOS (ng/L)	PFOA (ng/L)	PFHxS (ng/L)	PFHpA (ng/L)	PFBS (ng/L)
Influent	40630	32,194	2,391	4,996	314	736
Effluent Lead (A)	586	22	15	52	37	461
Effluent Lag (B)	<27	6	<1	<1	< 1	18
Removal	>99.93%	99.98%	>99.96%	> 99.98%	> 99.79%	97.50%

Figure 20. UCMR3 Removal with a Two-Stage SPAC-CMF System at Willow Grove NAS (Test 3 A-B)

Together, the two-stage system was able to reduce concentrations of all the UCMR3 compounds from 40,630 ng/L to a 25 ng/L effluent (99.94 percent removal). It should be noted that PFNA was not detected in the raw water at measurable levels and is omitted from the UCMR3 chart for clarity.

The SAR capacity remained high in two-stage operation, accounting for the sorbent mass in both the first and second stage operations. Despite the high UCMR3 compound removal from about 45,000 ng/L to 40 ng/L, the SAR exceeded 2,100 µg PFAS per gram of sorbent used. **Figure 21** illustrates the influent and final effluent UCMR3 concentrations illustrating the SAR associated with the 40 ng/L effluent target.

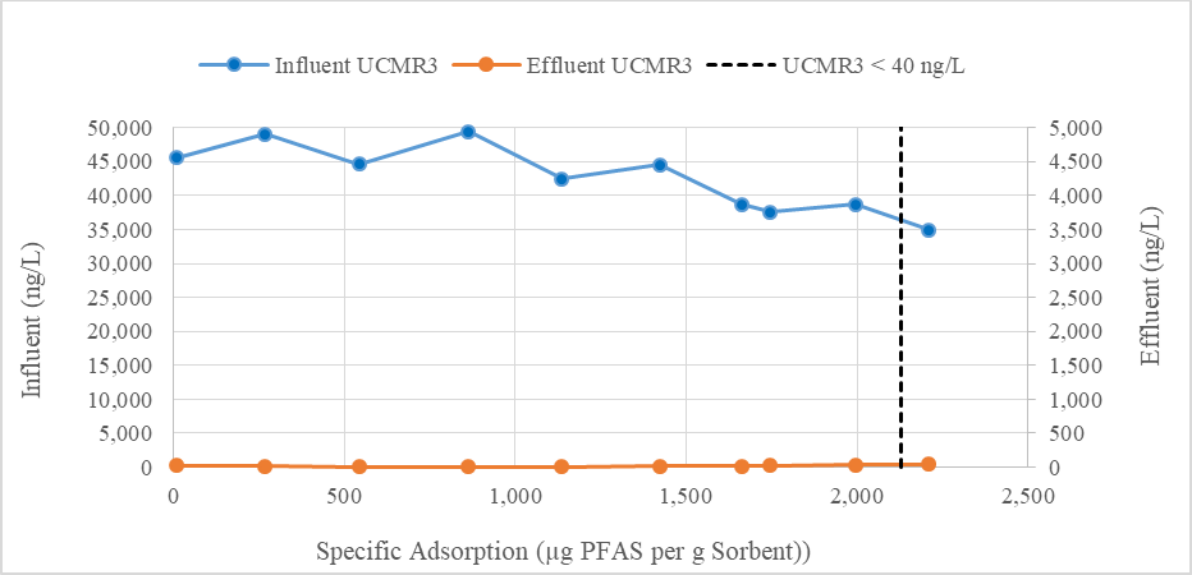
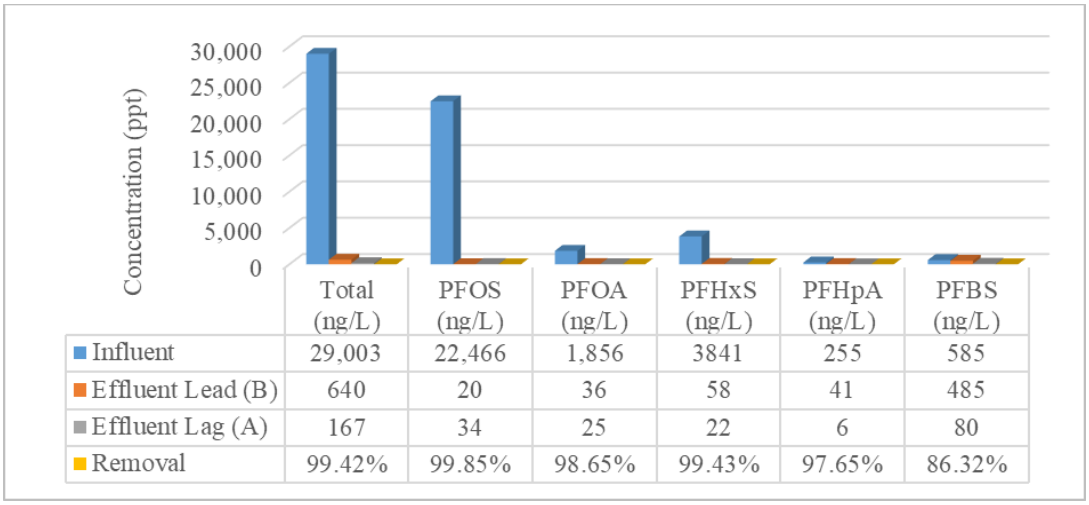


Figure 21. UCMR3 Removal to < 40 ng/L with a Two-Stage SPAC-CMF System at Willow Grove NAS (Test 3 A-B)

6.4.6 Reverse Lead-Lag Operation with 50 Percent Sorbent Replacement

To understand how well the system would operate if the lead and lag positions were switched at the end of the test period, The lead and lag vessels were switched with new sorbent added only to the new lag reactor. In other words, the former lag reactor, which was lightly loaded with PFAS, now had become the lead reactor and kept the original sorbent material from the previous test. The former lead reactor, heavily loaded with PFAS, was now set to be the lag reactor and refreshed with new sorbent.

Figure 22 shows the results from this testing after the second operational period (interval). Overall, PFAS removals were quite high, with the system producing filtrate containing concentrations below the 40 ng/L target level for combined PFOA and PFOS (99.8 percent removal). There was a slight reduction in the ability to remove PFBS to a level that would bring the combined UCMR3 compound concentrations below 40 ng/L. While the new sorbent in the lead reactor was effective, the overall system performance was only slightly lower, with only 50 percent of the used sorbent replaced with new material.



	Total (ng/L)	PFOS (ng/L)	PFOA (ng/L)	PFHxS (ng/L)	PFHpA (ng/L)	PFBS (ng/L)
Influent	29,003	22,466	1,856	3841	255	585
Effluent Lead (B)	640	20	36	58	41	485
Effluent Lag (A)	167	34	25	22	6	80
Removal	99.42%	99.85%	98.65%	99.43%	97.65%	86.32%

Figure 22. Series Operation with 50 Percent New Sorbent at Willow Grove NAS (Test 4)

From an operational perspective, a decision could be made to conserve sorbent and further minimize disposal costs if these effluent levels were acceptable. Conversely, they could replace some or all of the lead-train's sorbent with new product to realize the results shown previously in **Figure 20.**

6.4.7 Sorbent Advancement from AquaPR-206 to AquaPR-312

Advancements in research and development on the manufacturability of the sorbent material continued throughout the test program. Original bench testing was performed on a wood-based SPAC manufactured by METAWATER in Japan. AASI developed an alternative sorbent material early in this study, which is identified as AquaPR-206. The key objective of this work was to confirm manufacture and supply of this material from within the U.S. Parallel testing was conducted to confirm that the product's performance attributes matched or exceeded that of the original SPAC material. The resultant AquaPR-206 sorbent material was used as the basis of operation after the initial testing of the Horsham AGS study.

Subsequent product development continued to advance the materials, manufacturing, and testing to create a product that could be produced on a large scale and further scaled up to address potentially high customer demands. The resulting product, identified as AquaPR-312, was able to be generated in less than 10 percent of the prevailing production times with improved controls to improve particle uniformity and significantly increase stock (slurry) concentrations. The manufacturing innovations were facilitated to drastically reduce lead times, improve storage, and reduce transport and material costs.

One last step was to validate the PFAS removal performance of the AquaPR-312 material under the same conditions as AquaPR-206. Test 5 at the Willow Grove NAS system operated Trains A and B identically, with the only difference being the sorbents used. **Figure 23** shows the results of side-by-side testing of the two sorbent materials. Both performed well, achieving greater than 99.5 percent removal over a test period, which was about twice the targeted operational interval. Both sorbents were able to achieve the 70 ng/L combined target for PFOA and PFOS beyond the anticipated sorbent replacement level, with a slightly better performance exhibited with the new AquaPR-312 media.

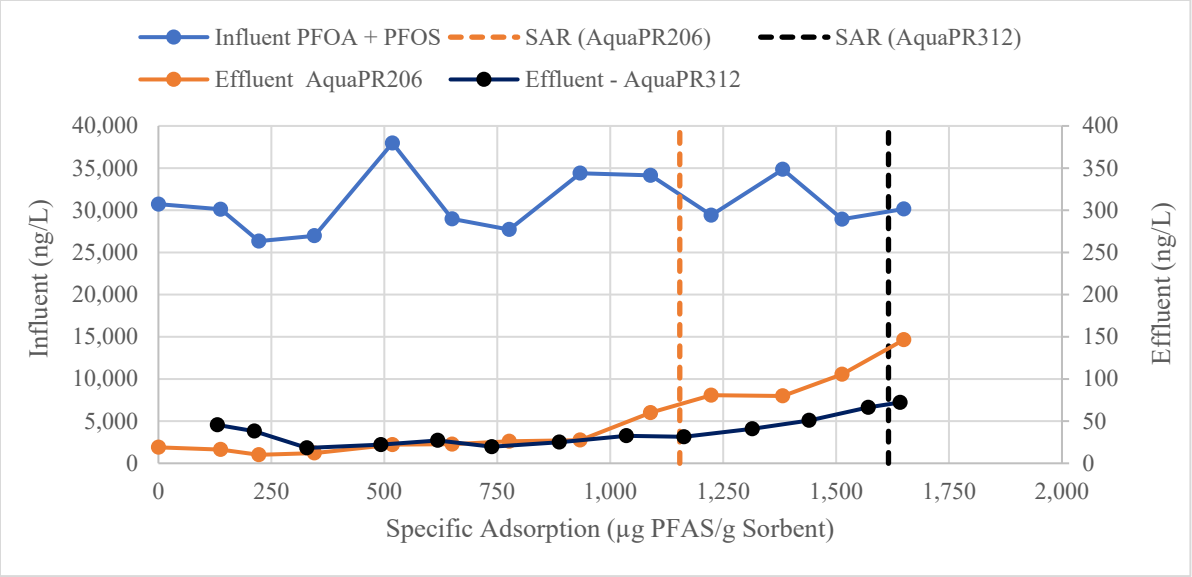


Figure 23. Performance Comparison of AquaPR-206 and AquaPR-312 Sorbent Materials at Willow Grove NAS (Test 5)

Standard SPAC can be procured independently through existing tolling companies but may differ in physical and chemical properties. Further, commercially available SPAC will not be the same product used in the AquaPRS system. Continued development of the sorbent material is already underway to tailor the media to site-specific requirements to remove a variety of micropollutants. Aqua-Aerobic Systems, Inc. has developed and implemented the manufacturing processes and production capacities required to support the commercial production of the AquaPRS system to meet current and future demands.

7.0 PERFORMANCE ASSESSMENT

The overarching objectives of this study are to field-demonstrate the effectiveness of the AquaPRS system for the removal of a broad range of PFASs from contaminated groundwater at a typical DoD site, understand the long-term performance of the sorbent media, and gather the necessary data to perform a detailed cost analysis as described in Section 3. The results of the performance review are summarized in the following sections for Horsham AGS and Willow Grove NAS. The cost analysis results are discussed in Section 8.

7.1 HORSHAM AGS

Treatment at the Horsham AGS was applied to a combined groundwater surface water discharge location at Outfall 9. Thirteen tests were completed as summarized in **Table 8** in Section 6.3. Tests 1 through 3 were completed before the application of AASI's prefiltration system; the result was an evaluation of conventional cannisters for prefiltration and ultimately integration of the AASI automated filter equipment. Tests 4 through 13 varied operating conditions including detention time, sorbent concentrations, and flow rate through the system. Tests 4 through 10 were conducted as single-stage tests, with two AquaPRS systems parallel and providing opportunity to evaluate two sets of conditions simultaneously. Tests 11 through 13 were completed using a two-stage or series operation with a lead-lag vessel configuration. This suite of tests enabled assessment of performance in the context of continued optimization of the on- and two-stage treatment approaches, which ultimately facilitated evaluation of the performance metrics summarized in **Appendix E** and discussed in the following sub-sections.

7.2 WILLOW GROVE NAS

Treatment at the Willow Grove NAS was applied to a combined influent from groundwater wells identified as EW-1S and EW-1I. Five tests were completed as summarized in **Table 16**. All five tests were fed with the combined well influent, which was passed through a 5 µm prefilter before reaching the AquaPRS. Tests 1, 2, and 5 were single-stage tests, whereas Tests 3 and 4 were two-stage, alternating the lead/ lag positions per train. For Tests 1 and 2, sorbent concentration and detention time were varied, whereas for Tests 3 and 4, these conditions remained fixed while the operating mode was changed to two-stage operation, varying the lead/lag position per train. Test 5 tested two different sorbent types in single-stage operation (AquaPR-206 and AquaPR-312). Single-stage tests were conducted with two AquaPRS systems in parallel, providing opportunity to evaluate two sets of conditions simultaneously. Two-stage tests were conducted to evaluate enhanced removals from series operation with a lead-lag vessel configuration. This suite of tests enabled assessment of performance in the context of continued optimization of the single- and two-stage treatment approaches, which ultimately facilitated evaluation of the performance metrics summarized in **Appendix F** and discussed in the following sub-sections.

7.3 PFAS TREATMENT LONGEVITY AND SELECTIVITY

PFAS treatment longevity and selectivity were tracked using breakthrough curves to maintain concentrations less than 70 ng/L for PFOS + PFOA, less than 40 ng/L for the sum of the UCMR3 list of six PFASs, and sum of Table B-15 PFAS at 90 percent treatment. Because the AquaPRS system periodically wastes and refreshes sorbent, the conventional use of BV longevity for GAC and IX treatment is not as relevant as the SAR metric, which focuses on the mass of PFASs per mass of sorbent while maintaining target PFAS compound concentrations below 40 ng/L. Using the SAR metric enables comparison of relative sorption performance for different targets and different media types. For example, the lifecycle cost analyses presented in Section 8.3.1 compares SPAC-CMF with GAC to meet a 70 ng/L USEPA HAL at Horsham AGS, whereas Section 8.3.3 evaluates SPAC-CMF with a single-use IX resin to meet the USEPA 2022 RSLs at Willow Grove NAS. Like IX and GAC, increased PFAS concentrations and more stringent effluent targets requires more SPAC mass. AquaPRS systems can be optimized using detention time and/or by increasing the reactor SPAC concentration, which provides additional operating flexibility compared to IX and GAC.

8.0 COST ASSESSMENT

A cost assessment methodology was developed to compare the AquaPRS technology with IX and GAC treatment on both CAPEX and operation and maintenance (OPEX) costs. The team used industry values for IX and GAC system performance during the proposal stage to offer an initial framework for comparison with the intent to refine the model using actual data. Based on the wide range of values suggested for BV's MU rates for these technologies, it was evident that the validity of such a comparison was highest when using performance data from the same water source. Specific water characteristics (such as anions, cations, soluble organic compounds, and sediment) greatly impacted the sorbent's PFAS loading capacity, having a pronounced effect on the technology's LCCA.

While both the Horsham AGS and Willow Grove NAS sites operated full-scale treatment systems, obtaining cost data from the two sites proved challenging due to limited availability of information related to:

1. Original equipment purchase;
2. Installation costs;
3. Replacement intervals;
4. Media replacement costs;
5. PFAS loading conditions;
6. Disposal method and costs; and
7. Infrastructure requirements.

In response, the team developed a baseline comparison that evaluated the LCCA based on economic parameters that were unique to each technology in order to gauge the relative cost-effectiveness. The cost evaluation used performance data obtained either from previous testing or RSSCT results performed as part of this study on the actual waste.

This assessment's primary goal is to identify whether the SPAC-CMF system offers a viable PFAS cleanup option for DoD sites relative to other technologies but is not intended to be used to estimate the actual costs to build a treatment system.

8.1 COST MODEL

The cost model used a theoretical flow rate for each site but included the actual inlet PFAS levels measured during testing. The primary PFAS compounds were PFOA, PFOS, and combined PFOA+PFOS with a 70 ng/L effluent target for each technology. The costs assumed that the technologies would require similar infrastructure such as land, buildings, excavation, concrete pads, electrical supply, piping, lighting, and pre-treatment equipment. Cost differences were based only on the unique design, performance, and operational characteristics of each technology. A 20-year life cycle was assumed in order to facilitate a payback-period analysis where technologies had significantly different initial capital costs.

8.2 COST DRIVERS

The sorbent media replacement costs proved to be the most significant factor in determining the technology's cost-effectiveness, exceeding the initial capital equipment investment. Media replacement was driven by its capacity to remove PFOA and PFOS mass while maintaining effluent concentrations below the 70 ng/L HAL target. This same approach could be used for other individual or collective PFAS compounds (such as the UCMR3 compounds). However, data were either not available or (in the case of Horsham AGS) the GAC did not effectively remove short-chained compounds (such as PFBS or PFHxS), making such a comparison difficult.

Media replacement costs were primary governed by the SAR, which related the PFAS mass removed to the sorbent mass applied to the systems. The SAR was most impacted by volume treated, average PFAS concentration, and the presence of co-contaminants. The SARs were derived for each of the two waste types based on actual test results and should provide a reasonable comparison between the technologies.

Disposal costs also played a significant factor in the cost evaluation, albeit to a much lesser extent than media replacement. In the case of GAC, the disposal costs were effectively set to zero based on the assumptions that it would be reactivated by the supplier. Each of the Horsham AGS and Willow Grove NAS evaluations used IX estimates based on single-use, non-regenerated resins to reduce capital, chemical, and operational costs. In the case of single-use resins, the disposal methods and unit pricing were applied similarly to the assumptions made for SPAC.

Power, chemicals, and performance compliance testing were also quantified for each technology but did not represent a determining factor in the cost comparison.

8.3 COST ANALYSIS

The cost analysis was developed using nominal media rates in terms of $/lb. of sorbent, with values either obtained or assumed based on publicly available data. As such, some variability is anticipated based on project size, proximity to regeneration facilities, and specific media manufacturer. It also assumes a reactor design based on the observed contact times and anticipated system design conditions. GAC unit costs were based on $2.00 per lb. including removal, transportation, reactivation, and replacement. IX resin costs were based on $29.66 per lb. of sorbent with an additional $0.13 per lb. for waste transport and $0.53 per lb. for disposal using incineration for the single-use resin. SPAC costs were based on $22.00 per lb. of sorbent (dry-solids basis) and used the same cost values for transportation and disposal.

Incineration was selected as the prime disposal mode for purposes of this LCCA. However, it is recognized that other disposal techniques could be used for each of the sorbent media and may affect the cost relationships. For example, each of the sorbent media could be considered for solidification and disposed in a RCRA Subtitle C landfill.

Alternatively, a variety of emerging destructive technologies may offer an alternative, particularly for the SPAC, based on its slurried composition and potential energy (in British thermal units [BTU]) value.

8.3.1 Horsham AGS – Surface Water

Performance data on the existing interim treatment system was not available during the Horsham AGS testing. The team collected water from the site, and CSM performed RSSCT on the GAC. The GAC testing was not successful at reaching the 70 ng/L target, rendering a direct comparison impossible. For evaluation purposes, SAR values for PFOS and PFOA of 4 and 2 µg per g of GAC were used, even though these values were not attained in the RSSCT testing. Similarly, the existing IX system was unable to produce SAR values because the pre-treatment system included media filtration and GAC, which preceded the IX system. As such, a cost comparison with IX is not provided. The SPAC-CMF evaluation was based on Test 10A's actual results, which realized 400 and 34 µg per g SPAC for PFOS and PFOA, respectively. **Table 19** illustrates the comparative LCCA for the SPAC and GAC sorbent technologies.

Table 19. Relative Cost Comparison for a 100 gpm System Treating 6,000 ng/L Combined PFOA and PFOS to 70 ng/L

			AquaPRS		GAC
Capital	Equipment	$	800,000	$	50,000
	Construction	$	500,000	$	500,000
O&M	Media Supply	$	143,114	$	1,231,202
	Service	$	2,400	$	2,400
	Power	$	1,584	$	660
	Chemicals	$	-	$	-
	Monitoring & Compliance	$	75,000	$	75,000
	Replacement Parts	$	-	$	-
	Disposal	$	7,775	$	-
Lifecycle Cost[1]		**$**	**4,719,936**	**$**	**20,128,507**

Notes:

[1]20-year Present Value based on 3% annual rate of return.

O&M = operation and maintenance

The AquaPRS system showed a higher capital equipment cost for the 100 gpm application, which was estimated at more than three times that of GAC. The 20-year life-cycle cost for GAC was more than four times higher than that for AquaPRS, primarily due to the difference in adsorption rates. A value of $2 per lb of carbon was assumed based on replacements using regenerated GAC. The SPAC costs were based on the use of new material at each replacement and therefore included an allowance for disposal costs. For estimating purposes, the disposal costs were based on incineration at $0.66 per lb of spent sorbent including transportation costs. The savings in the AquaPRS operating costs result in its payback of less than 8 months when compared with GAC (See **Figure 24**). An overall life-cycle savings of approximately $15,000,000 was determined based on a 20-year life-cycle present value with costs discounted at 3 percent.

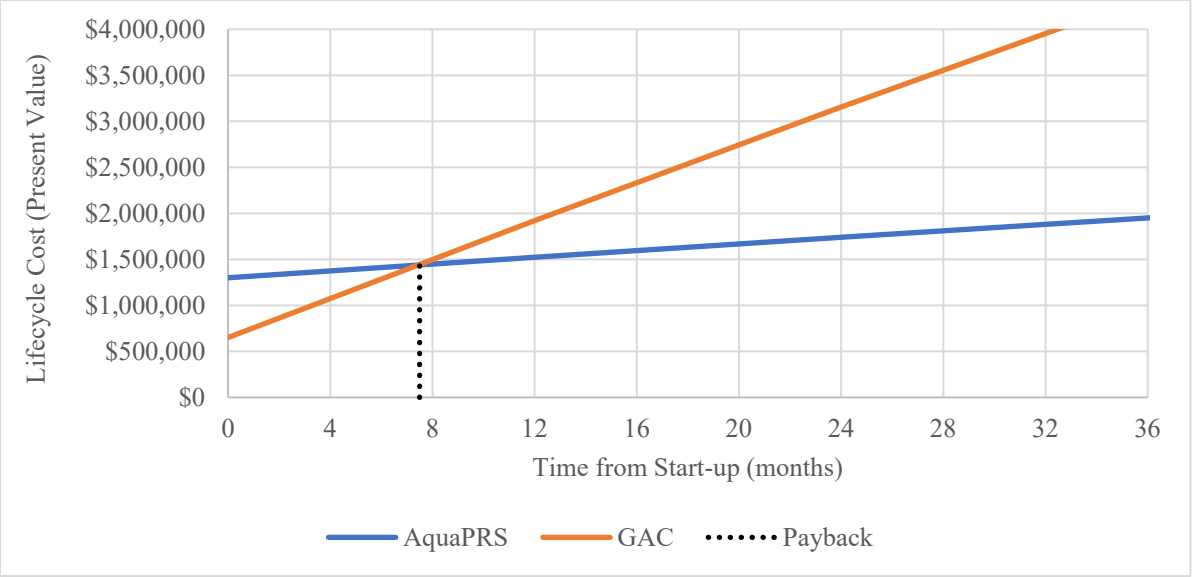


Figure 24. Payback Period for SPAC-CMF versus GAC and IX at Horsham AGS

8.3.2 Willow Grove NAS – Groundwater

The economic evaluation for the Willow Grove NAS application was based on a lower, 20 gpm flow rate to match the existing treatment system's design capacity. This would allow a direct comparison of the AquaPRS technology with the actual costs borne by the site to operate the IX system. Similar to the Horsham AGS application, such a direct comparison would prove challenging, as the existing treatment system includes IX, GAC, and zeolite filters. The zeolite pre-treatment filters were eventually replaced with GAC during the study. Based on this modification, a total of four IX vessels with a total of approximately 470 gallons of capacity were preceded by five GAC vessels, providing a total capacity of approximately 880 gallons. The long EBCT of 23 minutes for IX and 44 minutes for GAC resulted in more than a year of operation without media replacement. The resulting site OPEX costs would not reflect a more typical application at approximately 10 to 20 minutes of EBCT for GAC and 2 to 5 minutes for IX. Further investigation into actual CAPEX and OPEX for the existing system was not pursued.

8.3.3 Willow Grove NAS – Groundwater Treated to USEPA 2022 Risk-Based Screening Levels (RSL)

Previous work at this site (Ellis et al. 2022) yielded performance data for both single-use and regenerable IX resins on the Willow Grove NAS water as presented in **Table 20**. These data reflect the SAR values observed when performing to a level compliant with the USEPA RSLs for PFOS, PFOA, PFBS, PFNA, PFHxS, and hexafluoropropylene oxide-dimer acid (HFPO-DA). GAC data were not available for this site, and the team did not carry out RSSCT testing based on the availability of IX data and the likelihood that anticipated GAC performance would result in high OPEX that would not compete with either AquaPRS or IX.

Table 20. Basis for Cost Comparison used for the Willow Grove NAS Application Based on Specific Adsorption Rate Determination on this Water

Chemical	RSL for Tap Water (ng/L)	AquaPRS (µg PFAS/g Sorbent)	IX (Single use) (µg PFAS/g Sorbent)	IX (Regen) (µg PFAS/g Sorbent)
PFOS	4	2,731	2,632	658
PFOA	6	317	631	114
PFBS	601	56	105	26
PFNA	6	-	-	-
PFHxS	39	426	634	159
HFPO-DA	6	-	-	-

The AquaPRS and single-use resins yielded similar adsorption capacities, while values reported for regenerable resins were significantly lower. The SPAC-CMF adsorption data are based on the results from Test 3A through one-stage treatment and 10-minute contact, while the IX (single-use) results are also based one-stage treatment but with a 2-minute EBCT. The IX adsorption data are derived from a previous study at the Willow Grove NAS site, in which five IX resins were evaluated including three single-use and two regenerable resins (Ellis et al. 2022). The specific SAR values were drawn from the top performing resin based on meeting the RSL concentrations (**Table 20)**. The cost evaluation for regenerable resins was not included due to the significantly poorer performance exhibited compared with single-use resins tested in that study. Further, limited data on the production of brine and organic co-solvents during the regeneration process rendered such an evaluation difficult. The 20-year life-cycle cost analysis assumed two-stage (series) treatment for all systems, and the results are summarized in **Table 21**.

Table 21. Relative Cost Comparison for a 20 gpm System Treating 31,800 ng/L Combined PFOA and PFOS

			AquaPRS		IX (Single Use)
Capital	Equipment	$	275,000	$	250,000
	Construction	$	100,000	$	100,000
O&M	Media Supply	$	24,219	$	41,590
	Service	$	2,400	$	2,400
	Power	$	317	$	183
	Chemicals	$	-	$	-
	Monitoring & Compliance	$	75,000	$	75,000
	Replacement Parts	$	-	$	-
	Disposal	$	1,316	$	837
Lifecycle Cost[1]		**$**	**1,911,128**	**$**	**2,135,445**

Note:
[1]20-year Present Value based on 3% annual rate of return.

As shown on **Figure 25**, the AquaPRS system compared similarly in CAPEX and OPEX when evaluated against the best performing IX single-use resin. The cost advantage in media replacement offset the AquaPRS' slightly higher CAPEX and disposal costs in about 20 months, resulting in a 10 percent cost savings over a 20-year period for the 20 gpm system.

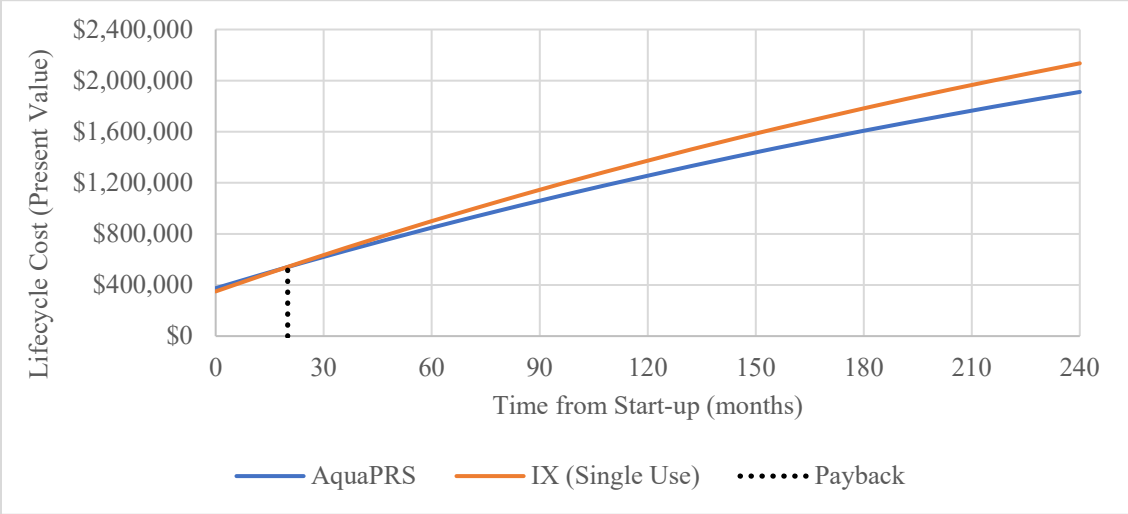


Figure 25. Payback Period for SPAC-CMF versus IX Single-Use Resin at Willow Grove NAS

8.3.4 Willow Grove – Groundwater Treated to US EPA HAL of 70 ng/L

In order to understand the cost sensitivity to effluent objectives, the cost simulation was performed based on a lesser effluent target of 70 ng/L combined PFOA and PFOS to compare the SPAC-CMF technology to the single-use IX system. **Table 22** summarizes the results, indicating that the life-cycle costs for the two technologies are comparable at the low, 20 gpm flow rate condition.

Table 22. Relative Cost Comparison for a 20 gpm System Treating 31,800 ng/L Combined PFOA and PFOS to the 70 ng/L USEPA Health Advisory Level

			AquaPRS		IX (Single Use)
Capital	Equipment	$	275,000	$	250,000
	Construction	$	100,000	$	100,000
O&M	Media Supply	$	11,009	$	13,863
	Service	$	2,400	$	2,400
	Power	$	317	$	183
	Chemicals	$	-	$	-
	Monitoring & Compliance	$	75,000	$	75,000
	Replacement Parts	$	-	$	-
	Disposal	$	598	$	79
Lifecycle Cost[1]		**$**	**1,703,910**	**$**	**1,714,638**

Note:
[1]20-year Present Value based on 3% annual rate of return.

At the lower flow rate, the CAPEX for both systems is comparable with a slight advantage for the SPAC-CMF system in OPEX due to the media costs. **Figure 26** illustrates a nearly equivalent 20-year life-cycle cost under this condition.

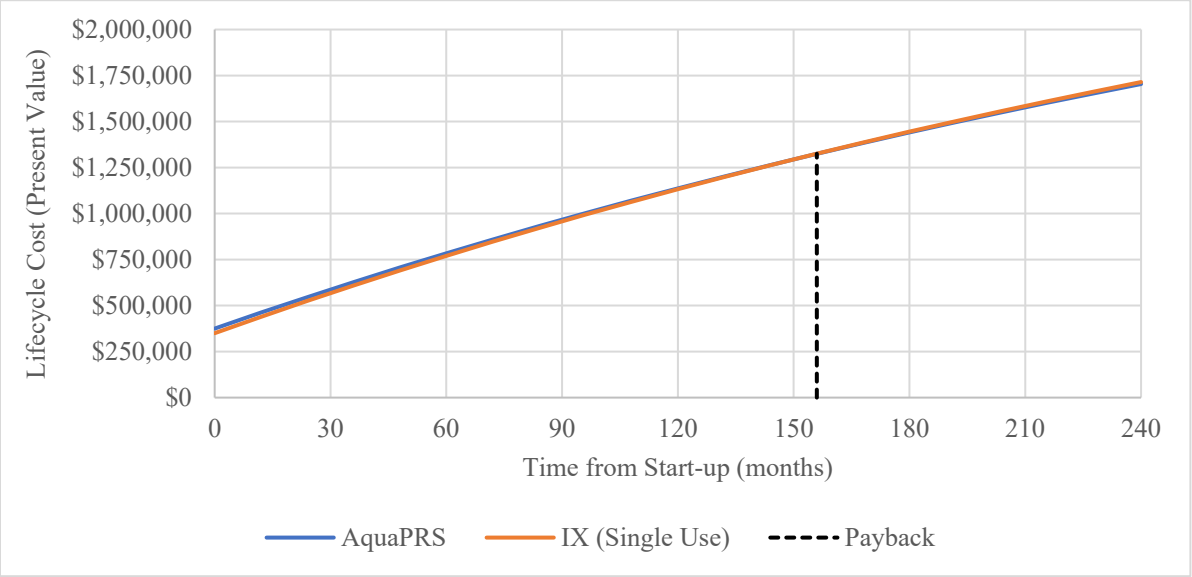


Figure 26. Payback Period for SPAC-CMF versus IX Single-Use Resin at Willow Grove NAS Treating to 70 ng/L Combined PFOA and PFOS

Additionally, the cost increase to treat to the more stringent USEPA 2022 RSL limits is only about 12 percent for the AquaPRS system compared with 24 percent for the IX system. This suggests that the AquaPRS system offers an advantage over IX when the sorbent media demands are greater due to factors such as broad-spectrum PFAS compounds, co-contaminants, fouling, or increased discharge limitations.

8.3.5 O&M Considerations

Annual O&M requirements for the AquaPRS are projected to be similar to those required for single-use IX resins despite differences in equipment and methods. Under ideal conditions, the IX system was anticipated to require about 12 labor hours per pressure vessel in order complete the following activities:

- Remove the vessel from service, sluice out spend media with clean water
- Clean equipment, hoses
- Rinse vessel to remove media, fines, and loose residue
- Pressure-wash the vessel internals
- Load fresh media, soak, and forward rinse (diverting effluent)
- Collect and dispose of rinse water and spent media.

The total, idealized O&M to replace IX media was 24 labor hours per year for the single-train, two-stage system. It should be noted that such media changes could require as much as 4 to 5 days if confined space entry and PFAS confirmation testing of the vessel are required. While much of the GAC replacement O&M is addressed in its reactivation fees, the frequent media replacement for the Horsham cost comparison assumed a similar amount of O&M required of the site personnel.

Media replacement and system cleaning for the AquaPRS differs from IX and GAC due to its significantly different configuration. Rather than loading the reactor to meet 100% of the annual requirements, planned sorbent replacement occurs weekly or biweekly at 2 to 4% of the yearly demand on each event. The operator-initiated replacement process is automatic and the sequence is completed in approximately 30 minutes. Fresh sorbent is recirculated for 5 to 10 minutes to adsorb any residual PFAS before effluent is released from the membranes in order to reduce rinse water. The operator is required to observe the operation, but is not actively involved in sluicing media. The ideal time for AquaPRS sorbent replacement is expected to be close to that for IX (approximately 26 labor hours per year).

Sorbent storage and disposal is also similar between the two technologies. Additional sorbent thickening occurs in the AquaPRS system once the spent sorbent is removed and pumped to the sorbent thickening tank. The sorbent is allowed to settle for a 16- to 24-hour period, resulting in a 25% solids concentration (250 g/L) at the tank bottom with clear supernatant occupying the upper 60 to 70% of the tank depth. The clear liquid is pumped to the system inlet for further treatment, leaving only the concentrated solids in the bottom of the thickening tank. These spent solids are then transferred to a long-term holding tank for ultimate disposal on a schedule consistent between AquaPRS and IX.

Idealized conditions used for lifecycle cost comparisons are described above; however, any system can be subject to practical challenges that can increase the required O&M. Consideration for the shorter, planned sorbent replacement interval in the AquaPRS potentially avoids some common problems such as biofouling and scaling faced by IX and GAC. Use of a 0.1 μm separator with a crossflow reactor further avoids issues of channelling, clogged underdrains, sorbent loss, bacterial release and migration. The technology also permits the use of special cleaning chemicals that may be desirable such as oxidants, acids or bases.

The AquaPRS is a new technology that will yield more O&M data through increased implementation. However, this 2-year program suggests that the long-term O&M requirements will not be significantly different from IX and that media replacement costs will provide the best indication of viability.

9.0 IMPLEMENTATION ISSUES

9.1 HORSHAM AGS

The feed water source at the Horsham AGS test site, designated "Storm water outfall #9," presented some challenges to the testing objectives. The first challenge was how to deliver feed water to the treatment unit without drawing bottom sediment from the outfall when the water level dropped to shallow depths. The outfall water level is not controlled and was subject to significant changes based on prevailing weather events. **Figure 27** shows outfall #9 under normal, low-turbidity conditions (left), and during flood conditions (center). To minimize impacts from fluctuating water level and sediment suctioning, the feed supply pump was mounted to a floating frame (Figure 1, right), which kept the pump's intake from reaching the floor of the outfall. This provided consistent flow to the treatment system and with minimal sediment suctioning.

Figure 27. Horsham ANG Test Site - Feed Water Source "Storm Water Outfall #9" under Normal Flow Condition (left) and Storm Water Flooding Conditions (center), Floating Sump Frame Intake (right)

The next challenge was determining how to minimize impacts from co-competing organics (i.e., organic material competing with PFAS for sorbent adsorption) found in the feed water. The feed water supply was frequently impacted by surface water runoff during rain and snow events, resulting in high-turbidity conditions (see **Figure 33** for storm water condition). To minimize impacts from high-turbidity events and increased co-competing TOC levels, a pre-treatment system was implemented. The pre-treatment system comprised a coarse screen filter, followed by a 5 µm cloth media filter system with automatic backwashing, and finally a 5 µm pleated cartridge filter as backup (refer to **Figures 28 and 29**). The coarse filter (left, bottom of Figure 26) feeding to two legs (two-leg filter manifold, **Figure 28**) of two, 20-inch filter cartridge housings. Each of the housings contained a 5 µm pleated filter cartridge. A remote-controlled valve permitted switching between the 5 µm filter legs when flow through one leg was reduced due to filter fouling (fouled filter comparison to new filter, **Figure 29**). A 20 µm filter cartridge was used in early tests, followed by a 5 µm filter. However, this method quickly proved unsustainable due to frequent poor feed water quality conditions, which caused rapid fouling on the cartridge filters. With this method, the cartridge filters required 3- to 4-day replacement due to rapid fouling. With the two-leg filter manifold system, roughly a week of operation could be achieved with both filter legs used.

To overcome this problem and achieve longer filter run times, an automatic back-washable filter system was implemented: the AquaBOT 3 (AB3) cloth media system (**Figure 30**). With the AB3 system in place, longer filter run times of up to 2 weeks were achieved. **Figures 31 and 32** show the clean and fouled 5 m cloth media filter as used during the testing at Horsham AGS.

Figure 28. Pre-treatment System – 5 µm Filter Cartridges

Figure 29. New and Spent Filter Cartridges. White = 5 µm / Blue = 20 µm

Figure 30. AASI Automatic Cloth Media Filtration System

Figure 31. 5 µm Cloth Media Filter – Clean

Figure 32. 5 µm Cloth Media Filter – Fouled

The following data graphs show how effective the AB3 system was during pilot testing at Horsham AGS. The data used for the following graphs were recorded during CMF-PFAS treatment Test #11 (from February 5 to February 23, 2021) and were selected as an example of AB3 system effectiveness. **Figure 33** displays influent turbidity data as recorded during the test period. This graph shows that influent turbidity ranged 1.2 to 90 NTU and averaged 13 NTU. **Figure 34** shows effluent turbidity from the AB3 system, which provided reduced feed water turbidity to the CMF system. The benefits from using the AB3 system were observed with reduced organic compound loading to the CMF system and reduced frequency prefilter replacement, which doubled operation time before requiring filter replacement.

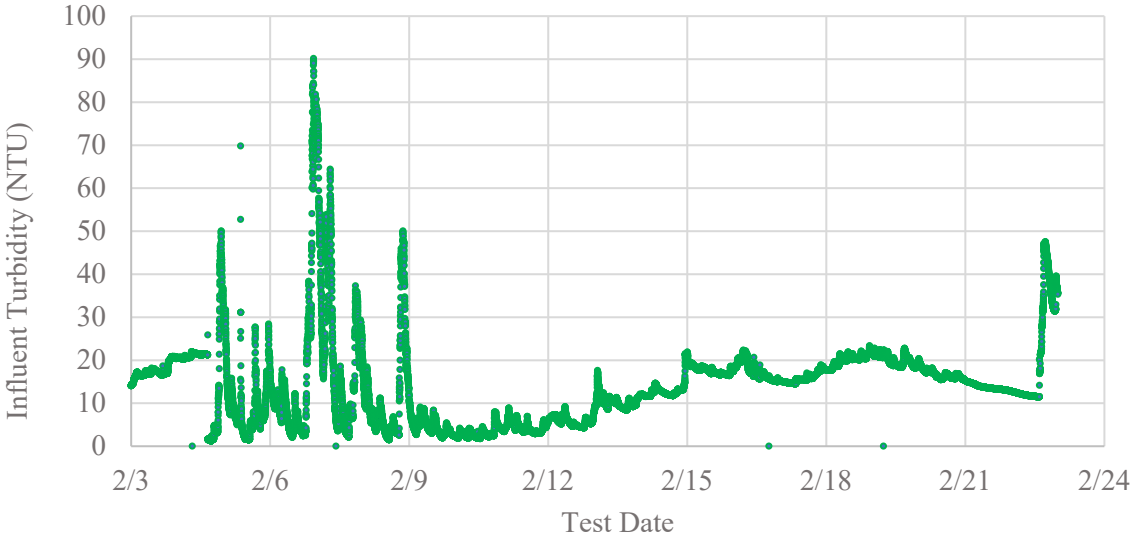


Figure 33. Influent Turbidity to the 5 µm Cloth Media Filter System (Test 11)

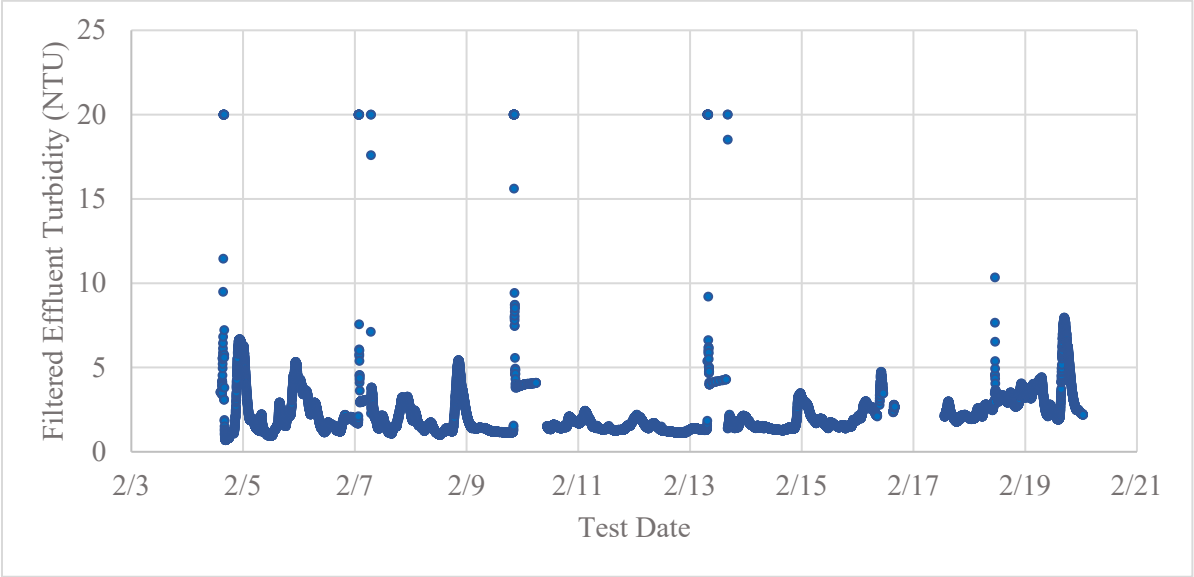


Figure 34. Effluent Turbidity to the 5 µm Cloth Media Filter System (Test 11)

9.2 WILLOW GROVE NAS

Tests at the Willow Grove NAS site was conducted without the use of automated pre-filtration (as used for Tests 4 through 13 conducted at Horsham AGS) due to the absence of TSS and turbidity in the influent feed water. Feed water was sourced from two combined groundwater wells with high PFAS contamination. The feed stream first passed through a 5 µm cartridge prefilter and then directly to the AquaPRS. No significant operational challenges were experienced during testing at the Willow Grove NAS site.

10.0 GUIDANCE FOR IMPLEMENTATION OF AQUAPRS

Pilot testing plays a key role in mitigating the technical risks associated with adopting new technologies. This is particularly true if the pilot system provides the proper geometric and dynamic similitude to permit proper scale-up to full-scale design. Contaminated sites present added challenges for PFAS removal due to the wide variety of factors that affect performance including water quality characteristics such as total organic carbon, anions, cations, sediment, scaling, and biofouling potential and variability. The relative PFAS composition and concentration varies dramatically among water sources, often even within the same project site. It is therefore critical to pilot any PFAS removal technology on each application to elucidate the technology's feasibility, economics, and constraints in meeting the discharge limits.

RSSCT tests are commonly used with sorbents like GAC or IX resins to simulate full-scale conditions. As it is impractical to mirror BVs treated (i.e., media longevity) in a short test, modifications are necessary for these technologies to yield breakthrough data. Such modifications result in different media dimensions, residence times, and geometric dissimilarities in order to limit BVs to a practical time period. As a result, correlation factors and modeling tools are often necessary to extrapolate RSSCT data to full-scale operation. Ultimately, whether the RSSCT testing accurately reflected full-scale performance may not be validated until months after the plant is commissioned, and changes are difficult or costly.

Figure 35. Dual-trained SPAC-CMF Bench-scale Pilot System

The AquaPRS technology overcomes these limitations by employing the production-level sorbent (i.e., AquaPR-206 media), separator technology, detention time, and hydraulic regime used in full-scale operation. Because full-scale media replacement is performed weekly, a 1-week bench-scale study will accurately simulate actual design conditions provided the feed characteristics are representative of anticipated operating conditions. Such testing will typically be extended beyond the 1-week timeframe to identify the potential breakthrough threshold based on the effluent target.

To support implementation of this new technology, several bench-scale pilot systems have been developed (**Figure 35**), allowing real-time assessment of the AquaPRS process feasibility and cost-effectiveness. A complete 1-week performance evaluation can be achieved by collecting four 55-gallon containers (or one 230-gallon tote) of representative contaminated water from the study area. The sample can be shipped to AASI's factory for testing and evaluation and will yield accurate data on sorption capacities, loading rates, and detention times necessary to project full-scale system sizing, equipment, and operational costs. Allowing time for analysis and report development, the AquaPRS technology can be quickly implemented into LCCAs to compare with other technical approaches. An example of the information required to complete such an analysis is provided in **Appendix I**.

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Appendix A

Interim Progress Report

INTERIM PROGRESS REPORT

Improved Longevity and Selectivity of PFAS Groundwater Treatment using Sub-Micron Powdered Activated Carbon (SPAC) and Ceramic Membrane Filtration (CMF) Version #1

ER19-B3-5181

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November 2020

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1. EXECUTIVE SUMMARY

The Aqua Aerobic Systems, Inc. (AASI), Colorado School of Mines (CSM), and Arcadis team completed a series of sub-micron powdered activated carbon (SPAC) trials between June 24 and September 24 of 2020. While much of this testing contributed to results needed to satisfy the Phase 1, 2, and 3 requirements for the project, most of the value obtained from this work was in understanding the challenges faced at this installation. Specifically, the rapidly changing water quality characteristics associated with the combined groundwater/surface water at the detention pond collection point and access to the water represented difficult circumstances that will prove to be invaluable in addressing other U.S. Department of Defense (DoD) site conditions.

Initial measured per- and polyfluoroalkyl substances (PFAS) removal rates were below those observed in previous testing but remain higher than typical rates reported and observed with granular activated carbon (GAC) on other water types. The team believes the variability, high total organic carbon (TOC) content relative to groundwater systems, and sediment loading would offer similar reduction in GAC adsorption.

Three main phases of testing were completed in this preliminary testing with the following results:

Phase 1 – Validate SPAC Removal Efficiency

The sub-micron powdered activated carbon (SPAC) and ceramic membrane filtration (CMF) system was able to achieve significant removals of combined perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) with specific adsorption rates approximately 200 to 250 micrograms (µg) removed per gram of carbon used. These removals were achieved despite significant variations in water quality and significant opportunity for system optimization.

Phase 2 – Waste Minimization

Operating SPAC concentrations of 2.5 to 3.5 grams of carbon per liter (g/L) were concentrated to 250 g/L through a combination of membrane dewatering and gravity thickening. The membranes were effective at concentrating the SPAC, as the original 34 L of waste was reduced to approximately 1.4 L. The membranes increased the waste carbon to a final concentration of approximately 145 g/L, with 24-hour gravity sedimentation increasing the SPAC concentration to 250 g/L. The permeate from the concentrating process recorded no total suspended solids (TSS) in the analysis, whereas the supernatant drawn from the settling container measured < 5 mg/L.

Phase 3 – Membrane Restoration

A clean-in-place (CIP) protocol was evaluated for effectiveness between test runs 4 and 5. Using separate 4- to 8-hour soaks in 0.1 percent sodium hypochlorite and 0.3 percent citric acid fully recovered the membrane permeability.

The first 3 months of testing was successfully completed under myriad site and environmental challenges that rapidly escalated the team's developmental process. The data gathered in this initial testing is vital for proving this technology's performance and economic benefits over the next testing phase. The team has taken advantage of various opportunities to increase system

reliability and performance by integrating experiences in developing subsequent testing protocols. A summary of planned actions for the next steps in testing is outlined in Section 7.

1. INTRODUCTION

This Interim Progress Report (IPR) provides an update on the system performance of the field application of Sub-Micron Powdered Activated Carbon (SPAC) coupled with Ceramic Membrane Filtration (CMF) to remove per- and polyfluoroalkyl substances (PFAS) in support of the Environmental Security Technology Certification Program (ESTCP) Project ER19-B3-5181 (the Project).

This report covers operation over 90 days from June 23 to September 24, 2020, which details the preliminary results from a three-phase test plan using a mobile pilot system deployed at the U.S. Department of Defense's (DoD's) Horsham Air Guard Station (1051 Fairchild St., Horsham, PA 19044; the Site). The primary test phases included:

Phase 1 – Validate SPAC Removal Efficiency.

Phase 2 – Demonstrate Waste Minimization Plans.

Phase 3 – Report finding from Membrane Restoration Efforts.

This IPR summarizes the preliminary results at a mid-point in the 6- to 9-month planned testing phases and provides an overview of the technical approach, system performance, and implications for executing the second half of the study which will evaluate design optimization and series operation.

2. DEMONSTRATION OBJECTIVES

The purpose and scope of this demonstration are to exhibit and validate the application of the SPAC-CMF treatment approach to reduce the total life-cycle cost of treating PFAS-impacted groundwater. The objectives of the study are to:

1) Demonstrate the SPAC's sorption capacity to remove key PFAS compounds (perfluorooctane sulfonate [PFOS], perfluorooctanoic acid [PFOA], and perfluorohexane sulfonate [PFHxS]) to a combined target below 40 nanograms per liter (ng/L).
2) Quantify the relative reductions of 21 other PFAS compounds as per United States Environmental Protection Agency (USEPA) Method 537/DoD QSM 5.1
3) Use preliminary data screening and waste treatment (concentration) trials to develop operational protocols to optimize removal efficiencies while reducing bulk-carbon requirements.
4) Identify the presence of co-contaminants, specifically dissolved organic carbon (DOC), and determine its influence on the technology's operation and performance.
5) Characterize the crossflow CMF system operation to permit scale-up design for the technology's application at this and other DoD sites.
6) Employ systematic approaches to reducing carbon disposal through concentrating the sorbent using membrane filtration.

This IPR provides preliminary findings from a series of five separate tests conducted over 90 days as part of the Phase 1 study (validating SPAC removal efficiency). The report also presents the results from Phase 2 (Waste Minimization) and Phase 3 (Membrane Restoration) testing.

3. TECHNOLOGY DESCRIPTION

The technology employs a wood-based powdered activated carbon (PAC) milled to a mean particle diameter (MPD) below 1 micrometer (micron [µm]). Compared to conventional PAC and GAC, which have respective ~45 and ~1,600 µm MPDs, the SPAC presents a significantly higher surface area per unit mass to permit contaminant adsorption, which permits greater contaminant penetration into the carbon's interior meso-, micro-, and macropores. The smaller particle improves the effective carbon utilization, thereby reducing demand while improving unit removal efficiencies. The technology has shown to be particularly effective in targeting chain-length-dependent compounds with high adsorption of 4-, 6-, and 7-carbon chained PFAS compounds. The sub-micron MPD also permits suspension of the carbon medium to accelerate absorbance and improve predictive measures of carbon exhaustion.

The SPAC is separated from the bulk liquid with CMF technology using a 0.1 µm nominal pore size barrier. The CMF's narrow pore size distribution results in high permeability and less pressure loss across each membrane unit when compared to polymeric membrane (PM) media. CMF was specifically selected for SPAC separation due to the mechanical, thermal, and chemical superiority over PMs, thereby permitting high suspended SPAC concentrations to maximize PFAS absorbance. A rapid backwash method is used to increase recovery and reduce backwash waste to improve SPAC inventory control. Unlike nanofiltration (NF) and ultrafiltration (UF) technologies, the more porous 0.1 µm microfiltration (MF) membrane will not remove dissolved salts and relies on the carbon particles to remove the PFAS. As a result, the backwash volume (waste) is significantly reduced to a small fraction of what would be expected with NF/reverse osmosis (RO) systems.

The system design accelerates PFAS adsorption while minimizing carbon disposal costs by conserving SPAC usage. The membranes are operated in crossflow filtration whereby treated water is produced as permeate and the SPAC is returned to the upstream sorption reactor. The high velocity and SPAC scouring on the membrane surface maintains permeability and reduces cleaning (backwash) requirements. A sorption tank with 10 to 60 minutes of contact time in combination with crossflow operation permits suspended SPAC concentrations of 1 to 5 g/L to mix with the incoming waste to facilitate PFAS adsorption.

The robust design of the ceramic membrane system offers a unique solution to SPAC dewatering. The CMS system described above will be used to re-concentrate the SPAC at the end of each run as the system approaches breakthrough. Waste concentration trials performed as part of Task 3.0 of this study have shown that carbon levels can be concentrated to 5 to 10 percent of the original working volumes to drastically reduce hauling and disposal costs. Preliminary testing also revealed that extended carbon replacement intervals may permit additional thickening through prolonged gravity storage.

This IPR will discuss the latest findings as of Test 5 for PFAS removal, SPAC adsorption capacity, and waste minimization efforts.

4. TESTING OBJECTIVES

The objective of this initial portion of the study was to assess the effectiveness of SPAC-CMF for the removal of a broad range of PFASs from contaminated groundwater at a typical DoD site. Results from the first few months of testing were critical in understanding the challenges associated with variable water quality characteristics, identifying optimal system operating variables, and assessing the implications of sampling methods.

Water for the testing was drawn from Outfall No. 9 (Figure 1), which holds a combination of surface water and groundwater. Unlike a typical groundwater treatment application, surface waters are exposed to a much broader range of contaminants including dissolved and particulate organic matter, silt, and any contaminants that may come in contact with the water. Further, surface water quality can be significantly and adversely impacted by local and regional weather events. The photo shows an example of the water quality treated by the SPAC-CMF system during testing. Wind, rainfall, and high flows in the outfall routinely mixed bottom sediments, which can dramatically impact PFAS removal performance in surface water compared to groundwater with much more consistent water quality. The team developed a pre-treatment approach to contend with the changing water quality (Appendix A1).

Figure 1. Outfall No. 9

With consideration for the requirements set forth in the original proposal, three testing phases were completed with the following objectives:

Phase 1 – Validate SPAC Removal Efficiency

Two independent SPAC-CMF treatment trains were deployed at the Horsham site using a climate-controlled containerized treatment unit with testing to be conducted over a 6- to 9-month period. Water was drawn with a floating decanter from Storm Water Outfall #9 and pumped into the pilot system, treated, and discharged back into the outfall.

A series of ten independent tests was performed using both Trains A and B over 90 days (*i.e.,* five tests for each train). A summary of the test conditions is provided in Table 1. Testing between the two trains ran concurrent with Train B, targeting lower carbon concentrations to prompt an earlier breakthrough point and to compare with Train A operating conditions (See Table 2).

Emphasis was placed on the design and operational settings deemed necessary to reduce the PFAS compounds and extend the time before breakthrough. A primary objective of this test phase was to assess the time to reach breakthrough and identify control adjustments to reduce the time between carbon replacements. The original test plan was followed but adjusted to benefit

from functional learning.

The key variables investigated in this initial testing included:

1) Pre-treatment requirements;
2) SPAC reactor concentration;
3) SPAC reactor detention time;
4) Membrane flux;
5) Cross flow rate; and
6) Membrane transmembrane pressure (TMP).

The need for pre-treatment was confirmed and reported separately (Appendix A1). Automatic samplers were set to collect weekly composite influent samples and daily effluent grab samples for analysis by the CSM testing lab. Reactor carbon levels varied between 250 and 3,500 milligrams per liter (mg/L; as carbon). Flux rates and reactor detention times were adjusted in response to water quality, performance, and PFAS results. Specific adsorption rates for targeted PFAS compounds were evaluated based on effluent performance (breakthrough) under a range of loading conditions.

Phase 2 – Waste Minimization

Upon completion of Phase 1 testing, Phase 2 evaluated the system's ability to re-concentrate the SPAC, first using the ceramic membranes and then with application of gravity settling. The data provided in this report update previous preliminary work performed for Tasks 2 and 3 (Waste Concentration Trials), which were reported in the Quarterly Progress Report (QPR) dated October 15, 2020.

The stock SPAC was manufactured to a nominal concentration of 10 percent by weight (100 g/L). A small amount of stock SPAC was added to the sorption reactor at the start of each test to target the operating concentrations (which ranged from 250 mg/L to as high as 3.5 g/L). Upon completion of a test, the sorption reactor contents were dewatered with the membrane system and the contents transferred to a settling reactor for further carbon compaction. Total suspended solids (TSS) were measured for each sample using Standard Methods SM2450-D with both 0.2 and 0.45 μm filter papers to address the SPAC's particle size variability and confirm all of the sorbent was captured in the analysis. Further discussion of the protocol used for this study phase is attached in Appendix A2.

This data will be used to project long-term disposal costs and determine what additional equipment may be beneficial to expedite the process.

Phase 3 – Membrane Restoration

Upon completion of each Phase 1 test, the membranes were evaluated for potential fouling, and a cleaning strategy was developed to restore the membrane performance. Specific permeability was used as the key metric to establish the cleaning method's effectiveness. A CIP strategy evaluated the ability for hydrochloric acid (HCl) and an oxidant (sodium hypochlorite [NaOCl]) to address potential scaling, organic fouling, or carbon buildup.

As this testing represents the first application of the SPAC-CMF technology at an actual DoD site, these first few months of testing yielded critical data that the team needed to refine the design and operation ahead of further final testing.

5. RESULTS

This section summarizes the results documented over an operational period from June 23 through September 24, 2020.

5.1 PHASE 1 – VALIDATE SPAC REMOVAL

The AASI, CSM, and Arcadis team completed a significant amount of testing between June and September of 2020. While much of this testing contributed to results needed to satisfy the Phase 1, 2, and 3 requirements, most of the value obtained from this work was in understanding the challenges faced at this installation. Specifically, the rapidly changing water quality characteristics associated with the combined groundwater/surface water at the detention pond and access to the water represented difficult circumstances that will prove to be invaluable in addressing other DoD site conditions.

Phase 1 testing during this period resulted in the following actions:

- The team implemented a new sediment filtration pre-treatment process using AASI's cloth filter media to screen debris and solids before processing.
- A series of five individual tests was competed for each of Trains A and B, which evaluated performance across a range of SPAC concentrations from 250 to 3,500 mg/L.
- Hundreds of influent and permeate samples from the HAGS facility were sampled and analyzed for 18 different PFAS compounds.
- Feed and permeate total organic carbon (TOC) were characterized.

A summary of the test conditions is provided in Table 1 (below):

Table 1. Testing Conducted between June and September 2020

Test	Start	End	Objective	Result
1	6/22/2020	6/26/2020	Initial testing with 0.5 and 0.25 g/L carbon for Trains A and B.	Source water quality (turbidity, solids) prevented sustained operation.
2	7/08/2020	7/23/2020	Repeat Test 1 conditions with cartridge filter(s) in place.	PFAS loads higher than anticipated; cartridge filters unable to process flow during upset conditions.
3	7/23/2020	8/1/2020	Increase carbon levels; Upgraded pre-treatment system for multiple cartridge filters.	Pre-treatment modifications unable to consistently produce flow to SPAC-CMF system; Team evaluated solutions.
4	8/6/2020	8/27/2020	Higher SPAC concentrations (3.5 g/L) and shorter detention time; Partial operation with automatic backwashing filter.	Significant improvement of feed quality (turbidity) to SPAC-CMF; Good removals of key PFAS compounds.

Test	Start	End	Objective	Result
5	9/2/2020	9/24/2020	Similar to Test 4, but with increased detention time and filter on-line; Membrane cleaning and SPAC dewatering (Tasks 2, 3).	Sustained SPAC-CMF operation despite significant weather events; Tasks 2, 3 to be completed.

After the first test, the protocol for each subsequent trial was informed by the results from the previous testing. Tests 1 through 3 focused on changes implemented to condition the water to a quality that was suitable for PFAS adsorption by the SPAC. In fact, this level of treatment would represent the minimum requirements ahead of other technologies such as GAC, ion exchange, and filtration technologies like RO and nanofiltration. While PFAS data were obtained during these runs, they are not representative of what should characterize the performance of any conventional PFAS removal technology. Results from Tests 1 through 4 were valuable in setting conditions for subsequent testing by confirming:

- Source water withdrawal must consider a varying surface level, subsurface removal, and maximum separation from bottom sediments.
- Coarse screening (2.3 mm) is necessary to eliminate larger debris.
- Pre-filtration with a nominal 5 to 10 µm pore size is critical to provide consistent water quality feed to the PFAS removal system.
- Pre-filter cleaning (backwash) systems must be automatic and on demand.
- Influent sampling must consider both long-term averages and short-term variability (spikes) due to rapidly changing water quality from surface water runoff.
- SPAC (carbon) levels must be increased to address significantly higher PFAS concentrations than originally identified.

All these conditions were encountered and addressed during Tests 1 through 4. The team's solution to the pre-treatment challenge is presented in Appendix A1.

Test 5 was the first long-term operation trial that yielded results that began to reflect the enhanced performance potential of the SPAC-CMF combination. While operation conditions were dramatically improved in this trial, the membrane operational conditions were not ideally calibrated to suit all the changes, leaving significant room for optimized performance in subsequent testing. For example, improvements in SPAC mixing, pH control and carbon levels are currently underway in Test 6, and the results will be reported in subsequent updates.

The test conditions used for Test 5 were as follows:

Table 2. Test 5 Operating Conditions

Parameter	Units	Train A	Train B
Flux	L/m^2-hr	100	100
Flow (Qi)	L/min.	0.67	0.67
Recycle Rate	% of Qi	500%	500%
Detention	Min.	30	30
SPAC	g C/L	3.5	2.5

5.1.1 Pre-Filtration Performance

Test 5 represented the first full trial that included the updated pre-treatment system. This system includes a floating pump with a submerged intake, 2.3 mm strainer, automated cloth media filter, and cartridge filters as backup (see Appendix A1).

On-line turbidimeters are provided with the cloth media filter to assess the influent and effluent water quality. The cloth media filter was effective at reducing turbidity, particularly during upset conditions when the water quality deteriorated (Table 3). The cloth media filter material is rated for a nominal 5µm particle size rejection and was able to reduce most (74 percent) of the turbidity during poor conditions and less (46 percent) under normal conditions in which the water quality is good. No polymers or coagulants (or other chemicals) were used to achieve these reductions.

Table 3. Cloth Media Filter Performance

	Filter Influent (NTU)	Filter Effluent (NTU)	Removal (%)
Average	3.29	1.78	46
Maximum	25.36	6.59	74
95 Percentile	8.18	2.86	65
75 Percentile	5.40	2.49	54
25 Percentile	1.67	1.21	28

NTU = nephelometric turbidity unit

The team was interested in understanding what, if any, PFAS reductions could be expected from the cloth media filter. If the filter achieved significant removals, then PFAS could be consolidated into the backwash. If PFAS compounds were not removed, then the backwash PFAS levels are similar to the source water conditions.

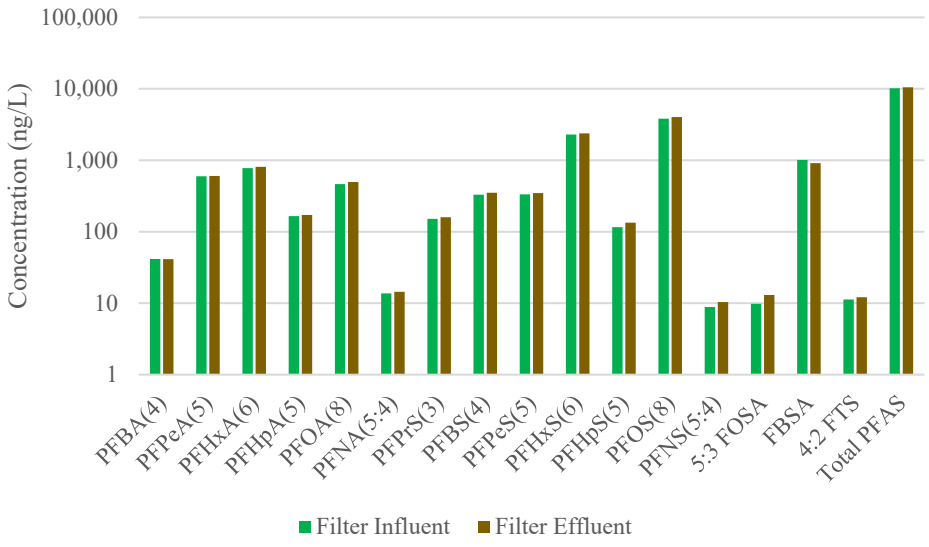


Figure 2. Cloth Media Filter PFAS Removal

As shown in Figure 2, the filter did not achieve measurable removals of PFAS, and the filter's backwash water exhibited a PFAS concentration similar to that of the filter influent and effluent streams. As such, returning backwash water to the source did not change the water source's PFAS concentration.

5.1.2 SPAC-CMF Influent PFAS Levels

Influent and permeate sampling collected 250 mL every 12-hours during Test 5 for PFAS analyses. The sampling was arranged with a slight time lag between influent and effluent sampling to address temporal variations in water quality to match influent with effluent. For SPAC-CMF performance evaluation, the PFAS samples were taken after the pre-treatment system but before the sorption tank. The sampling method was a revision from Test 4, which composited the influent samples to quantify the total mass of PFAS applied to the system over 1 week. Future sampling improvements will be necessary to accurately capture both the total PFAS mass loading and short-term spikes that can impact performance but can also be missed in sampling and testing.

Average influent PFAS composite values and species are presented on Figure 3 (below).

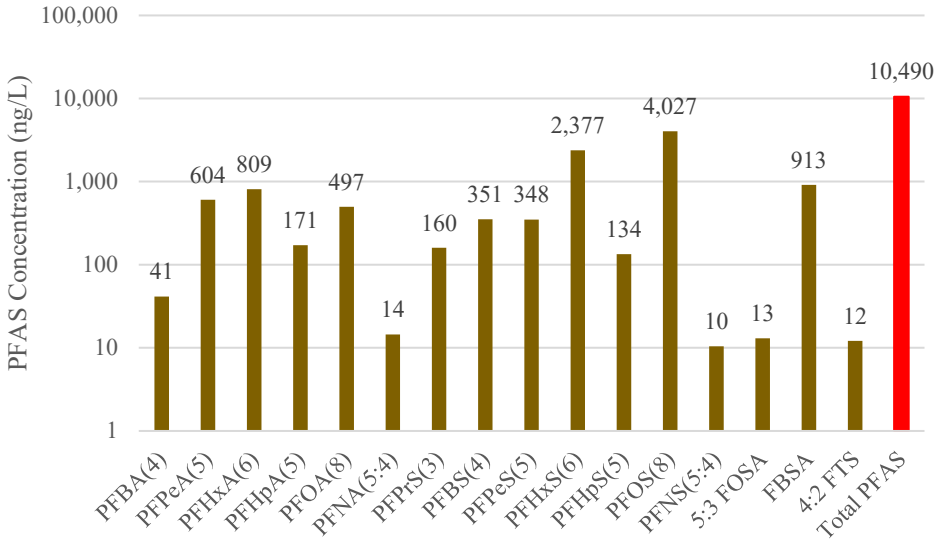


Figure 3. Test 5 Average Membrane Influent PFAS

PFAS levels varied widely, with total concentrations ranging from 9,121 to 20,517 ng/L. Because grab samples are collected every 12 hours, variability may be much greater than we were able to measure in Test 5. Subsequent sampling will modify the collection and timing methods to best characterize the PFAS concentrations detected in this outfall.

5.1.3 Combined PFOA + PFOS Removal

The combination of PFOA and PFOS was the primary focus of Test 5 as necessary to calibrate the design and operational parameters for optimized performance. Except for one sample, the removal rates were high (90 to 99 percent) during the initial portions of the study. The percentage removal of combined PFOA and PFOS for Test 5 Train A and B are presented in Figure 4 and Figure 5, respectively.

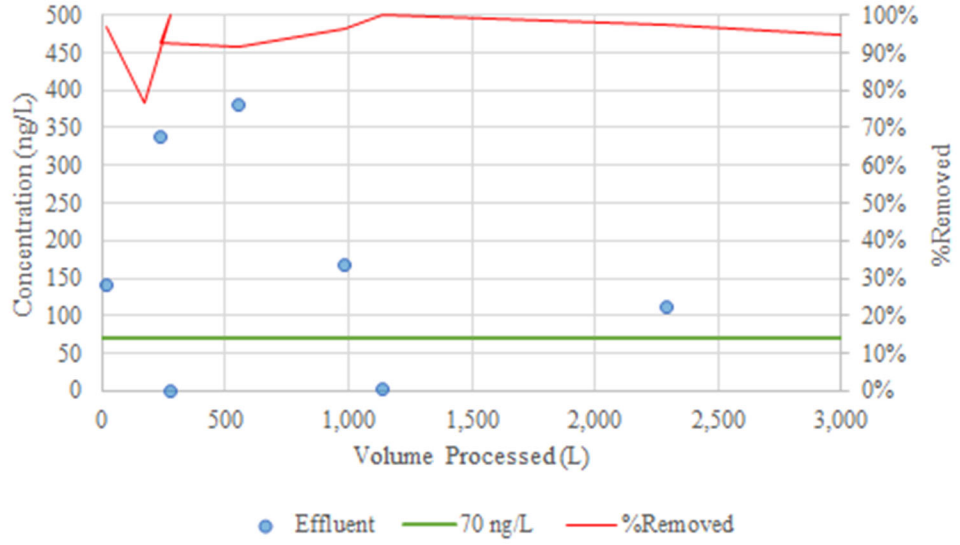


Figure 4. Combined PFOA and PFOS Test 5, Train A

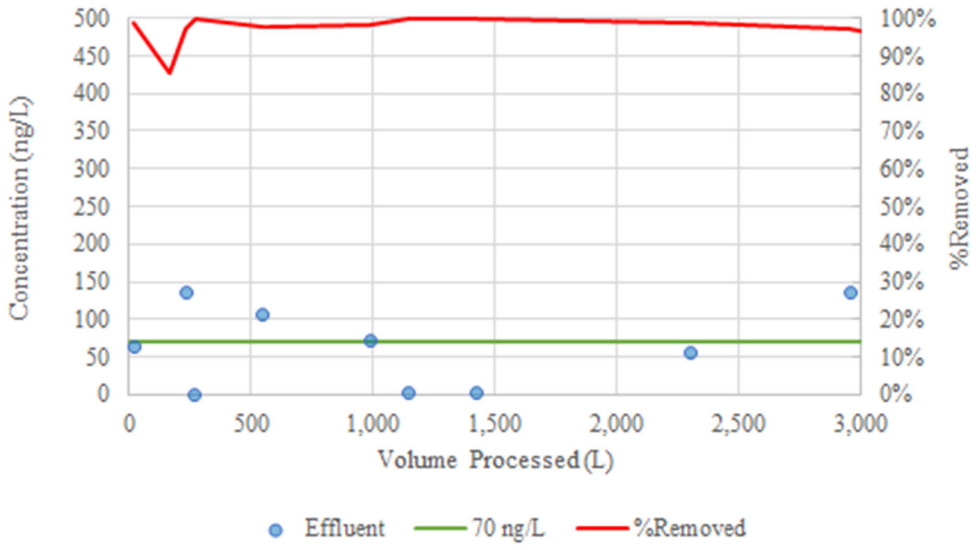


Figure 5. Combined PFOA and PFOS Test 5, Train B

Several initial readings were higher than the 70 ng/L target, despite a fresh supply of SPAC. This may be attributed to residual water in the permeate piping system from the previous Test 4. The team also reviewed sampling practices and autosampler bottle cleaning techniques in advance of further testing. Subsequent measurements met the target as well, but PFAS removal rates

dropped off significantly after 4,000 L of treatment. This happened to coincide with a period of storm events that hit the area in the middle of September, and feed turbidities as high as 25 NTU were measured. This also matched a period during which membrane permeability dropped unexpectedly (discussed further in Phase 2).

5.1.4 Specific Adsorption Rates

The combination of PFOA and PFOS was the primary focus of Test 5 as necessary to calibrate the design and operational parameters for optimized performance. Except for the initial anomalous sample, the removal rates were high (90 to 99 percent) during the initial operation. The specific adsorption and percentage removal for combined PFOA and PFOS of Test 5 Train A and B are presented in Figure 6 and Figure 7, respectively.

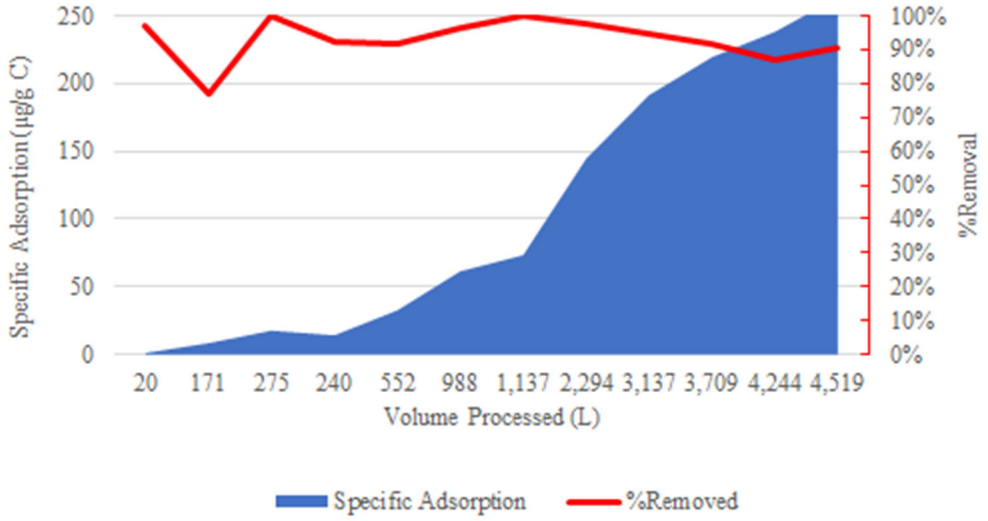


Figure 6. Specific Adsorption Rate for combined PFOA, PFOS – Train A

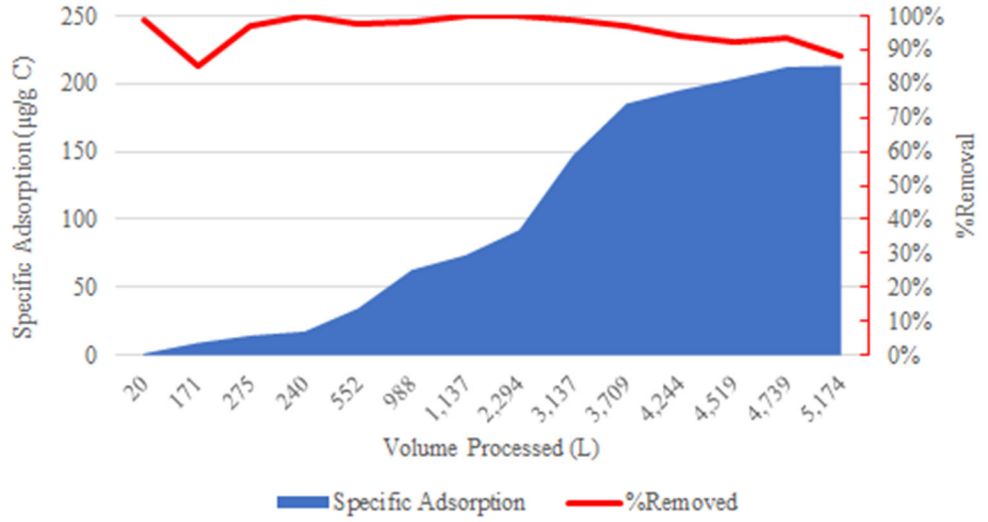


Figure 7. Specific Adsorption Rate for combined PFOA, PFOS – Train B

The surface water proved to be challenging due to the high TSS variability and elevated TOC content. Compared to previous work with SPAC on PFAS-impacted groundwater, sorption rates and broad-spectrum PFAS compound removal were quite a bit lower. The specific adsorption rates observed for the combined PFOA and PFOS ranged between 200 and 250 micrograms per gram (µg/g) carbon. While lower than anticipated, they remain significantly higher than those observed for GAC on much cleaner PFAS-impacted groundwater, for which sorption rates were about 6 µg/g carbon. For comparison, the team will investigate the comparative specific adsorption rate for GAC at this Site. If the SPAC is negatively affected by the water quality characteristics at this Site, the same may be true for the GAC currently operating. This comparative information will be important in the economic evaluation of this technology.

5.1.5 SPAC Carbon Concentrations

The specific adsorption rates were based on the nominal operation targets of 3.5 and 2.5 g C/L for Trains A and B, respectively. While this represented an increase in carbon from previous tests, the hydraulic detention time was reduced to 30 minutes. Further, previous operation suggested that a lower crossflow recycling rate could be maintained without increasing the TMP). While these changes for Test 5 represented a positive step in most regards, it did result in a loss of SPAC mixing in the sorption tank. During much of the study, the actual carbon levels dropped below the target concentration until the final portion of the test, when the mixer position and speed were adjusted. As shown in Figure 8, the final measurements matched the initial conditions once the mixing energy was adjusted. As such, the actual, effective specific adsorption rates were higher than the 200 to 250 µg/g calculated values, as much of the carbon was not suspended during Test 5. Subsequent testing will address the recycle rates and mixing energy to ensure maintenance of consistent carbon levels in the reactor.

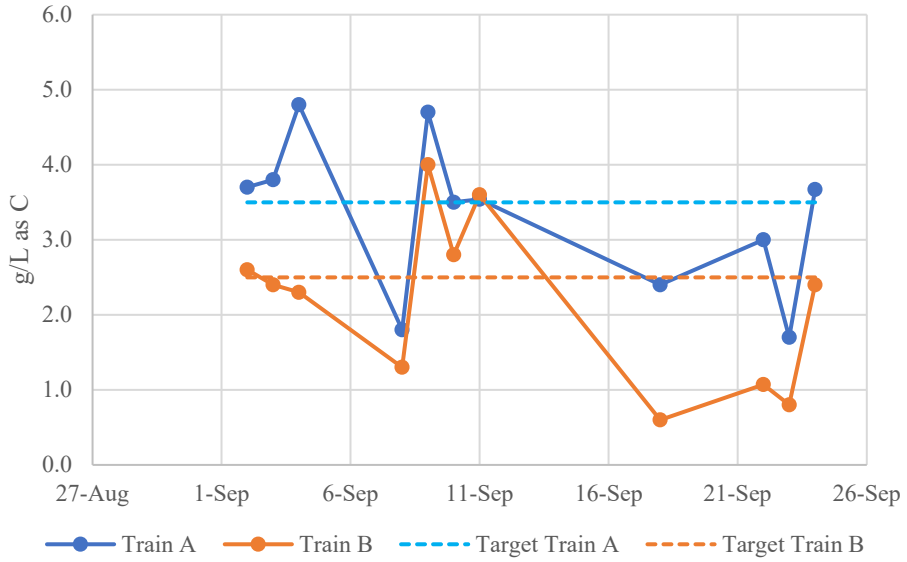


Figure 8. SPAC Concentration in the Sorption Reactor for Test 5

A full summary of data is provided in Appendix A3**.**

5.2 PHASE 2 – WASTE MINIMIZATION

SPAC disposal at the end of testing represents a potentially significant cost savings over conventional PFAS treatment. Phase 2 testing conducted as part of Test 5 was designed to evaluate the concentration of SPAC (as carbon) at various points in the system based on waste minimization efforts. The details of the testing protocol are provided in Appendix A2, and the results are provided below.

Carbon was analyzed using Standard Methods SM2450D with a 0.2 µm filter medium. This filter rating was selected in response to ESTCP's previous comments and to confirm that the filter would capture > 99 percent of the SPAC based on the original particle size distribution data.

At the conclusion of Phase 1 testing, the team attempted to use the membrane for sorbent concentration but was limited by the reactor depth. In other words, the operation depth of about 8 inches left little room for further concentrating with the membranes due to the wide and shallow geometry of the sorption tank and the location of the level sensor. ultimately, the team collected the SPAC from the system (tanks, piping, and membrane housing) and shipped it to AASI's factory for testing on a membrane of the same size. In this testing, a replica system (Figure 9) was set up to use a sorption reactor with a high depth-to-diameter ratio. This improved reactor design will be shipped to the HAGS site for testing over the next few months.

Figure 9. Waste Minimization and Concentration Testing

Figure 10 shows the results from measurements obtained during Phase 2 testing. The stock SPAC solution was originally manufactured to a specified 10 percent concentration (or 100 g/L). This material was originally shipped with the pilot system and was the carbon used for Tests 1 through 5 as well as previous bench trials for this project.

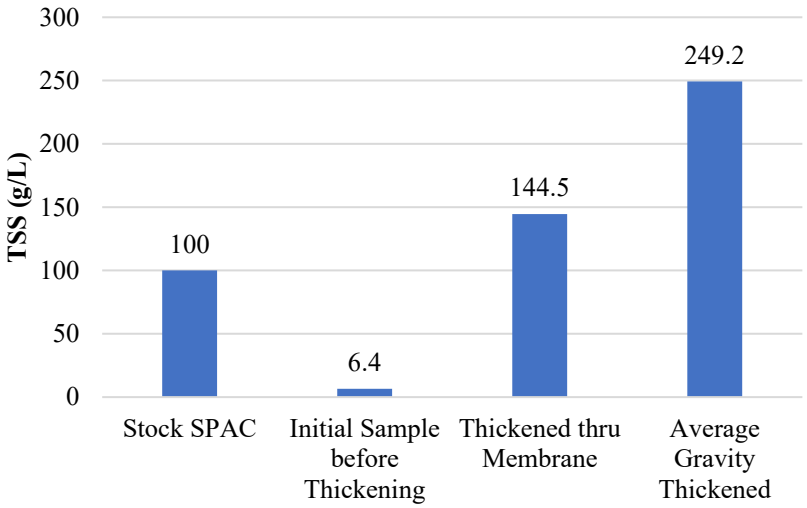


Figure 10. SPAC Concentrations during Waste Minimization

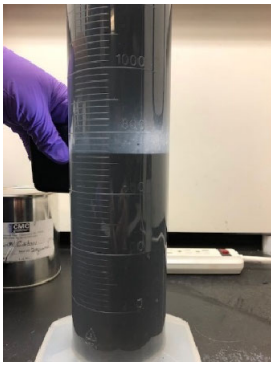
A total volume of 34 L of waste (including clean wash water) was sent to and received by AASI to perform the testing. This waste was collected, mixed, and measured to be 6.4 g/L of SPAC. This was slightly higher than the operational concentration, which was due to the initial attempt for on-site concentration and the difference in measurement techniques.

The membranes were effective at concentrating the SPAC, as the original 34 L of waste was reduced to approximately 1.4 L using the membranes alone. In other words, the membrane was able to concentrate the SPAC by a factor of approximately 24 times by removing about 32.6 L of water from the original 34 L of waste. The resulting TSS concentration measured in the thickened material was 144.5 g/L, or 23 times higher than the starting concentration. The 8 percent difference in the volumetric reduction (24 times) versus the increase in TSS concentration (23 times) could be attributed to errors in volume readings, sampling methods, or standard error in the TSS measurements. However, the results do support the premise that membranes can potentially reduce waste volumes by more than 20 times as observed in earlier trials.

The remaining 1.5 L of thickened waste was then placed in a gravity settling container and allowed to separate for several days (Figure 11). As shown, SPAC can achieve most of its compaction capabilities within 24 hours. TSS analyses of the compacted carbon after 24 hours of settling revealed a thickened concentration of approximately 249 g/L from the original 145 g/L after concentrating with the membranes. Settling for a period of 24 hours enabled the gravity settling to offer another 1.72 times concentration factor, which was supported by visual inspection as shown in the photo.

The supernatant collected from the gravity settling container was also measured for TSS and yielded a value of < 5 mg/L.

Finally, the 32.6L of permeate produced by the membrane during the concentration trial was measured but did not contain any measurable solids on the 0.2 µm filter paper.



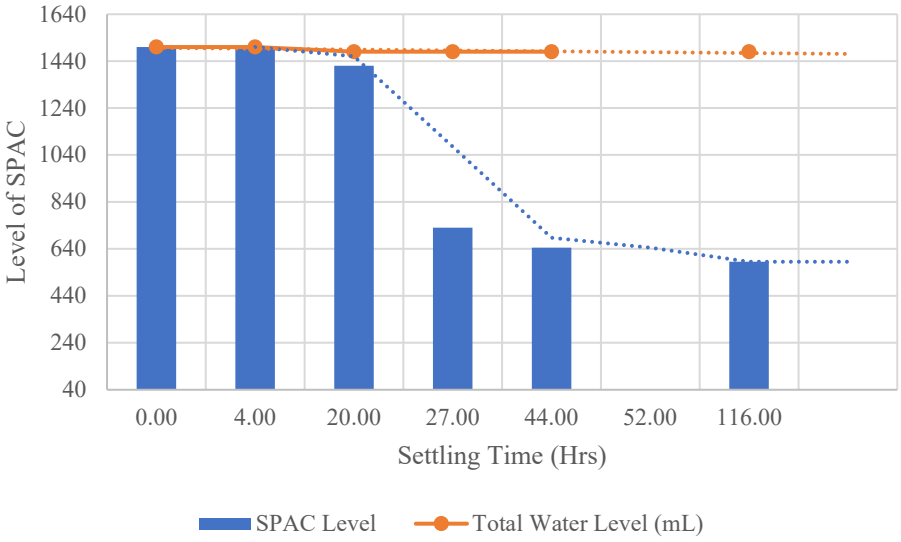


Figure 11. Concentrated SPAC Settling

5.3 PHASE 3 – MEMBRANE RESTORATION

The ceramic membranes used during testing for PFAS removal at the Site were cleaned at the end of each test run to restore permeability to baseline conditions. During a test run, membrane permeability is expected to decrease over time due to increased solids content and organic loading (i.e., as accumulated foulants). One of the objectives of this pilot test was to determine a chemical cleaning strategy to restore membrane permeability. To achieve this, a chemical CIP process was conducted at the end of Test 4 to restore membrane permeability in preparation for Test 5.

The CIP procedure used to clean the membranes was based on a previously developed cleaning regime used for typical water treatment applications. This regime includes the use of two chemicals (heated to 30 degrees Celsius) separately in a static soak for 4 to 8 hours followed by a heated clean water rinse. The chemicals used were: (a) NaOCl, 12.5% solution and (b) citric acid powder. The specific steps used in the cleaning regime are detailed below.

The cleaning regime was developed as follows:

1) Upon completion of a test, the TMP and permeability are assessed, and a decision to conduct a CIP is evaluated. In this case, the TMP had risen (and permeability had reduced) to a point at which CIP was selected.
2) Typically, the membrane is cleaned in place (with chemicals added to the housing). For this test, the membrane was removed for inspection, and the CIP was performed in a separate housing.
3) A heated (to 30 deg. C) clean water rinse was applied to the tube, and the contents of the rinse were removed after 30 minutes.
4) Next, a heated (30 deg. C), 0.3 percent NaOCl solution was applied to remove organic fouling on the membrane and was allowed to soak undisturbed for 4 to 8 hours. Upon completion, the contents were collected as waste for disposal.
5) A second heated clean water rinse was applied. The contents were removed after 30 minutes.
6) A heated (30 deg. C), 1 percent citric acid solution was then applied to remove inorganic fouling (scaling) on the membrane and was allowed to soak undisturbed for 4 to 8 hours. Upon completion, the contents were neutralized and collected as waste for disposal.
7) A final heated clean water rinse was applied, and the contents were confirmed for neutral pH.

The CIP measures used in this study represent a common approach used in water and wastewater treatment applications. The concentrations and soaking durations vary from site to site and depend on water quality and the length of previous operation and monitoring key performance indicators such as TMP and permeability. As this water has a higher input of TOC and sediment from the surface water drawn from the outfall, the CIP requirements at other sites (i.e., groundwater) may be less frequent or shorter.

The effectiveness of the CIP operations was determined by comparing the TMP and permeability data from the previous test (Test 4) and the later test (Test 5), which commenced after the CIP. Success of the CIP operation would result in initial permeability from Test 5 matching that of

Test 4. If a reduction from Test 4 to Test 5 was observed, the CIP operations could be modified to extend the soaking time or increase the chemical concentration.

Test 4 data (Figure 12) show the initial temperature-corrected permeability at about 500 to 550 liters per square meter per bar (lmh/bar), which is typical for this type of application. As the pre-treatment system was not fully developed at the beginning of Test 4, the system experienced flow interruptions and bypass of influent directly to the sorption reactor (without pre-filtration). As a result, the system realized a reduction in permeability to a range of 50 to 100 lmh/bar. Due to its high mechanical strength, the membrane system is fully capable of operating at these elevated pressures (reduced permeability). However, this condition indicated that a CIP would benefit the system energy requirements (having less pressure to produce the same rate of permeate).

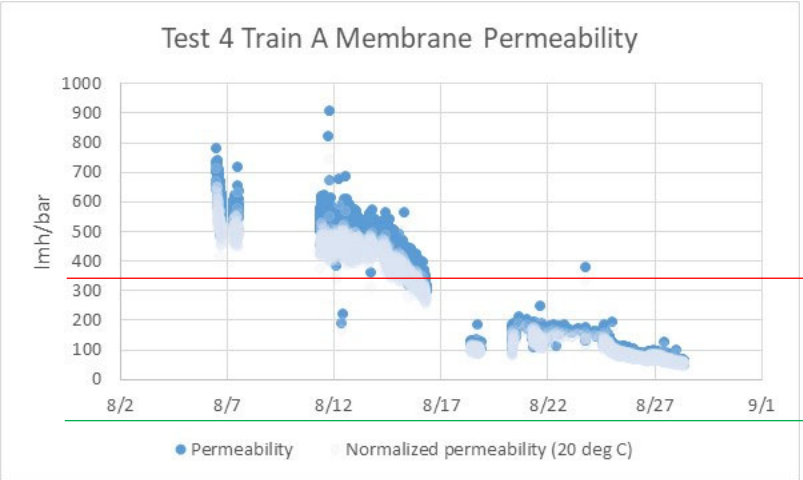


Figure 122. Test 4 Train A Membrane Permeability Data

After cleaning with the CIP procedure, the temperature-corrected membrane permeability was restored as shown in data for Test 5 (illustrated on Figure 13).

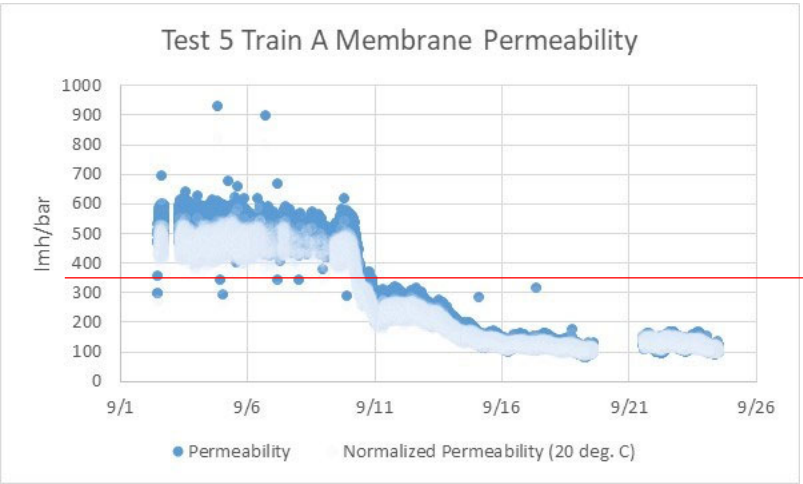


Figure 133. Test 5 Train A Membrane Permeability Data

Strong storms in the Horsham, PA area that occurred around September 10 resulted in reduced water quality fed to the system, as shown by the turbidity profile on Figure 14. This appears to correlate with the observed reduction in permeability observed in Test 5 over the same timeframe. Although this had a significant impact on the membrane permeability, the system pressures stabilized between 100 and 150 lmh/bar for the remainder of the test.

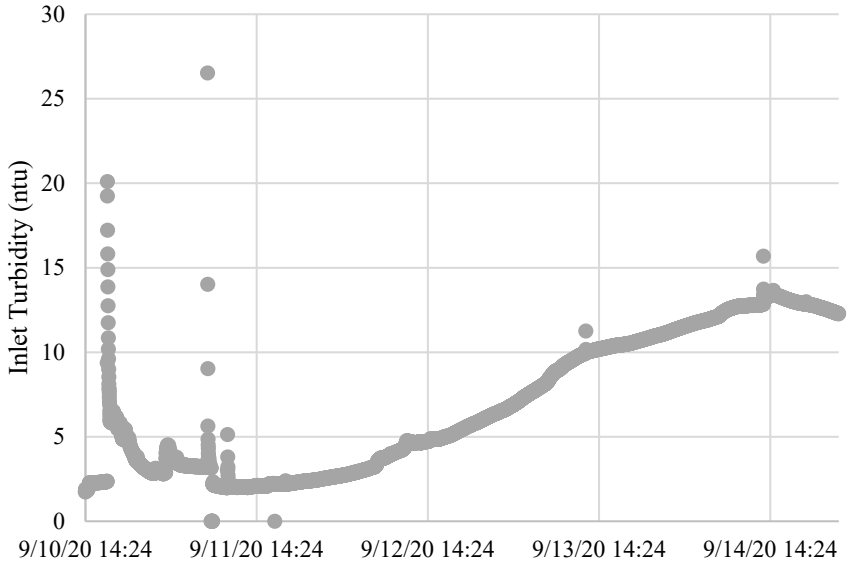


Figure 144. Feed Turbidity September 10 through 14, 2020

During such events, in which the outfall's water level is high due to storm runoff, the existing system (site installation) is temporarily taken off-line until conditions improve. For Test 5, the SPAC-CMF system was maintained in operation throughout the storm events. The updated pre-treatment system with the automated cloth media filtration system was an important reason the SPAC-CMF system was able to operate continuously during this event.

In summary, Phase 2 objectives were fully met with the proposed CIP instructions developed for this Site. The membrane system's initial, specific permeability of 500 to 600 lmh/bar could be recovered from as low as 50 to 100 lmh/bar with the prescribed chemical conditioning. Further, flexibility in this cleaning process should support typical membrane restoration efforts in other applications that may present conditions more favorable than those experienced at this Site.

6. FUTURE STUDY & LESSONS LEARNED

The unique challenges faced in the first 3 months of this study have been vital for gaining insight into situational events that may not be uncommon in surface water at other DoD sites. While the SPAC-CMF technology has been studied in other groundwater applications, this study represents its first exposure to the dramatically changing water quality associated with combined surface water and groundwater treatment. These initial PFAS removal data have allowed the team to compare operational conditions with PFAS adsorption performance in a way that each test informs the design conditions of the next. For Test 5, the incorporated learning actions included:

- Pre-treatment: Prefiltration to remove sediments and particulate organic compounds during even brief upsets within the outfall is critical. Further, the filtration system must be robust and self-cleaning to permit long-term, unattended operation.
- SPAC levels: The ability to adjust the carbon content in the reactor is beneficial to address changes in feed water PFAS content and extend run-times between replacements.
- Waste disposal: Both membrane dewatering and gravity compaction of SPAC may offer more opportunities for volumetric waste reductions than originally anticipated. The ceramic membranes have been shown to offer a greater capacity for concentrating SPAC without increasing feed pressures.

As the team enters Test 6 and beyond, the following additional measures will be implemented to further optimize performance:

- Sorption reactor design: Providing sufficient detention time is important, but so is the physical geometry of the sorption reactor as it relates to both mixing and SPAC concentrating with the membranes. The team will evaluate an updated sorption reactor for future testing to improve both SPAC adsorption and thickening ability.
- Crossflow rates: The team was able to increase SPAC levels and decrease crossflow rates without negative impact to permeability. However, reduced recycle rates were also related to drops in reactor SPAC levels. Future testing will evaluate increased crossflow rates to maintain sufficient carbon levels and optimize abrasive cleaning on the membrane surface.
- Mixing: Settling properties of the SPAC have been shown to allow excellent gravity compaction. Adjustments at the end of Test 5 showed that proper mixing levels need to be maintained to support a consistent SPAC concentration and optimized adsorption rates.
- System preparation: Improved sample bottle preparation and line cleaning techniques between tests will reduce the potential for cross-contamination of effluent samples from test to test. Based on membrane restoration efforts, removal of the membrane for inspection is not deemed necessary, and CIP activities will aid in cleaning system piping as well.
- GAC Comparison: Comparing SPAC adsorption rates at this facility to those in unrelated groundwater applications may not offer insight for the true economics of this technology. Further testing will benchmark the SPAC performance against GAC on the same water.

APPENDIX A1

Pre-Treatment Assessment Report

Pre-Treatment Report
Improved Longevity and Selectivity of PFAS Groundwater Treatment using Superfine Powdered Activated Carbon (SPAC) and Ceramic Membrane Filtration (CMF)

ESTCP #ER19-B3-5181

15 October 2020

INTRODUCTION

The pilot system operating at the Horsham AGS draws water from Outfall #9 which receives its water from a storm water detention basin on the property. The turbidity and solids content of the water is typically good, with system inlet values often below 1 NTU. However, the surface water in the outfall can encounter extreme variability in flows and quality which are subject to local weather conditions. High winds and rainfall events can churn the surface water resulting in highly turbid waters. To address this, the current, full-scale treatment system (sand filter, granular activated carbon, and ion exchange) is designed to interrupt operations based upon the water surface level rising to a specific elevation to avoid loading sediment and organics to the sensitive PFAS treatment process.

The original SPAC-CMF treatment scheme included a 2.3 mm strainer prior to the SPAC sorption tank and ceramic membrane system. The strainer's intent was to prevent ingress of large debris into the system if drawn from the submersible pump. The robust design of the ceramic membrane permits some variation in water quality of the contaminants are smaller than the 2.5 mm feed channels. Water quality data available to the team prior to the first GO/NO-GO gate did not indicate the need for further pre-treatment.

INITIAL OPERATION

Operation of the SPAC-CMF system began on June 23, 2020, with a series of five (5) tests concluded over the first 3-month operational period. Of these tests, the first four were significantly impacted by deteriorated source water quality. Several notable weather events and channel grubbing operations interfered with continuous operation. Further, excessive solids and organics from upset conditions were expected to impede PFAS adsorption kinetics.

In response, the team evaluated modifications to the inlet pumping system. The intake structure for the existing treatment system uses a baffled arrangement to limit energy and prevent sediment disturbance. Drawing from this area was not an option to express concerns for negative impacts to the existing treatment system. After the initial tests, AASI constructed a floating, baffled pump system to avoid drawing surface material or sediment from the channel bottom (Figure 1, center).

Figure 1. Outfall (left), Floating Pump (center), Storm event (Right)

Shortly after operation, the team also installed sediment (cartridge) filters after the pump and the 2.3 mm strainer. A series of different filter types were used including 5, 10 and 20 µm filters (Figure 2). These filters effectively reduced the sediment load to the SPAC/CMF system, but quickly fouled under high solids loading conditions. The time between manual replacements ranged from a few minutes to a few hours. In response, filters were installed in series from coarse to fine media.

Figure 2. Cartridge filters (2.3 mm, 100 µm, 20 µm, 5 µm, from left to right)

This extended the replacement interval from hours to a few days. Unfortunately, site access due to COVID-19 restrictions and distance from team personnel prevented immediate cartridge replacements. As result, the system was frequently starved for flow in Tests 1-4, causing interruptions and related issues associated with the pre-treatment requirements. To address site access issues, the team installed redundant cartridge filters and remote-controlled bypass valves to regain normal operations over weekends and evenings when personnel were not able to access the site.

SOLUTION

Aqua-Aerobic Systems, Inc. (AASI) pioneered the use of self-cleaning cloth media filtration (CF) in tertiary, reuse, and advanced primary treatment applications. There are currently over 3,000 CF installations in applications from 100,000 gallons/day to over 300 million gallons/day. This technology has recently gained popularity in the combined sewer overflow (CSO) and sanitary sewer overflow (SSO) and is ideal for use in surface water treatment.

Figure 3. Cloth Media Filter at HAGS

AASI's R&D department maintains over 15 CF pilot systems that are typically deployed in commercial demonstrations across a wide range of applications. Despite the high demand for these units, AASI redirected a small, 0.5 ft^2 CF to the HAGS site to address the poor water quality prior to the SPAC-CMF system (Figure 3). This unit was installed during Test 4 but was not fully operational until Test 5. The small CF was deployed with a nominal 5 µm cloth media (Figure 4) to reduce turbidity and protect the downstream SPAC-CMF system. As an added measure of safety, the cartridge filters were kept in-place but located downstream of the cloth filter.

The filter operates by gravity flow from inlet to outlet. As the filter removes sediment and other solids, the media encounters hydraulic resistance and the filter tank's water level rises. When the water level rises about 12", the system backwashes and cleans the filter media. Backwashing (Figure 5) is 'on-demand' based on the water quality fed to the system. As such, the backwash requirements (as a % of applied flow) are about 80-90% less than that required by a comparative sand filter.

Figure 4. Pile Cloth Media

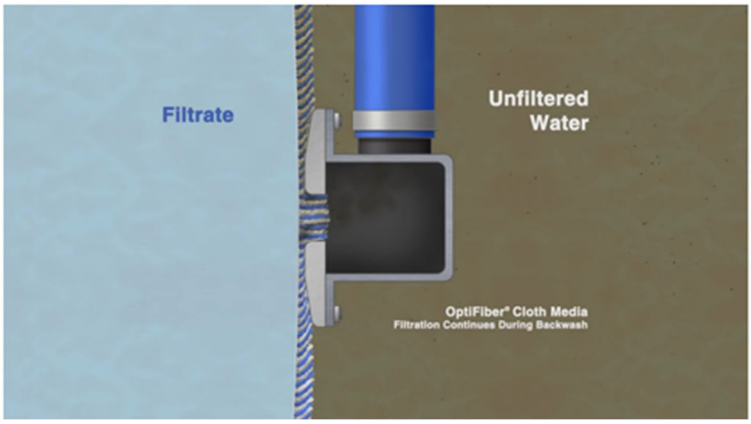


Figure 5. Backwashing the Cloth Media Filter

RESULT

The AASI cloth media filtration system has proven to be an effective technology to protect downstream PFAS treatment systems in surface water applications increasing system uptime and reducing servicing and attention over a wide range of influent conditions. Filtration continues during the backwash (without interruption of treatment) and eliminating flow interruptions encountered with other types of media filtration devices. After the CF system was placed on-line, Test 5 operated without a major interruption despite continuing episodes of weather-related water quality issues in the outfall. As a result, the team has not implemented a strategy to limit treatment to only low flow, high quality events as with the on-site, full-scale system.

APPENDIX A2

SPAC Membrane Dewatering and Gravity Thickening Protocol

Test 5: SPAC Membrane Concentration & Gravity Thickening
Improved Longevity and Selectivity of PFAS Groundwater Treatment using Superfine Powdered Activated Carbon (SPAC) and Ceramic Membrane Filtration (CMF)

ESTCP #ER19-B3-5181

October 15, 2020

Background

Test 5 was conducted at the HAGS facility from September 2 through 24, 2020 on both Trains A and B. The goal of this testing was to evaluate PFAS removal at 3.5 g C/L (Train A) and 2.0 g C/L (Train B) SPAC levels. Results from this testing are reported separately. As part of Test 5, the AASI/Arcadis/CSoM team was to demonstrate SPAC concentration abilities using ceramic membranes (Task 2) and gravity thickening (Task 3) of the concentrated SPAC. Due to the short detention time (30 minutes), the active volume in the sorption tanks did not permit significant volume reductions due to depth restrictions. The team elected to send the waste to AASI's test facilities in Rockford, IL to perform the SPAC thickening Tasks 2 and 3 of Test 5.

Objective

The overall objective is to identify the maximum SPAC concentration (in g C/L) that can be established through a combination of membrane concentration and gravity compaction. The minimum target is 60 g/L, which meets the original proposal conditions. However, subsequent testing indicates the SPAC can be increased to greater than 100 g/L and will be the subject of this demonstration.

Set-up

AASI has collected seven (7) containers of SPAC removed from Trains A and B at Test 5's conclusion. These samples were sent and received by AASI at their laboratory at the Rockford, IL manufacturing facility. A 1m by 30mm ceramic membrane and sorption tank was configured to simulate the actual conditions at the HAGS test facility. By performing the work off-site, several important design considerations can be addressed:

- Improved sorption tank geometry using a 1.5m (60 inch) tall tank that is 50 mm (2 inches) in diameter. This will allow determination of a maximum SPAC concentration with a 10X concentration factor.
- Settling conditions that will allow monitoring the SPAC concentration over a 24-hour period.
- Unlimited access to the test apparatus, lab equipment and test personnel.
- No interference in proceeding with the next test conditions (Test 6) at the HAGS facility

Test Setup

The testing will be conducted using the following primary components:

A. SPAC Mixing Tank: All of Train A samples collected from the HAGS facility will be added to this tank, and mixed. The contents of this tank will be measured for TSS using a 0.2µm filter paper to ensure >99% capture of all carbon.
B. SPAC Transfer Pump: This pump will transfer the SPAC from the mixing tank to the sorption reactor at a 300 ml/min. rate[1].
C. Sorption Reactor: This tank is approximately 1.5m tall and is the source of SPAC fed to the membrane.
D. Recycle Pump: The SPAC will be drawn from the Sorption Reactor, pumped through the membrane, and returned to the sorption reactor at a 3L/minute rate (less the rate of permeate removed).
E. Ceramic Membrane: A duplicate 0.4 m^2 (1m by 30mm) membrane used at HAGS facility will be used to separate permeate from SPAC (Figure 15). The crossflow retentate will be returned to the sorption reactor whereas permeate will be collected in a separate container.
F. Permeate Tank: Initially empty, this container will collect the treated water.

System

Figure 1. 0.4 m2 membrane concentration system

Procedure

Depending on the volume treated, the testing is anticipated to take longer than would normally be realized in the field as the sample includes wash-down water used to clean-out the membrane system. The volume and initial carbon concentration will be determined at the beginning and end of the testing.

Once the system components have been set up and functionally tested, the following procedure will be followed:

1. Confirm initial valve positions
2. Confirm all tanks, the membrane and reactor are empty before starting.
3. Fill the mixing tank (A) with the entire contents from Train A's sample. It is acceptable to use a limited amount of tap water to remove any residual carbon. Confirm contents are fully mixed and the mixer/agitator is keeping the carbon suspended off the tank bottom. Confirm volume in tank.
4. Take a 50 mL sample from Tank A for TSS analyses.
5. Use transfer pump (B) to fill sorption reactor (C) to the halfway point (about 30 inches) using transfer pump (B). This will take about 5 minutes.
6. At the halfway point mentioned above, turn on recycle pump (D) and adjust to a 3 L/min flow
7. When the sorption tank becomes full (about 60 inches) turn off the feed pump (B). This will again take about 5 minutes to fill the remainder of the sorption tank.
8. Allow 2-3 minutes for the system to stabilize.
9. Throttle the recycle valve to create pressure and produce permeate. Target a permeate flow of 300[1] mL/min.
10. Monitor the level in the sorption reactor (C), turn on the transfer pump (B) when the level drops 12 inches.
11. Monitor the system operation, trying to match the transfer pump (B) flow with the throttled permeate flow.
12. Continue testing until the contents are removed from the mixing tank (A). NOTE: When the mixing tank volume becomes too low (< 2 L), stop operating pump (B). This will result in a volume (depth) reduction in the sorption tank. At this point, pour the contents of tank A directly into the sorption reactors (C). It may be easier to first move the contents of tank (A) into a smaller 2L container and pour this container into the sorption tank (C).
13. Stop the test when one of the following occurs:
    a. Membrane TMP exceeds 20 psi
    b. Sorption tank reaches 6" depth (i.e., 1/10th of its full volume)
14. Record the following:
    a. Permeate flow during the test
    b. Feed and recycle pressure during test (permeate pressure NR unless this valve is throttled)
15. After the operation concludes, drain, and collect the following:
    a. Contents from mixing tank (A)
    b. Contents from membrane (E) into a separate container.
    c. Record the volume of (A) and (E) before using water to wash out carbon.
16. Record volumes:
    a. Tanks A, C and F: at the beginning and end of the test
    b. Membrane (E) and feed/recycle tubing: Drain any tubing/lines for the recycle and feed into the sample collected with membrane draining (E). Record the volume if able.

17. Grab 50 mL samples at the beginning and end of the tests (where possible) for tanks A, C and F and drainage from membrane (E).

[1]Target 300 ml/min but try to keep above 100 ml/minute if 45 lmh is too high for membrane.

Reporting

Note: The time for the test will depend on the sample volume. For example, if 10 gallons (37.9 L) of sample is to be processed, it could require two hours to filter 90% of the sample. In this case, recording values every 15 minutes may be appropriate.

Time (min)	Permeate Flow (ml/min)	Permeate Volume (L)	Recycle Flow (L/min)	Feed Pressure (psig)	Recycle Pressure (psig)
0					
15					
30					
45					
60					
75					
90					
105					
120					

Location (50 mL Samples Taken)	Initial Volume (L)	Initial TSS (mg/L)	Final Volume (L)	Final TSS (mg/L)
(A) Mixing Tank[2]				
(C) Sorption Reactor				
(E) Membrane Housing				
(F) Permeate Tank[2]				

[2]Record pH and temperature of SPAC at the beginning of the test and permeate at the end.

APPENDIX A3

Test 5 Data Tables and Figures

Table 1. PFAS Analyses for Test 5

Sample ID	Volume Treated (L)	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFBS	PFHxS	PFPeS	PFHpS	PFOS	PFNS	FOSA	FBSA	4:2 FTS	6:2 FTS	8:2 FTS
		PFAS Analyte Concentration & 0 (ng/L)																
		0.1	0.5	0.5	0.5	0.10	1.00	0.1	0.5	0.1	1	0.1	10.00	0.5	0.5	2	0.5		2
Train A Permeate																			
TA_PERM_20200902_20L	20	16.0	34.3	0.0	0.0	0.59	0.00	8.9	0.0	2.3	0.0	2.5	140.86	0.0	0.0	0.0	0.0		0
TA_PERM_20200902_171L	171	60.7	184.2	111.6	17.3	54.36	0.00	41.1	38.7	34.5	26.2	29.7	998.62	3.4	5.7	108	4.8		0
TA_PERM_20200903_275L	275	48.0	326.8	36.7	0.0	0.00	0.00	67.0	19.3	2.1	0	0.5	0.00	0.0	0.0	82	0.0		0
TA_PERM_20200903_240L	240	42.9	265.7	29.0	0.0	4.50	0.00	61.1	15.5	4.5	1.5	4.1	332.42	0.0	0.0	65	0.0		0
TA_PERM_20200903_552L	552	52.8	568.2	128.5	0.0	2.14	0.00	132.6	64.4	6.7	0	2.8	377.52	0.0	0.0	226	0.0		0
TA_PERM_20200904_988L	988	30.3	434.2	348.0	6.6	0.00	0.00	107.7	137.0	19.6	0	1.2	166.39	0.0	0.0	557	0.0		0
TA_PERM_20200904_1137L	1,137	63.5	466.9	472.0	11.9	2.48	0.00	110.2	180.2	36.0	0	0.0	0.00	0.0	0.0	508	2.6		0
TA_PERM_20200905_2294L	2,294	48.4	548.6	741.0	77.9	43.55	0.00	148.5	334.9	136.0	11.4	2.4	68.67	0.0	0.0	760	9.3		0
TA_PERM_20200906_3137L	3,137	79.3	670.8	920.7	152.1	144.00	0.00	166.7	391.6	261.7	39.4	5.0	106.80	0.0	0.0	1061	15.5		0
TA_PERM_20200907_3709L	3,709	42.4	717.3	975.4	192.7	223.80	0.00	178.2	409.4	345.6	101.9	10.4	157.27	0.0	0.0	902	15.3		0
TA_PERM_20200908_4244L	4,244	60.4	689.5	922.9	199.0	311.40	0.00	176.2	384.8	368.9	138.9	33.4	282.67	0.0	0.0	856	16.3		0
TA_PERM_20200909_4519L	4,519	64.6	654.8	902.9	200.4	188.56	0.00	151.0	368.4	356.1	130.0	13.1	252.67	0.0	0.0	1259	16.3		0
TA_PERM_20200909_4739L	4,739	69.4	632.9	817.2	183.4	358.42	4.78	159.3	347.6	337.4	153.7	24.3	378.16	0.0	0.0	821	15.0		0
TA_PERM_20200910_5174L	5,174	40.0	527.3	738.7	176.7	458.28	6.81	136.6	315.3	368.3	207.4	28.5	901.97	0.0	0.0	1568	14.3		0
TA_PERM_20200910_5444L	5,444	49.2	447.1	610.6	140.1	345.15	8.55	107.3	245.3	259.3	186.4	76.2	1262.21	0.0	0.0	947	10.8		0
TA_PERM_20200910_1A	5,645	51.6	518.5	649.3	163.2	439.22	0.00	122.4	275.2	341.0	206.2	24.9	1835.86	0.0	0.0	5431	9.9		0
TA_PERM_20200911_2A	6,044	39.0	470.6	563.6	139.6	439.68	0.00	104.4	236.3	316.7	189.2	15.2	2354.33	0.0	0.0	20401	11.8		0
TA_PERM_20200911_3A	6,372	25.2	603.3	764.3	171.9	495.22	8.88	140.6	317.1	349.3	226.1	52.0	2084.38	0.0	0.0	2114	12.3		0
TA_PERM_20200912_4A	6,807	64.3	606.9	766.5	168.3	444.05	11.12	148.4	325.7	310.2	211.4	64.3	1197.91	0.0	0.0	1167	13.1		0
TA_PERM_20200912_5A	7,239	35.4	701.3	876.0	199.9	534.82	17.38	172.8	371.3	357.9	251.0	100.4	3098.98	2.6	5.7	1173	12.8		0
TA_PERM_20200913_6A	7,674	59.3	614.7	767.9	172.8	371.37	0.00	149.5	321.8	473.3	222.9	12.5	6817.20	0.0	0.0	0	12.2		0
TA_PERM_20200913_7A	8,105	54.3	663.0	789.3	171.3	407.39	7.35	152.7	331.9	349.5	234.7	63.6	2392.38	0.0	0.0	4610	12.5		0
TA_PERM_20200914_8A	8,542	57.1	598.7	738.3	166.8	466.49	14.72	149.9	319.8	308.7	228.6	107.8	1702.70	6.2	2.5	811	12.9		0
TA_COMPOSITE_20200914_9A	8,921	42.2	631.6	824.4	168.9	564.07	0.00	155.5	337.4	426.8	243.5	36.8	2182.87	0.0	0.0	11938	14.2		0
TA_PERM_20200915_10A	9,352	61.9	565.4	742.8	158.4	401.87	0.00	149.5	314.6	368.3	219.2	49.8	4774.32	0.0	0.0	13867	10.0		0
TA_PERM_20200915_11A	9,783	56.0	573.2	750.1	156.6	366.30	6.86	147.5	304.4	346.3	221.7	78.8	5544.96	0.0	2.7	4044	10.1		0
TA_PERM_20200916_12A	10,218	54.1	567.7	696.8	150.5	442.23	11.47	138.2	305.3	281.4	207.9	108.2	2782.06	6.0	6.6	1069	9.8		0
TA_PERM_20200XXX_13A	10,650	84.3	579.6	733.7	165.8	457.82	15.59	143.0	306.7	285.7	213.6	111.8	4442.83	7.6	7.3	845	11.7		0
TA_PERM_20200917_14A	11,081	59.6	570.0	755.6	168.1	397.36	14.04	150.8	333.6	321.1	225.9	104.6	3568.20	8.2	8.0	792	10.4		0
TA_PERM_20200917_15A	11,518	74.0	663.5	805.3	178.7	417.42	17.88	159.7	345.6	323.2	240.7	125.6	3162.82	9.8	11.9	871	12.7		12
TA_PERM_20200918_16A	11,951	47.7	576.8	744.6	163.6	443.69	13.78	143.5	318.3	307.3	218.4	116.0	2831.30	9.7	8.2	749	10.8		0
Train B Permeate																			
TB_PERM_20200902_20L	20	40.1	78.7	0.0	0.0	0.00	0.00	14.2	0.0	0.6	0	0.6	62.93	0.0	0.0	10	0.0		0
TB_PERM_20200902_165L	165	55.5	384.0	117.9	12.1	39.87	0.00	108.2	52.6	31.3	16.2	5.4	617.42	0.0	0.0	1286	2.5		0
TB_PERM_20200903_233L	233	41.5	564.5	162.0	0.0	2.76	0.00	135.7	70.3	8.8	0	1.9	138.29	0.0	0.0	256	0.0		0
TB_PERM_20200903_271L	271	53.6	562.2	195.9	0.0	0.00	0.00	125.0	74.0	14.2	0	0.0	0.00	15.6	0.0	8240	0.0		0
TB_PERM_20200903_549L	549	68.4	623.4	482.4	14.0	1.32	0.00	154.3	181.3	34.5	17	1.1	104.38	0.0	0.0	532	2.9		0
TB_PERM_20200904_990L	990	58.0	396.9	562.7	78.3	26.92	0.00	101.6	236.6	120.1	18.7	2.6	45.60	0.0	0.0	561	7.3		0
TB_PERM_20200904_1143L	1,143	17.8	348.7	29.6	3.2	3.27	0.00	31.3	16.3	9.1	1.0	0.8	0.00	0.0	0.0	78	0.0		0
TB_PERM_20200904_1429L	1,429	31.8	437.6	361.6	20.4	2.30	0.00	109.8	139.2	50.2	4.1	0.0	0.00	0.0	0.0	7916	3.5		0
TB_PERM_20200905_2308L	2,308	33.1	643.0	781.6	76.7	56.18	0.00	160.8	310.0	170.5	20.9	0.8	0.00	0.0	0.0	11924	10.0		0
TB_PERM_20200906_2959L	2,959	51.8	710.9	931.6	139.9	69.95	0.00	167.1	371.1	222.9	43.0	3.2	66.35	0.0	0.0	1433	12.4		0
TB_PERM_20200907_3209L	3,209	49.2	705.9	950.3	164.5	162.38	0.00	164.8	398.9	344.0	39.6	3.3	101.39	0.0	0.0	22212	15.2		0
TB_PERM_20200908_3410L	3,410	41.4	732.3	1001.4	194.4	180.32	0.00	169.4	401.9	334.7	77.5	5.7	164.98	0.0	0.0	2028	14.7		0
TB_PERM_20200909_3524L	3,524	61.7	686.3	940.3	199.7	209.30	0.00	158.5	393.0	351.4	91.6	16.2	93.43	0.0	0.0	1072	17.4		0
TB_PERM_20200909_2743L	3,743	37.0	684.5	899.7	180.8	311.33	0.00	161.5	368.9	521.2	120.7	4.9	223.58	0.0	0.0	17661	17.4		0
TB_PERM_20200910_4185L	4,185	57.9	513.5	710.4	194.0	290.24	0.00	126.9	297.0	434.9	368.4	42.5	282.31	0.0	0.0	1051	12.3		0
TB_PERM_20200910_4462L	4,462	40.5	446.3	551.8	136.6	358.37	5.30	104.7	233.0	253.9	163.6	39.0	714.10	0.0	0.0	510	9.6		0
TB_PERM_20200910_18	4,662	35.8	449.7	592.8	138.9	351.30	0.00	136.0	241.6	270.4	159.3	24.7	787.97	0.0	0.0	1252	9.2		0
TB_PERM_20200911_28	5,061	40.7	440.1	583.7	141.6	332.06	7.37	120.7	242.9	260.9	180.0	56.0	821.71	0.0	0.0	674	12.2		0
TB_PERM_20200911_38	5,393	40.1	589.2	734.6	163.3	370.50	8.41	145.5	309.3	364.4	206.6	62.1	753.77	0.0	0.0	1463	14.0		0
TB_PERM_20200912_48	5,826	65.4	628.4	753.8	163.4	412.36	9.68	149.1	313.7	306.1	202.4	65.4	862.30	3.6	3.0	760	12.7		0
TB_PERM_20200912_58	6,261	35.3	651.2	827.6	171.1	467.40	13.10	155.7	322.3	288.1	217.9	83.6	1444.15	4.7	4.9	795	12.2		0
TB_PERM_20200913_68	6,603	56.0	693.6	891.0	194.0	533.98	8.70	253.9	579.6	701.3	393.2	98.0	12430.56	6.1	0.0	5367	10.6		0
TB_PERM_20200913_78	7,124	53.6	610.6	779.8	161.7	478.80	17.71	146.2	317.3	353.2	231.5	73.0	2288.66	3.3	7.3	1850	11.7		0
TB_PERM_20200914_88	7,554	42.8	632.0	776.6	170.9	535.34	6.06	154.8	325.6	411.3	232.9	36.9	3689.50	0.0	0.0	6001	12.8		0
TB_PERM_20200914_98	7,911	50.8	654.4	788.0	179.6	498.85	14.35	159.5	319.2	380.7	234.4	46.7	3408.58	0.0	2.4	3729	12.8		0
TB_PERM_20200915_108	8,344	78.0	581.9	742.8	156.8	448.80	11.20	147.2	312.9	426.6	214.6	40.7	2230.75	0.0	0.0	6078	9.9		0
TB_PERM_20200915_118	8,782	55.1	610.1	754.7	164.9	451.21	17.03	153.3	321.8	312.5	222.3	146.4	2682.19	8.8	8.0	751	10.5		0
TB_PERM_20200916_128	9,213	54.5	624.7	756.0	167.6	397.81	0.00	156.5	322.2	398.9	223.1	52.4	2719.13	0.0	7.7	5052	10.1		0
TB_PERM_20200916_138	9,644	42.1	709.5	864.3	184.3	524.40	16.98	175.9	351.8	466.0	252.6	55.0	3692.23	3.0	0.0	6539	13.4		0
TB_PERM_20200917_148	10,074	57.8	593.3	759.7	169.8	385.68	0.00	151.8	324.0	394.4	219.3	30.9	4646.64	0.0	2.8	9781	9.1		17
TB_PERM_20200917_158	10,509	50.5	688.1	844.3	185.9	518.93	4.66	173.0	362.2	449.5	246.2	51.0	6435.92	2.8	4.4	8240	13.1		0
TB_PERM_20200918_168	10,940	63.3	613.3	777.9	172.2	500.23	0.00	162.1	338.5	423.8	232.3	36.7	3429.12	0.0	0.0	9681	14.0		0
Influent																			
BOT_IN_20200921		63.6	631.1	833.1	181.2	528.50	9.11	165.2	363.2	469.7	248.6	42.5	3797.57	0.0	0.0	10930	15.8		0
BOT_OUT_20200921		35.6	650.3	835.8	180.4	508.44	14.33	166.6	363.9	339.2	242.5	183.0	4027.39	11.9	13.9	910	14.2		11
BOT_IN_1009_20200918		69.2	587.8	725.0	163.0	441.68	14.44	140.4	339.2	316.4	224.7	120.5	3678.55	9.6	12.9	864	8.5		14
BOT_OUT_1007_20200918		55.3	586.4	772.5	164.0	479.26	11.88	154.8	336.5	302.6	228.0	130.7	4144.13	15.5	15.3	0	10.5		11
BOT_IN_20200924		81.9	604.7	840.0	177.0	485.38	13.34	164.7	368.5	339.5	243.0	173.0	4015.99	12.2	13.4	950	15.1		19
BOT_OUT_20200924		33.1	575.5	819.4	169.8	508.42	17.16	157.8	353.6	403.0	242.6	88.4	3908.83	3.8	9.8	1828	11.6		0
SUM_PREFILTER_EFF_20200908		33.8	590.1	787.1	171.3	381.58	0.00	155.7	333.9	425.4	239.9	53.4	4655.76	0.0	8.2	8203	14.4		0
FEED_20200911_3F	6,262	41.8	619.7	781.1	160.1	426.86	10.58	145.4	322.9	342.5	229.2	92.8	3868.70	8.0	7.5	0	12.1		14
FEED_20200912_4F	6,699	51.4	643.4	760.2	175.9	445.30	13.86	154.1	321.8	397.1	232.0	76.8	3824.02	4.4	6.8	2475	12.3		18
FEED_20200914_8F	8,432	45.4	565.4	750.1	157.2	450.21	13.69	144.0	306.6	292.7	214.6	116.6	3368.47	9.6	7.6	726	9.2		12
FEED_20200914_9F	8,843	42.7	589.6	745.6	162.7	438.22	13.52	145.3	320.2	298.2	217.9	110.7	3611.98	6.7	7.6	1386	11.4		11
FEED_20200917_14F	10,975	26.2	554.5	742.4	155.3	454.68	14.40	146.5	317.7	298.2	222.8	127.0	3860.04	10.8	9.8	767	8.8		17

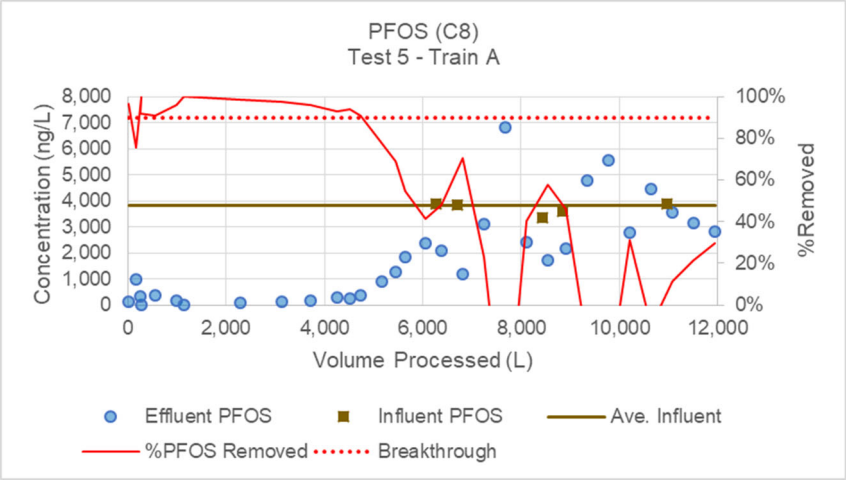


Figure 1. PFOS Train A

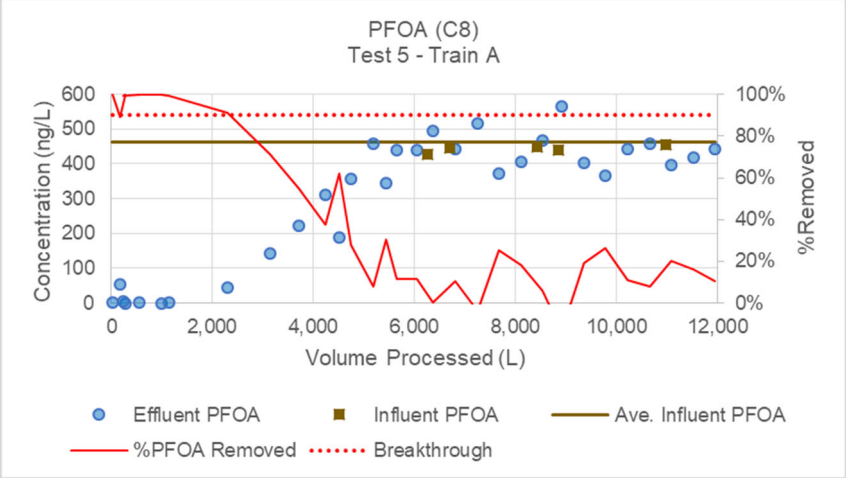


Figure 2. PFOA Train A

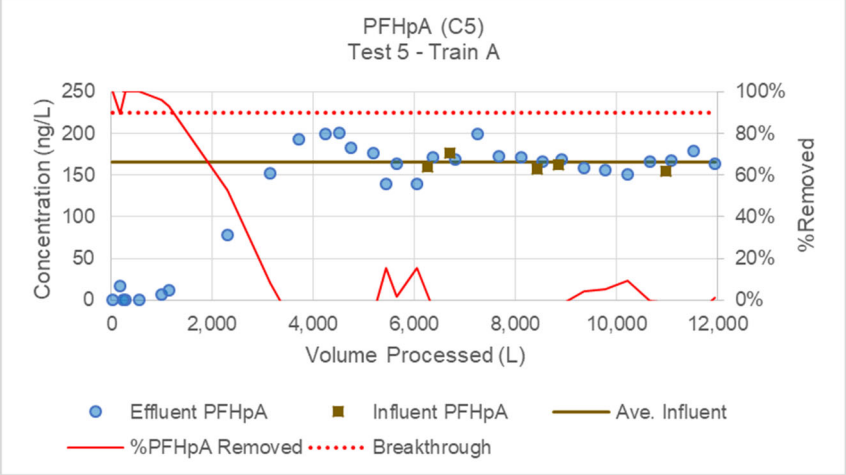


Figure 3. PFHpA Train A

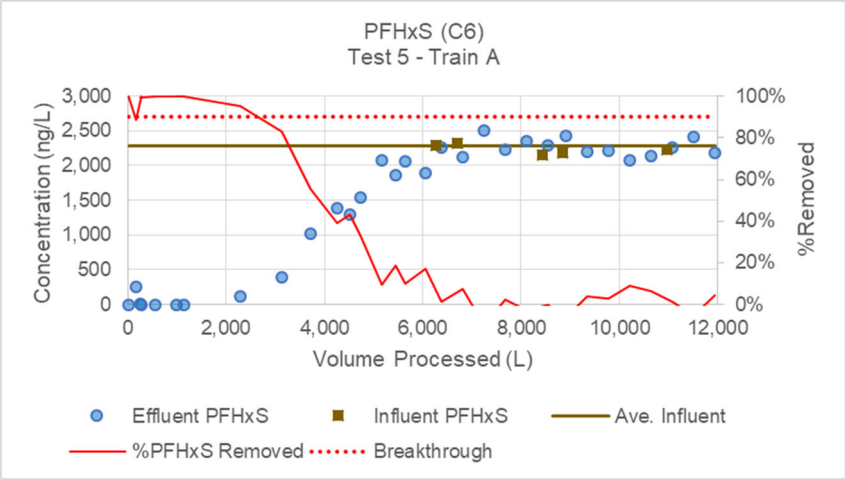


Figure 4. PFHxS Train A

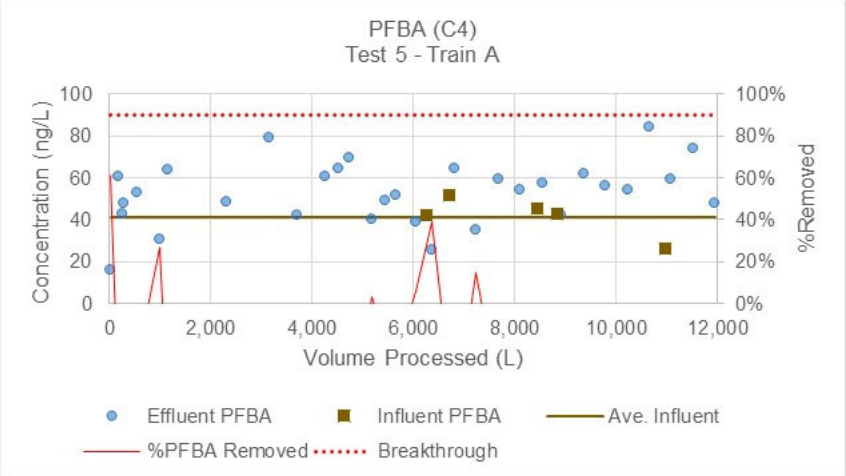


Figure 5. PFBA Train A

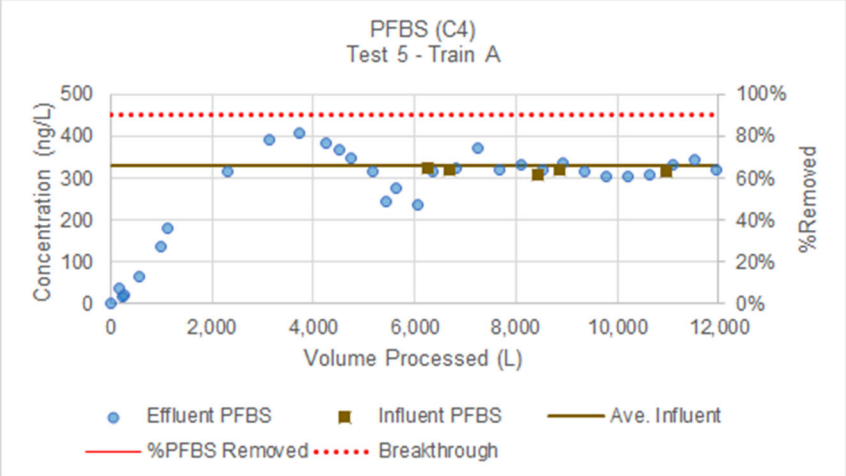


Figure 6. PFBS Train A

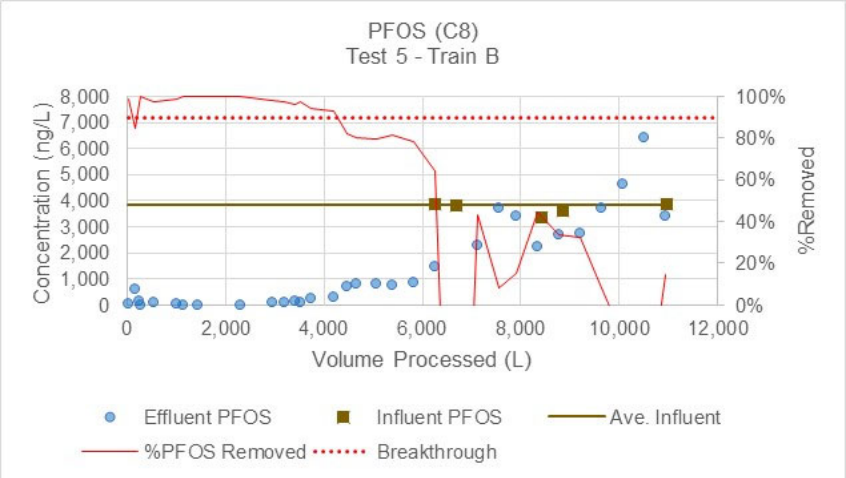


Figure 7. PFOS Train B

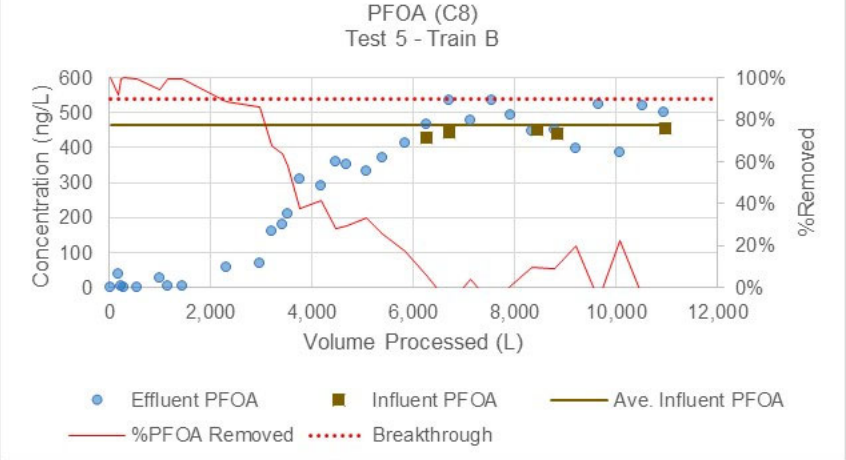


Figure 8. PFOA Train B

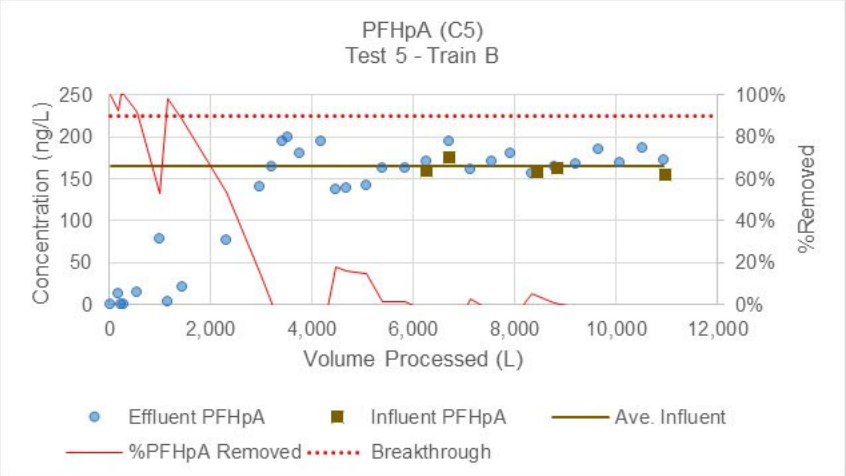


Figure 9. PFHpA Train B

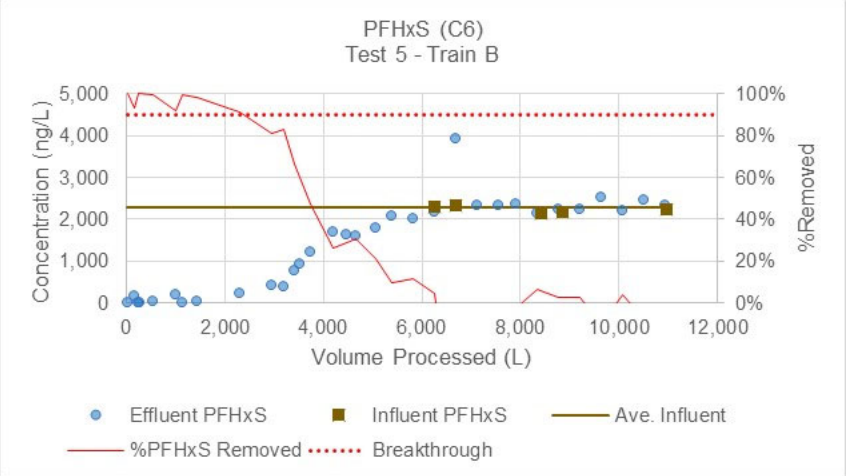


Figure 10. PFHxS Train B

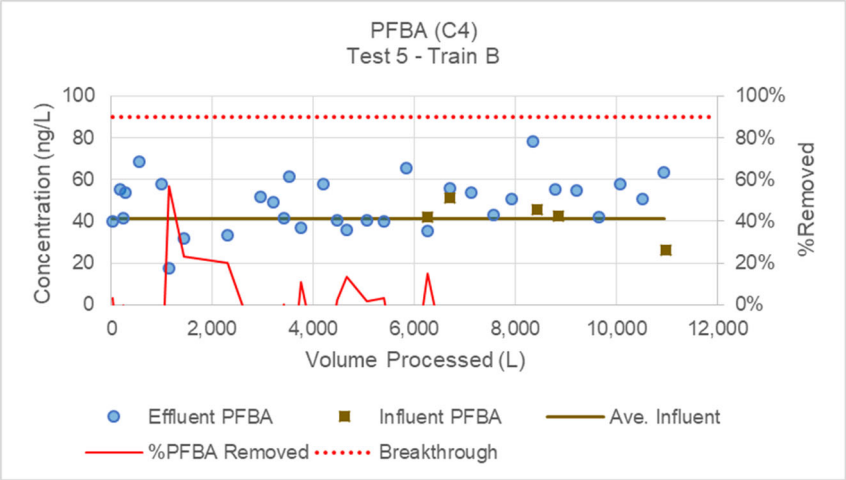


Figure 11. PFBA Train B

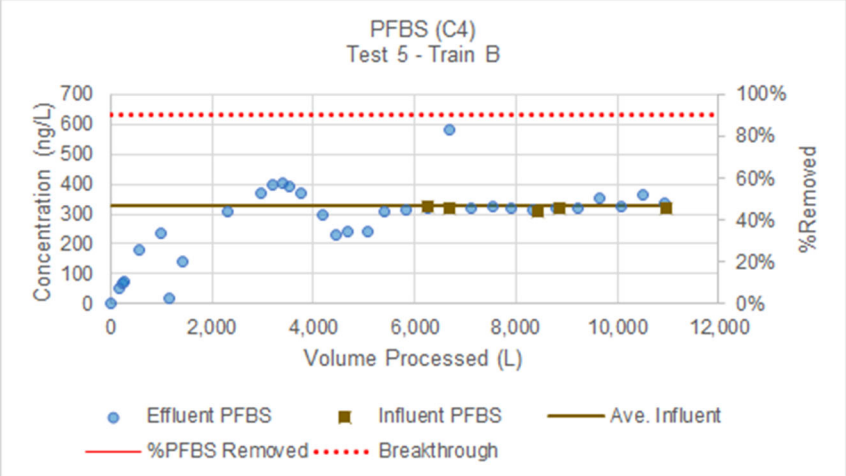


Figure 12. PFBS Train B

Appendix B

Sampling Methods (SOP)

Appendix B

Sampling Methods Standard Operating Procedure

Field samples were collected while closely following guidelines established by the United States Environmental Protection Agency and Pace Analytical (Pace).

Three sample point sources were identified for each test: (1) feed source, (2) Train A effluent source, and (3) Train B effluent source. Each of these were routed to a dedicated ISCO auto-sampler unit, which collected 1 liter of sample daily for each. Polypropylene bottles and polyethylene-lined caps were used for sample collection inside the ISOC sample units. The bottles were reused for each test but were cleaned between tests using a 10% methanol solution and rinsed with distilled water. All samples were collected by the sampler using nitrile gloves, which were replaced after sampling at each sample point source.

At the end of each test, water samples collected in the ISCO sampler bottles (1-liter volume) were transferred to Pace and Colorado School of Mines (CSM) using separate sample bottles. Pace required a total volume of 500 milliliters (mL) (2 x 250 mL bottles) per sample analysis; whereas the CSM laboratory required 50 mL (collected in 50 mL polypropylene centrifuge tubes) per sample analysis. Each bottle was labeled after sealing the bottle with a cap. Sample bottles were then kept in cold storage until shipment to the laboratory. Pace samples were sent to the Pace laboratory via a chilled cooler (using bagged ice). Samples sent to the CSM laboratory were not chilled and were sent to the laboratory in sealed polyethylene bags.

The following should also be noted:

- Attention was made to minimize contamination impacts from clothing and other items near the sample collection area.
- Samples were not filtered upon collection to sample bottles for lab submission.
- Effluent samples were collected first.
- Sample bottle caps were held in a gloved hand prior to filling the bottle and then closed onto bottle after filling.
- After the sample bottle label was applied, the sample was kept in refrigerated storage (less than 6 degrees Celsius) until shipment to the laboratory.
- The sample set is composed of samples collected from the same sample site and at the same time.

Appendix C

Analytical White Paper

ANALYTICAL CONFIRMATION WHITE PAPER
ESTCP PROJECT ER19-5181

Introduction and Overview

Poly- and perfluoroalkyl substances (PFAS) are a class of highly stable synthetic fluorinated organic compounds. PFAS contain both hydrophobic, highly fluorinated, aliphatic chains and hydrophilic functional groups. PFAS are known to be highly persistent in the environment due to the exceptionally strong C-F bond and have been widely documented in environmental media and human blood and tissue samples. Some PFAS are considered toxic and bioaccumulative.

To improve recovery and repeatability, the Colorado School of Mines (Mines) has successfully developed and validated a method for the whole-sample collection, preparation and analysis of selected anionic PFASs in unfiltered low-volume (3-7 mL) water samples. This Standard Operating Procedure for the Collection, Preparation, and Analysis of Aqueous Samples (SOP) describes protocols and provides guidelines for personnel who collect, process, and analyze aqueous samples related to groundwater resources managed by the U.S. Department of Defense (DoD). Training and/or apprenticeship in both the laboratory and field are necessary to correctly implement the procedures described in this SOP.

The procedures described in this SOP represent protocols that are generally applicable to Mines' studies involving the collection of groundwater as well as groundwater-derived aqueous samples collected during various aspects of a water treatment process.

Purpose and Scope

The purpose of this SOP is to provide field and laboratory personnel and other applicable parties with a description of the requirements, recommendations, and guidelines routinely used in Mines' studies involving the collection and processing of groundwater and groundwater-derived aqueos samples from DoD sites for the analysis of PFAS The information provided covers topics required by the SERDP ESTCP program as identified in the "Requirements for SERDP & ESTCP Projects Addressing PFAS-Related Issues" document (rev. January 7, 2020).

The information provided does not attempt to encompass the entire spectrum of data-collection objectives, site characteristics, environmental conditions, and technological advances or troubleshooting of related technology related to environmental studies. This SOP does not include sample collection protocols for flowing (e.g., streams or rivers) or non-flowing surface water (e.g., lakes, ponds, or wetlands). Also, beyond the scope of this SOP is discussion of protocols to collect, prepare, and analyze samples for suspended, particulate, or biological materials related to PFAS. Collection of data related to onsite measurements such as pH and alkalinity as well as other water-quality parameters (e.g., nitrate) are also not addressed in this SOP.

Analytical Method Validation

Within three months of contract award, Mines will split a sample with detectable PFAS concentrations into two (2) identical sets of three (3) replicates. One set of replicates will be analyzed for PFAS by Mines following the procedures described in the below SOP. The remaining set of replicates will be delivered to a third-party DoD Environmental Laboratory Accreditation Program (ELAP) accredited laboratory under Chain-of-Custody protocol for PFAS analysis. The resulting analytical reports will be evaluated for statistically significant differences in reported PFAS concentrations. PFAS detections that exceed 30% of the DoD ELAP-accredited laboratory detections will be evaluated in a follow up Analytical White Paper submitted within 60 days of receipt of the final analytical reports.

Alternatively, Mines may elect to purchase PFAS containing Standard Reference Material (SRM) from the National Institute of Standards and Technology (NIST) for PFAS analysis by the Mines analytical method described in the below SOP. The detected PFAS concentrations will be compared to the published tolerance of the certified value for each detected PFAS. Should Mines PFAS concentrations fall outside of the published tolerances, an evaluation and subsequent explanation will be provided in a follow up Analytical White Paper submitted within 60 days of receipt of the final analytical report.

Mines shall perform analytical confirmation by one or both of the above described methods on an annual basis. However, Mines may request a modified analytical confirmation schedule based on project specific considerations.

Moreover, non-drinking water media samples collected during the project to demonstrate the efficacy of field based PFAS removal technologies shall be collected as field duplicates. A minimum of 20% of the initial and final sample duplicates shall be sent to a DoD ELAP-accredited laboratory under Chain-of-Custody protocol for confirmatory PFAS analysis. PFAS detections that exceed 30% of the DoD ELAP-accredited laboratory results shall be addressed in the Final Report.

Review and Revision

Components of this SOP are reviewed, revised, and reissued to SERDP & ESTCP as needed to correct any errors, incorporate technological or analytical advancements, and address additional topics. A summary of requirements outlined in QSM v5.3 Table B15 for PFAS analysis of non-drinking water media and how this SOP addresses to these requirements is shown in Table 2 (Section 5).

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1. Collection of Aqueous Samples

This section describes established standard methods for the routine collection of representative groundwater samples as well as groundwater-derived aqueous samples collected during various aspects of a water treatment process conducted in connection with Mines related studies.

1.1 Media and Analytes

Groundwaters may be collected with this method for subsequent quantitative analysis of PFASs listed in Table 1 and qualitative suspect screening of the PFASs listed in Table 4.

1.2 Equipment/Supplies

The materials listed below have been used previously with minimal PFAS contamination. Any new material should be tested for contamination before use. Additionally, it is our practice to routinely include extraction and method blanks in analysis to ensure that materials utilized during sampling activities are free of PFAS contamination.

A. Distilled or deionized water
B. Sample cooler
C. Ice
D. Methanol - ThermoFisher Scientific A433
E. 15 mL polypropylene centrifuge tubes for sample collection - VWR, 21008-918
F. Sample Pump :
    a. Geotech Geopump Peristaltic Pump (sampling depths <25 feet below ground surface [ft bgs])
    b. Geotech PFAS-Free Portable Bladder Pump (sampling depths >25 ft bgs)
G. Power source for pump - standard 12V car battery
H. Silicon or HDPE sample tubing
I. Water level indicator
    a. Dual-phase (if NAPL is suspected)
    b. Single Phase
J. Multiparameter Water Quality Sensor - YSI 6920
K. 100 mL polyethylene graduated cylinder
L. 40 mL amber vial with 25 mg ascorbic acid (if performing VOC sampling)
M. 1:1 reagent grade HCl (If performing VOC sampling)
N. Paper towels
O. Trash bags
P. Ziploc bags
Q. Labels or labeling tape
R. Permanent marker
S. Chain of Custody form
T. Untreated loose leaf paper on aluminum clipboard
U. Appropriate personal protective equipment (PPE), including but not limited to nitrile gloves, steel-toed boots, and safety glasses
V. Steel 55-gallon drum(s) for purge water containment
W. Drum labels

1.3 Groundwater Sample Collection Process

Collection will follow the recommendations in the 2018 ITRC Site Characterization Fact Sheet and the Draft [2019] ITRC PFAS Tech Reg Document. Equipment used should not contain any

known fluoropolymers. Products that should be avoided include: polytetrafluoroethylene (PTFE), that includes the trademarks Teflon® and Hostaflon®, polyvinylidene fluoride (PVDF), that includes the trademark Kynar®, polycholotrifluoroethylene (PCTFE), that includes the trademark Neoflon ®, ethylene-tetrafluoro-ethylene (ETFE), that includes the trademark Tefzel®, fluorinated ethylene propylene (FEP), that includes the trademarks Teflon® FEP and Hostaflon® FEP. Field or laboratory personnel may refer to the Michigan Department of Environmental Quality PFAS Sampling Quick Reference Field Guide for additional information on generally prohibited and acceptable items for field collection of PFAS-impacted groundwater samples.

Additionally, no clothing or boots containing Gore-Tex, Tyvek, or treated with aftermarket waterproofing agents or fabric softeners shall be allowed in the sampling area. Wearing clothing manufactured from natural fibers is preferred. No cosmetics, moisturizers, creams, etc. shall be applied the day of sampling. Use of authorized sunscreens and insect repellents is permitted during sampling activities but should be applied outside of the sampling area. No food containers or packaging shall be handled onsite other than water or hydration related beverages that are to be stored outside of the sampling area.

A. Field sampling equipment, including but not limited to water level indicators, multi-parameter water quality sensors, and other non-dedicated equipment used at each sample location, require decontamination before initial use and between sample collection events. Refer Section 1.4 for detailed information on decontamination procedures.
B. Choice of pump should account for the groundwater depth, for example, peristaltic pumps are not appropriate for sampling groundwater more than 25 ft bgs. If sampling for VOCs, pump flow rate should be optimized for lowest flow conditions to reduce sample disturbance.
C. If known and as condition permit, groundwater samples shall be collected from historically least impacted to most impacted wells.
D. All field instruments to be utilized in association with groundwater sample activities (e.g. water quality sensors)) will be calibrated prior to each sampling event and as needed during the sampling event per the manufacturers recommendations.
E. Don personal protective equipment (PPE) including but not limited to nitrile gloves, steel-toed boots, and appropriately rated safety glasses. Nitrile gloves should be changed frequently any time there is an opportunity for cross-contamination, including immediately prior to sample collection.
F. Ensure new sample collection tubing is used for each well. Reagent-grade methanol solvent shall be sprayed onto paper towel and used to decontaminate outer pump lines, level sensor lines, and any other lines entering well casing.
G. If utilizing a bladder pump or other PFAS free well downhole pump, load a clean container with deionized water, place well pump inside, and power the pump to flush pump contents. A minimum of three dead pump volumes should be discharged during the pump purging process. Discharged liquid shall be containerized for proper disposal.
H. If sampling from well, open well cover, then slowly lower pump, pump tubing, or sampling device to the water surface to minimize resuspension of solids.
I. Connect pump to power supply.
J. If sampling a private water supply well or an intermittently used public water supply well, the sampling port will be opened and allowed to purge for at least 15 minutes, when possible. When sampling from a drinking water well that is not in regular use, water shall be purged until field-measured water-quality parameters (e.g., pH, specific conductance, dissolved oxygen, oxidation-reduction potential, turbidity, and temperature) have stabilized. Modify pump flow rate as necessary to ensure steady state drawdown within the well. An adequate purge is achieved when the pH and specific conductance of the potable water have stabilized (i.e.: pH readings are within 0.2 pH units and specific

conductance remains within 10% variance for three consecutive readings) and the turbidity has either stabilized or is below 10 Nephelometric Turbidity Units (NTUs).

K. Record the starting and final water-quality parameters in field notes.
L. Record well depth and flow rate using graduated cylinder and stop watch method. Using a flow meter is difficult for low flows (e.g. flows less than 0.2 gpm).
M. If performing VOC sampling, drop 2 mL of 1:1 reagent grade HCl into 40 mL amber vial containing 25 mg ascorbic acid. Fill vial completely with water so meniscus forms. Close cap tightly and invert. Carefully observe any air bubbles. If present, carefully add sample until meniscus forms once more. If air bubbles are still present, repeat sampling process with new vial. Take care to not overfill the sample and dilute preservative. Fill another 40 mL amber vial with 2 mL of 1:1 reagent grade HCl and 25 mg ascorbic acid with deionized water. Repeat process to ensure no air bubbles and label as field blank.
N. Uncap the centrifuge tube immediately before sample collection. Collect sample by directing pump discharge to 15 mL centrifuge tube. Once centrifuge tube contains 3 – 7 mL, immediately cap the container tightly and dry outside with clean paper towel. Place sample container in individual Ziploc bag. If sample collection tube overfilled, recollect sample into new 15 mL centrifuge tube and discard overflowed sample for proper disposal.
O. Place sample container in cooler packed with ice sufficient to maintain the cooler temperature of 4℃.
P. Record the sample location, volume, date and time, sampling party, and analysis the sample has been collected for on the sample container and in a sampling log book.

1.4 Groundwater Derived Aqueous Sample Collection Process

Similarly, samples generated during laboratory-scale experiments (e.g., column tests, membrane tests, batch studies, degradation experiments) will follow the recommendations in the 2018 ITRC Site Characterization Fact Sheet and the Draft [2019] ITRC PFAS Tech Reg Document. Equipment used should not contain any known fluoropolymers. Products that should be avoided include: polytetrafluoroethylene (PTFE), that includes the trademarks Teflon® and Hostaflon®, polyvinylidene fluoride (PVDF), that includes the trademark Kynar®, polychlorotrifluoroethylene (PCTFE), that includes the trademark Neoflon ®, ethylene-tetrafluoro-ethylene (ETFE), that includes the trademark Tefzel®, fluorinated ethylene propylene (FEP), that includes the trademarks Teflon® FEP and Hostaflon® FEP. Field or laboratory personnel may refer to the Michigan Department of Environmental Quality PFAS Sampling Quick Reference Field Guide for additional information on generally prohibited and acceptable items for field collection of PFAS-impacted groundwater samples.

Additionally, no clothing or boots containing Gore-Tex, Tyvek, or treated with aftermarket waterproofing agents or fabric softeners shall be allowed in the sampling area. Wearing clothing manufactured from natural fibers is preferred. No cosmetics, moisturizers, creams, etc. shall be applied the day of sampling. Use of authorized sunscreens and insect repellents is permitted during sampling activities but should be applied outside of the sampling area. No food containers or packaging shall be handled onsite other than water or hydration related beverages that are to be stored outside of the sampling area.

Prior to system operation and subsequent sample collection, evaluation of PFAS leaching or other PFAS sources within the experimental equipment should be evaluated though sampling and analysis. Typically, this can be achieved through controlled system operation with deionized water. For PFAS treatment systems, unintentional adsorption of PFAS to system components should also be evaluated through sampling events around specific system components (e.g., plumbing, sampling ports). Aqueous sample collection will follow the procedure defined below.

A. Prior to sample collection, PPE appropriate shall be donned, including but not limited to nitrile gloves, steel-toed boots, and safety glasses.
B. Sampling ports and/or lines should be purged for a minimum 1-minute prior to sample collection and/or a minimum of 5-dead volumes. Water generated during the purge process shall be containerized for proper disposal.
C. Relevant water quality parameters (e.g.: temperature, specific conductance, pH, etc.) shall be recorded during sample collection from instrumentation embedded within the experimental equipment or measured concurrently to sample collection in separate containers using sensors calibrated immediately prior to sample collection and as needed per the manufacturers recommendations during sample collection activities.
D. Upon completion of sample port and/or line purging, sample water will be directed to a 15-mL centrifuge tube. A minimum of 5 mL of sample shall be collected.
E. Following sample collection, the cap shall be immediately placed on the centrifuge tube and the sample shall be labeled with the designated sample identification.
F. The sample container shall be immediately placed within an ice packed cooler or refrigerator to maintain a maximum temperature of 4℃.
G. Samples shall be collected in triplicate following the procedure defined above. Certain situations may not require sampling in triplicate, e.g., treatment system effluent samples collected on a weekly basis over periods of months. However, whenever possible, appropriate replicates should be collected.
H. Sample information, including but not limited to sample identification, collection date and time, number of sample bottles, etc. shall be recorded on a Chain-of-Custody form.

1.5 Decontamination Procedures

A. All new and reusable equipment used in the sampling process should be decontaminated prior to being handled and between sample collection sites.
B. Wash new and reusable supplies with diluted Micro-90® cleaning solution and distilled or deionized water (Alconox® , Liquinox® , and Citranox® or other cleaning solutions that do not contain fluoro-surfactants also can be used for equipment decontamination); then triple rinse all new and reusable supplies with distilled or deionized water. When possible, triple rinse reusable components that come into contact with sample water with reagent-grade methanol solvent and let air dry. Distilled water and reagent-grade methanol should be verified as PFAS-free (i.e., below the lower quantitation limit for compounds with reference standards) by the manufacturer or in the analyzing laboratory prior to use in the field. Alternatively, HPLC-grade Optima™ water and Optima™ Methanol can be used.
C. Deposit spent disposable sampling equipment, such as tubing and nitrile gloves, in trash bag before mobilizing to the next sampling site.
D. Wipe down pump and outside of sampling container with distilled or deionized wetted paper towels. If equipment has come into contact with oily material or grease, it should be wiped down with paper towels that have been wetted with methanol.
E. At the culmination of the sampling event, place remaining disposable PPE in trash bag and dispose of contaminated waste appropriately.

1.6 Bottle type(s)

A. 15 mL centrifuge tubes - (VWR, 21008-918)

1.7Field QC Sample Types, Collection Frequency, and Criteria

A. Field equipment blanks - should be collected at a frequency of at least one per sampling day. They should be prepared by pumping distilled or deionized water through the pumping apparatus and collecting the discharge in a sample container or by pouring distilled or deionized water over non-dedicated downhole sensors and collecting the water in a sample container. Appropriate sample collection procedures shall be adhered to as to not generated cross contamination during field equipment blank collection. Field equipment blanks should be collected after or between samples suspected of having high concentrations and following standard decontamination procedures. The field equipment blank should otherwise be treated as a normal sample. The purpose of the field equipment blank is to validate the field decontamination procedures.
B. Field blanks - should be collected at a frequency of at least one per sampling day. They should be prepared by pouring distilled water directly into a sample collection vial while at a sample site. This field blank should otherwise be treated as a normal sample. The purpose of the field blank is to validate that the field environment and sample collection process, exclusive of the well pump decontamination procedures, is not introducing contamination.
C. Field replicates - should be collected at a frequency of at least one per ten samples collected. They should be prepared by repeating the entire sampling process at a single sampling location. The field replicate should otherwise be treated as a normal sample.
D. Field sample precision is assessed through the analysis of field replicates. Sample precision is validated if the relative percent difference between the field sample and its field sample duplicate is ≤ 30% of concentration of selected analytes for quantification (Table 1). Should the relative percent difference between the field sample and its field sample duplicate exceed 30%, a thorough analysis of the sample collection, analysis, and

processing will be completed and some or all of the samples collected during the sampling event may be discounted.

1.8 Sample preservation, shipping and holding time requirements

A. Samples should be preserved by maintaining temperatures <4℃, no chemical preservation is required. Samples should be shipped as quickly as possible and analyzed as soon as possible. Field-collected samples should be stored at -20°C upon receipt at the laboratory. Laboratory-generated samples will be stored at 4°C, unless microbial activity (i.e. soil column effluents) is suspected, in which case they will be stored at -20°C.
B. Samples should be analyzed within 6 months of collection.

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3. Aqueous Sample Preparation – Colorado School of Mines

This section of the SOP describes standard Mines' methods for the routine sample preparation of groundwater samples and samples generated during laboratory and field experimentation, as well as groundwater-derived aqueous samples for the analysis of PFAS. At least 10% of samples are analyzed in triplicate, unless the sample batch includes experimental replicates.

3.1 Media and analytes

Sample media for this SOP includes unfiltered groundwater or groundwater-derived aqueous samples obtained from various stages of a bench-scale or pilot-scale water treatment process being designed for the removal and treatment of PFAS. The list of analytes (as of August 2018), their common acronym, neutral molecular formula, and internal standard are shown in Table 1.

Ideally each analyte should be quantified using its corresponding labeled internal standard. As of the compilation of this SOP, not all analytes have internal standards. The existing commercially available reference standards and mass-labeled (stable isotope) internal standards are listed in Table 1. Additional internal standards and perfluorinated reference standards become available over time, and matched standards will be used if available.

Table 1. List of targeted analytes for PFAS analysis.

Chemical Name	Acronym	Neutral Molecular Formula	Internal Standard
Perfluoroalkanoic acids			
Perfluoro-n-butanoic acid	PFBA	C4HO2F7	13C4-PFBA
Perfluoro-n-pentanoic acid	PFPeA	C5HO2F9	13C5-PFPeA
Perfluoro-n-hexanoic acid	PFHxA	C6HO2F11	13C2-PFHxA
Perfluoro-n-heptanoic acid	PFHpA	C7HO2F13	13C4-PFHpA
Perfluoro-n-octanoic acid	PFOA	C8HO2F15	13C4-PFOA
Perfluoro-n-nonanoic acid	PFNA	C9HO2F17	13C5-PFNA
Perfluoro-n-decanoic acid	PFDA	C10HO2F19	13C2-PFDA
Perfluoro-n-undecanoic acid	PFUdA	C11HO2F21	13C2-PFUdA
Perfluoro-n-dodecanoic acid	PFDoA	C12HO2F23	13C2-PFDoA
Perfluoro-n-tridecanoic acid	PFTrDA	C13HO2F25	13C2-PFTeDA
Perfluoro-n-tetradecanoic acid	PFTeDA	C14HO2F27	13C2-PFTeDA
Perfluoro-n-hexadecanoic acid[ii]	PFHxDA	C16HO2F31	13C2-PFHxDA
Perfluoro-n-octadecanoic acid[ii]	PFODA	C18HO2F35	13C2-PFHxDA

Perfluoroalkane Sulfonates			
Perfluoropropane sulfonate	PFPrS	C3HO3SF7	13C3-PFBS
Perfluorobutane sulfonate	PFBS	C4HO3SF9	13C3-PFBS
Perfluoropentane sulfonate	PFPeS	C5HO3SF11	13C2-PFOS
Perfluorohexane sulfonate[i]	PFHxS	C6HO3SF13	18O2-PFHxS
Perfluoroheptane sulfonate	PFHpS	C7HO3SF15	18O2-PFHxS
Perfluorooctane sulfonate[i]	PFOS	C8HO3SF17	13C4-PFOS
Perfluorononane sulfonate	PFNS	C9HO3SF19	13C4-PFOS
Perfluorodecane sulfonate	PFDS	C10HO3SF21	13C4-PFOS
Perfluoroundecane sulfonate	PFUdS	C11HO3SF23	13C4-PFOS
Perfluorododecane sulfonate	PFDoS	C12HO3SF25	13C4-PFOS
Chlorinated perfluoroalkane sulfonates and ether sulfonates			
8-chloro-perfluorooctane sulfonate	Cl-PFOS	C8HO3SClF16	13C4-PFOS
9-chloro-3-oxa-perfluorononane sulfonate	Cl-O-PFNS	C8HO4SClF16	13C4-PFOS
11-chloro-3-oxa-perfluoroundecane sulfonate	Cl-O-PFUdS	C10HO4SClF20	13C4-PFOS
Perfluoroalkane sulfonamides			
Perfluorooctane sulfonamide	FOSA	C8H2O2SNF17	13C8-FOSA
N-methylperfluoro-1-octane sulfonamide	MeFOSA	C9H4O2SNF17	d3-MeFOSA
N-ethylperfluoro-1-octane sulfonamide	EtFOSA	C10H6O2SNF17	d5-EtFOSA
Perfluoroalkane sulfonamido acetic acids			
Perfluorooctane sulfonamido acetic acid[ii]	FOSAA	C10H4O4SNF17	d3-MeFOSAA
N-methylperfluorooctane sulfonamido acetic acid[i, ii]	MeFOSAA	C11H6O4SNF17	d3-MeFOSAA
N-ethylperfluorooctane sulfonamido acetic acid[i, ii]	EtFOSAA	C12H8O4SNF17	d5-EtFOSAA
Fluorotelomer Sulfonates			
4:2 fluorotelomer sulfonate	4:2 FTS	C6H5O3SF9	13C2-4:2 FTS
6:2 fluorotelomer sulfonate	6:2 FTS	C8H5F13SO3	13C2-6:2 FTS
8:2 fluorotelomer sulfonate	8:2 FTS	C10H5O3SF17	13C2-8:2 FTS
10:2 fluorotelomer sulfonate	10:2 FTS	C12H5O3SF21	13C2-8:2 FTS
Fluorotelomer Alkanoic Acids			
3:3 fluorotelomer carboxylic acid	3:3 FTCA	C6H5O2F7	13C2-6:2 FTCA
5:3 fluorotelomer carboxylic acid	5:3 FTCA	C8H5O2F11	13C2-8:2 FTCA
7:3 fluorotelomer carboxylic acid	7:3 FTCA	C10H5O2F15	13C2-10:2 FTCA
6:2 fluorotelomer carboxylic acid[iii]	6:2 FTCA	C8H3O2F13	13C2-6:2 FTCA
8:2 fluorotelomer carboxylic acid[iii]	8:2 FTCA	C10H3O2F17	13C2-8:2 FTCA
10:2 fluorotelomer carboxylic acid[iii]	10:2 FTCA	C12H3O2F21	13C2-10:2 FTCA
2H-Perfluoro-2-octenoic acid (6:2)[iii]	6:2 UFTCA	C8H2O2F12	13C2-6:2 UFTCA
2H-Perfluoro-2-decenoic acid (8:2)[iii]	8:2 UFTCA	C10H2O2F16	13C2-8:2 UFTCA
2H-Perfluoro-2-dodecenoic acid (10:2)[iii]	10:2 UFTCA	C12H2O2F20	13C2-10:2 UFTCA
Miscellaneous Emerging			
Dodecafluoro-3H-4,8-dioxanonanoate	ADONA	C7H2O4F12	13C4-PFOA
Perfluoro-4-ethylcyclohexane sulfonate	PFEtCHxS	C8HO3SF15	13C4-PFOS
Tetrafluoro-2-(heptafluoropropoxy)propanoic acid	HFPO-DA	C6HO3F11	13C3-HFPO-DA

i. Exist in the standard as the linear and branched isomers.

ii. PFHxDA, PFODA, FOSAA, MeFOSAA, and EtFOSAA excluded from high-level (>3.85 ng/mL) calibration standards to prevent instrument carryover.

iii. Stored in 100% Optima® HPLC-grade 2-isopropanol (IPA) to limit potential degradation. (All other compounds stored in 100% Optima® HPLC-grade methanol.)

3.2 Equipment/Supplies

The following specific equipment and supplies are used for sample preparation of aqueous samples. In addition, common laboratory equipment (e.g., pipettes and pipette tips, volumetric flasks, nitrile gloves, glass pasteur pipettes, and kimwipes) are used throughout the sample preparation process. Every effort is made to ensure a clean, PFAS-free sample preparation environment, including, but not limited to, frequent changes of gloves, avoidance of known PFAS-containing materials (e.g., PTFE, Gortex™ or Teflon™-coated materials, etc.), use of single-use racked pipette tips, triple methanol-rinsed pre-cleaned equipment, a quality assurance program including various types of blanks (see Section 3.7), and PFAS-dedicated laboratory bench areas.

3.3 Sample Equipment

A. Agilent HPLC autosampler vials, screw, 2 mL, amber, WrtOn, cert, P/N 5182-0716
B. Phenomenex Verex Cert+ Cap (one-piece), 9 mm PE w/ Starburst pre-slit, P/N AR0-89P6-13-C
C. Falcon 50 mL polypropylene conical centrifuge tubes, P/N 352098
D. Falcon 15 mL polypropylene conical centrifuge tubes, P/N 352096

3.3 Reagents/Chemicals/Water for Sample Preparation

A. 100% Optima® LC/MS grade methanol (MeOH) (Fisher Chemical)
B. 100% Optima® LC/MS grade 2-isopropanol (IPA) (Fisher Chemical)
C. 100% Optima® LC/MS grade water (Fisher Chemical)
D. 0.01% Ammonium Hydroxide in Optima® LC/MS grade water (aka “basic water,” 5 µL NH_4OH:50000 µL Optima® LC-MS grade water; made fresh weekly; Fisher Chemical Ammonium Hydroxide Optima® LC/MS grade 20-22% as NH_3; Fisher Chemical water)
E. Methanol-based Internal PFAS standard mix (0.77 ng/mL), made from standards purchased from Wellington Laboratories, Guelph, Ontario, Canada (aka “MeOH IS”), Optima® LC/MS grade methanol, and Optima® LC/MS grade water.
F. IPA-based Internal PFAS standard mix (0.77 ng/mL), made from standards purchased from Wellington Laboratories, Guelph, Ontario, Canada (aka “IPA IS”) and Optima® LC/MS grade 2-isopropanol.
G. Injection standard solution: 10 ng/mL mass-labeled M2PFOA (Wellington Laboratories) in 80:20 methanol:water
H. 99.8% ACROS Organics™ Extra Pure 2,2,2-trifluoroethanol

3.4 Homogenization and subsampling process

Using “clean hand” techniques (new gloves for each sample), collect a minimum of 5 mL of an unfiltered water sample directly in new 15 mL polypropylene Falcon tube. Do not pour out excess sample volume. If the sample tube is overfilled, dispose of the over-filled tube and collect an appropriate volume of the sample in a new 15 mL Falcon tube. Cap the 15 mL tube and place on ice or refrigerator until processed.

With each batch of samples prepared in the laboratory, quality control samples will be concurrently processed. A sample batch is defined as a group of 20 samples or less that are processed at the same time. The quality control samples include a method blank, a matrix spike, a laboratory control sample (LCS), and a laboratory control sample duplicate (LCS Duplicate).

Method blanks (internal standard added) consist of 5 mL of HPLC-grade water prepared by the same procedure used for the groundwater samples and are processed within new, pre-weighed 15 mL polypropylene Falcon tubes. The LCS is also prepared by spiking HPLC-grade water with a known concentration of standards upon receiving the samples in the lab. The LCS Duplicate is prepared in an identical way. The LCS and LCS Duplicate are then stored alongside the samples until the time of sample preparation and analysis. The matrix spike is prepared by spiking a randomly selected sample from the batch at mid-level concentrations.

3.5 Preparation technique

This protocol assumes no pre-filtering step is necessary as it is designed for analysis of drinking water (i.e., tap water) samples or unfiltered groundwater. If solids are present, the sample shall be centirfuged and the supernatant decanted into a new 15 mL Falcon tube. Samples shall not be filtered through glass fiber filters as they have demonstrated the ability to sorb PFAS. Samples collected should be within a pH of 5 to 9 (pH 6 to 8 is ideal) or adjusted to be within this range with HPLC Optima-Grade ammonium hydroxide (to raise pH) or HPLC Optima-Grade hydrochloric acid (to lower pH) and without elevated levels of salts prior to analysis to ensure consistent chromatography and reduce potential for instrument corrosion.

A. Pipette 1 mL of sample directly from the sample container into a new Falcon Tube.
B. Within the new falcon tube each sample is diluted so that the water sample represents 64% of total volume with 23% Optima® LC/MS grade methanol (Fisher Scientific), 3% of 0.01% Optima® LC/MS grade ammonium hydroxide (Fisher Scientific, Fair Lawn, NJ) in Optima® LC/MS grade water (Fisher Scientific), and 10% Optima® LC/MS grade isopropanol (Fisher Scientific). 2,2,2-trifluoroethanol is then added to make up 10% of the total volume. Internal standards (labeled PFASs in methanol and isopropanol; see **Table (1**) are spiked directly into the vessel at 74 pg/mL.
C. Prepare samples by adding the computed amounts of reagents listed in step B. Re-vortex solutions every 5 samples.
D. Once all reagents and IS solutions are added, cap and vortex samples thoroughly in 15 mL Falcon tubes for 30-45 seconds.
E. If samples are unfiltered and/or may contain particulates, centrifuge samples for 10 minutes at 4000 rpm.
F. Transfer a 1.35 mL aliquot of prepared sample to a new, pre-labeled 2-mL amber glass HPLC vial. (Re-vortex in HPLC vials if samples sit for more than 24 hours prior to analysis.)
G. Cap with PE StarBurst cap and store in refrigerator until analysis. Sample preparation is typically completed less than 24-hours prior to analysis.

3.6 Clean-up Procedures

No additional sample clean-up procedures are required for the unfiltered aqueous samples.

3.7 Sample Preparation QC Types, Frequency and Criteria

Quality assurance samples are included during sample preparation. For each sample batch a method blank and a laboratory control sample should be included. As stated above, 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 5 mL of HPLC-grade water prepared by the same procedure used for the groundwater samples and are processed within new 15 mL polypropylene Falcon tubes. A laboratory control sample is also prepared by spiking optima-grade water with a known concentration of standards. The sample should be spiked so that the final concentration

of PFAS is greater than the limit of quantification of all PFAS, but also falls below the midpoint of the calibration curve. The laboratory control sample is then treated as a regular sample.

All samples, including all QC samples, will be spiked with internal standards and injection standard. All concentrations in all field samples and QC samples will be corrected for internal standard recoveries. Analytes with internal standard recoveries outside of 50-150% will be flagged.

The method blanks allow researchers to check for contamination that occurred during the sample preparation process. The laboratory control sample will be used as a check that analytes were not lost during the preparation process. Analytical replicates prepared in triplicate gives %Relative Standard Deviation ≤ 30% (in case of duplicate, %Relative Percent Difference ≤ 30%).

$$\%Relative\ Standard\ Deviation = \frac{Standard\ deviation\ of\ replicates}{Average\ of\ replicates} * 100$$

$$\%Relative\ Percent\ Difference = \frac{(Sample\ result - sample\ duplicate\ result)}{(Sample\ result - sample\ duplicate\ result)/2} * 100$$

3.8 Sample extract storage and hold time requirements

It is recommended that samples, standards, and CCVs be prepared no more than 24-hours in advance of an analytical run. Upon preparation, all samples are stored in a dedicated refrigerator in the limited-access sample preparation laboratory until analysis.

5. LC-MS Analysis

This section of the SOP describes standard Mines' methods for the routine analysis of groundwater samples and soil extracts for PFASs. It also covers the procedure for calibration standards and quality assurance of the analysis. It is specific to the analyses using a LC-QToF X500R. AB Sciex 3200 QTRAP triple quadrupole mass spectrometer can be used as an alternative to the QToF X500R only for targeted analysis of compounds described in Table 1.

Table 2. Requirements of Table B-15 of DoD QSM and how they are addressed in this SOP

QC Type	Requirement	Mines' Response
Aqueous Sample Prep	SPE (or serial dilution with pre-approval)	All our aqueous samples are prepared in their original sampling containers to prevent losses. We want to avoid the inherent bias of SPE since we are looking for the broadest possible suite of compounds, primarily by LC-QTOF-MS.
Soil/Sed Prep	Samples must be homogenized before subsampling	Soil and sediment sampling is not an anticipated aspect of this project,.
Sample Clean Up	ENVI-Carb for samples/QC samples	Since SPE is not being used for aqueous samples, ENVI-Carb is also omitted. In our experience, dilution is sufficient for aqueous analysis.

Mass Calibration	Performed prior to use and after major maintenance	This is in our SOP
Tune Check	Tuning is required when masses fall outside of 0.5 amu	This standard is not relevant to QToF analysis, and mass calibration checks are already performed every 5 injections. For LC-MS/MS, we perform preventative maintenance once per year and tune checks once every 6 months (the manufacturer recommended frequency). We have not observed any problems with our current tuning frequency.
Mass Spectral Acquisition Rate	A minimum of 10 points are required for each analyte and internal standard.	This is in our SOP
Calibration, Calibration Verification, Spiking Standards	Must use standards with branched and linear isomers wherever commercially available (excluding technical mixtures).	We will add all available standards with branched and linear isomers as they become available.
Ion Transitions	Ion transitions must be documented, multiple transitions are required per analyte.	This standard is not relevant to QToF analysis. It is addressed for LC-MS/MS analysis section in Table 3 of our SOP.
Initial Calibration	S/N > 10:1 for all peaks, %RSD of RF for all analytes must be < 20% **or** calibrations must have r2 > 0.99 for each analyte, and all analytes must be within 70-130% of true value.	All integrated peaks are required to have a S/N > 10:1. We use weighted (typically 1/x^2) calibrations due to our need to ensure a broad range in our calibrations. Our SOP specifies that calibrations will have r^2>0.99
Retention time	RT of each analyte and EIS analyte must fall within 0.4 minutes of the predicted retention times from the daily calibration verification or on days when ICAL is performed, from the midpoint standard of the ICAL. Analytes must elute within 0.1 minutes of the associated EIS. This criterion applies only to analyte and labeled analog pairs.	This is in our SOP.
Instrument Sensitivity Check	Standard at LOQ must be +-30% of true value and they must be run every 12 hours.	All standards at the LOQ must be within 30% of their true value. For the frequency requirement, as we analyze a broad suite of compounds with a wide range of instrumental sensitivities (i.e., our targeted list is > 40 PFASs), it would be very laborious to run standards at the LOQ of all possible compounds every 12 hours. LOQs can vary up to two orders of magnitude between compounds in the same run. Instead, we run a CCV at a concentration above the typical LOQ after a maximum every 10 field samples, which is less than every five hours.

Initial Calibration Verification	Run after calibration,should be from second source, analytes must be +-30%.	We run a standard mixture from Oregon State University as a secondary source with every sample batch and will continue to add more second source compounds as they become available.
Continuing Calibration Verification	Must run prior to samples, then every 10 field samples, and at the end of the analytical sequence. Range from LOQ to mid-cal, recovery must be +-30%	We have updated our SOP to include a CCV prior to samples. Our CCVs are at a single midpoint concentration, since LOQs for different compounds vary significantly.
Instrument Blanks	Must run immediately following high standard, must be < 1/2 LOQ. Also daily prior to sample analysis.	We have updated our SOP to include this.
Extracted Internal Standard Analytes	IS must be added prior to extraction of field samples and QC samples, recovery must be 50-150%.	We believe a wider range (30-200%) of IS recovery is acceptable, especially for more complicated matrices such as soil and in light of the broad suite of PFAS we are targeting in our analyses. Values outside of 50-150% will be flagged but still reported. Internal standard recoveries are determined based on all standards in the calibration curve.
Method Blank	1 per batch, standard is 1/10th the lowest sample or 1/2 LOQ	If our method blanks (at least 1 per batch of samples) 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.
Laboratory Control Sample	1 spiked blank per batch, at concentration between LOQ and mid-cal. There are no set recovery standards.	This has been added to our SOP. The LCS concentrations must be between 70-130% of the expected concentration.
Matrix Spike	1 spiked sample per batch, at concentration between LOQ and mid-cal. There are no set recovery standards.	A LCS Duplicate is being included with each batch of aqueous samples to calculate batch precision.
Matrix Spike Duplicate or Matrix Duplicate	MSD: 1 spiked sample duplicate per batch, RPD with MS must be < 30%. MD is required for all samples prepared by serial dilution. RPD must be < 30%	We are analyzing at least 10% of all of our samples in triplicate for field samples or laboratory experimental samples (though experimental replicates, if available, are preferred). This, we are not performing matrix duplicates as articulated here.
Post Spike Sample	For aqueous samples prepared by dilution, all analytes that have results <LOQ must be spiked at LOW, recovery 70-130%.	While we recognize the importance of this criterion for ensuring minimal false negatives, this is impractical for our analysis, as we are targeting >40 analytes and prepare many of our aqueous samples by serial dilution. We still perform a matrix spike with each batch.

5.1 Media and Analytes

This section of the SOP describes the analysis of prepared groundwater or groundwater derived aqueous samples..

5.2 Sample Equipment

A. Agilent HPLC autosampler vials, screw, 2 mL, amber, WrtOn, cert, P/N 5182-0716

B. Phenomenex Verex Cert+ Cap (one-piece), 9 mm PE w/ Starburst pre-slit, P/N AR0-89P6-13-C
C. Agilent HPLC autosampler vial caps, 9mm, blue screw, silicone/PTFE, P/N 5185-5820 (Note: this cap is only for AB Sciex LC-MS/MS 3200 with CTC Pal autosampler using a syringe not capable of penetrating Starburst septum)

5.3 Reagents/Chemicals/Water for Calibration Curve Preparation

A. 100% Optima® LC/MS grade methanol (MeOH) (Fisher Chemical)
B. 100% Optima® LC/MS grade 2-isopropanol (IPA) (Fisher Chemical)
C. 100% Optima® LC/MS grade water (Fisher Chemical)
D. 0.01% Ammonium Hydroxide in Optima® LC/MS grade water (aka "basic water," 5 µL NH_4OH:50000 µL Optima® LC-MS grade water; made fresh weekly; Fisher Chemical Ammonium Hydroxide Optima® LC/MS grade 20-22% as NH_3; Fisher Chemical water)
E. Methanol-based Internal PFAS standard mix (0.77 ng/mL), made from standards purchased from Wellington Laboratories, Guelph, Ontario, Canada (aka "MeOH IS"), Optima® LC/MS grade methanol, and Optima® LC/MS grade water.
F. IPA-based Internal PFAS standard mix (0.77 ng/mL), made from standards purchased from Wellington Laboratories, Guelph, Ontario, Canada (aka "IPA IS") and Optima® LC/MS grade 2-isopropanol.

5.4 Analytical Equipment and Chemicals

A. SCIEX X500R LC/QTOF-MS Note: all Teflon solvent lines were replaced with PEEK (polyether ether ketone) tubing; stainless steel tubing is used between the injection port and the analytical column and the detector. A 1 mL sample loop is used to allow large volume injections (LVI). Note: Maximum pressure for a 1 mL PEEK sample loop is ~3200 psi, if chromatographic conditions result in higher pressures, a stainless-steel sample loop can be used.
B. AB Sciex 3200 LC-MS/MS (Note: Teflon solvent lines used for Agilent LC system; PEEK tubing was used between LC system mixer and the detector except a sample loop. A 1 ml stainless steel sample loop was used to allow large volume injections (LVI).)
C. Delay column (1) - Luna® 5 µm C18(2) 100 Å, LC Column 30 x 3 mm, P/N 00A-4252-Y0; to improve chromatographic separation.
D. DIOL guard columns (2) - Zorbax DIOL 4.6 x 12.5 mm 6 um, P/N 820950-911; the hydrophilic diol bonded phase facilitates retention of the shorter chain PFASs. Replace first DIOL (after C18) with 2nd DIOL and add new DIOL to 2nd position (preceding analytical column). Make this switch approximately every 100 sample injections.
E. DIOL column guard holders (2) Agilent ZGC guard column holders, P/N 820999-901
F. C18 guard column - Phenomenex Gemini C18 4x2.00 mm ID, P/N AJ0-7596, this guard column protects the C18 analytical column and is preemptively changed approximately every 100 sample injections.
G. C18 guard column holder – Phenomenex SecurityGuard™ Guard Cartridge Kit, P/N KJ0-4282.
H. C18 analytical column - Phenomenex Gemini C18, 5 µm, 100 x 3 mm, P/N OOD-4435-Y0.
I. Mobile phase A - 20 mM Optima LC/MC grade ammonium acetate in Optima LC/MS grade water (1.54 g / 1 L, eluent).
J. Mobile phase B - 100% Optima LC/MS grade MeOH.
K. HPLC Rinse solution - 100% HPLC grade Acetonitrile.
L. Negative-mode calibrant solution - ESI Negative Calibration Solution for the SCIEX x500 System P/N 5042913.

5.5 Types of Standards Utilized

Analytical standards stored in MeOH or IPA as well as mass-labeled standards stored in MeOH or IPA and from Wellington Laboratories (Guelph, Ontario, Canada) are used for the calibration curve. See Table 1 for details, including standards purchased as branched or linear.

5.6 Calibration Procedure

All mass-labeled (aka “internal”) and unlabeled (aka “native”) analytical standards were purchased from Wellington Laboratories (Guelph, Ontario). Up to a 15-point calibration curve (0.074 ng/L to 7,400 ng/L) is established for the individual analytes listed in Table 1. Calibration curves are prepared using a serial dilution method from 200 ng/mL native stock standard and mass-labeled internal standard solutions. Following the recommendation by Wellington Laboratories, native standards and mass labeled internal standards are stored in 80/20 Optima MeOH/Optima water or 100% Optima IPA. Additionally, the native standards for five PFAS (PFHxDA, PFODA, FOSAA, MeFOSAA, and EtFOSAA) are added separately to a subset of the calibration solutions to exclude them from the calibration points >500 ng/L due to instrument carryover at higher concentrations.

5.7 Instrument Cleanliness Requirements

Prior to each sample run the front end of the detector is wiped clean with methanol. Additionally, the instrument undergoes a complete pump down and cleaning approximately one time per two weeks, following an established protocol recommended by SCIEX. As detailed in the Section 5.9, instrument blanks as well as double blanks are run throughout the analysis. Prior to running the calibration curve, a double blank is run to verify that there is no instrumental contamination. If contamination is found, corrective actions are taken prior to starting the run.

5.8 Calibration Verification Procedure

The calibration curve, unique for each analyte, is determined for quantification of PFAS concentrations in samples. At a minimum, a 5-point curve with a r^2 value > 0.99 and deviation within +/- 30% is established by excluding upper or lower points of the curve not meeting these requirements. No points in the middle of the calibration curve are discounted. Lower and upper limits of quantitation (LOQs) are determined as the lowest and highest calibration standards calculated to be within 30% of the expected value, respectively. The regression fit for the calibration curve is typically $1/x^2$, although for some analytes a regression fit of 1/x is used when it provides an improved fit. A calibration curve will be run every 48 hours, with a requirement that a minimum 5-point curve meeting these parameters must be met within the 48-hour period. If these criteria cannot be met, the analyte is not quantified for the run.

5.9. Analytical Quality Control

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 (all reagents described in Table 1 plus IS) 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., 7,400 ng/L) 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 for that run if they are greater than <½ LOQ. The reporting limit will be set to 3 times the highest instrument blank concentration.

5.10 Known Interferences

Because we are using the parent ion in QTOF for quantitation, there are interferences caused by the in-source fragmentation of some of our internal standards. Specifically, the internal standard M-PFDoA (monoisotopic mass of the parent ion 615.9609) undergoes a decarboxylation in the source, forming an ion with m/z of 569.9710. This is within ~7 ppm mass error of the parent ion m/z of MeFOSAA (monoisotopic mass of 569.9667). Similar interferences occur for many of the other mass-labeled PFCAs. The peak that elutes later is consistently the inference from the internal standards undergoing in-source fragmentation.

Also, due to isotopic interference of the mass-labeled 4:2, 6:2, and 8:2 FTS with their corresponding native standards, the 79.95 Da fragment is used to quantitate the internal standards for these compounds.

5.11 Verification of Numeric Detection/Quantitation Value if Numeric Values Provided for Sample Results

A list of target analytes and internal standards used for quantitation is provided in **Table 1**. Concentrations of target analytes are corrected for internal standard recovery. The sample analysis components are described below.

5.12 Chromatographic Method

The chromatographical method condition is identical for both instruments but using different LC system. LC-QToF X500R contains SCIEX ExionLC™ high-pressure liquid chromatography system. AB Sciex 3200 LC-MS/MS compartment contains Agilent 1200 series LC system, HTS PAL autosampler, and Cole-Parmer column oven.

Unless otherwise specified, a 1 mL aliquot of each water sample is injected using a LC system using a Gemini C18 analytical column (3 mm x 100 mm x 5 µm; Phenomenex, Torrance, CA) preceded by one SecurityGuard™ C18 Guard Cartridge (4 mm x 2 mm I.D.; Phenomenex) and two Zorbax DIOL guard columns (4.6 mm x 12.5 mm x 6 µm; Agilent, Santa Clara, CA). Smaller injection volumes are used for other matrices, such as soil, as well as high concentration samples. A Luna 5 um C18(2) 100 Ä LC column 30 x 3 mm is used as a delay column to aid in

chromatographic separation. The column oven is held at 40 ºC. The aqueous mobile phase (A) is 20 mM ammonium acetate (Fisher Scientific) in Optima® HPLC-grade water and the organic mobile phase (B) is 100% Optima® HPLC-grade methanol. Eluent flow rate is held at 0.60 mL/min, and composition is ramped from 90% A to 50% A over the first 0.5 minutes, then to 1.0% A at 8 minutes and held until 13 minutes, then ramped to 90% A at 13.5 minutes and held to 20 minutes. The chromatographical method condition is identical for both instruments. Expected retention time for each analyte is set based on a calibration point near the middle of the calibration curve that ran at the beginning of the sequence. The acceptance criteria are that each quantified analyte must elute within 0.4 minutes of the retention time from this calibration point. For analytes for which there are matched isotopically labeled internal standards, the retention time for that analyte must be within 0.1 minute of its matched internal standard.

5.13 Mass spectrometry method

5.13.1 QTOF-MS Method

PFASs are measured on a SCIEX X500R QTOF-MS system (Framingham, MA) using electrospray ionization in negative mode (ESI-) with SWATH® Data-Independent Acquisition for both TOFMS and MS/MS mode. Precursor ion data is collected for m/z 100-1200 for 1283 cycles with a total scan time of 842 ms and accumulation time of 20 ms, with ion spray voltage set at -4500 V and temperature set to 550 ºC. The ion source, curtain, and collision (CAD) gas are set to 60 psi, 35 psi, and 10 psi, respectively. For QTOF scanning, the collision energy is set to -5 V and the declustering potential to -20 V, both with no spread. Product ion (MS/MS) scanning is conducted for m/z 50-1200 Da. The accumulation time for each SWATH window is 50 ms and collision energy is -35 V with 30 V spread. The instrument is mass calibrated every 5 injections using SCIEX ESI Negative Calibration Solution.

5.13.2 MS/MS Method

PFASs measurement is available using an AB Sciex 3200 LC-MS/MS system (Framingham, MA) equipped with electrospray ionization in negative mode (ESI-) in multiple reaction monitoring (MRM) mode. Data is collected for 400 cycles with a total scan time of 3.04 sec. Interface Heater(ihe) was on and accumulation time of 20 ms, with ion spray voltage set at -4500 V and temperature set to 650 ºC. The curtain gas (CUR), collision gas (CAD), ion source Gas1 (GS1), and ion source Gas2 (GS2) are set to 20 psi, Medium, 60 psi, and 60 psi, respectively. The declustering potential (DP), collision energy (CE), entrance potential (EP), and collision cell exit potential (CXP) vary between analytes (**Table 3**).

5.14 Data Acquisition Parameters

5.14.1 Data from QTOF-MS

Quantitative Analysis: Quantitative data acquisition and processing are done using SCIEX OS Version 1.6 to quantify targeted analytes and identify unknown PFASs from the MS/MS library and XIC list. Confirmation of targeted analytes with signal:noise ratio > 10:1 is based on retention time and accurate mass (XIC window 0.02 Da) compared to analytical standards. Expected retention time for each analyte is set based on a calibration point near the middle of the calibration curve that ran at the beginning of the sequence. Initial integration parameters included defining 90% of lowest-intensity peaks as noise, using a baseline-subtract window of 2 minutes, a minimum peak intensity of 100, and a peak width of 10 points. Some peaks with peak intensity below the threshold are manually integrated where retention time, accurate mass, and isotope

confidence are determined to be satisfactory. Confirmation of targeted analytes is based on retention time and accurate mass compared to analytical standards (<10 ppm).

A list of target analytes and internal standards used for quantitation is provided in **Table 1**. Calibration range, limit of quantitation, and linear fit (r^2) of calibration curves for all analytes are recorded for each analytical run. 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.

Qualitative Analysis: Qualitative suspect screening is the comparison of identified mass spectral features against an extracted ion chromatogram (XIC) list. The current Mines' PFAS XIC list is presented in Table 4. To identify additional PFASs of interest beyond the target analyte list, high-resolution QTOF data collected via SWATH® Data-Independent Acquisition is screened using a custom spectral library containing spectra for >300 AFFF-associated PFASs and a custom XIC list containing molecular formulas and neutral masses for >1,400 PFASs (**Table 4**), including a wide variety of well-characterized PFASs, PFASs reported in literature, and theoretical homologs.

Identification of unknown PFASs is based on accurate mass measurement for the molecular ion, isotopic pattern matching scores, and, for compounds present in the MS/MS library, the library purity score. Samples are screened by searching for the deprotonated molecular ion $[M-H]^-$ using an XIC window of 0.008 Da, a signal:noise threshold of 10:1, a minimum peak intensity 100, and baseline subtraction over 2 minutes. In cases where there are multiple possible hits for one peak, the largest peak found was reported unless other lines of evidence, such as retention times of homologous compounds, supported the identification of a smaller peak. The HRMS MS/MS library was screened for matches using a mass error threshold of 0.1 Da for the precursor ion and 0.4 Da for the product ion, and an intensity threshold of 5% of the highest peak in the MS/MS spectrum. Library purity score was calculated by an algorithm in SCIEX OS software based on the quality of match between the library and experimental MS/MS spectrum (both presence/absence of expected fragments and relative fragment abundance).

Data are exported from SCIEX OS and parsed using an R script (R v 3.4.3) to identify MS/MS library and XIC list matches. Only matches with purity score $\geq$ 70%, mass error < 10 ppm, and isotopic pattern error < 20% are considered library matches. For features with library scores < 70%, or no match located in the library, the peak is considered to be an XIC list match only for mass error < 5 ppm and isotopic pattern error < 10%. Features for which there is more than one possible identification based on mass and isotope pattern are flagged as isomers. After processing, the list of hits is evaluated manually to ensure that all matches are well-defined peaks and retention times are consistent for homologue series, and a confidence level is assigned to each identification based on the Schymanski scale. Results are typically reported in terms of area counts with associated confidence levels; depending on project-specific needs, semi-quantitation can also be done to obtain estimated concentrations of compounds lacking analytical standards..

5.14.2 Data from MS/MS

Data acquisition and processing are done using MultiQuant Version 3.0.1 to quantify targeted analytes of PFASs. A list of target analytes and internal standards used for quantitation is provided in **Table 1**. LC-MS/MS analysis specific acquisition masses, parameters, and internal standard are provided in **Table 3**. Each analyst has a pair of precursor-product ion transitions for quantification and confirmation, respectively. Calibration range, limit of quantitation, and linear fit (r2) of calibration curves for all analytes are recorded for each analytical run. Minimum reporting limits are adjusted to be three times the highest concentration in the blanks and applied to quantify these analytes.

Table 3. PFAS analytes names (acronyms), acquisition masses, parameters, internal standard used for LC-MS/MS analysis. Number next to analytes name represents selected for quantification (1) or confirmation (2).

Name (Acronym)	Precursor > Product ion	DP	EP	CE	CXP	IS
PFBA(1)	212.83 > 168.9	-10	-4.5	-12	0	MPFBA(1)
3.3FTA(1)	240.863 > 116.8	-15	-9	-40	0	MPFBA(1)
3.3FTA(2)	240.863 > 62.9	-15	-9	-14	-2	MPFBA(1)
PFPrS(1)	248.803 > 79.9	-45	-9.5	-42	0	M3PFBS(1)
PFPrS(2)	248.803 > 99	-45	-8	-36	0	M3PFBS(1)
PFPeA(1)	262.84 > 218.9	-10	-5	-12	0	M5PFPeA(1)
PFBS(1)	298.855 > 80	-45	-8	-50	-2	M3PFBS(1)
PFBS(2)	298.855 > 98.9	-45	-8	-42	0	M3PFBS(1)
PFHxA(1)	312.906 > 269	-10	-6	-12	0	M2PFHxA(1)
PFHxA(2)	312.906 > 118.8	-10	-6	-30	-4	M2PFHxA(1)
4.2FTS(1)	326.87 > 307	-35	-5.5	-26	0	M2-4.2FTS(1)
4.2FTS(2)	326.87 > 81	-35	-5.5	-48	-6	M2-4.2FTS(1)
HFPO-DA(1)	328.87 > 285	-5	-2.5	-8	-2	M2PFHxA(1)
HFPO-DA(2)	328.87 > 168.9	-5	-2.5	-18	-6	M2PFHxA(1)
5.3FTA(1)	340.942 > 217.1	-20	-6	-36	-6	M6.2FTUA(1)
5.3FTA(2)	340.942 > 237	-20	-6	-20	0	M6.2FTUA(1)
PFPeS(1)	348.873 > 79.9	-40	-9.5	-62	-6	M3PFBS(1)
PFPeS(2)	348.873 > 99.1	-40	-9.5	-46	-2	M3PFBS(1)
6.2FTUA(1)	356.912 > 293	-15	-4.5	-20	-2	M6.2FTUA(1)
6.2FTUA(2)	356.912 > 243.1	-15	-4.5	-48	-30	M6.2FTUA(1)
PFHpA(1)	362.9 > 319.1	-10	-4	-12	-2	M4PFHpA(1)
PFHpA(2)	362.9 > 168.9	-10	-4	-26	0	M4PFHpA(2)
ADONA(1)	376.904 > 251	-10	-5.5	-18	-2	M6.2FTUA(1)
ADONA(2)	376.904 > 84.9	-10	-5.5	-42	0	M6.2FTUA(1)
6:2 FTA (1)	376.911 > 292.79	-15	-4.5	-20	-2	M6.2FTUA(1)
6:2 FTA (2)	376.911 > 62.911	-15	-4.5	-16	0	M6.2FTUA(1)
PFHxS(1)	398.825 > 79.9	-65	-8	-56	-6	MPFHxS(1)
PFHxS(2)	398.825 > 98.9	-65	-8	-50	0	MPFHxS(1)
PFOA(1)	412.912 > 369	-10	-4.5	-14	-2	M4PFOA(1)
PFOA(2)	412.912 > 168.9	-10	-4.5	-24	-4	M4PFOA(1)
6.2FTS(1)	426.927 > 407	-40	-7.5	-28	-2	M2-6.2FTS(2)
6.2FTS(2)	426.927 > 79.836	-40	-5.5	-62	0	M2-6.2FTS(2)
7.3FTA(1)	440.995 > 337	-20	-6.5	-16	0	M8.2FTUA(1)
7.3FTA(2)	440.995 > 317	-20	-6.5	-28	-2	M8.2FTUA(1)
PFHpS(1)	448.898 > 79.9	-65	-10.5	-66	0	MPFHxS(1)
PFHpS(2)	448.898 > 98.9	-65	-10.5	-56	0	MPFHxS(1)
8.2FTUA(1)	456.975 > 393	-15	-7	-24	-4	M8.2FTUA(1)
8.2FTUA(2)	456.975 > 342.9	-15	-7	-54	0	M8.2FTUA(1)
PFCHxS(1)	460.912 > 98.9	-40	-10	-52	0	MPFOS(1)
PFCHxS(2)	460.912 > 381	-40	-10	-32	-4	MPFOS(1)
PFNA(1)	462.933 > 419	-10	-7.5	-16	0	M5PFNA(1)
PFNA(2)	462.933 > 168.9	-10	-7.5	-28	-2	M5PFNA(1)
8.2FTA(1)	476.978 > 393	-30	-9	-17	-4	M8.2FTA(1)
8.2FTA(2)	476.978 > 62.9	-20	-3	-26	-4	M8.2FTA(1)
FOSA(1)	497.94 > 77.9	-55	-9.5	-58	-6	M8FOSA-1(1)

FOSA(2)	497.94 > 168.9	-55	-9.5	-42	-2	M8FOSA-1(1)
PFOS(1)	498.897 > 79.9	-70	-7.5	-86	-6	MPFOS(1)
PFOS(2)	498.897 > 98.9	-70	-7.5	-54	0	MPFOS(1)
MeFOSA(1)	511.951 > 168.9	-45	-8.5	-36	-6	d-N-MeFOSA-M(1)
MeFOSA(2)	511.951 > 219	-45	-8.5	-34	0	d-N-MeFOSA-M(1)
PFDA(1)	512.991 > 469	-15	-4.5	-16	0	MPFDA(2)
PFDA(2)	512.991 > 219	-15	-4.5	-26	-2	MPFDA(2)
Cl-PFOS(1)	514.924 > 79.9	-75	-9.5	-70	0	MPFOS(1)
Cl-PFOS(2)	514.924 > 98.8	-75	-9.5	-64	0	MPFOS(1)
EtFOSA(1)	525.96 > 168.8	-50	-10	-38	0	d-N-EtFOSA-M(1)
EtFOSA(2)	525.96 > 218.9	-50	-10	-32	-2	d-N-EtFOSA-M(1)
8.2FTS(1)	526.99 > 507	-45	-9.5	-36	0	M2-8.2FTS(1)
8.2FTS(2)	526.99 > 80.6	-45	-9.5	-70	0	M2-8.2FTS(1)
Cl-PF3ONS(1)	530.914 > 351	-40	-10.5	-38	-6	MPFOS(1)
Cl-PF3ONS(2)	530.914 > 82.8	-40	-10.5	-50	-4	MPFOS(1)
PFNS(1)	548.946 > 79.8	-70	-10	-84	-4	MPFOS(1)
PFNS(2)	548.946 > 98.8	-70	-10	-68	0	MPFOS(1)
FOSAA(1)	555.963 > 419.1	-45	-10	-34	-6	d3-N-MeFOSAA(1)
FOSAA(2)	555.963 > 498	-45	-10	-34	-2	d3-N-MeFOSAA(1)
10.2FTUA(1)	556.996 > 493	-20	-9	-17	-2	M10.2FTUA(1)
10.2FTUA(2)	556.996 > 243	-15	-5	-24	0	M10.2FTUA(1)
PFUdA(1)	563.03 > 519	-15	-7.5	-16	0	MPFUdA(1)
PFUdA(2)	563.03 > 268.9	-15	-7.5	-28	-2	MPFUdA(1)
MeFOSAA(1)	569.991 > 419	-25	-8.5	-24	0	d3-N-MeFOSAA(1)
MeFOSAA(2)	569.991 > 218.9	-25	-8.5	-36	0	d3-N-MeFOSAA(1)
10.2FTA(1)	576.98 > 493.1	-20	-3	-10	-4	M10.2FTA(1)
10.2FTA(2)	576.98 > 62.9	-10	-5	-24	-2	M10.2FTA(1)
EtFOSAA(1)	583.997 > 419	-25	-9	-28	0	d5-N-EtFOSAA(1)
EtFOSAA(2)	583.997 > 526.1	-25	-9	-28	0	d5-N-EtFOSAA(1)
PFDS(1)	598.962 > 79.9	-80	-12	-96	0	MPFOS(1)
PFDS(2)	598.962 > 98.9	-80	-12	-72	0	MPFOS(1)
PFDoA(1)	613.031 > 569.1	-15	-7	-18	0	MPFDoA(1)
PFDoA(2)	613.031 > 269.1	-15	-7	-28	0	MPFDoA(1)
10.2FTS(1)	627.066 > 607.1	-55	-10.5	-38	0	M2-8.2FTS(1)
10.2FTS(2)	627.066 > 80.9	-55	-10.5	-76	-4	M2-8.2FTS(1)
Cl-PF3OUdS(1)	630.951 > 451	-60	-4	-36	0	MPFOS(1)
Cl-PF3OUdS(2)	630.951 > 82.7	-60	-4	-58	-4	MPFOS(1)
PFTrDA(1)	663.048 > 619.1	-15	-7.5	-20	0	M2PFTeDA(1)
PFTrDA(2)	663.048 > 168.9	-15	-7.5	-46	-6	M2PFTeDA(1)
PFDoS(1)	698.967 > 79.9	-70	-9	-130	0	MPFOS(1)
PFDoS(2)	698.967 > 98.9	-70	-9	-86	0	MPFOS(1)
PFTeDA(1)	713.036 > 669.1	-20	-4.5	-20	0	M2PFTeDA(1)
PFTeDA(2)	713.036 > 168.9	-20	-4.5	-38	0	M2PFTeDA(1)
PFHxDA(1)	812.99 > 768.9	-50	-4.5	-26	0	M2PFHxDA(1)
PFHxDA(2)	812.99 > 218.9	-50	-4.5	-44	-2	M2PFHxDA(1)
PFODA(1)	912.981 > 869.1	-30	-9	-26	0	M2PFHxDA(1)
PFODA(2)	912.981 > 168.9	-30	-9	-52	-4	M2PFHxDA(1)

MPFBA(1)	216.859 > 171.8	-10	-4.5	-16	0	
MPFBA(2)	216.859 > 80.1	-10	-4.5	-62	0	
M5PFPeA(1)	267.852 > 222.9	-10	-4	-12	-2	
M5PFPeA(2)	267.852 > 69.9	-10	-4	-56	0	
M3PFBS(1)	301.897 > 79.9	-40	-11	-50	-2	
M3PFBS(2)	301.897 > 98.9	-40	-11	-40	0	
M2PFHxA(1)	314.98 > 269.98	-10	-6	-12	-2	
M2PFHxA(2)	314.98 > 120	-10	-6	-30	0	
M2-4.2FTS(1)	328.926 > 80.8	-35	-8.5	-48	-2	
M2-4.2FTS(2)	328.926 > 308.839	-35	-8.5	-26	-4	
M3HFPO-DA(1)	331.906 > 168.8	-5	-3	-18	-6	
M3HFPO-DA(2)	331.906 > 184.9	-5	-3	-30	-2	
M6.2FTUA(1)	358.918 > 294	-15	-6.5	-18	0	
M6.2FTUA(2)	358.918 > 243.5	-15	-6.5	-48	-6	
M4PFHpA(1)	366.898 > 322	-15	-5.5	-12	-2	
M4PFHpA(2)	366.898 > 171.9	-15	-5.5	-24	0	
MPFHxS(1)	402.892 > 83.9	-60	-10	-64	-6	
MPFHxS(2)	402.892 > 102.9	-60	-10	-50	-6	
M4PFOA(1)	416.929 > 372.1	-10	-4	-14	0	
M4PFOA(2)	416.929 > 171.9	-10	-4	-28	-4	
M2-6.2FTS(1)	428.97 > 409	-45	-7.5	-32	-4	
M2-6.2FTS(2)	428.97 > 80.9	-45	-7.5	-58	0	
M8.2FTUA(1)	458.957 > 394	-10	-4	-18	0	
M8.2FTUA(2)	458.957 > 118.9	-10	-4	-60	-4	
M5PFNA(1)	467.974 > 423	-10	-4.5	-16	0	
M5PFNA(2)	467.974 > 218.9	-10	-4.5	-24	-4	
M8.2FTA(1)	478.985 > 394.1	-10	-4	-30	-2	
M8.2FTA(2)	478.985 > 63.9	-10	-4	-20	-4	
MPFOS(1)	502.968 > 79.9	-70	-7	-74	-6	
MPFOS(2)	502.968 > 98.9	-70	-7	-66	0	
M8FOSA-1(1)	505.967 > 77.9	-45	-9.5	-58	0	
M8FOSA-1(2)	505.967 > 63.9	-45	-9.5	-130	-4	
MPFDA(1)	514.98 > 470	-15	-4.5	-16	0	
MPFDA(2)	514.98 > 220	-15	-4.5	-26	0	
d-N-MeFOSA-M(1)	514.981 > 168.9	-50	-7.5	-42	-2	
d-N-MeFOSA-M(2)	514.981 > 219	-50	-7.5	-34	0	
M2-8.2FTS(1)	528.935 > 80.7	-50	-10	-52	-2	

M2-8.2FTS(2)	528.935 > 79.8	-50	-10	-66	-4	
d-N-EtFOSA-M(1)	531.005 > 168.9	-45	-9	-42	-4	
d-N-EtFOSA-M(2)	531.005 > 218.9	-45	-9	-34	-2	
M10.2FTUA(1)	559.021 > 494.1	-20	-7.5	-24	0	
M10.2FTUA(2)	559.021 > 243.9	-20	-7.5	-52	-6	
MPFUdA(1)	565.01 > 520	-15	-4.5	-18	-4	
MPFUdA(2)	565.01 > 168.8	-15	-4.5	-34	-4	
d3-N-MeFOSAA(1)	573 > 419.1	-30	-9.5	-26	0	
d3-N-MeFOSAA(2)	573 > 219	-30	-9.5	-34	0	
M10.2FTA(1)	579 > 494	-10	-4	-22	0	
M10.2FTA(2)	579 > 63.9	-10	-4	-20	0	
d5-N-EtFOSAA(1)	589.088 > 419	-35	-8	-28	0	
d5-N-EtFOSAA(2)	589.088 > 531.1	-35	-8	-28	0	
MPFDoA(1)	615.059 > 570.1	-15	-6.5	-18	-2	
MPFDoA(2)	615.059 > 168.9	-15	-6.5	-36	-4	
M2PFTeDA(1)	715.045 > 670	-20	-8.5	-22	-6	
M2PFTeDA(2)	715.045 > 169	-15	-6.5	-44	-2	
M2PFHxDA(1)	815.013 > 770.1	-25	-7	-24	0	
M2PFHxDA(2)	815.013 > 168.8	-25	-7	-44	-4	
M2 6.2 FTA (1)	378.98 > 292.8	-15	-5	-20	-2	
M2 6.2 FTA (2)	378.98 > 63.9	-15	-5	-15	-2	

(1) Selected for Quantification; (2), selected for confirmation; DP, declustering potential; CE, collision energy; EP, entrance potential; CXP, collision cell exit potential; IS, used IS the native compound

Table 4. PFASs that may be qualitatively identified in samples by this SOP

Compound Name	Individual Acronym	Neutral Mass Formula	Class Name	Class Acronym
perfluoro-n-ethanoic acid	PFEtA	C2HO2F3	perfluoro-n-alkanoic acid	PFCA
perfluoro-n-propanoic acid	PFPrA	C3HO2F5	perfluoro-n-alkanoic acid	PFCA
perfluoro-n-butanoic acid	PFBA	C4HO2F7	perfluoro-n-alkanoic acid	PFCA
perfluoro-n-pentanoic acid	PFPeA	C5HO2F9	perfluoro-n-alkanoic acid	PFCA
perfluoro-n-hexanoic acid	PFHxA	C6HO2F11	perfluoro-n-alkanoic acid	PFCA
perfluoro-n-heptanoic acid	PFHpA	C7HO2F13	perfluoro-n-alkanoic acid	PFCA
perfluoro-n-octanoic acid	PFOA	C8HO2F15	perfluoro-n-alkanoic acid	PFCA
perfluoro-n-nonanoic acid	PFNA	C9HO2F17	perfluoro-n-alkanoic acid	PFCA
perfluoro-n-decanoic acid	PFDA	C10HO2F19	perfluoro-n-alkanoic acid	PFCA
perfluoro-n-undecanoic acid	PFUdA	C11HO2F21	perfluoro-n-alkanoic acid	PFCA
perfluoro-n-dodecanoic acid	PFDoA	C12HO2F23	perfluoro-n-alkanoic acid	PFCA
perfluoro-n-tridecanoic acid	PFTrDA	C13HO2F25	perfluoro-n-alkanoic acid	PFCA
perfluoro-n-tetradacanoic acid	PFTeDA	C14HO2F27	perfluoro-n-alkanoic acid	PFCA
perfluoro-n-pentadecanoic acid	PFPeDA	C15HO2F29	perfluoro-n-alkanoic acid	PFCA
perfluoro-n-hexadecanoic acid	PFHxDA	C16HO2F31	perfluoro-n-alkanoic acid	PFCA
perfluoro-n-heptadecanoic acid	PFHpDA	C17HO2F33	perfluoro-n-alkanoic acid	PFCA
perfluoro-n-octadecanoic acid	PFODA	C18HO2F35	perfluoro-n-alkanoic acid	PFCA
perfluoro-n-nonadecanoic acid	PFNdA	C19HO2F37	perfluoro-n-alkanoic acid	PFCA
perfluoromethane sulfonate	PFMeS	C1HO3SF3	Perfluoroalkane sulfonate	PFAS
perfluoroethane sulfonate	PFEtS	C2HO3SF5	Perfluoroalkane sulfonate	PFAS
perfluoropropane sulfonate	PFPrS	C3HO3SF7	Perfluoroalkane sulfonate	PFAS
perfluorobutane sulfonate	PFBS	C4HO3SF9	Perfluoroalkane sulfonate	PFAS
perfluoropentane sulfonate	PFPeS	C5HO3SF11	Perfluoroalkane sulfonate	PFAS
perfluorohexane sulfonate	PFHxS	C6HO3SF13	Perfluoroalkane sulfonate	PFAS
perfluoroheptane sulfonate	PFHpS	C7HO3SF15	Perfluoroalkane sulfonate	PFAS
perfluorooctane sulfonate	PFOS	C8HO3SF17	Perfluoroalkane sulfonate	PFAS
perfluorononane sulfonate	PFNS	C9HO3SF19	Perfluoroalkane sulfonate	PFAS
perfluorodecane sulfonate	PFDS	C10HO3SF21	Perfluoroalkane sulfonate	PFAS
perfluoroundecane sulfonate	PFUdS	C11HO3SF23	Perfluoroalkane sulfonate	PFAS
perfluorododecane sulfonate	PFDoS	C12HO3SF25	Perfluoroalkane sulfonate	PFAS
perfluorotridecane sulfonate	PFTrDS	C13HO3SF27	Perfluoroalkane sulfonate	PFAS
perfluorotetradacane sulfonate	PFTeDS	C14HO3SF29	Perfluoroalkane sulfonate	PFAS
perfluoropentadecane sulfonate	PFPeDS	C15HO3SF31	Perfluoroalkane sulfonate	PFAS

perfluorohexadecane sulfonate	PFHxDS	C16HO3SF33	Perfluoroalkane sulfonate	PFAS
perfluoroheptadecane sulfonate	PFHpDS	C17HO3SF35	Perfluoroalkane sulfonate	PFAS
perfluorooctadecane sulfonate	PFODS	C18HO3SF37	Perfluoroalkane sulfonate	PFAS
perfluorononadecane sulfonate	PFNDS	C19HO3SF39	Perfluoroalkane sulfonate	PFAS
Chloro-perfluoropropane carboxylate	Cl-PFPrA	C3HO2ClF4	Chloro-Perfluoroalkane carboxylate	Cl-PFCA
Chloro-perfluorobutane carboxylate	Cl-PFBA	C4HO2ClF6	Chloro-Perfluoroalkane carboxylate	Cl-PFCA
Chloro-perfluoropentane carboxylate	Cl-PFPeA	C5HO2ClF8	Chloro-Perfluoroalkane carboxylate	Cl-PFCA
Chloro-perfluorohexane carboxylate	Cl-PFHxA	C6HO2ClF10	Chloro-Perfluoroalkane carboxylate	Cl-PFCA
Chloro-perfluoroheptane carboxylate	Cl-PFHpA	C7HO2ClF12	Chloro-Perfluoroalkane carboxylate	Cl-PFCA
Chloro-perfluorooctane carboxylate	Cl-PFOA	C8HO2ClF14	Chloro-Perfluoroalkane carboxylate	Cl-PFCA
Chloro-perfluorononane carboxylate	Cl-PFNA	C9HO2ClF16	Chloro-Perfluoroalkane carboxylate	Cl-PFCA
Chloro-perfluorodecane carboxylate	Cl-PFDA	C10HO2ClF18	Chloro-Perfluoroalkane carboxylate	Cl-PFCA
Chloro-perfluoroundecane carboxylate	Cl-PFUdA	C11HO2ClF20	Chloro-Perfluoroalkane carboxylate	Cl-PFCA
Chloro-perfluorododecane carboxylate	Cl-PFDoA	C12HO2ClF22	Chloro-Perfluoroalkane carboxylate	Cl-PFCA
Chloro-perfluorotridecane carboxylate	Cl-PFTrDA	C13HO2ClF24	Chloro-Perfluoroalkane carboxylate	Cl-PFCA
Chloro-perfluorotetradecane carboxylate	Cl-PFTeDA	C14HO2ClF26	Chloro-Perfluoroalkane carboxylate	Cl-PFCA
PentaFluoroSulfide PerFluoroethanoic Acid	F5S-PFEtA	C2HO2SF7	PentaFluoroSulfide-PerFluoroAlkanoic Acid	F5S-PFAA
PentaFluoroSulfide PerFluoropropanoic Acid	F5S-PFPrA	C3HO2SF9	PentaFluoroSulfide-PerFluoroAlkanoic Acid	F5S-PFAA
PentaFluoroSulfide PerFluorobutanoic Acid	F5S-PFBA	C4HO2SF11	PentaFluoroSulfide-PerFluoroAlkanoic Acid	F5S-PFAA
PentaFluoroSulfide PerFluoropentanoic Acid	F5S-PFPeA	C5HO2SF13	PentaFluoroSulfide-PerFluoroAlkanoic Acid	F5S-PFAA
PentaFluoroSulfide PerFluorohexanoic Acid	F5S-PFHxA	C6HO2SF15	PentaFluoroSulfide-PerFluoroAlkanoic Acid	F5S-PFAA
PentaFluoroSulfide PerFluoroheptanoic Acid	F5S-PFHpA	C7HO2SF17	PentaFluoroSulfide-PerFluoroAlkanoic Acid	F5S-PFAA
PentaFluoroSulfide PerFluorooctanoic Acid	F5S-PFOA	C8HO2SF19	PentaFluoroSulfide-PerFluoroAlkanoic Acid	F5S-PFAA
PentaFluoroSulfide PerFluorononanoic Acid	F5S-PFNA	C9HO2SF21	PentaFluoroSulfide-PerFluoroAlkanoic Acid	F5S-PFAA
PentaFluoroSulfide PerFluorodecanoic Acid	F5S-PFDA	C10HO2SF23	PentaFluoroSulfide-PerFluoroAlkanoic Acid	F5S-PFAA
PentaFluoroSulfide PerFluoroundecanoic Acid	F5S-PFUdA	C11HO2SF25	PentaFluoroSulfide-PerFluoroAlkanoic Acid	F5S-PFAA
PentaFluoroSulfide PerFluorododecanoic Acid	F5S-PFDoA	C12HO2SF27	PentaFluoroSulfide-PerFluoroAlkanoic Acid	F5S-PFAA
PentaFluoroSulfide PerFluorotridecanoic Acid	F5S-PFTrDA	C13HO2SF29	PentaFluoroSulfide-PerFluoroAlkanoic Acid	F5S-PFAA
PentaFluoroSulfide PerFluorotetradecanoic Acid	F5S-PFTeDA	C14HO2SF31	PentaFluoroSulfide-PerFluoroAlkanoic Acid	F5S-PFAA
PentaFluoroSulfide PerFluoropentadecanoic Acid	F5S-PFPeDA	C15HO2SF33	PentaFluoroSulfide-PerFluoroAlkanoic Acid	F5S-PFAA
Hydrido-perfluoropropanoic acid	H-PFPrA	C3H2O2F4	Hydrido-PerFluoroAlkanoic Acid	H-PFAA
Hydrido-perfluorobutanoic acid	H-PFBA	C4H2O2F6	Hydrido-PerFluoroAlkanoic Acid	H-PFAA
Hydrido-perfluoropentanoic acid	H-PFPeA	C5H2O2F8	Hydrido-PerFluoroAlkanoic Acid	H-PFAA
Hydrido-perfluorohexanoic acid	H-PFHxA	C6H2O2F10	Hydrido-PerFluoroAlkanoic Acid	H-PFAA
Hydrido-perfluoroheptanoic acid	H-PFHpA	C7H2O2F12	Hydrido-PerFluoroAlkanoic Acid	H-PFAA
Hydrido-perfluorooctanoic acid	H-PFOA	C8H2O2F14	Hydrido-PerFluoroAlkanoic Acid	H-PFAA
Hydrido-perfluorononanoic acid	H-PFNA	C9H2O2F16	Hydrido-PerFluoroAlkanoic Acid	H-PFAA

Hydrido-perfluorodecananoic acid	H-PFDA	C10H2O2F18	Hydrido-PerFluoroAlkanoic Acid	H-PFAA
Hydrido-perfluoroundecanoic acid	H-PFUdA	C11H2O2F20	Hydrido-PerFluoroAlkanoic Acid	H-PFAA
Hydrido-perfluorododecanoic acid	H-PFDoA	C12H2O2F22	Hydrido-PerFluoroAlkanoic Acid	H-PFAA
Hydrido-perfluorotridecanoic acid	H-PFTrDA	C13H2O2F24	Hydrido-PerFluoroAlkanoic Acid	H-PFAA
Hydrido-perfluorotetradacanoic acid	H-PFTeDA	C14H2O2F26	Hydrido-PerFluoroAlkanoic Acid	H-PFAA
Hydrido-perfluoropentadecanoic acid	H-PFPeDA	C15H2O2F28	Hydrido-PerFluoroAlkanoic Acid	H-PFAA
Hydrido-perfluorohexadecanoic acid	H-PFHxDA	C16H2O2F30	Hydrido-PerFluoroAlkanoic Acid	H-PFAA
Hydrido-perfluoroheptadecanoic acid	H-PFHpDA	C17H2O2F32	Hydrido-PerFluoroAlkanoic Acid	H-PFAA
Chloro-perfluoroethane sulfonate	Cl-PFEtS	C2HO3SClF4	Chloro-PerFluoroAlkaneSulfonate	Cl-PFAS
Chloro-perfluoropropane sulfonate	Cl-PFPrS	C3HO3SClF6	Chloro-PerFluoroAlkaneSulfonate	Cl-PFAS
Chloro-perfluorobutane sulfonate	Cl-PFBS	C4HO3SClF8	Chloro-PerFluoroAlkaneSulfonate	Cl-PFAS
Chloro-perfluoropentane sulfonate	Cl-PFPeS	C5HO3SClF10	Chloro-PerFluoroAlkaneSulfonate	Cl-PFAS
Chloro-perfluorohexane sulfonate	Cl-PFHxS	C6HO3SClF12	Chloro-PerFluoroAlkaneSulfonate	Cl-PFAS
Chloro-perfluoroheptane sulfonate	Cl-PFHpS	C7HO3SClF14	Chloro-PerFluoroAlkaneSulfonate	Cl-PFAS
Chloro-perfluorooctane sulfonate	Cl-PFOS	C8HO3SClF16	Chloro-PerFluoroAlkaneSulfonate	Cl-PFAS
Chloro-perfluorononane sulfonate	Cl-PFNS	C9HO3SClF18	Chloro-PerFluoroAlkaneSulfonate	Cl-PFAS
Chloro-perfluorodecane sulfonate	Cl-PFDS	C10HO3SClF20	Chloro-PerFluoroAlkaneSulfonate	Cl-PFAS
Chloro-perfluoroundecane sulfonate	Cl-PFUdS	C11HO3SClF22	Chloro-PerFluoroAlkaneSulfonate	Cl-PFAS
Chloro-perfluorododecane sulfonate	Cl-PFDoS	C12HO3SClF24	Chloro-PerFluoroAlkaneSulfonate	Cl-PFAS
Chloro-perfluorotridecane sulfonate	Cl-PFTrDS	C13HO3SClF26	Chloro-PerFluoroAlkaneSulfonate	Cl-PFAS
Chloro-perfluorotetradacane sulfonate	Cl-PFTeDS	C14HO3SClF28	Chloro-PerFluoroAlkaneSulfonate	Cl-PFAS
Chloro-perfluoropentadacane sulfonate	Cl-PFPeDS	C15HO3SClF30	Chloro-PerFluoroAlkaneSulfonate	Cl-PFAS
Dichlorinated perfluoropropyl sulfonate	DiCl-PFPrS	C3HO3SCl2F5	Dichlorinated perfluoroalkyl sulfonates	DiCl-PFAS
Dichlorinated perfluorobutyl sulfonate	DiCl-PFBS	C4HO3SCl2F7	Dichlorinated perfluoroalkyl sulfonates	DiCl-PFAS
Dichlorinated perfluoropentyl sulfonate	DiCl-PFPeS	C5HO3SCl2F9	Dichlorinated perfluoroalkyl sulfonates	DiCl-PFAS
Dichlorinated perfluorohexyl sulfonate	DiCl-PFHxS	C6HO3SCl2F11	Dichlorinated perfluoroalkyl sulfonates	DiCl-PFAS
Dichlorinated perfluoroheptyl sulfonate	DiCl-PFHpS	C7HO3SCl2F13	Dichlorinated perfluoroalkyl sulfonates	DiCl-PFAS
Dichlorinated perfluorooctyl sulfonate	DiCl-PFOS	C8HO3SCl2F15	Dichlorinated perfluoroalkyl sulfonates	DiCl-PFAS
Dichlorinated perfluorononyl sulfonate	DiCl-PFNS	C9HO3SCl2F17	Dichlorinated perfluoroalkyl sulfonates	DiCl-PFAS
Dichlorinated perfluorodecyl sulfonate	DiCl-PFDS	C10HO3SCl2F15	Dichlorinated perfluoroalkyl sulfonates	DiCl-PFAS
Dichlorinated perfluoroundecyl sulfonate	DiCl-PFUdS	C11HO3SCl2F17	Dichlorinated perfluoroalkyl sulfonates	DiCl-PFAS
Dichlorinated perfluorododecyl sulfonate	DiCl-PFDoS	C12HO3SCl2F19	Dichlorinated perfluoroalkyl sulfonates	DiCl-PFAS
Dichlorinated perfluorotridecyl sulfonate	DiCl-PFTrDS	C13HO3SCl2F21	Dichlorinated perfluoroalkyl sulfonates	DiCl-PFAS
PentaFluoroSulfide-perfluoromethane sulfonate	F5S-PFMeS	C1HO3S2F7	PentaFluoroSulfide-PerFluoroAlkane Sulfonate	F5S-PFAS
PentaFluoroSulfide-perfluoroethane sulfonate	F5S-PFEtS	C2HO3S2F9	PentaFluoroSulfide-PerFluoroAlkane Sulfonate	F5S-PFAS
PentaFluoroSulfide perfluoropropane sulfonate	F5S-PFPrS	C3HO3S2F11	PentaFluoroSulfide-PerFluoroAlkane Sulfonate	F5S-PFAS
PentaFluoroSulfide perfluorobutane sulfonate	F5S-PFBS	C4HO3S2F13	PentaFluoroSulfide-PerFluoroAlkane Sulfonate	F5S-PFAS

PentaFluoroSulfide perfluoropentane sulfonate	F5S-PFPeS	C5HO3S2F15	PentaFluoroSulfide-PerFluoroAlkane Sulfonate	F5S-PFAS
PentaFluoroSulfide perfluorohexane sulfonate	F5S-PFHxS	C6HO3S2F17	PentaFluoroSulfide-PerFluoroAlkane Sulfonate	F5S-PFAS
PentaFluoroSulfide perfluoroheptane sulfonate	F5S-PFHpS	C7HO3S2F19	PentaFluoroSulfide-PerFluoroAlkane Sulfonate	F5S-PFAS
PentaFluoroSulfide perfluorooctane sulfonate	F5S-PFOS	C8HO3S2F21	PentaFluoroSulfide-PerFluoroAlkane Sulfonate	F5S-PFAS
PentaFluoroSulfide perfluorononane sulfonate	F5S-PFNS	C9HO3S2F23	PentaFluoroSulfide-PerFluoroAlkane Sulfonate	F5S-PFAS
PentaFluoroSulfide perfluorodecane sulfonate	F5S-PFDS	C10HO3S2F25	PentaFluoroSulfide-PerFluoroAlkane Sulfonate	F5S-PFAS
PentaFluoroSulfide perfluoroundecane sulfonate	F5S-PFUdS	C11HO3S2F27	PentaFluoroSulfide-PerFluoroAlkane Sulfonate	F5S-PFAS
PentaFluoroSulfide perfluorododecane sulfonate	F5S-PFDoS	C12HO3S2F29	PentaFluoroSulfide-PerFluoroAlkane Sulfonate	F5S-PFAS
PentaFluoroSulfide perfluorotridecane sulfonate	F5S-PFTrDS	C13HO3S2F31	PentaFluoroSulfide-PerFluoroAlkane Sulfonate	F5S-PFAS
PentaFluoroSulfide perfluorotetradacane sulfonate	F5S-PFTeDS	C14HO3S2F33	PentaFluoroSulfide-PerFluoroAlkane Sulfonate	F5S-PFAS
Hydrido-PerFluoroEthane Sulfonate	H-PFEtS	C2H2O3SF4	Hydrido-PerFluoroAlkane Sulfonate	H-PFAS
Hydrido-PerFluoroPropane Sulfonate	H-PFPrS	C3H2O3SF6	Hydrido-PerFluoroAlkane Sulfonate	H-PFAS
Hydrido-PerFluoroButane Sulfonate	H-PFBS	C4H2O3SF8	Hydrido-PerFluoroAlkane Sulfonate	H-PFAS
Hydrido-PerFluoroPentane Sulfonate	H-PFPeS	C5H2O3SF10	Hydrido-PerFluoroAlkane Sulfonate	H-PFAS
Hydrido-PerFluoroHexane Sulfonate	H-PFHxS	C6H2O3SF12	Hydrido-PerFluoroAlkane Sulfonate	H-PFAS
Hydrido-PerFluoroHeptane Sulfonate	H-PFHpS	C7H2O3SF14	Hydrido-PerFluoroAlkane Sulfonate	H-PFAS
Hydrido-PerFluoroOctane Sulfonate	H-PFOS	C8H2O3SF16	Hydrido-PerFluoroAlkane Sulfonate	H-PFAS
Hydrido-PerFluoroNonane Sulfonate	H-PFNS	C9H2O3SF18	Hydrido-PerFluoroAlkane Sulfonate	H-PFAS
Hydrido-PerFluoroDecane Sulfonate	H-PFDS	C10H2O3SF20	Hydrido-PerFluoroAlkane Sulfonate	H-PFAS
Hydrido-PerFluoroUndecane Sulfonate	H-PFUdS	C11H2O3SF22	Hydrido-PerFluoroAlkane Sulfonate	H-PFAS
Hydrido-PerFluoroDodecane Sulfonate	H-PFDoS	C12H2O3SF24	Hydrido-PerFluoroAlkane Sulfonate	H-PFAS
Hydrido-PerFluoroTridecane Sulfonate	H-PFTrDS	C13H2O3SF26	Hydrido-PerFluoroAlkane Sulfonate	H-PFAS
Hydrido-PerFluoroTetradecane Sulfonate	H-PFTeDS	C14H2O3SF28	Hydrido-PerFluoroAlkane Sulfonate	H-PFAS
Keto-perfluoropropane sulfonate	K-PFPrS	C3HO4SF5	Keto-PerFluoroAlkaneSulfonate	K-PFAS
Keto-perfluorobutane sulfonate	K-PFBS	C4HO4SF7	Keto-PerFluoroAlkaneSulfonate	K-PFAS
Keto-perfluoropentane sulfonate	K-PFPeS	C5HO4SF9	Keto-PerFluoroAlkaneSulfonate	K-PFAS
Keto-perfluorohexane sulfonate	K-PFHxS	C6HO4SF11	Keto-PerFluoroAlkaneSulfonate	K-PFAS
Keto-perfluoroheptane sulfonate	K-PFHpS	C7HO4SF13	Keto-PerFluoroAlkaneSulfonate	K-PFAS
Keto-perfluorooctane sulfonate	K-PFOS	C8HO4SF15	Keto-PerFluoroAlkaneSulfonate	K-PFAS
Keto-perfluorononane sulfonate	K-PFNS	C9HO4SF17	Keto-PerFluoroAlkaneSulfonate	K-PFAS
Keto-perfluorodecane sulfonate	K-PFDS	C10HO4SF19	Keto-PerFluoroAlkaneSulfonate	K-PFAS
Keto-perfluoroundecane sulfonate	K-PFUdS	C11HO4SF21	Keto-PerFluoroAlkaneSulfonate	K-PFAS
Keto-perfluorododecane sulfonate	K-PFDoS	C12HO4SF23	Keto-PerFluoroAlkaneSulfonate	K-PFAS
Keto-perfluorotridecane sulfonate	K-PFTrDS	C13HO4SF25	Keto-PerFluoroAlkaneSulfonate	K-PFAS
Keto-perfluorotetradecane sulfonate	K-PFTeDS	C14HO4SF27	Keto-PerFluoroAlkaneSulfonate	K-PFAS
Oxa-perfluoropropane sulfonate	O-PFPrS	C2HO4SF5	Oxa-PerFluoroAlkaneSulfonate	O-PFAS
Oxa-perfluorobutane sulfonate	O-PFBS	C3HO4SF7	Oxa-PerFluoroAlkaneSulfonate	O-PFAS

Oxa-perfluoropentane sulfonate	O-PFPeS	C4HO4SF9	Oxa-PerFluoroAlkaneSulfonate	O-PFAS
Oxa-perfluorohexane sulfonate	O-PFHxS	C5HO4SF11	Oxa-PerFluoroAlkaneSulfonate	O-PFAS
Oxa-perfluoroheptane sulfonate	O-PFHpS	C6HO4SF13	Oxa-PerFluoroAlkaneSulfonate	O-PFAS
Oxa-perfluorooctane sulfonate	O-PFOS	C7HO4SF15	Oxa-PerFluoroAlkaneSulfonate	O-PFAS
Oxa-perfluorononane sulfonate	O-PFNS	C8HO4SF17	Oxa-PerFluoroAlkaneSulfonate	O-PFAS
Oxa-perfluorodecane sulfonate	O-PFDS	C9HO4SF19	Oxa-PerFluoroAlkaneSulfonate	O-PFAS
Oxa-perfluoroundecane sulfonate	O-PFUdS	C10HO4SF21	Oxa-PerFluoroAlkaneSulfonate	O-PFAS
Oxa-perfluorododecane sulfonate	O-PFDoS	C11HO4SF23	Oxa-PerFluoroAlkaneSulfonate	O-PFAS
Oxa-perfluorotridecane sulfonate	O-PFTrDS	C12HO4SF25	Oxa-PerFluoroAlkaneSulfonate	O-PFAS
Oxa-perfluorotetradacane sulfonate	O-PFTeDS	C13HO4SF27	Oxa-PerFluoroAlkaneSulfonate	O-PFAS
Oxa-perfluorotpentaecane sulfonate	O-PFPeDS	C14HO4SF29	Oxa-PerFluoroAlkaneSulfonate	O-PFAS
Oxa-perfluorohexadacane sulfonate	O-PFHxDS	C15HO4SF31	Oxa-PerFluoroAlkaneSulfonate	O-PFAS
perfluoro cyclohexane carboxylic acid	PFCHxCA	C7HO2F11	perfluoro cyclohexane carboxylic acid	PFCHxCA
perfluoro methyl cyclohexane carboxylic acid	PFMeCHxCA	C8HO2F13	perfluoro cyclohexane carboxylic acid	PFCHxCA
perfluoro ethyl cyclohexane carboxylic acid	PFEtCHxCA	C9HO2F15	perfluoro cyclohexane carboxylic acid	PFCHxCA
perfluoro propyl cyclohexane carboxylic acid	PFPrCHxCA	C10HO2F17	perfluoro cyclohexane carboxylic acid	PFCHxCA
perfluoro butyl cyclohexane carboxylic acid	PFBCHxCA	C11HO2F19	perfluoro cyclohexane carboxylic acid	PFCHxCA
perfluoro pentyl cyclohexane carboxylic acid	PFPeCHxCA	C12HO2F21	perfluoro cyclohexane carboxylic acid	PFCHxCA
perfluoro hexyl cyclohexane carboxylic acid	PFHxCHxCA	C13HO2F23	perfluoro cyclohexane carboxylic acid	PFCHxCA
perfluoro cyclopentane carboxylic acid	PFCPeCA	C6HO2F9	perfluoro cyclopentane carboxylic acid	PFCPeCA
perfluoro methyl cyclopentane carboxylic acid	PFMeCPeCA	C7HO2F11	perfluoro cyclopentane carboxylic acid	PFCPeCA
perfluoro ethyl cyclopentane carboxylic acid	PFEtCPeCA	C8HO2F13	perfluoro cyclopentane carboxylic acid	PFCPeCA
perfluoro propyl cyclopentane carboxylic acid	PFPrCPeCA	C9HO2F15	perfluoro cyclopentane carboxylic acid	PFCPeCA
perfluoro butyl cyclopentane carboxylic acid	PFBCPeCA	C10HO2F17	perfluoro cyclopentane carboxylic acid	PFCPeCA
perfluoropropane unsaturated ether/alcohol (-1F, +1H)	H-UPFPr-O/OH	C3H2OF4	unsaturated perfluoroalkane ether/alcohol (-1F, +1H)	H-UPFA-O/OH
perfluorobutane unsaturated ether/alcohol (-1F, +1H)	H-UPFB-O/OH	C4H2OF6	unsaturated perfluoroalkane ether/alcohol (-1F, +1H)	H-UPFA-O/OH
perfluoropentane unsaturated ether/alcohol (-1F, +1H)	H-UPFPe-O/OH	C5H2OF8	unsaturated perfluoroalkane ether/alcohol (-1F, +1H)	H-UPFA-O/OH
perfluorohexane unsaturated ether/alcohol (-1F, +1H)	H-UPFHx-O/OH	C6H2OF10	unsaturated perfluoroalkane ether/alcohol (-1F, +1H)	H-UPFA-O/OH
perfluoroheptane unsaturated ether/alcohol (-1F, +1H)	H-UPFHp-O/OH	C7H2OF12	unsaturated perfluoroalkane ether/alcohol (-1F, +1H)	H-UPFA-O/OH
perfluorooctane unsaturated ether/alcohol (-1F, +1H)	H-UPFO-O/OH	C8H2OF14	unsaturated perfluoroalkane ether/alcohol (-1F, +1H)	H-UPFA-O/OH
perfluorononane unsaturated ether/alcohol (-1F, +1H)	H-UPFN-O/OH	C9H2OF16	unsaturated perfluoroalkane ether/alcohol (-1F, +1H)	H-UPFA-O/OH
perfluorodecane unsaturated ether/alcohol (-1F, +1H)	H-UPFD-O/OH	C10H2OF18	unsaturated perfluoroalkane ether/alcohol (-1F, +1H)	H-UPFA-O/OH
perfluoroundecane unsaturated ether/alcohol (-1F, +1H)	H-UPFUd-O/OH	C11H2OF20	unsaturated perfluoroalkane ether/alcohol (-1F, +1H)	H-UPFA-O/OH
perfluoroethane unsaturated chlorinated ether/alcohol (-1F, +1Cl)	Cl-UPFEt-O/OH	C2HOClF2	unsaturated chlorinated ether/alcohol (-1F, +1Cl)	Cl-UPFA-O/OH
perfluoropropane unsaturated chlorinated ether/alcohol (-1F, +1Cl)	Cl-UPFPr-O/OH	C3HOClF4	unsaturated chlorinated ether/alcohol (-1F, +1Cl)	Cl-UPFA-O/OH
perfluorobutane unsaturated chlorinated ether/alcohol (-1F, +1Cl)	Cl-UPFB-O/OH	C4HOClF6	unsaturated chlorinated ether/alcohol (-1F, +1Cl)	Cl-UPFA-O/OH
perfluoropentane unsaturated chlorinated ether/alcohol (-1F, +1Cl)	Cl-PFPe-O/OH	C5HOClF8	unsaturated chlorinated ether/alcohol (-1F, +1Cl)	Cl-UPFA-O/OH

perfluorohexane unsaturated chlorinated ether/alcohol (-1F, +1Cl)	Cl-PFHx-O/OH	C6HOClF10	unsaturated chlorinated ether/alcohol (-1F, +1Cl)	Cl-UPFA-O/OH
perfluoroheptane unsaturated chlorinated ether/alcohol (-1F, +1Cl)	Cl-PFHp-O/OH	C7HOClF12	unsaturated chlorinated ether/alcohol (-1F, +1Cl)	Cl-UPFA-O/OH
perfluorooctane unsaturated chlorinated ether/alcohol (-1F, +1Cl)	Cl-PFO-O/OH	C8HOClF14	unsaturated chlorinated ether/alcohol (-1F, +1Cl)	Cl-UPFA-O/OH
perfluorononane unsaturated chlorinated ether/alcohol (-1F, +1Cl)	Cl-PFN-O/OH	C9HOClF16	unsaturated chlorinated ether/alcohol (-1F, +1Cl)	Cl-UPFA-O/OH
perfluorodecane unsaturated chlorinated ether/alcohol (-1F, +1Cl)	Cl-PFD-O/OH	C10HOClF18	unsaturated chlorinated ether/alcohol (-1F, +1Cl)	Cl-UPFA-O/OH
Oxa-Unsaturated-PerFluoroHexanoic Acid	O-U-PFHxA	C5HO3F7	Oxa-Unsaturated-PerFluoroAlkanoic Acid	O-U-PFAA
Oxa-Unsaturated-PerFluoroHeptanoic Acid	O-U-PFHpA	C6HO3F9	Oxa-Unsaturated-PerFluoroAlkanoic Acid	O-U-PFAA
Oxa-Unsaturated-PerFluoroOctanoic Acid	O-U-PFOA	C7HO3F11	Oxa-Unsaturated-PerFluoroAlkanoic Acid	O-U-PFAA
Oxa-Unsaturated-PerFluoroNonanoic Acid	O-U-PFNA	C8HO3F13	Oxa-Unsaturated-PerFluoroAlkanoic Acid	O-U-PFAA
Oxa-Unsaturated-PerFluoroDecanoic Acid	O-U-PFDA	C9HO3F15	Oxa-Unsaturated-PerFluoroAlkanoic Acid	O-U-PFAA
Oxa-Unsaturated-PerFluoroUndecanoic Acid	O-U-PFUdA	C10HO3F17	Oxa-Unsaturated-PerFluoroAlkanoic Acid	O-U-PFAA
Oxa-Unsaturated-PerFluoroDodecanoic Acid	O-U-PFDoA	C11HO3F19	Oxa-Unsaturated-PerFluoroAlkanoic Acid	O-U-PFAA
Oxa-Unsaturated-PerFluoroTridecanoic Acid	O-U-PFTrDA	C12HO3F21	Oxa-Unsaturated-PerFluoroAlkanoic Acid	O-U-PFAA
Oxa-Unsaturated-PerFluoroTetradecanoic Acid	O-U-PFTeDA	C13HO3F23	Oxa-Unsaturated-PerFluoroAlkanoic Acid	O-U-PFAA
Oxa-Unsaturated-PerFluoroPentadecanoic Acid	O-U-PFPeDA	C14HO3F25	Oxa-Unsaturated-PerFluoroAlkanoic Acid	O-U-PFAA
Oxa-Unsaturated-PerFluoroHexadecanoic Acid	O-U-PFHxDA	C15HO3F27	Oxa-Unsaturated-PerFluoroAlkanoic Acid	O-U-PFAA
Oxa-Unsaturated-PerFluoroHeptadecanoic Acid	O-U-PFHpDA	C16HO3F29	Oxa-Unsaturated-PerFluoroAlkanoic Acid	O-U-PFAA
Oxa-Unsaturated-PerFluoroOctadecanoic Acid	O-U-PFODA	C17HO3F31	Oxa-Unsaturated-PerFluoroAlkanoic Acid	O-U-PFAA
perfluoro cyclohexane sulfonate	PFCHxS	C6HO3SF11	cyclohexane sulfonate	CHxS
perfluoro methyl cyclohexane sulfonate	PFMeCHxS	C7HO3SF13	cyclohexane sulfonate	CHxS
perfluoro ethyl cyclohexane sulfonate	PFEtCHxS	C8HO3SF15	cyclohexane sulfonate	CHxS
perfluoro propyl cyclohexane sulfonate	PFPrCHxS	C9HO3SF17	cyclohexane sulfonate	CHxS
perfluoro butyl cyclohexane sulfonate	PFBCHxS	C10HO3SF19	cyclohexane sulfonate	CHxS
perfluoro pentyl cyclohexane sulfonate	PFPeCHxS	C11HO3SF21	cyclohexane sulfonate	CHxS
perfluoro hexyl cyclohexane sulfonate	PFHxCHxS	C12HO3SF23	cyclohexane sulfonate	CHxS
perfluoro cyclopentane sulfonic acid	PFCPeS	C5HO3SF9	perfluoro cyclopentane sulfonic acid	PFCPeS
perfluoro methyl cyclopentane sulfonic acid	PFMeCPeS	C6HO3SF11	perfluoro cyclopentane sulfonic acid	PFCPeS
perfluoro ethyl cyclopentane sulfonic acid	PFEtCPeS	C7HO3SF13	perfluoro cyclopentane sulfonic acid	PFCPeS
perfluoro propyl cyclopentane sulfonic acid	PFPrCPeS	C8HO3SF15	perfluoro cyclopentane sulfonic acid	PFCPeS
perfluoro butyl cyclopentane sulfonic acid	PFBCPeS	C9HO3SF17	perfluoro cyclopentane sulfonic acid	PFCPeS
Hydrido-Unsaturated PerFluoroPentane Sulfonate	H-UPFPeS	C5H2O3SF8	Hydrido-Unsaturated PerFluoroAlkane Sulfonate	H-UPFAS
Hydrido-Unsaturated PerFluoroHexane Sulfonate	H-UPFHxS	C6H2O3SF10	Hydrido-Unsaturated PerFluoroAlkane Sulfonate	H-UPFAS
Hydrido-Unsaturated PerFluoroHeptane Sulfonate	H-UPFHpS	C7H2O3SF12	Hydrido-Unsaturated PerFluoroAlkane Sulfonate	H-UPFAS
Hydrido-Unsaturated PerFluoroOctane Sulfonate	H-UPFOS	C8H2O3SF14	Hydrido-Unsaturated PerFluoroAlkane Sulfonate	H-UPFAS
Hydrido-Unsaturated PerFluoroNonane Sulfonate	H-UPFNS	C9H2O3SF16	Hydrido-Unsaturated PerFluoroAlkane Sulfonate	H-UPFAS
Hydrido-Unsaturated PerFluoroDecane Sulfonate	H-UPFDS	C10H2O3SF18	Hydrido-Unsaturated PerFluoroAlkane Sulfonate	H-UPFAS
Hydrido-Unsaturated PerFluoroUndecane Sulfonate	H-UPFUdS	C11H2O3SF20	Hydrido-Unsaturated PerFluoroAlkane Sulfonate	H-UPFAS

Hydrido-Unsaturated PerFluoroDodecane Sulfonate	H-UPFDoS	C12H2O3SF22	Hydrido-Unsaturated PerFluoroAlkane Sulfonate	H-UPFAS
Hydrido-Unsaturated PerFluoroTridecane Sulfonate	H-UPFTrDS	C13H2O3SF24	Hydrido-Unsaturated PerFluoroAlkane Sulfonate	H-UPFAS
Hydrido-Unsaturated PerFluoroTetradecane Sulfonate	H-UPFTeDS	C14H2O3SF26	Hydrido-Unsaturated PerFluoroAlkane Sulfonate	H-UPFAS
Hydrido-Unsaturated PerFluoroPentadecane Sulfonate	H-UPFPeDS	C15H2O3SF28	Hydrido-Unsaturated PerFluoroAlkane Sulfonate	H-UPFAS
Hydrido-Unsaturated PerFluoroHexadecane Sulfonate	H-UPFHxDS	C16H2O3SF30	Hydrido-Unsaturated PerFluoroAlkane Sulfonate	H-UPFAS
Unsaturated perfluorobutane sulfonate	UPFBS	C4HO3SF7	Unsaturated PerFluoroAlkane Sulfonate	UPFAS
Unsaturated perfluoropentane sulfonate	UPFPeS	C5HO3SF9	Unsaturated PerFluoroAlkane Sulfonate	UPFAS
Unsaturated perfluorohexane sulfonate	UPFHxS	C6HO3SF11	Unsaturated PerFluoroAlkane Sulfonate	UPFAS
Unsaturated perfluoroheptane sulfonate	UPFHpS	C7HO3SF13	Unsaturated PerFluoroAlkane Sulfonate	UPFAS
Unsaturated perfluorooctane sulfonate	UPFOS	C8HO3SF15	Unsaturated PerFluoroAlkane Sulfonate	UPFAS
Unsaturated perfluorononane sulfonate	UPFNS	C9HO3SF17	Unsaturated PerFluoroAlkane Sulfonate	UPFAS
Unsaturated perfluorodecane sulfonate	UPFDS	C10HO3SF19	Unsaturated PerFluoroAlkane Sulfonate	UPFAS
Unsaturated perfluoroundecane sulfonate	UPFUdS	C11HO3SF21	Unsaturated PerFluoroAlkane Sulfonate	UPFAS
Unsaturated perfluorododecane sulfonate	UPFDoS	C12HO3SF23	Unsaturated PerFluoroAlkane Sulfonate	UPFAS
Unsaturated perfluorotridecane sulfonate	UPFTrDS	C13HO3SF25	Unsaturated PerFluoroAlkane Sulfonate	UPFAS
Unsaturated perfluorotetradecane sulfonate	UPFTeDS	C14HO3SF27	Unsaturated PerFluoroAlkane Sulfonate	UPFAS
Unsaturated perfluoropentadecane sulfonate	UPFPeDS	C15HO3SF29	Unsaturated PerFluoroAlkane Sulfonate	UPFAS
perfluoromethane sulfinate	PFMeSi	C1HO2SF3	PerFluoroAlkaneSulfinate	PFASi
perfluoroethane sulfinate	PFEtSi	C2HO2SF5	PerFluoroAlkaneSulfinate	PFASi
perfluoropropane sulfinate	PFPrSi	C3HO2SF7	PerFluoroAlkaneSulfinate	PFASi
perfluorobutane sulfinate	PFBSi	C4HO2SF9	PerFluoroAlkaneSulfinate	PFASi
perfluoropentane sulfinate	PFPeSi	C5HO2SF11	PerFluoroAlkaneSulfinate	PFASi
perfluorohexane sulfinate	PFHxSi	C6HO2SF13	PerFluoroAlkaneSulfinate	PFASi
perfluoroheptane sulfinate	PFHpSi	C7HO2SF15	PerFluoroAlkaneSulfinate	PFASi
perfluorooctane sulfinate	PFOSi	C8HO2SF17	PerFluoroAlkaneSulfinate	PFASi
perfluorononane sulfinate	PFNSi	C9HO2SF19	PerFluoroAlkaneSulfinate	PFASi
perfluorodecane sulfinate	PFDSi	C10HO2SF21	PerFluoroAlkaneSulfinate	PFASi
perfluoroundecane sulfinate	PFUdSi	C11HO2SF23	PerFluoroAlkaneSulfinate	PFASi
perfluorododecane sulfinate	PFDoSi	C12HO2SF25	PerFluoroAlkaneSulfinate	PFASi
perfluoromethane sulfate	PFMe-OS	C1HO4SF3	perfluoroalkane sulfate	PFA-OS
perfluoroethane sulfate	PFEt-OS	C2HO4SF5	perfluoroalkane sulfate	PFA-OS
perfluoropropane sulfate	PFPr-OS	C3HO4SF7	perfluoroalkane sulfate	PFA-OS
perfluorobutane sulfate	PFB-OS	C4HO4SF9	perfluoroalkane sulfate	PFA-OS
perfluoropentane sulfate	PFPe-OS	C5HO4SF11	perfluoroalkane sulfate	PFA-OS
perfluorohexane sulfate	PFHx-OS	C6HO4SF13	perfluoroalkane sulfate	PFA-OS
perfluoroheptane sulfate	PFHp-OS	C7HO4SF15	perfluoroalkane sulfate	PFA-OS
perfluorooctane sulfate	PFO-OS	C8HO4SF17	perfluoroalkane sulfate	PFA-OS

perfluorononane sulfate	PFN-OS	C9HO4SF19	perfluoroalkane sulfate	PFA-OS
perfluorodecane sulfate	PFD-OS	C10HO4SF21	perfluoroalkane sulfate	PFA-OS
perfluoroundecane sulfate	PFUd-OS	C11HO4SF23	perfluoroalkane sulfate	PFA-OS
perfluorododecane sulfate	PFDo-OS	C12HO4SF25	perfluoroalkane sulfate	PFA-OS
perfluorotridecane sulfate	PFTrD-OS	C13HO4SF27	perfluoroalkane sulfate	PFA-OS
perfluorotetradacane sulfate	PFTeD-OS	C14HO4SF29	perfluoroalkane sulfate	PFA-OS
pentahydrido-fluoropropane sulfate	PeH-FPrOS	C3H2O4SF6	pentahydrido-fluoroalkane sulfate	PeH-FAOS
pentahydrido-fluoropentane sulfate	PeH-FPeOS	C5H4O4SF8	pentahydrido-fluoroalkane sulfate	PeH-FAOS
pentahydrido-fluoroheptane sulfate	PeH-FHpOS	C7H6O4SF10	pentahydrido-fluoroalkane sulfate	PeH-FAOS
pentahydrido-fluorononane sulfate	PeH-FNOS	C9H8O4SF12	pentahydrido-fluoroalkane sulfate	PeH-FAOS
pentahydrido-fluoroundecane sulfate	PeH-FUdOS	C11H10O4SF14	pentahydrido-fluoroalkane sulfate	PeH-FAOS
pentahydrido-fluorotridecane sulfate	PeH-FTrDOS	C13H12O4SF16	pentahydrido-fluoroalkane sulfate	PeH-FAOS
pentahydriso-fluoropentadecane sulfate	PeH-FPeDOS	C15H14O4SF18	pentahydrido-fluoroalkane sulfate	PeH-FAOS
perfluoromethane sulfonamide	FMeSA	CH2O2NSF3	perFluoroAlkane SulfonAmide	FASA
perfluoroethane sulfonamide	FEtSA	C2H2O2NSF5	perFluoroAlkane SulfonAmide	FASA
perfluoropropane sulfonamide	FPrSA	C3H2O2NSF7	perFluoroAlkane SulfonAmide	FASA
perfluorobutane sulfonamide	FBSA	C4H2O2NSF9	perFluoroAlkane SulfonAmide	FASA
perfluoropentane sulfonamide	FPeSA	C5H2O2NSF11	perFluoroAlkane SulfonAmide	FASA
perfluorohexane sulfonamide	FHxSA	C6H2O2NSF13	perFluoroAlkane SulfonAmide	FASA
perfluoroheptane sulfonamide	FHpSA	C7H2O2NSF15	perFluoroAlkane SulfonAmide	FASA
perfluorooctane sulfonamide	FOSA	C8H2O2NSF17	perFluoroAlkane SulfonAmide	FASA
perfluorononane sulfonamide	FNSA	C9H2O2NSF19	perFluoroAlkane SulfonAmide	FASA
perfluorodecane sulfonamide	FDSA	C10H2O2NSF21	perFluoroAlkane SulfonAmide	FASA
perfluoroundecane sulfonamide	FUdSA	C11H2O2NSF23	perFluoroAlkane SulfonAmide	FASA
perfluorododecane sulfonamide	FDoSA	C12H2O2NSF25	perFluoroAlkane SulfonAmide	FASA
perfluorotridecane sulfonamide	FTrDSA	C13H2O2NSF27	perFluoroAlkane SulfonAmide	FASA
perfluorotetradacane sulfonamide	FTeDSA	C14H2O2NSF29	perFluoroAlkane SulfonAmide	FASA
N-methyl perfluoro-1-methane sulfonamide	MeFMeSA	C2H4O2NSF3	N-methyl perfluoroalkane sulfonamide	MeFASA
N-methyl perfluoro-1-ethane sulfonamide	MeFEtSA	C3H4O2NSF5	N-methyl perfluoroalkane sulfonamide	MeFASA
N-methyl perfluoro-1-propane sulfonamide	MeFPrSA	C4H4O2NSF7	N-methyl perfluoroalkane sulfonamide	MeFASA
N-methyl perfluoro-1-butane sulfonamide	MeFBSA	C5H4O2NSF9	N-methyl perfluoroalkane sulfonamide	MeFASA
N-methyl perfluoro-1-pentane sulfonamide	MeFPeSA	C6H4O2NSF11	N-methyl perfluoroalkane sulfonamide	MeFASA
N-methyl perfluoro-1-hexane sulfonamide	MeFHxSA	C7H4O2NSF13	N-methyl perfluoroalkane sulfonamide	MeFASA
N-methyl perfluoro-1-heptane sulfonamide	MeFHpSA	C8H4O2NSF15	N-methyl perfluoroalkane sulfonamide	MeFASA
N-methyl perfluoro-1-octane sulfonamide	MeFOSA	C9H4O2NSF17	N-methyl perfluoroalkane sulfonamide	MeFASA
N-methyl perfluoro-1-nonane sulfonamide	MeFNSA	C10H4O2NSF19	N-methyl perfluoroalkane sulfonamide	MeFASA
N-methyl perfluoro-1-decane sulfonamide	MeFDSA	C11H4O2NSF21	N-methyl perfluoroalkane sulfonamide	MeFASA

N-methyl perfluoro-1-undecane sulfonamide	MeFUdSA	C12H4O2NSF23	N-methyl perfluoroalkane sulfonamide	MeFASA
N-methyl perfluoro-1-dodecane sulfonamide	MeFDoSA	C13H4O2NSF25	N-methyl perfluoroalkane sulfonamide	MeFASA
N-methyl perfluoro-1-tridecane sulfonamide	MeFTrDSA	C14H4O2NSF27	N-methyl perfluoroalkane sulfonamide	MeFASA
N-methyl perfluoro-1-tetradecane sulfonamide	MeFTeDSA	C15H4O2NSF29	N-methyl perfluoroalkane sulfonamide	MeFASA
N-ethylperfluoro-1-methane sulfonamide	EtFMeSA	C3H6O2NSF3	N-ethylperfluoro-1-alkanesulfonamide	EtFASA
N-ethylperfluoro-1-ethane sulfonamide	EtFEtSA	C4H6O2NSF5	N-ethylperfluoro-1-alkanesulfonamide	EtFASA
N-ethylperfluoro-1-propane sulfonamide	EtFPrSA	C5H6O2NSF7	N-ethylperfluoro-1-alkanesulfonamide	EtFASA
N-ethylperfluoro-1-butane sulfonamide	EtFBSA	C6H6O2NSF9	N-ethylperfluoro-1-alkanesulfonamide	EtFASA
N-ethylperfluoro-1-pentane sulfonamide	EtFPeSA	C7H6O2NSF11	N-ethylperfluoro-1-alkanesulfonamide	EtFASA
N-ethylperfluoro-1-hexane sulfonamide	EtFHxSA	C8H6O2NSF13	N-ethylperfluoro-1-alkanesulfonamide	EtFASA
N-ethylperfluoro-1-heptane sulfonamide	EtFHpSA	C9H6O2NSF15	N-ethylperfluoro-1-alkanesulfonamide	EtFASA
N-ethylperfluoro-1-octane sulfonamide	EtFOSA	C10H6O2NSF17	N-ethylperfluoro-1-alkanesulfonamide	EtFASA
N-ethylperfluoro-1-nonane sulfonamide	EtFNSA	C11H6O2NSF19	N-ethylperfluoro-1-alkanesulfonamide	EtFASA
N-ethylperfluoro-1-decane sulfonamide	EtFDSA	C12H6O2NSF21	N-ethylperfluoro-1-alkanesulfonamide	EtFASA
N-ethylperfluoro-1-undecane sulfonamide	EtFUdSA	C13H6O2NSF23	N-ethylperfluoro-1-alkanesulfonamide	EtFASA
N-ethylperfluoro-1-dodecane sulfonamide	EtFDoSA	C14H6O2NSF25	N-ethylperfluoro-1-alkanesulfonamide	EtFASA
N-ethylperfluoro-1-tridecane sulfonamide	EtFTrDSA	C15H6O2NSF27	N-ethylperfluoro-1-alkanesulfonamide	EtFASA
N-ethylperfluoro-1-tetradecane sulfonamide	EtFTeDSA	C16H6O2NSF29	N-ethylperfluoro-1-alkanesulfonamide	EtFASA
Perfluoromethane sulfonamido acetic acid	FMeSAA	C3H4O4NSF3	perfluoroAlkaneSulfonamidoAcetic Acid	FASAA
Perfluoroethane sulfonamido acetic acid	FEtSAA	C4H4O4NSF5	perfluoroAlkaneSulfonamidoAcetic Acid	FASAA
Perfluoropropane sulfonamido acetic acid	FPrSAA	C5H4O4NSF7	perfluoroAlkaneSulfonamidoAcetic Acid	FASAA
Perfluorobutane sulfonamido acetic acid	FBSAA	C6H4O4NSF9	perfluoroAlkaneSulfonamidoAcetic Acid	FASAA
Perfluoropentane sulfonamido acetic acid	FPeSAA	C7H4O4NSF11	perfluoroAlkaneSulfonamidoAcetic Acid	FASAA
Perfluorohexane sulfonamido acetic acid	FHxSAA	C8H4O4NSF13	perfluoroAlkaneSulfonamidoAcetic Acid	FASAA
Perfluoroheptane sulfonamido acetic acid	FHpSAA	C9H4O4NSF15	perfluoroAlkaneSulfonamidoAcetic Acid	FASAA
Perfluorooctane sulfonamido acetic acid	FOSAA	C10H4O4NSF17	perfluoroAlkaneSulfonamidoAcetic Acid	FASAA
Perfluorononane sulfonamido acetic acid	FNSAA	C11H4O4NSF19	perfluoroAlkaneSulfonamidoAcetic Acid	FASAA
Perfluorodecane sulfonamido acetic acid	FDSAA	C12H4O4NSF21	perfluoroAlkaneSulfonamidoAcetic Acid	FASAA
Perfluoroundecane sulfonamido acetic acid	FUdSAA	C13H4O4NSF23	perfluoroAlkaneSulfonamidoAcetic Acid	FASAA
Perfluorododecane sulfonamido acetic acid	FDoSAA	C14H4O4NSF25	perfluoroAlkaneSulfonamidoAcetic Acid	FASAA
Perfluorotridecane sulfonamido acetic acid	FTrDSAA	C15H4O4NSF27	perfluoroAlkaneSulfonamidoAcetic Acid	FASAA
Perfluorotetradecane sulfonamido acetic acid	FTeDSAA	C16H4O4NSF29	perfluoroAlkaneSulfonamidoAcetic Acid	FASAA
N-methylperfluoromethane sulfonamido acetic acid	MeFMeSAA	C4H6O4NSF3	N-MethylperFluoroAlkaneSulfonamidoAcetic Acid	MeFASAA
N-methylperfluoroethane sulfonamido acetic acid	MeFEtSAA	C5H6O4NSF5	N-MethylperFluoroAlkaneSulfonamidoAcetic Acid	MeFASAA
N-methylperfluoropropane sulfonamido acetic acid	MeFPrAA	C6H6O4NSF7	N-MethylperFluoroAlkaneSulfonamidoAcetic Acid	MeFASAA
N-methylperfluorobutane sulfonamido acetic acid	MeFBSAA	C7H6O4NSF9	N-MethylperFluoroAlkaneSulfonamidoAcetic Acid	MeFASAA
N-methylperfluoropentane sulfonamido acetic acid	MeFPeSAA	C8H6O4NSF11	N-MethylperFluoroAlkaneSulfonamidoAcetic Acid	MeFASAA

N-methylperfluorohexane sulfonamido acetic acid	MeFHxSAA	C9H6O4NSF13	N-MethylperFluoroAlkaneSulfonamidoAcetic Acid	MeFASAA
N-methylperfluoroheptane sulfonamido acetic acid	MeFHpSAA	C10H6O4NSF15	N-MethylperFluoroAlkaneSulfonamidoAcetic Acid	MeFASAA
N-methylperfluorooctane sulfonamido acetic acid	MeFOSAA	C11H6O4NSF17	N-MethylperFluoroAlkaneSulfonamidoAcetic Acid	MeFASAA
N-methylperfluorononane sulfonamido acetic acid	MeFNSAA	C12H6O4NSF19	N-MethylperFluoroAlkaneSulfonamidoAcetic Acid	MeFASAA
N-methylperfluorodecane sulfonamido acetic acid	MeFDSAA	C13H6O4NSF21	N-MethylperFluoroAlkaneSulfonamidoAcetic Acid	MeFASAA
N-methylperfluoroundecane sulfonamido acetic acid	MeFUdSAA	C14H6O4NSF23	N-MethylperFluoroAlkaneSulfonamidoAcetic Acid	MeFASAA
N-methylperfluorododecane sulfonamido acetic acid	MeFDoSAA	C15H6O4NSF25	N-MethylperFluoroAlkaneSulfonamidoAcetic Acid	MeFASAA
N-methylperfluorotridecane sulfonamido acetic acid	MeFTrDSAA	C16H6O4NSF27	N-MethylperFluoroAlkaneSulfonamidoAcetic Acid	MeFASAA
N-methylperfluorotetradecane sulfonamido acetic acid	MeFTeDSAA	C17H6O4NSF29	N-MethylperFluoroAlkaneSulfonamidoAcetic Acid	MeFASAA
N-ethylperfluoromethane sulfonamido acetic acid	EtFMeSAA	C5H8O4NSF3	N-EthylperFluoroAlkaneSulfonamidoAcetic Acid	EtFASAA
N-ethylperfluoroethane sulfonamido acetic acid	EtFEtSAA	C6H8O4NSF5	N-EthylperFluoroAlkaneSulfonamidoAcetic Acid	EtFASAA
N-ethylperfluoropropane sulfonamido acetic acid	EtFPrSAA	C7H8O4NSF7	N-EthylperFluoroAlkaneSulfonamidoAcetic Acid	EtFASAA
N-ethylperfluorobutane sulfonamido acetic acid	EtFBSAA	C8H8O4NSF9	N-EthylperFluoroAlkaneSulfonamidoAcetic Acid	EtFASAA
N-ethylperfluoropentane sulfonamido acetic acid	EtFPeSAA	C9H8O4NSF11	N-EthylperFluoroAlkaneSulfonamidoAcetic Acid	EtFASAA
N-ethylperfluorohexane sulfonamido acetic acid	EtFHxSAA	C10H8O4NSF13	N-EthylperFluoroAlkaneSulfonamidoAcetic Acid	EtFASAA
N-ethylperfluoroheptane sulfonamido acetic acid	EtFHpSAA	C11H8O4NSF15	N-EthylperFluoroAlkaneSulfonamidoAcetic Acid	EtFASAA
N-ethylperfluorooctane sulfonamido acetic acid	EtFOSAA	C12H8O4NSF17	N-EthylperFluoroAlkaneSulfonamidoAcetic Acid	EtFASAA
N-ethylperfluorononane sulfonamido acetic acid	EtFNSAA	C13H8O4NSF19	N-EthylperFluoroAlkaneSulfonamidoAcetic Acid	EtFASAA
N-ethylperfluorodecane sulfonamido acetic acid	EtFDSAA	C14H8O4NSF21	N-EthylperFluoroAlkaneSulfonamidoAcetic Acid	EtFASAA
N-ethylperfluoroundecane sulfonamido acetic acid	EtFUdSAA	C15H8O4NSF23	N-EthylperFluoroAlkaneSulfonamidoAcetic Acid	EtFASAA
N-ethylperfluorododecane sulfonamido acetic acid	EtFDoSAA	C16H8O4NSF25	N-EthylperFluoroAlkaneSulfonamidoAcetic Acid	EtFASAA
N-ethylperfluorotridecane sulfonamido acetic acid	EtFTrDSAA	C17H8O4NSF27	N-EthylperFluoroAlkaneSulfonamidoAcetic Acid	EtFASAA
N-ethylperfluorotetradecane sulfonamido acetic acid	EtFTeDSAA	C18H8O4NSF29	N-EthylperFluoroAlkaneSulfonamidoAcetic Acid	EtFASAA
N-dimethyl ammonio propyl perfluoromethane sulfonamide	AmPr-FMeSA	C6H13O2N2SF3	N-dimethyl ammonio propyl perfluoroalkane sulfonamide	AmPr-FASA
N-dimethyl ammonio propyl perfluoroethane sulfonamide	AmPr-FEtSA	C7H13O2N2SF5	N-dimethyl ammonio propyl perfluoroalkane sulfonamide	AmPr-FASA
N-dimethyl ammonio propyl perfluoropropane sulfonamide	AmPr-FPrSA	C8H13O2N2SF7	N-dimethyl ammonio propyl perfluoroalkane sulfonamide	AmPr-FASA
N-dimethyl ammonio propyl perfluorobutane sulfonamide	AmPr-FBSA	C9H13O2N2SF9	N-dimethyl ammonio propyl perfluoroalkane sulfonamide	AmPr-FASA
N-dimethyl ammonio propyl perfluoropentane sulfonamide	AmPr-FPeSA	C10H13O2N2SF11	N-dimethyl ammonio propyl perfluoroalkane sulfonamide	AmPr-FASA
N-dimethyl ammonio propyl perfluorohexane sulfonamide	AmPr-FHxSA	C11H13O2N2SF13	N-dimethyl ammonio propyl perfluoroalkane sulfonamide	AmPr-FASA
N-dimethyl ammonio propyl perfluoroheptane sulfonamide	AmPr-FHpSA	C12H13O2N2SF15	N-dimethyl ammonio propyl perfluoroalkane sulfonamide	AmPr-FASA
N-dimethyl ammonio propyl perfluorooctane sulfonamide	AmPr-FOSA	C13H13O2N2SF17	N-dimethyl ammonio propyl perfluoroalkane sulfonamide	AmPr-FASA

N-dimethyl ammonio propyl perfluorononane sulfonamide	AmPr-FNSA	C14H13O2N2SF19	N-dimethyl ammonio propyl perfluoroalkane sulfonamide	AmPr-FASA
N-dimethyl ammonio propyl perfluorodecane sulfonamide	AmPr-FDSA	C15H13O2N2SF21	N-dimethyl ammonio propyl perfluoroalkane sulfonamide	AmPr-FASA
N-dimethyl ammonio propyl perfluoroundecane sulfonamide	AmPr-FUdSA	C16H13O2N2SF23	N-dimethyl ammonio propyl perfluoroalkane sulfonamide	AmPr-FASA
N-dimethyl ammonio propyl perfluorododecane sulfonamide	AmPr-FDoSA	C17H13O2N2SF25	N-dimethyl ammonio propyl perfluoroalkane sulfonamide	AmPr-FASA
N-dimethyl ammonio propyl perfluorotridecane sulfonamide	AmPr-FTrDSA	C18H13O2N2SF27	N-dimethyl ammonio propyl perfluoroalkane sulfonamide	AmPr-FASA
N-dimethyl ammonio propyl perfluorotetradecane sulfonamide	AmPr-FTeDSA	C19H13O2N2SF29	N-dimethyl ammonio propyl perfluoroalkane sulfonamide	AmPr-FASA
N-dimethylammoniocarboxypropyl-perfluoromethane sulfonamide	Am-CPr-FMeSA	C7H13O4SN2F3	N-dimethylammoniocarboxypropyl-perfluoroalkane sulfonamide	Am-CPr-FASA
N-dimethylammoniocarboxypropyl-perfluoroethane sulfonamide	Am-CPr-FEtSA	C8H13O4SN2F5	N-dimethylammoniocarboxypropyl-perfluoroalkane sulfonamide	Am-CPr-FASA
N-dimethylammoniocarboxypropyl-perfluoropropane sulfonamide	Am-CPr-FPrSA	C9H13O4SN2F7	N-dimethylammoniocarboxypropyl-perfluoroalkane sulfonamide	Am-CPr-FASA
N-dimethylammoniocarboxypropyl-perfluorobutane sulfonamide	Am-CPr-FBSA	C10H13O4SN2F9	N-dimethylammoniocarboxypropyl-perfluoroalkane sulfonamide	Am-CPr-FASA
N-dimethylammoniocarboxypropyl-perfluoropentane sulfonamide	Am-CPr-FPeSA	C11H13O4SN2F11	N-dimethylammoniocarboxypropyl-perfluoroalkane sulfonamide	Am-CPr-FASA
N-dimethylammoniocarboxypropyl-perfluorohexane sulfonamide	Am-CPr-FHxSA	C12H13O4SN2F13	N-dimethylammoniocarboxypropyl-perfluoroalkane sulfonamide	Am-CPr-FASA
N-dimethylammoniocarboxypropyl-perfluoroheptane sulfonamide	Am-CPr-FHpSA	C13H13O4SN2F15	N-dimethylammoniocarboxypropyl-perfluoroalkane sulfonamide	Am-CPr-FASA
N-dimethylammoniocarboxypropyl-perfluorooctane sulfonamide	Am-CPr-FOSA	C14H13O4SN2F17	N-dimethylammoniocarboxypropyl-perfluoroalkane sulfonamide	Am-CPr-FASA
N-dimethylammoniocarboxypropyl-perfluorononane sulfonamide	Am-CPr-FNSA	C15H13O4SN2F19	N-dimethylammoniocarboxypropyl-perfluoroalkane sulfonamide	Am-CPr-FASA
N-dimethylammoniocarboxypropyl-perfluorodecane sulfonamide	Am-CPr-FDSA	C16H13O4SN2F21	N-dimethylammoniocarboxypropyl-perfluoroalkane sulfonamide	Am-CPr-FASA
N-dimethylammoniocarboxypropyl-perfluoroundecane sulfonamide	Am-CPr-FUdSA	C17H13O4SN2F23	N-dimethylammoniocarboxypropyl-perfluoroalkane sulfonamide	Am-CPr-FASA
N-dimethylammoniocarboxypropyl-perfluorododecane sulfonamide	Am-CPr-FDoSA	C18H13O4SN2F25	N-dimethylammoniocarboxypropyl-perfluoroalkane sulfonamide	Am-CPr-FASA
N-dimethyl ammonio propyl perfluoromethane sulfonamido propanoic acid	AmPr-FMeSA-PrA	C9H17O4N2SF3	N-dimethyl ammonio propyl perfluoralkane sulfonamido propanoic acid	AmPr-FASA-PrA
N-dimethyl ammonio propyl perfluoroethane sulfonamido propanoic acid	AmPr-FEtSA-PrA	C10H17O4N2SF5	N-dimethyl ammonio propyl perfluoralkane sulfonamido propanoic acid	AmPr-FASA-PrA
N-dimethyl ammonio propyl perfluoropropane sulfonamido propanoic acid	AmPr-FPrSA-PrA	C11H17O4N2SF7	N-dimethyl ammonio propyl perfluoralkane sulfonamido propanoic acid	AmPr-FASA-PrA

N-dimethyl ammonio propyl perfluorbutoane sulfonamido propanoic acid	AmPr-FBSA-PrA	C12H17O4N2SF9	N-dimethyl ammonio propyl perfluoralkane sulfonamido propanoic acid	AmPr-FASA-PrA
N-dimethyl ammonio propyl perfluoropentane sulfonamido propanoic acid	AmPr-FPeSA-PrA	C13H17O4N2SF11	N-dimethyl ammonio propyl perfluoralkane sulfonamido propanoic acid	AmPr-FASA-PrA
N-dimethyl ammonio propyl perfluorohexane sulfonamido propanoic acid	AmPr-FHxSA-PrA	C14H17O4N2SF13	N-dimethyl ammonio propyl perfluoralkane sulfonamido propanoic acid	AmPr-FASA-PrA
N-dimethyl ammonio propyl perfluoroheptane sulfonamido propanoic acid	AmPr-FHpSA-PrA	C15H17O4N2SF15	N-dimethyl ammonio propyl perfluoralkane sulfonamido propanoic acid	AmPr-FASA-PrA
N-dimethyl ammonio propyl perfluorooctane sulfonamido propanoic acid	AmPr-FOSA-PrA	C16H17O4N2SF17	N-dimethyl ammonio propyl perfluoralkane sulfonamido propanoic acid	AmPr-FASA-PrA
N-dimethyl ammonio propyl perfluorononane sulfonamido propanoic acid	AmPr-FNSA-PrA	C17H17O4N2SF19	N-dimethyl ammonio propyl perfluoralkane sulfonamido propanoic acid	AmPr-FASA-PrA
N-dimethyl ammonio propyl perfluorodecane sulfonamido propanoic acid	AmPr-FDSA-PrA	C18H17O4N2SF21	N-dimethyl ammonio propyl perfluoralkane sulfonamido propanoic acid	AmPr-FASA-PrA
N-dimethyl ammonio propyl perfluoroundecane sulfonamido propanoic acid	AmPr-FUdSA-PrA	C19H17O4N2SF23	N-dimethyl ammonio propyl perfluoralkane sulfonamido propanoic acid	AmPr-FASA-PrA
N-dimethyl ammonio propyl perfluorododecane sulfonamido propanoic acid	AmPr-FDoSA-PrA	C20H17O4N2SF25	N-dimethyl ammonio propyl perfluoralkane sulfonamido propanoic acid	AmPr-FASA-PrA
N-dimethyl ammonio propyl perfluorotridecane sulfonamido propanoic acid	AmPr-FTrDSA-PrA	C21H17O4N2SF27	N-dimethyl ammonio propyl perfluoralkane sulfonamido propanoic acid	AmPr-FASA-PrA
N-dimethyl ammonio propyl perfluorotetradecane sulfonamido propanoic acid	AmPr-FTeDSA-PrA	C22H17O4N2SF29	N-dimethyl ammonio propyl perfluoralkane sulfonamido propanoic acid	AmPr-FASA-PrA
N-Carboxymethyldimethylammoniopropyl-perfluoroethanesulfonamide	CMeAmPr-FEtSA	C9H15O4SN2F5	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamide	CMeAmPr-FASA
N-Carboxymethyldimethylammoniopropyl-perfluoropropanesulfonamide	CMeAmPr-FPrSA	C10H15O4SN2F7	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamide	CMeAmPr-FASA
N-Carboxymethyldimethylammoniopropyl-perfluorobutanesulfonamide	CMeAmPr-FBSA	C11H15O4SN2F9	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamide	CMeAmPr-FASA
N-Carboxymethyldimethylammoniopropyl-perfluoropentanesulfonamide	CMeAmPr-FPeSA	C12H15O4SN2F11	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamide	CMeAmPr-FASA
N-Carboxymethyldimethylammoniopropyl-perfluorohexanesulfonamide	CMeAmPr-FHxSA	C13H15O4SN2F13	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamide	CMeAmPr-FASA
N-Carboxymethyldimethylammoniopropyl-perfluoroheptanesulfonamide	CMeAmPr-FHpSA	C14H15O4SN2F15	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamide	CMeAmPr-FASA
N-Carboxymethyldimethylammoniopropyl-perfluorooctanesulfonamide	CMeAmPr-FOSA	C15H15O4SN2F17	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamide	CMeAmPr-FASA
N-Carboxymethyldimethylammoniopropyl-perfluorononanesulfonamide	CMeAmPr-FNSA	C16H15O4SN2F19	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamide	CMeAmPr-FASA
N-Carboxymethyldimethylammoniopropyl-perfluorodecanesulfonamide	CMeAmPr-FDSA	C17H15O4SN2F21	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamide	CMeAmPr-FASA
N-Carboxymethyldimethylammoniopropyl-perfluoroundecanesulfonamide	CMeAmPr-FUdSA	C18H15O4SN2F23	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamide	CMeAmPr-FASA

N-Carboxymethyldimethylammoniopropyl-perfluorododecanesulfonamide	CMeAmPr-FDoSA	C19H15O4SN2F25	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamide	CMeAmPr-FASA
N-carboxymethyl dimethylammoniopropyl-perfluoroethane sulfonamido acetic acid	CMeAmPr-FEtSAA	C11H17O6SN2F5	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Acetic Acid	CMeAmPr-FASAA
N-carboxymethyl dimethylammoniopropyl-perfluoropropane sulfonamido acetic acid	CMeAmPr-FPrSAA	C12H17O6SN2F7	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Acetic Acid	CMeAmPr-FASAA
N-carboxymethyl dimethylammoniopropyl-perfluorobutane sulfonamido acetic acid	CMeAmPr-FBSAA	C13H17O6SN2F9	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Acetic Acid	CMeAmPr-FASAA
N-carboxymethyl dimethylammoniopropyl-perfluoropentane sulfonamido acetic acid	CMeAmPr-FPeSAA	C14H17O6SN2F11	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Acetic Acid	CMeAmPr-FASAA
N-carboxymethyl dimethylammoniopropyl-perfluorohexane sulfonamido acetic acid	CMeAmPr-FHxSAA	C15H17O6SN2F13	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Acetic Acid	CMeAmPr-FASAA
N-carboxymethyl dimethylammoniopropyl-perfluoroheptane sulfonamido acetic acid	CMeAmPr-FHpSAA	C16H17O6SN2F15	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Acetic Acid	CMeAmPr-FASAA
N-carboxymethyl dimethylammoniopropyl-perfluorooctane sulfonamido acetic acid	CMeAmPr-FOSAA	C17H17O6SN2F17	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Acetic Acid	CMeAmPr-FASAA
N-carboxymethyl dimethylammoniopropyl-perfluorononane sulfonamido acetic acid	CMeAmPr-FNSAA	C18H17O6SN2F19	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Acetic Acid	CMeAmPr-FASAA
N-carboxymethyl dimethylammoniopropyl-perfluorodecane sulfonamido acetic acid	CMeAmPr-FDSAA	C19H17O6SN2F21	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Acetic Acid	CMeAmPr-FASAA
N-carboxymethyl dimethylammoniopropyl-perfluoroundecane sulfonamido acetic acid	CMeAmPr-FUdSAA	C20H17O6SN2F23	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Acetic Acid	CMeAmPr-FASAA
N-carboxymethyl dimethylammoniopropyl-perfluorododecane sulfonamido acetic acid	CMeAmPr-FDoSAA	C21H17O6SN2F25	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Acetic Acid	CMeAmPr-FASAA
N-carboxymethyldimethyl ammoniopropyl-perfluoroethane sulfonamido propanoic acid	CMeAmPr-FEtSAPrA	C12H19O6SN2F5	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Propanoic acid	CMeAmPr-FASAPrA
N-carboxymethyldimethyl ammoniopropyl-perfluoropropane sulfonamido propanoic acid	CMeAmPr-FPrSAPrA	C13H19O6SN2F7	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Propanoic acid	CMeAmPr-FASAPrA
N-carboxymethyldimethyl ammoniopropyl-perfluorobutane sulfonamido propanoic acid	CMeAmPr-FBSAPrA	C14H19O6SN2F9	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Propanoic acid	CMeAmPr-FASAPrA
N-carboxymethyldimethyl ammoniopropyl-perfluoropentane sulfonamido propanoic acid	CMeAmPr-FPeSAPrA	C15H19O6SN2F11	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Propanoic acid	CMeAmPr-FASAPrA
N-carboxymethyldimethyl ammoniopropyl-perfluorohexane sulfonamido propanoic acid	CMeAmPr-FHxSAPrA	C16H19O6SN2F13	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Propanoic acid	CMeAmPr-FASAPrA
N-carboxymethyldimethyl ammoniopropyl-perfluoroheptane sulfonamido propanoic acid	CMeAmPr-FHpSAPrA	C17H19O6SN2F15	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Propanoic acid	CMeAmPr-FASAPrA
N-carboxymethyldimethyl ammoniopropyl-perfluorooctane sulfonamido propanoic acid	CMeAmPr-FOSAPrA	C18H19O6SN2F17	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Propanoic acid	CMeAmPr-FASAPrA
N-carboxymethyldimethyl ammoniopropyl-perfluorononane sulfonamido propanoic acid	CMeAmPr-FNSAPrA	C19H19O6SN2F19	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Propanoic acid	CMeAmPr-FASAPrA
N-carboxymethyldimethyl ammoniopropyl-perfluorodecane sulfonamido propanoic acid	CMeAmPr-FDSAPrA	C20H19O6SN2F21	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Propanoic acid	CMeAmPr-FASAPrA

N-carboxymethyldimethyl ammoniopropyl-perfluoroundecane sulfonamido propanoic acid	CMeAmPr-FUdSAPrA	C21H19O6SN2F23	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Propanoic acid	CMeAmPr-FASAPrA
N-carboxymethyldimethyl ammoniopropyl-perfluorododecane sulfonamido propanoic acid	CMeAmPr-FDoSAPrA	C22H19O6SN2F25	N-CarboxyMethyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Propanoic acid	CMeAmPr-FASAPrA
N-carboxyethyl dimethyl ammonio propyl perfluoroethane sulfonamide	CEtAmPr-FMeSA	C9H17O4N2SF3	N-carboxy ethyl dimethyl ammonio propyl perfluoralkane sulfonamide	CEtAmPr-FASA
N-carboxyethyl dimethyl ammonio propyl perfluoromethane sulfonamide	CEtAmPr-FEtSA	C10H17O4N2SF5	N-carboxy ethyl dimethyl ammonio propyl perfluoralkane sulfonamide	CEtAmPr-FASA
N-carboxyethyl dimethyl ammonio propyl perfluoropropane sulfonamide	CEtAmPr-FPrSA	C11H17O4N2SF7	N-carboxy ethyl dimethyl ammonio propyl perfluoralkane sulfonamide	CEtAmPr-FASA
N-carboxyethyl dimethyl ammonio propyl perfluorobutane sulfonamide	CEtAmPr-FBSA	C12H17O4N2SF9	N-carboxy ethyl dimethyl ammonio propyl perfluoralkane sulfonamide	CEtAmPr-FASA
N-carboxyethyl dimethyl ammonio propyl perfluoropentane sulfonamide	CEtAmPr-FPeSA	C13H17O4N2SF11	N-carboxy ethyl dimethyl ammonio propyl perfluoralkane sulfonamide	CEtAmPr-FASA
N-carboxyethyl dimethyl ammonio propyl perfluorohexane sulfonamide	CEtAmPr-FHxSA	C14H17O4N2SF13	N-carboxy ethyl dimethyl ammonio propyl perfluoralkane sulfonamide	CEtAmPr-FASA
N-carboxyethyl dimethyl ammonio propyl perfluoroheptane sulfonamide	CEtAmPr-FHpSA	C15H17O4N2SF15	N-carboxy ethyl dimethyl ammonio propyl perfluoralkane sulfonamide	CEtAmPr-FASA
N-carboxyethyl dimethyl ammonio propyl perfluorooctane sulfonamide	CEtAmPr-FOSA	C16H17O4N2SF17	N-carboxy ethyl dimethyl ammonio propyl perfluoralkane sulfonamide	CEtAmPr-FASA
N-carboxyethyl dimethyl ammonio propyl perfluorononane sulfonamide	CEtAmPr-FNSA	C17H17O4N2SF19	N-carboxy ethyl dimethyl ammonio propyl perfluoralkane sulfonamide	CEtAmPr-FASA
N-carboxyethyl dimethyl ammonio propyl perfluorodecane sulfonamide	CEtAmPr-FDSA	C18H17O4N2SF21	N-carboxy ethyl dimethyl ammonio propyl perfluoralkane sulfonamide	CEtAmPr-FASA
N-carboxyethyl dimethyl ammonio propyl perfluoroundecane sulfonamide	CEtAmPr-FUdSA	C19H17O4N2SF23	N-carboxy ethyl dimethyl ammonio propyl perfluoralkane sulfonamide	CEtAmPr-FASA
N-carboxyethyl dimethyl ammonio propyl perfluorododecane sulfonamide	CEtAmPr-FDoSA	C20H17O4N2SF25	N-carboxy ethyl dimethyl ammonio propyl perfluoralkane sulfonamide	CEtAmPr-FASA
N-carboxyethyl dimethyl ammonio propyl perfluorotridecane sulfonamide	CEtAmPr-FTrDSA	C21H17O4N2SF27	N-carboxy ethyl dimethyl ammonio propyl perfluoralkane sulfonamide	CEtAmPr-FASA
N-carboxyethyl dimethyl ammonio propyl perfluorotetradecane sulfonamide	CEtAmPr-FTeDSA	C22H17O4N2SF29	N-carboxy ethyl dimethyl ammonio propyl perfluoralkane sulfonamide	CEtAmPr-FASA
N-carboxyethyl dimethyl ammonio propyl perfluoromethane sulfonamido propanoic acid	CEtAmPr-FMeSA-PrA	C12H21O6N2SF3	N-carboxy ethyl dimethyl ammonio propyl perfluoroalkane sulfonamido propanoic acid	CEtAmPr-FASA-PrA
N-carboxyethyl dimethyl ammonio propyl perfluoroethane sulfonamido propanoic acid	CEtAmPr-FEtSA-PrA	C13H21O6N2SF5	N-carboxy ethyl dimethyl ammonio propyl perfluoroalkane sulfonamido propanoic acid	CEtAmPr-FASA-PrA
N-carboxyethyl dimethyl ammonio propyl perfluoropropane sulfonamido propanoic acid	CEtAmPr-FPrSA-PrA	C14H21O6N2SF7	N-carboxy ethyl dimethyl ammonio propyl perfluoroalkane sulfonamido propanoic acid	CEtAmPr-FASA-PrA
N-carboxyethyl dimethyl ammonio propyl perfluorobutane sulfonamido propanoic acid	CEtAmPr-FBSA-PrA	C15H21O6N2SF9	N-carboxy ethyl dimethyl ammonio propyl perfluoroalkane sulfonamido propanoic acid	CEtAmPr-FASA-PrA
N-carboxyethyl dimethyl ammonio propyl perfluoropentane sulfonamido propanoic acid	CEtAmPr-FPeSA-PrA	C16H21O6N2SF11	N-carboxy ethyl dimethyl ammonio propyl perfluoroalkane sulfonamido propanoic acid	CEtAmPr-FASA-PrA

N-carboxyethyl dimethyl ammonio propyl perfluorohexane sulfonamido propanoic acid	CEtAmPr-FHxSA-PrA	C17H21O6N2SF13	N-carboxy ethyl dimethyl ammonio propyl perfluoroalkane sulfonamido propanoic acid	CEtAmPr-FASA-PrA
N-carboxyethyl dimethyl ammonio propyl perfluoroheptane sulfonamido propanoic acid	CEtAmPr-FHpSA-PrA	C18H21O6N2SF15	N-carboxy ethyl dimethyl ammonio propyl perfluoroalkane sulfonamido propanoic acid	CEtAmPr-FASA-PrA
N-carboxyethyl dimethyl ammonio propyl perfluorooctane sulfonamido propanoic acid	CEtAmPr-FOSA-PrA	C19H21O6N2SF17	N-carboxy ethyl dimethyl ammonio propyl perfluoroalkane sulfonamido propanoic acid	CEtAmPr-FASA-PrA
N-carboxyethyl dimethyl ammonio propyl perfluorononane sulfonamido propanoic acid	CEtAmPr-FNSA-PrA	C20H21O6N2SF19	N-carboxy ethyl dimethyl ammonio propyl perfluoroalkane sulfonamido propanoic acid	CEtAmPr-FASA-PrA
N-carboxyethyl dimethyl ammonio propyl perfluorodecane sulfonamido propanoic acid	CEtAmPr-FDSA-PrA	C21H21O6N2SF21	N-carboxy ethyl dimethyl ammonio propyl perfluoroalkane sulfonamido propanoic acid	CEtAmPr-FASA-PrA
N-carboxyethyl dimethyl ammonio propyl perfluoroundecane sulfonamido propanoic acid	CEtAmPr-FUdSA-PrA	C22H21O6N2SF23	N-carboxy ethyl dimethyl ammonio propyl perfluoroalkane sulfonamido propanoic acid	CEtAmPr-FASA-PrA
N-carboxyethyl dimethyl ammonio propyl perfluorododecane sulfonamido propanoic acid	CEtAmPr-FDoSA-PrA	C23H21O6N2SF25	N-carboxy ethyl dimethyl ammonio propyl perfluoroalkane sulfonamido propanoic acid	CEtAmPr-FASA-PrA
N-carboxyethyl dimethyl ammonio propyl perfluorotridecane sulfonamido propanoic acid	CEtAmPr-FTrDSA-PrA	C24H21O6N2SF27	N-carboxy ethyl dimethyl ammonio propyl perfluoroalkane sulfonamido propanoic acid	CEtAmPr-FASA-PrA
N-carboxyethyl dimethyl ammonio propyl perfluorotetradecane sulfonamido propanoic acid	CEtAmPr-FTeDSA-PrA	C25H21O6N2SF29	N-carboxy ethyl dimethyl ammonio propyl perfluoroalkane sulfonamido propanoic acid	CEtAmPr-FASA-PrA
N-carboxyethyl dimethylammoniopropyl-N-ethyl perfluoroethane sulfonamide	CEtAmPr-N-EtFEtSA	C12H21O4SN2F5	N-CarboxyEthyldimethylAmmonioPropyl-N-Ethyl perFluoroAlkaneSulfonAmide	CEtAmPr-N-EtFASA
N-carboxyethyl dimethylammoniopropyl-N-ethyl perfluoropropane sulfonamide	CEtAmPr-N-EtFPrSA	C13H21O4SN2F7	N-CarboxyEthyldimethylAmmonioPropyl-N-Ethyl perFluoroAlkaneSulfonAmide	CEtAmPr-N-EtFASA
N-carboxyethyl dimethylammoniopropyl-N-ethyl perfluorobutane sulfonamide	CEtAmPr-N-EtFBSA	C14H21O4SN2F9	N-CarboxyEthyldimethylAmmonioPropyl-N-Ethyl perFluoroAlkaneSulfonAmide	CEtAmPr-N-EtFASA
N-carboxyethyl dimethylammoniopropyl-N-ethyl perfluoropentane sulfonamide	CEtAmPr-N-EtFPeSA	C15H21O4SN2F11	N-CarboxyEthyldimethylAmmonioPropyl-N-Ethyl perFluoroAlkaneSulfonAmide	CEtAmPr-N-EtFASA
N-carboxyethyl dimethylammoniopropyl-N-ethyl perfluorohexane sulfonamide	CEtAmPr-N-EtFHxSA	C16H21O4SN2F13	N-CarboxyEthyldimethylAmmonioPropyl-N-Ethyl perFluoroAlkaneSulfonAmide	CEtAmPr-N-EtFASA
N-carboxyethyl dimethylammoniopropyl-N-ethyl perfluoroheptane sulfonamide	CEtAmPr-N-EtFHpSA	C17H21O4SN2F15	N-CarboxyEthyldimethylAmmonioPropyl-N-Ethyl perFluoroAlkaneSulfonAmide	CEtAmPr-N-EtFASA
N-carboxyethyl dimethylammoniopropyl-N-ethyl perfluorooctane sulfonamide	CEtAmPr-N-EtFOSA	C18H21O4SN2F17	N-CarboxyEthyldimethylAmmonioPropyl-N-Ethyl perFluoroAlkaneSulfonAmide	CEtAmPr-N-EtFASA
N-carboxyethyl dimethylammoniopropyl-N-ethyl perfluorononane sulfonamide	CEtAmPr-N-EtFNSA	C19H21O4SN2F19	N-CarboxyEthyldimethylAmmonioPropyl-N-Ethyl perFluoroAlkaneSulfonAmide	CEtAmPr-N-EtFASA
N-carboxyethyl dimethylammoniopropyl-N-ethyl perfluorodecane sulfonamide	CEtAmPr-N-EtFDSA	C20H21O4SN2F21	N-CarboxyEthyldimethylAmmonioPropyl-N-Ethyl perFluoroAlkaneSulfonAmide	CEtAmPr-N-EtFASA
N-carboxyethyl dimethylammoniopropyl-N-ethyl perfluoroundecane sulfonamide	CEtAmPr-N-EtFUdSA	C21H21O4SN2F23	N-CarboxyEthyldimethylAmmonioPropyl-N-Ethyl perFluoroAlkaneSulfonAmide	CEtAmPr-N-EtFASA
N-carboxyethyl dimethylammoniopropyl-N-ethyl perfluorododecane sulfonamide	CEtAmPr-N-EtFDoSA	C22H21O4SN2F25	N-CarboxyEthyldimethylAmmonioPropyl-N-Ethyl perFluoroAlkaneSulfonAmide	CEtAmPr-N-EtFASA
N-dihydroxybutyl dimethylammoniopropyl perfluoromethane sulfonamide	diOHBAmPr-FMSA	C10H21O4SN2F3	N-dihydroxybutyl dimethylAmmonioPropyl perFluoroAlkaneSulfonAmide	diOHBAmPr-FASA

N-dihydroxybutyl dimethylammoniopropyl perfluoroethane sulfonamide	diOHBAmPr-FEtSA	C11H21O4SN2F5	N-dihydroxybutyl dimethylAmmonioPropyl perFluoroAlkaneSulfonAmide	diOHBAmPr-FASA
N-dihydroxybutyl dimethylammoniopropyl perfluoropropane sulfonamide	diOHBAmPr-FPrSA	C12H21O4SN2F7	N-dihydroxybutyl dimethylAmmonioPropyl perFluoroAlkaneSulfonAmide	diOHBAmPr-FASA
N-dihydroxybutyl dimethylammoniopropyl perfluorobutane sulfonamide	diOHBAmPr-FBSA	C13H21O4SN2F9	N-dihydroxybutyl dimethylAmmonioPropyl perFluoroAlkaneSulfonAmide	diOHBAmPr-FASA
N-dihydroxybutyl dimethylammoniopropyl perfluoropentane sulfonamide	diOHBAmPr-FPeSA	C14H21O4SN2F11	N-dihydroxybutyl dimethylAmmonioPropyl perFluoroAlkaneSulfonAmide	diOHBAmPr-FASA
N-dihydroxybutyl dimethylammoniopropyl perfluorohexane sulfonamide	diOHBAmPr-FHxSA	C15H21O4SN2F13	N-dihydroxybutyl dimethylAmmonioPropyl perFluoroAlkaneSulfonAmide	diOHBAmPr-FASA
N-dihydroxybutyl dimethylammoniopropyl perfluoroheptane sulfonamide	diOHBAmPr-FHpSA	C16H21O4SN2F15	N-dihydroxybutyl dimethylAmmonioPropyl perFluoroAlkaneSulfonAmide	diOHBAmPr-FASA
N-dihydroxybutyl dimethylammoniopropyl perfluorooctane sulfonamide	diOHBAmPr-FOSA	C17H21O4SN2F17	N-dihydroxybutyl dimethylAmmonioPropyl perFluoroAlkaneSulfonAmide	diOHBAmPr-FASA
N-dihydroxybutyl dimethylammoniopropyl perfluorononane sulfonamide	diOHBAmPr-FNSA	C18H21O4SN2F19	N-dihydroxybutyl dimethylAmmonioPropyl perFluoroAlkaneSulfonAmide	diOHBAmPr-FASA
N-dihydroxybutyl dimethylammoniopropyl perfluorodecane sulfonamide	diOHBAmPr-FDSA	C19H21O4SN2F21	N-dihydroxybutyl dimethylAmmonioPropyl perFluoroAlkaneSulfonAmide	diOHBAmPr-FASA
N-dihydroxybutyl dimethylammoniopropyl perfluoroundecane sulfonamide	diOHBAmPr-FUdSA	C20H21O4SN2F23	N-dihydroxybutyl dimethylAmmonioPropyl perFluoroAlkaneSulfonAmide	diOHBAmPr-FASA
N-dihydroxybutyl dimethylammoniopropyl perfluorododecane sulfonamide	diOHBAmPr-FDoSA	C21H21O4SN2F25	N-dihydroxybutyl dimethylAmmonioPropyl perFluoroAlkaneSulfonAmide	diOHBAmPr-FASA
N-dimethylaminohydroxybutyl-perfluoroethanesulfonamidopropylsulfonate	DiMeA-MeOHPr-FEtSAPrS	C11H21O6S2N2F5	N-dimethylAminohydroxymethyl propyl-perFluoroAlkaneSulfonamidoPropylSulfonate	DiMeA-MeOHPr-FASAPrS
N-dimethylaminohydroxybutyl-perfluoropropanesulfonamidopropylsulfonate	DiMeA-MeOHPr-FPrSAPrS	C12H21O6S2N2F7	N-dimethylAminohydroxymethyl propyl-perFluoroAlkaneSulfonamidoPropylSulfonate	DiMeA-MeOHPr-FASAPrS
N-dimethylaminohydroxybutyl-perfluorobutanesulfonamidopropylsulfonate	DiMeA-MeOHPr-FBSAPrS	C13H21O6S2N2F9	N-dimethylAminohydroxymethyl propyl-perFluoroAlkaneSulfonamidoPropylSulfonate	DiMeA-MeOHPr-FASAPrS
N-dimethylaminohydroxybutyl-perfluoropentanesulfonamidopropylsulfonate	DiMeA-MeOHPr-FPeSAPrS	C14H21O6S2N2F11	N-dimethylAminohydroxymethyl propyl-perFluoroAlkaneSulfonamidoPropylSulfonate	DiMeA-MeOHPr-FASAPrS
N-dimethylaminohydroxybutyl-perfluorohexanesulfonamidopropylsulfonate	DiMeA-MeOHPr-FHxSAPrS	C15H21O6S2N2F13	N-dimethylAminohydroxymethyl propyl-perFluoroAlkaneSulfonamidoPropylSulfonate	DiMeA-MeOHPr-FASAPrS
N-dimethylaminohydroxybutyl-perfluoroheptanesulfonamidopropylsulfonate	DiMeA-MeOHPr-FHpSAPrS	C16H21O6S2N2F15	N-dimethylAminohydroxymethyl propyl-perFluoroAlkaneSulfonamidoPropylSulfonate	DiMeA-MeOHPr-FASAPrS
N-dimethylaminohydroxybutyl-perfluorooctanesulfonamidopropylsulfonate	DiMeA-MeOHPr-FOSAPrS	C17H21O6S2N2F17	N-dimethylAminohydroxymethyl propyl-perFluoroAlkaneSulfonamidoPropylSulfonate	DiMeA-MeOHPr-FASAPrS
N-dimethylaminohydroxybutyl-perfluorononanesulfonamidopropylsulfonate	DiMeA-MeOHPr-FNSAPrS	C18H21O6S2N2F19	N-dimethylAminohydroxymethyl propyl-perFluoroAlkaneSulfonamidoPropylSulfonate	DiMeA-MeOHPr-FASAPrS
N-dimethylaminohydroxybutyl-perfluorodecanesulfonamidopropylsulfonate	DiMeA-MeOHPr-FDSAPrS	C19H21O6S2N2F21	N-dimethylAminohydroxymethyl propyl-perFluoroAlkaneSulfonamidoPropylSulfonate	DiMeA-MeOHPr-FASAPrS
N-dimethylaminohydroxybutyl-perfluoroundecanesulfonamidopropylsulfonate	DiMeA-MeOHPr-FUdSAPrS	C20H21O6S2N2F23	N-dimethylAminohydroxymethyl propyl-perFluoroAlkaneSulfonamidoPropylSulfonate	DiMeA-MeOHPr-FASAPrS

N-dimethylaminohydroxybutyl-perfluorododecanesulfonamidopropylsulfonate	DiMeA-MeOHPr-FDoSAPrS	C21H21O6S2N2F25	N-dimethylAminohydroxymethyl propyl-perFluoroAlkaneSulfonamidoPropylSulfonate	DiMeA-MeOHPr-FASAPrS
N-dihydroxy propyl dimethyl ammonio hydroxymethyl propyl-perfluoroethane sulfonamide	diOHPrAm-MeOHPr-FEtSA	C11H21O5SN2F5	N-dihydrox PropyldimethylAmmonio hydroxymethyl propyl perfluoroalkane sulfonamide	diOHPrAm-MeOHPr-FASA
N-dihydroxy propyl dimethyl ammonio hydroxymethyl propyl-perfluoropropanesulfonamide	diOHPrAm-MeOHPr-FPrSA	C12H21O5SN2F7	N-dihydrox PropyldimethylAmmonio hydroxymethyl propyl perfluoroalkane sulfonamide	diOHPrAm-MeOHPr-FASA
N-dihydroxy propyl dimethyl ammonio hydroxymethyl propyl-perfluorobutanesulfonamide	diOHPrAm-MeOHPr-FBSA	C13H21O5SN2F9	N-dihydrox PropyldimethylAmmonio hydroxymethyl propyl perfluoroalkane sulfonamide	diOHPrAm-MeOHPr-FASA
N-dihydroxy propyl dimethyl ammonio hydroxymethyl propyl-perfluoropentanesulfonamide	diOHPrAm-MeOHPr-FPeSA	C14H21O5SN2F11	N-dihydrox PropyldimethylAmmonio hydroxymethyl propyl perfluoroalkane sulfonamide	diOHPrAm-MeOHPr-FASA
N-dihydroxy propyl dimethyl ammonio hydroxymethyl propyl-perfluorohexanesulfonamide	diOHPrAm-MeOHPr-FHxSA	C15H21O5SN2F13	N-dihydrox PropyldimethylAmmonio hydroxymethyl propyl perfluoroalkane sulfonamide	diOHPrAm-MeOHPr-FASA
N-dihydroxy propyl dimethyl ammonio hydroxymethyl propyl-perfluoroheptanesulfonamide	diOHPrAm-MeOHPr-FHpSA	C16H21O5SN2F15	N-dihydrox PropyldimethylAmmonio hydroxymethyl propyl perfluoroalkane sulfonamide	diOHPrAm-MeOHPr-FASA
N-dihydroxy propyl dimethyl ammonio hydroxymethyl propyl-perfluorooctanesulfonamide	diOHPrAm-MeOHPr-FOSA	C17H21O5SN2F17	N-dihydrox PropyldimethylAmmonio hydroxymethyl propyl perfluoroalkane sulfonamide	diOHPrAm-MeOHPr-FASA
N-dihydroxy propyl dimethyl ammonio hydroxymethyl propyl-perfluorononanesulfonamide	diOHPrAm-MeOHPr-FNSA	C18H21O5SN2F19	N-dihydrox PropyldimethylAmmonio hydroxymethyl propyl perfluoroalkane sulfonamide	diOHPrAm-MeOHPr-FASA
N-dihydroxy propyl dimethyl ammonio hydroxymethyl propyl-perfluorodecanesulfonamide	diOHPrAm-MeOHPr-FDSA	C19H21O5SN2F21	N-dihydrox PropyldimethylAmmonio hydroxymethyl propyl perfluoroalkane sulfonamide	diOHPrAm-MeOHPr-FASA
N-dihydroxy propyl dimethyl ammonio hydroxymethyl propyl-perfluoroundecanesulfonamide	diOHPrAm-MeOHPr-FUdSA	C20H21O5SN2F23	N-dihydrox PropyldimethylAmmonio hydroxymethyl propyl perfluoroalkane sulfonamide	diOHPrAm-MeOHPr-FASA
N-dihydroxy propyl dimethyl ammonio hydroxymethyl propyl-perfluorododecanesulfonamide	diOHPrAm-MeOHPr-FDoSA	C21H21O5SN2F25	N-dihydrox PropyldimethylAmmonio hydroxymethyl propyl perfluoroalkane sulfonamide	diOHPrAm-MeOHPr-FASA
N-dihydroxypropyldimethylammoniohydroxymethyl propyl-perfluoroethane sulfonamido propyl sulfonate	diOHPrAm-MeOHPr-FEtSAPrS	C14H27O8S2N2F5	N-dihydroxy Propyldimethylammoniohydroxymethylpropyl-perFluoroalkane Sulfonamidopropyl Sulfonate	diOHPrAm-MeOHPr-FASAPrS
N-dihydroxy propyldimethyl ammoniohydroxymethyl propyl-perfluoropropane sulfonamido propyl sulfonate	diOHPrAm-MeOHPr-FPrSAPrS	C15H27O8S2N2F7	N-dihydroxy Propyldimethylammoniohydroxymethylpropyl-perFluoroalkane Sulfonamidopropyl Sulfonate	diOHPrAm-MeOHPr-FASAPrS
N-dihydroxy propyldimethyl ammoniohydroxymethyl propyl-perfuorobutane sulfonamido propyl sulfonate	diOHPrAm-MeOHPr-FBSAPrS	C16H27O8S2N2F9	N-dihydroxy Propyldimethylammoniohydroxymethylpropyl-perFluoroalkane Sulfonamidopropyl Sulfonate	diOHPrAm-MeOHPr-FASAPrS
N-dihydroxy propyldimethyl ammoniohydroxymethyl propyl-perfluoropentane sulfonamidopropyl sulfonate	diOHPrAm-MeOHPr-FPeSAPrS	C17H27O8S2N2F11	N-dihydroxy Propyldimethylammoniohydroxymethylpropyl-perFluoroalkane Sulfonamidopropyl Sulfonate	diOHPrAm-MeOHPr-FASAPrS
N-dihydroxy propyldimethyl ammoniohydroxymethyl propyl-perfluorohexane sulfonamido propyl sulfonate	diOHPrAm-MeOHPr-FHxSAPrS	C18H27O8S2N2F13	N-dihydroxy Propyldimethylammoniohydroxymethylpropyl-perFluoroalkane Sulfonamidopropyl Sulfonate	diOHPrAm-MeOHPr-FASAPrS
N-dihydroxy propyldimethyl ammoniohydroxymethyl propyl-perfluoroheptane sulfonamido propyl sulfonate	diOHPrAm-MeOHPr-FHpSAPrS	C19H27O8S2N2F15	N-dihydroxy Propyldimethylammoniohydroxymethylpropyl-perFluoroalkane Sulfonamidopropyl Sulfonate	diOHPrAm-MeOHPr-FASAPrS

N-dihydroxy propyldimethyl ammoniohydroxymethyl propyl-perfluorooctane sulfonamido propyl sulfonate	diOHPrAm-MeOHPr-FOSAPrS	C20H27O8S2N2F17	N-dihydroxy Propyldimethylammoniohydroxymethylpropyl-perFluoroalkane Sulfonamidopropyl Sulfonate	diOHPrAm-MeOHPr-FASAPrS
N-dihydroxy propyldimethyl ammoniohydroxymethyl propyl-perfluorononane sulfonamido propyl sulfonate	diOHPrAm-MeOHPr-FNSAPrS	C21H27O8S2N2F19	N-dihydroxy Propyldimethylammoniohydroxymethylpropyl-perFluoroalkane Sulfonamidopropyl Sulfonate	diOHPrAm-MeOHPr-FASAPrS
N-dihydroxy propyldimethyl ammoniohydroxymethyl propyl-perfluorodecane sulfonamido propyl sulfonate	diOHPrAm-MeOHPr-FDSAPrS	C22H27O8S2N2F21	N-dihydroxy Propyldimethylammoniohydroxymethylpropyl-perFluoroalkane Sulfonamidopropyl Sulfonate	diOHPrAm-MeOHPr-FASAPrS
N-dihydroxy propyldimethyl ammoniohydroxymethyl propyl-perfluoroundecane sulfonamido propyl sulfonate	diOHPrAm-MeOHPr-FUdSAPrS	C23H27O8S2N2F23	N-dihydroxy Propyldimethylammoniohydroxymethylpropyl-perFluoroalkane Sulfonamidopropyl Sulfonate	diOHPrAm-MeOHPr-FASAPrS
N-dihydroxy propyldimethyl ammoniohydroxymethyl propyl-perfluorododecane sulfonamido propyl sulfonate	diOHPrAm-MeOHPr-FDoSAPrS	C24H27O8S2N2F25	N-dihydroxy Propyldimethylammoniohydroxymethylpropyl-perFluoroalkane Sulfonamidopropyl Sulfonate	diOHPrAm-MeOHPr-FASAPrS
N-ethyl dimethyl ammonio propyl perfluoroethane N-ethyl sulfonamide	EtAmPr-FEt-N-EtSA	C11H21O2SN2F5	N-ethyl dimethyl ammonio propyl perfluoroalkane N-ethyl sulfonamide	EtAmPr-FA-N-EtSA
N-ethyl dimethyl ammonio propyl perfluoropropane N-ethyl sulfonamide	EtAmPr-FPr-N-EtSA	C12H21O2SN2F7	N-ethyl dimethyl ammonio propyl perfluoroalkane N-ethyl sulfonamide	EtAmPr-FA-N-EtSA
N-ethyl dimethyl ammonio propyl perfluorobutane N-ethyl sulfonamide	EtAmPr-FB-N-EtSA	C13H21O2SN2F9	N-ethyl dimethyl ammonio propyl perfluoroalkane N-ethyl sulfonamide	EtAmPr-FA-N-EtSA
N-ethyl dimethyl ammonio propyl perfluoropentane N-ethyl sulfonamide	EtAmPr-FPe-N-EtSA	C14H21O2SN2F11	N-ethyl dimethyl ammonio propyl perfluoroalkane N-ethyl sulfonamide	EtAmPr-FA-N-EtSA
N-ethyl dimethyl ammonio propyl perfluorohexane N-ethyl sulfonamide	EtAmPr-FHx-N-EtSA	C15H21O2SN2F13	N-ethyl dimethyl ammonio propyl perfluoroalkane N-ethyl sulfonamide	EtAmPr-FA-N-EtSA
N-ethyl dimethyl ammonio propyl perfluoroheptane N-ethyl sulfonamide	EtAmPr-FHp-N-EtSA	C16H21O2SN2F15	N-ethyl dimethyl ammonio propyl perfluoroalkane N-ethyl sulfonamide	EtAmPr-FA-N-EtSA
N-ethyl dimethyl ammonio propyl perfluorooctane N-ethyl sulfonamide	EtAmPr-FO-N-EtSA	C17H21O2SN2F17	N-ethyl dimethyl ammonio propyl perfluoroalkane N-ethyl sulfonamide	EtAmPr-FA-N-EtSA
N-ethyl dimethyl ammonio propyl perfluorononane N-ethyl sulfonamide	EtAmPr-FN-N-EtSA	C18H21O2SN2F19	N-ethyl dimethyl ammonio propyl perfluoroalkane N-ethyl sulfonamide	EtAmPr-FA-N-EtSA
N-ethyl dimethyl ammonio propyl perfluorodecane N-ethyl sulfonamide	EtAmPr-FD-N-EtSA	C19H21O2SN2F21	N-ethyl dimethyl ammonio propyl perfluoroalkane N-ethyl sulfonamide	EtAmPr-FA-N-EtSA
N-ethyl dimethyl ammonio propyl perfluoroundecane N-ethyl sulfonamide	EtAmPr-FUd-N-EtSA	C20H21O2SN2F23	N-ethyl dimethyl ammonio propyl perfluoroalkane N-ethyl sulfonamide	EtAmPr-FA-N-EtSA
N-ethyl dimethyl ammonio propyl perfluorododecane N-ethyl sulfonamide	EtAmPr-FDo-N-EtSA	C21H21O2SN2F25	N-ethyl dimethyl ammonio propyl perfluoroalkane N-ethyl sulfonamide	EtAmPr-FA-N-EtSA
N-hydroxyethyldimethylammoniopropyl perfluoroethanesulfonamide	EtOH-AmPr-FEtSA	C9H17O3SN2F5	N-hydroxyethyldimethylammoniopropyl perfluoroalkanesulfonamide	EtOH-AmPr-FASA
N-hydroxyethyldimethylammoniopropyl perfluoropropanesulfonamide	EtOH-AmPr-FPrSA	C10H17O3SN2F7	N-hydroxyethyldimethylammoniopropyl perfluoroalkanesulfonamide	EtOH-AmPr-FASA
N-hydroxyethyldimethylammoniopropyl perfluorobutanesulfonamide	EtOH-AmPr-FBSA	C11H17O3SN2F9	N-hydroxyethyldimethylammoniopropyl perfluoroalkanesulfonamide	EtOH-AmPr-FASA

N-hydroxyethyldimethylammoniopropyl perfluoropentanesulfonamide	EtOH-AmPr-FPeSA	C12H17O3SN2F11	N-hydroxyethyldimethylammoniopropyl perfluoroalkanesulfonamide	EtOH-AmPr-FASA
N-hydroxyethyldimethylammoniopropyl perfluorohexanesulfonamide	EtOH-AmPr-FHxSA	C13H17O3SN2F13	N-hydroxyethyldimethylammoniopropyl perfluoroalkanesulfonamide	EtOH-AmPr-FASA
N-hydroxyethyldimethylammoniopropyl perfluoroheptanesulfonamide	EtOH-AmPr-FHpSA	C14H17O3SN2F15	N-hydroxyethyldimethylammoniopropyl perfluoroalkanesulfonamide	EtOH-AmPr-FASA
N-hydroxyethyldimethylammoniopropyl perfluorooctanesulfonamide	EtOH-AmPr-FOSA	C15H17O3SN2F17	N-hydroxyethyldimethylammoniopropyl perfluoroalkanesulfonamide	EtOH-AmPr-FASA
N-hydroxyethyldimethylammoniopropyl perfluorononanesulfonamide	EtOH-AmPr-FNSA	C16H17O3SN2F19	N-hydroxyethyldimethylammoniopropyl perfluoroalkanesulfonamide	EtOH-AmPr-FASA
N-hydroxyethyldimethylammoniopropyl perfluorodecanesulfonamide	EtOH-AmPr-FDSA	C17H17O3SN2F21	N-hydroxyethyldimethylammoniopropyl perfluoroalkanesulfonamide	EtOH-AmPr-FASA
N-hydroxyethyldimethylammoniopropyl perfluoroundecanesulfonamide	EtOH-AmPr-FUdSA	C18H17O3SN2F23	N-hydroxyethyldimethylammoniopropyl perfluoroalkanesulfonamide	EtOH-AmPr-FASA
N-hydroxyethyldimethylammoniopropyl perfluorododecanesulfonamide	EtOH-AmPr-FDoSA	C19H17O3SN2F25	N-hydroxyethyldimethylammoniopropyl perfluoroalkanesulfonamide	EtOH-AmPr-FASA
N-hydroxyethyl dimethylammoniopropyl perfluoroethane sulfonamido propylsulfonate	EtOH-AmPr-FEtSAPrS	C12H23O6S2N2F5	N-Hydroxyethyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamido PropylSulfonate	EtOH-AmPr-FASAPrS
N-hydroxyethyl dimethylammoniopropyl perfluoropropane sulfonamido propylsulfonate	EtOH-AmPr-FPrSAPrS	C13H23O6S2N2F7	N-Hydroxyethyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamido PropylSulfonate	EtOH-AmPr-FASAPrS
N-hydroxyethyl dimethylammoniopropyl perfluorobutane sulfonamido propylsulfonate	EtOH-AmPr-FBSAPrS	C14H23O6S2N2F9	N-Hydroxyethyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamido PropylSulfonate	EtOH-AmPr-FASAPrS
N-hydroxyethyl dimethylammoniopropyl perfluoropentane sulfonamido propylsulfonate	EtOH-AmPr-FPeSAPrS	C15H23O6S2N2F11	N-Hydroxyethyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamido PropylSulfonate	EtOH-AmPr-FASAPrS
N-hydroxyethyl dimethylammoniopropyl perfluorohexane sulfonamido propylsulfonate	EtOH-AmPr-FHxSAPrS	C16H23O6S2N2F13	N-Hydroxyethyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamido PropylSulfonate	EtOH-AmPr-FASAPrS
N-hydroxyethyl dimethylammoniopropyl perfluoroheptane sulfonamido propylsulfonate	EtOH-AmPr-FHpSAPrS	C17H23O6S2N2F15	N-Hydroxyethyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamido PropylSulfonate	EtOH-AmPr-FASAPrS
N-hydroxyethyl dimethylammoniopropyl perfluorooctane sulfonamido propylsulfonate	EtOH-AmPr-FOSAPrS	C18H23O6S2N2F17	N-Hydroxyethyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamido PropylSulfonate	EtOH-AmPr-FASAPrS
N-hydroxyethyl dimethylammoniopropyl perfluorononane sulfonamido propylsulfonate	EtOH-AmPr-FNSAPrS	C19H23O6S2N2F19	N-Hydroxyethyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamido PropylSulfonate	EtOH-AmPr-FASAPrS
N-hydroxyethyl dimethylammoniopropyl perfluorodecane sulfonamido propylsulfonate	EtOH-AmPr-FDSAPrS	C20H23O6S2N2F21	N-Hydroxyethyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamido PropylSulfonate	EtOH-AmPr-FASAPrS
N-hydroxyethyl dimethylammoniopropyl perfluoroundecane sulfonamido propylsulfonate	EtOH-AmPr-FUdSAPrS	C21H23O6S2N2F23	N-Hydroxyethyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamido PropylSulfonate	EtOH-AmPr-FASAPrS
N-hydroxyethyl dimethylammoniopropyl perfluorododecane sulfonamido propylsulfonate	EtOH-AmPr-FDoSAPrS	C22H23O6S2N2F25	N-Hydroxyethyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamido PropylSulfonate	EtOH-AmPr-FASAPrS
N-hydroxyethyl dimethylammoniohydroxypropyl perfluoroethanesulfonamide	EtOH-Am-OHPr-FEtSA	C9H17O4SN2F5	N-hydroxyethyldimethylammoniohydroxypropyl perfluoroalkanesulfonamide	EtOH-Am-OHPr-FASA
N-hydroxyethyl dimethylammoniohydroxypropyl perfluoropropanesulfonamide	EtOH-Am-OHPr-FPrSA	C10H17O4SN2F7	N-hydroxyethyldimethylammoniohydroxypropyl perfluoroalkanesulfonamide	EtOH-Am-OHPr-FASA

N-hydroxyethyl dimethylammoniohydroxypropyl perfluorobutanesulfonamide	EtOH-Am-OHPr-FBSA	C11H17O4SN2F9	N-hydroxyethyldimethylammoniohydroxypropyl perfluoroalkanesulfonamide	EtOH-Am-OHPr-FASA
N-hydroxyethyl dimethylammoniohydroxypropyl perfluoropentanesulfonamide	EtOH-Am-OHPr-FPeSA	C12H17O4SN2F11	N-hydroxyethyldimethylammoniohydroxypropyl perfluoroalkanesulfonamide	EtOH-Am-OHPr-FASA
N-hydroxyethyl dimethylammoniohydroxypropyl perfluorohexanesulfonamide	EtOH-Am-OHPr-FHxSA	C13H17O4SN2F13	N-hydroxyethyldimethylammoniohydroxypropyl perfluoroalkanesulfonamide	EtOH-Am-OHPr-FASA
N-hydroxyethyl dimethylammoniohydroxypropyl perfluoroheptanesulfonamide	EtOH-Am-OHPr-FHpSA	C14H17O4SN2F15	N-hydroxyethyldimethylammoniohydroxypropyl perfluoroalkanesulfonamide	EtOH-Am-OHPr-FASA
N-hydroxyethyl dimethylammoniohydroxypropyl perfluorooctanesulfonamide	EtOH-Am-OHPr-FOSA	C15H17O4SN2F17	N-hydroxyethyldimethylammoniohydroxypropyl perfluoroalkanesulfonamide	EtOH-Am-OHPr-FASA
N-hydroxyethyl dimethylammoniohydroxypropyl perfluorononanesulfonamide	EtOH-Am-OHPr-FNSA	C16H17O4SN2F19	N-hydroxyethyldimethylammoniohydroxypropyl perfluoroalkanesulfonamide	EtOH-Am-OHPr-FASA
N-hydroxyethyl dimethylammoniohydroxypropyl perfluorodecanesulfonamide	EtOH-Am-OHPr-FDSA	C17H17O4SN2F21	N-hydroxyethyldimethylammoniohydroxypropyl perfluoroalkanesulfonamide	EtOH-Am-OHPr-FASA
N-hydroxyethyl dimethylammoniohydroxypropyl perfluoroundecanesulfonamide	EtOH-Am-OHPr-FUdSA	C18H17O4SN2F23	N-hydroxyethyldimethylammoniohydroxypropyl perfluoroalkanesulfonamide	EtOH-Am-OHPr-FASA
N-hydroxyethyl dimethylammoniohydroxypropyl perfluorododecanesulfonamide	EtOH-Am-OHPr-FDoSA	C19H17O4SN2F25	N-hydroxyethyldimethylammoniohydroxypropyl perfluoroalkanesulfonamide	EtOH-Am-OHPr-FASA
N-hydroxyethyldimethylammoniopropyl perfluoroethanesulfonamidoethanol	EtOH-AmPr-FEtSA-EtOH	C11H21O4SN2F5	N-hydroxyethyl dimethylAmmonio Propyl perFluoroAlkane SulfonamidoEthanol	EtOH-AmPr-FASA-EtOH
N-hydroxyethyldimethylammoniopropyl perfluoropropanesulfonamidoethanol	EtOH-AmPr-FPrSA-EtOH	C12H21O4SN2F7	N-hydroxyethyl dimethylAmmonio Propyl perFluoroAlkane SulfonamidoEthanol	EtOH-AmPr-FASA-EtOH
N-hydroxyethyldimethylammoniopropyl perfluorobutanesulfonamidoethanol	EtOH-AmPr-FBSA-EtOH	C13H21O4SN2F9	N-hydroxyethyl dimethylAmmonio Propyl perFluoroAlkane SulfonamidoEthanol	EtOH-AmPr-FASA-EtOH
N-hydroxyethyldimethylammoniopropyl perfluoropentanesulfonamidoethanol	EtOH-AmPr-FPeSA-EtOH	C14H21O4SN2F11	N-hydroxyethyl dimethylAmmonio Propyl perFluoroAlkane SulfonamidoEthanol	EtOH-AmPr-FASA-EtOH
N-hydroxyethyldimethylammoniopropyl perfluorohexanesulfonamidoethanol	EtOH-AmPr-FHxSA-EtOH	C15H21O4SN2F13	N-hydroxyethyl dimethylAmmonio Propyl perFluoroAlkane SulfonamidoEthanol	EtOH-AmPr-FASA-EtOH
N-hydroxyethyldimethylammoniopropyl perfluoroheptanesulfonamidoethanol	EtOH-AmPr-FHpSA-EtOH	C16H21O4SN2F15	N-hydroxyethyl dimethylAmmonio Propyl perFluoroAlkane SulfonamidoEthanol	EtOH-AmPr-FASA-EtOH
N-hydroxyethyldimethylammoniopropyl perfluorooctanesulfonamidoethanol	EtOH-AmPr-FOSA-EtOH	C17H21O4SN2F17	N-hydroxyethyl dimethylAmmonio Propyl perFluoroAlkane SulfonamidoEthanol	EtOH-AmPr-FASA-EtOH
N-hydroxyethyldimethylammoniopropyl perfluorononanesulfonamidoethanol	EtOH-AmPr-FNSA-EtOH	C18H21O4SN2F19	N-hydroxyethyl dimethylAmmonio Propyl perFluoroAlkane SulfonamidoEthanol	EtOH-AmPr-FASA-EtOH
N-hydroxyethyldimethylammoniopropyl perfluorodecanesulfonamidoethanol	EtOH-AmPr-FDSA-EtOH	C19H21O4SN2F21	N-hydroxyethyl dimethylAmmonio Propyl perFluoroAlkane SulfonamidoEthanol	EtOH-AmPr-FASA-EtOH
N-hydroxyethyldimethylammoniopropyl perfluoroundecanesulfonamidoethanol	EtOH-AmPr-FUdSA-EtOH	C20H21O4SN2F23	N-hydroxyethyl dimethylAmmonio Propyl perFluoroAlkane SulfonamidoEthanol	EtOH-AmPr-FASA-EtOH
N-hydroxyethyldimethylammoniopropyl perfluorododecanesulfonamidoethanol	EtOH-AmPr-FDoSA-EtOH	C21H21O4SN2F25	N-hydroxyethyl dimethylAmmonio Propyl perFluoroAlkane SulfonamidoEthanol	EtOH-AmPr-FASA-EtOH
N-hydroxyethyl dimethylammoniopropyl perfluoroethane sulfonamido hydroxy propylsulfonate	EtOH-AmPr-FEtSA-OHPrS	C12H23O7S2N2F5	N-Hydroxyethyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamido hydroxy Propyl Sulfonate	EtOH-AmPr-FASA-OHPrS

N-hydroxyethyl dimethylammoniopropyl perfluoropropane sulfonamido hydroxy propylsulfonate	EtOH-AmPr-FPrSA-OHPrS	C13H23O7S2N2F7	N-Hydroxyethyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamido hydroxy Propyl Sulfonate	EtOH-AmPr-FASA-OHPrS
N-hydroxyethyl dimethylammoniopropyl perfluorobutane sulfonamido hydroxy propylsulfonate	EtOH-AmPr-FBSA-OHPrS	C14H23O7S2N2F9	N-Hydroxyethyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamido hydroxy Propyl Sulfonate	EtOH-AmPr-FASA-OHPrS
N-hydroxyethyl dimethylammoniopropyl perfluoropentane sulfonamido hydroxy propylsulfonate	EtOH-AmPr-FPeSA-OHPrS	C15H23O7S2N2F11	N-Hydroxyethyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamido hydroxy Propyl Sulfonate	EtOH-AmPr-FASA-OHPrS
N-hydroxyethyl dimethylammoniopropyl perfluorohexane sulfonamido hydroxy propylsulfonate	EtOH-AmPr-FHxSA-OHPrS	C16H23O7S2N2F13	N-Hydroxyethyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamido hydroxy Propyl Sulfonate	EtOH-AmPr-FASA-OHPrS
N-hydroxyethyl dimethylammoniopropyl perfluoroheptane sulfonamido hydroxy propylsulfonate	EtOH-AmPr-FHpSA-OHPrS	C17H23O7S2N2F15	N-Hydroxyethyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamido hydroxy Propyl Sulfonate	EtOH-AmPr-FASA-OHPrS
N-hydroxyethyl dimethylammoniopropyl perfluorooctane sulfonamido hydroxy propylsulfonate	EtOH-AmPr-FOSA-OHPrS	C18H23O7S2N2F17	N-Hydroxyethyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamido hydroxy Propyl Sulfonate	EtOH-AmPr-FASA-OHPrS
N-hydroxyethyl dimethylammoniopropyl perfluorononane sulfonamido hydroxy propylsulfonate	EtOH-AmPr-FNSA-OHPrS	C19H23O7S2N2F19	N-Hydroxyethyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamido hydroxy Propyl Sulfonate	EtOH-AmPr-FASA-OHPrS
N-hydroxyethyl dimethylammoniopropyl perfluorodecane sulfonamido hydroxy propylsulfonate	EtOH-AmPr-FDSA-OHPrS	C20H23O7S2N2F21	N-Hydroxyethyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamido hydroxy Propyl Sulfonate	EtOH-AmPr-FASA-OHPrS
N-hydroxyethyl dimethylammoniopropyl perfluoroundecane sulfonamido hydroxy propylsulfonate	EtOH-AmPr-FUdSA-OHPrS	C21H23O7S2N2F23	N-Hydroxyethyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamido hydroxy Propyl Sulfonate	EtOH-AmPr-FASA-OHPrS
N-hydroxyethyl dimethylammoniopropyl perfluorododecane sulfonamido hydroxy propylsulfonate	EtOH-AmPr-FDoSA-OHPrS	C22H23O7S2N2F25	N-Hydroxyethyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamido hydroxy Propyl Sulfonate	EtOH-AmPr-FASA-OHPrS
N-oxidedimethylammoniopropyl-perfluoroethanesulfonamide	OAmPr-FEtSA	C7H13O3SN2F5	N-oxidedimethylammoniopropyl-perfluoroalkanesulfonamide	OAmPr-FASA
N-oxidedimethylammoniopropyl-perfluoropropanesulfonamide	OAmPr-FPrSA	C8H13O3SN2F7	N-oxidedimethylammoniopropyl-perfluoroalkanesulfonamide	OAmPr-FASA
N-oxidedimethylammoniopropyl-perfluorobutanesulfonamide	OAmPr-FBSA	C9H13O3SN2F9	N-oxidedimethylammoniopropyl-perfluoroalkanesulfonamide	OAmPr-FASA
N-oxidedimethylammoniopropyl-perfluoropentanesulfonamide	OAmPr-FPeSA	C10H13O3SN2F11	N-oxidedimethylammoniopropyl-perfluoroalkanesulfonamide	OAmPr-FASA
N-oxidedimethylammoniopropyl-perfluorohexanesulfonamide	OAmPr-FHxSA	C11H13O3SN2F13	N-oxidedimethylammoniopropyl-perfluoroalkanesulfonamide	OAmPr-FASA
N-oxidedimethylammoniopropyl-perfluoroheptanesulfonamide	OAmPr-FHpSA	C12H13O3SN2F15	N-oxidedimethylammoniopropyl-perfluoroalkanesulfonamide	OAmPr-FASA
N-oxidedimethylammoniopropyl-perfluorooctanesulfonamide	OAmPr-FOSA	C13H13O3SN2F17	N-oxidedimethylammoniopropyl-perfluoroalkanesulfonamide	OAmPr-FASA
N-oxidedimethylammoniopropyl-perfluorononanesulfonamide	OAmPr-FNSA	C14H13O3SN2F19	N-oxidedimethylammoniopropyl-perfluoroalkanesulfonamide	OAmPr-FASA
N-oxidedimethylammoniopropyl-perfluorodecanesulfonamide	OAmPr-FDSA	C15H13O3SN2F21	N-oxidedimethylammoniopropyl-perfluoroalkanesulfonamide	OAmPr-FASA
N-oxidedimethylammoniopropyl-perfluoroundecanesulfonamide	OAmPr-FUdSA	C16H13O3SN2F23	N-oxidedimethylammoniopropyl-perfluoroalkanesulfonamide	OAmPr-FASA
N-oxidedimethylammoniopropyl-perfluorododecanesulfonamide	OAmPr-FDoSA	C17H13O3SN2F25	N-oxidedimethylammoniopropyl-perfluoroalkanesulfonamide	OAmPr-FASA

N-sulfo propyl perfluoromethane sulfonamide	SPr-FMeSA	C4H8O5S2NF3	N-Sulfo Propyl perFluoroAlkaneSulfonAmide	SPr-FASA
N-sulfo propyl perfluoroethane sulfonamide	SPr-FEtSA	C5H8O5S2NF5	N-Sulfo Propyl perFluoroAlkaneSulfonAmide	SPr-FASA
N-sulfo propyl perfluoropropane sulfonamide	SPr-FPrSA	C6H8O5S2NF7	N-Sulfo Propyl perFluoroAlkaneSulfonAmide	SPr-FASA
N-sulfo propyl perfluorobutane sulfonamide	SPr-FBSA	C7H8O5S2NF9	N-Sulfo Propyl perFluoroAlkaneSulfonAmide	SPr-FASA
N-sulfo propyl perfluoropentane sulfonamide	SPr-FPeSA	C8H8O5S2NF11	N-Sulfo Propyl perFluoroAlkaneSulfonAmide	SPr-FASA
N-sulfo propyl perfluorohexane sulfonamide	SPr-FHxSA	C9H8O5S2NF13	N-Sulfo Propyl perFluoroAlkaneSulfonAmide	SPr-FASA
N-sulfo propyl perfluoroheptane sulfonamide	SPr-FHpSA	C10H8O5S2NF15	N-Sulfo Propyl perFluoroAlkaneSulfonAmide	SPr-FASA
N-sulfo propyl perfluorooctane sulfonamide	SPr-FOSA	C11H8O5S2NF17	N-Sulfo Propyl perFluoroAlkaneSulfonAmide	SPr-FASA
N-sulfo propyl perfluorononane sulfonamide	SPr-FNSA	C12H8O5S2NF19	N-Sulfo Propyl perFluoroAlkaneSulfonAmide	SPr-FASA
N-sulfo propyl perfluorodecane sulfonamide	SPr-FSSA	C13H8O5S2NF21	N-Sulfo Propyl perFluoroAlkaneSulfonAmide	SPr-FASA
N-sulfo propyl perfluoroundecane sulfonamide	SPr-FUdSA	C14H8O5S2NF23	N-Sulfo Propyl perFluoroAlkaneSulfonAmide	SPr-FASA
N-sulfo propyl perfluorododecane sulfonamide	SPr-FDoSA	C15H8O5S2NF25	N-Sulfo Propyl perFluoroAlkaneSulfonAmide	SPr-FASA
N-sulfo propyl perfluorotridecane sulfonamide	SPr-FTrDSA	C16H8O5S2NF27	N-Sulfo Propyl perFluoroAlkaneSulfonAmide	SPr-FASA
N-sulfo propyl dimethyl ammonio propyl perfluoroethane sulfonamide	SPrAmPr-FEtSA	C10H19O5S2N2F5	N-Sulfo Propyl dimethyl Ammonio Propyl perFluoroAlkaneSulfonamide	SPrAmPr-FASA
N-sulfo propyl dimethyl ammonio propyl perfluoropropane sulfonamide	SPrAmPr-FPrSA	C11H19O5S2N2F7	N-Sulfo Propyl dimethyl Ammonio Propyl perFluoroAlkaneSulfonamide	SPrAmPr-FASA
N-sulfo propyl dimethyl ammonio propyl perfluorobutane sulfonamide	SPrAmPr-FBSA	C12H19O5S2N2F9	N-Sulfo Propyl dimethyl Ammonio Propyl perFluoroAlkaneSulfonamide	SPrAmPr-FASA
N-sulfo propyl dimethyl ammonio propyl perfluoropentane sulfonamide	SPrAmPr-FPeSA	C13H19O5S2N2F11	N-Sulfo Propyl dimethyl Ammonio Propyl perFluoroAlkaneSulfonamide	SPrAmPr-FASA
N-sulfo propyl dimethyl ammonio propyl perfluorohexane sulfonamide	SPrAmPr-FHxSA	C14H19O5S2N2F13	N-Sulfo Propyl dimethyl Ammonio Propyl perFluoroAlkaneSulfonamide	SPrAmPr-FASA
N-sulfo propyl dimethyl ammonio propyl perfluoroheptane sulfonamide	SPrAmPr-FHpSA	C15H19O5S2N2F15	N-Sulfo Propyl dimethyl Ammonio Propyl perFluoroAlkaneSulfonamide	SPrAmPr-FASA
N-sulfo propyl dimethyl ammonio propyl perfluorooctane sulfonamide	SPrAmPr-FOSA	C16H19O5S2N2F17	N-Sulfo Propyl dimethyl Ammonio Propyl perFluoroAlkaneSulfonamide	SPrAmPr-FASA
N-sulfo propyl dimethyl ammonio propyl perfluorononane sulfonamide	SPrAmPr-FNSA	C17H19O5S2N2F19	N-Sulfo Propyl dimethyl Ammonio Propyl perFluoroAlkaneSulfonamide	SPrAmPr-FASA
N-sulfo propyl dimethyl ammonio propyl perfluorodecane sulfonamide	SPrAmPr-FDSA	C18H19O5S2N2F21	N-Sulfo Propyl dimethyl Ammonio Propyl perFluoroAlkaneSulfonamide	SPrAmPr-FASA
N-sulfo propyl dimethyl ammonio propyl perfluoroundecane sulfonamide	SPrAmPr-FUdSA	C19H19O5S2N2F23	N-Sulfo Propyl dimethyl Ammonio Propyl perFluoroAlkaneSulfonamide	SPrAmPr-FASA
N-sulfo propyl dimethyl ammonio propyl perfluorododecane sulfonamide	SPrAmPr-FDoSA	C20H19O5S2N2F25	N-Sulfo Propyl dimethyl Ammonio Propyl perFluoroAlkaneSulfonamide	SPrAmPr-FASA
N-sulfopropyldimethylammoniopropyl-perfluoroethane sulfonamido acetic acid	SPrAmPr-FEtSAA	C12H21O7S2N2F5	N-SulfoPropyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Acetic Acid	SPrAmPr-FASAA
N-sulfopropyldimethylammoniopropyl-perfluoropropane sulfonamido acetic acid	SPrAmPr-FPrSAA	C13H21O7S2N2F7	N-SulfoPropyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Acetic Acid	SPrAmPr-FASAA

N-sulfopropyldimethylammoniopropyl-perfluorobutane sulfonamido acetic acid	SPrAmPr-FBSAA	C14H21O7S2N2F9	N-SulfoPropyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Acetic Acid	SPrAmPr-FASAA
N-sulfopropyldimethylammoniopropyl-perfluoropentane sulfonamido acetic acid	SPrAmPr-FPeSAA	C15H21O7S2N2F11	N-SulfoPropyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Acetic Acid	SPrAmPr-FASAA
N-sulfopropyldimethylammoniopropyl-perfluorohexane sulfonamido acetic acid	SPrAmPr-FHxSAA	C16H21O7S2N2F13	N-SulfoPropyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Acetic Acid	SPrAmPr-FASAA
N-sulfopropyldimethylammoniopropyl-perfluoroheptane sulfonamido acetic acid	SPrAmPr-FHpSAA	C17H21O7S2N2F15	N-SulfoPropyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Acetic Acid	SPrAmPr-FASAA
N-sulfopropyldimethylammoniopropyl-perfluorooctane sulfonamido acetic acid	SPrAmPr-FOSAA	C18H21O7S2N2F17	N-SulfoPropyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Acetic Acid	SPrAmPr-FASAA
N-sulfopropyldimethylammoniopropyl-perfluorononane sulfonamido acetic acid	SPrAmPr-FNSAA	C19H21O7S2N2F19	N-SulfoPropyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Acetic Acid	SPrAmPr-FASAA
N-sulfopropyldimethylammoniopropyl-perfluorodecane sulfonamido acetic acid	SPrAmPr-FDSAA	C20H21O7S2N2F21	N-SulfoPropyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Acetic Acid	SPrAmPr-FASAA
N-sulfopropyldimethylammoniopropyl-perfluoroundecane sulfonamido acetic acid	SPrAmPr-FUdSAA	C21H21O7S2N2F23	N-SulfoPropyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Acetic Acid	SPrAmPr-FASAA
N-sulfopropyldimethylammoniopropyl-perfluorododecane sulfonamido acetic acid	SPrAmPr-FDoSAA	C22H21O7S2N2F25	N-SulfoPropyldimethylAmmonioPropyl-perFluoroAlkaneSulfonamido Acetic Acid	SPrAmPr-FASAA
N-sulfopropyl dimethylammoniopropyl perfluoroethane sulfonamido propyl sulfonate	SPrAmPr-FEtSAPrS	C13H25O8S3N2F5	N-SulfoPropyldimethylAmmonioPropyl perFluoroAlkane SulfonAmidoPropylSulfonate	SPrAmPr-FASAPrS
N-sulfopropyl dimethylammoniopropyl perfluoropropane sulfonamido propyl sulfonate	SPrAmPr-FPrSAPrS	C14H25O8S3N2F7	N-SulfoPropyldimethylAmmonioPropyl perFluoroAlkane SulfonAmidoPropylSulfonate	SPrAmPr-FASAPrS
N-sulfopropyl dimethylammoniopropyl perfluorobutane sulfonamido propyl sulfonate	SPrAmPr-FBSAPrS	C15H25O8S3N2F9	N-SulfoPropyldimethylAmmonioPropyl perFluoroAlkane SulfonAmidoPropylSulfonate	SPrAmPr-FASAPrS
N-sulfopropyl dimethylammoniopropyl perfluoropentane sulfonamido propyl sulfonate	SPrAmPr-FPeSAPrS	C16H25O8S3N2F11	N-SulfoPropyldimethylAmmonioPropyl perFluoroAlkane SulfonAmidoPropylSulfonate	SPrAmPr-FASAPrS
N-sulfopropyl dimethylammoniopropyl perfluorohexane sulfonamido propyl sulfonate	SPrAmPr-FHxSAPrS	C17H25O8S3N2F13	N-SulfoPropyldimethylAmmonioPropyl perFluoroAlkane SulfonAmidoPropylSulfonate	SPrAmPr-FASAPrS
N-sulfopropyl dimethylammoniopropyl perfluoroheptane sulfonamido propyl sulfonate	SPrAmPr-FHpSAPrS	C18H25O8S3N2F15	N-SulfoPropyldimethylAmmonioPropyl perFluoroAlkane SulfonAmidoPropylSulfonate	SPrAmPr-FASAPrS
N-sulfopropyl dimethylammoniopropyl perfluorooctane sulfonamido propyl sulfonate	SPrAmPr-FOSAPrS	C19H25O8S3N2F17	N-SulfoPropyldimethylAmmonioPropyl perFluoroAlkane SulfonAmidoPropylSulfonate	SPrAmPr-FASAPrS
N-sulfopropyl dimethylammoniopropyl perfluorononane sulfonamido propyl sulfonate	SPrAmPr-FNSAPrS	C20H25O8S3N2F19	N-SulfoPropyldimethylAmmonioPropyl perFluoroAlkane SulfonAmidoPropylSulfonate	SPrAmPr-FASAPrS
N-sulfopropyl dimethylammoniopropyl perfluorodecane sulfonamido propyl sulfonate	SPrAmPr-FDSAPrS	C21H25O8S3N2F21	N-SulfoPropyldimethylAmmonioPropyl perFluoroAlkane SulfonAmidoPropylSulfonate	SPrAmPr-FASAPrS
N-sulfopropyl dimethylammoniopropyl perfluoroundecane sulfonamido propyl sulfonate	SPrAmPr-FUdSAPrS	C22H25O8S3N2F23	N-SulfoPropyldimethylAmmonioPropyl perFluoroAlkane SulfonAmidoPropylSulfonate	SPrAmPr-FASAPrS
N-sulfopropyl dimethylammoniopropyl perfluorododecane sulfonamido propyl sulfonate	SPrAmPr-FDoSAPrS	C23H25O8S3N2F25	N-SulfoPropyldimethylAmmonioPropyl perFluoroAlkane SulfonAmidoPropylSulfonate	SPrAmPr-FASAPrS
N-sulfopropyldimethylammoniopropyl N-methyl perfuoroethanesulfonamide	SPrAmPr-N-Me-FEtSA	C11H21O5S2N2F5	N-SulfoPropyldimethylAmmonioPropyl N-Methyl perFluoroAlkaneSulfonAmide	SPrAmPr-N-Me-FASA

N-sulfopropyldimethylammoniopropyl N-methyl perfuoropropanesulfonamide	SPrAmPr-N-Me-FPrSA	C12H21O5S2N2F7	N-SulfoPropyldimethylAmmonioPropyl N-Methyl perFluoroAlkaneSulfonAmide	SPrAmPr-N-Me-FASA
N-sulfopropyldimethylammoniopropyl N-methyl perfuorobutanesulfonamide	SPrAmPr-N-Me-FBSA	C13H21O5S2N2F9	N-SulfoPropyldimethylAmmonioPropyl N-Methyl perFluoroAlkaneSulfonAmide	SPrAmPr-N-Me-FASA
N-sulfopropyldimethylammoniopropyl N-methyl perfuoropentanesulfonamide	SPrAmPr-N-Me-FPeSA	C14H21O5S2N2F11	N-SulfoPropyldimethylAmmonioPropyl N-Methyl perFluoroAlkaneSulfonAmide	SPrAmPr-N-Me-FASA
N-sulfopropyldimethylammoniopropyl N-methyl perfuorohexanesulfonamide	SPrAmPr-N-Me-FHxSA	C15H21O5S2N2F13	N-SulfoPropyldimethylAmmonioPropyl N-Methyl perFluoroAlkaneSulfonAmide	SPrAmPr-N-Me-FASA
N-sulfopropyldimethylammoniopropyl N-methyl perfuoroheptanesulfonamide	SPrAmPr-N-Me-FHpSA	C16H21O5S2N2F15	N-SulfoPropyldimethylAmmonioPropyl N-Methyl perFluoroAlkaneSulfonAmide	SPrAmPr-N-Me-FASA
N-sulfopropyldimethylammoniopropyl N-methyl perfuorooctanesulfonamide	SPrAmPr-N-Me-FOSA	C17H21O5S2N2F17	N-SulfoPropyldimethylAmmonioPropyl N-Methyl perFluoroAlkaneSulfonAmide	SPrAmPr-N-Me-FASA
N-sulfopropyldimethylammoniopropyl N-methyl perfuorononanesulfonamide	SPrAmPr-N-Me-FNSA	C18H21O5S2N2F19	N-SulfoPropyldimethylAmmonioPropyl N-Methyl perFluoroAlkaneSulfonAmide	SPrAmPr-N-Me-FASA
N-sulfopropyldimethylammoniopropyl N-methyl perfuorodecanesulfonamide	SPrAmPr-N-Me-FDSA	C19H21O5S2N2F21	N-SulfoPropyldimethylAmmonioPropyl N-Methyl perFluoroAlkaneSulfonAmide	SPrAmPr-N-Me-FASA
N-sulfopropyldimethylammoniopropyl N-methyl perfuoroundecanesulfonamide	SPrAmPr-N-Me-FUdSA	C20H21O5S2N2F23	N-SulfoPropyldimethylAmmonioPropyl N-Methyl perFluoroAlkaneSulfonAmide	SPrAmPr-N-Me-FASA
N-sulfopropyldimethylammoniopropyl N-methyl perfuorododecanesulfonamide	SPrAmPr-N-Me-FDoSA	C21H21O5S2N2F25	N-SulfoPropyldimethylAmmonioPropyl N-Methyl perFluoroAlkaneSulfonAmide	SPrAmPr-N-Me-FASA
N-sulfopropyl (hydroxyethyl methyl) ammonio propyl perfluoroethane sulfonamide	SPr-EtOHAm-Pr-FEtSA	C11H21O6S2N2F5	N-Sulfo Propyl (Hydroxyethyl Methyl) Ammonio Propyl perFluoroAlkane SulfonAmide	SPr-EtOHAm-Pr-FASA
N-sulfopropyl (hydroxyethyl methyl) ammonio propylperfluoropropane sulfonamide	SPr-EtOHAm-Pr-FPrSA	C12H21O6S2N2F7	N-Sulfo Propyl (Hydroxyethyl Methyl) Ammonio Propyl perFluoroAlkane SulfonAmide	SPr-EtOHAm-Pr-FASA
N-sulfopropyl (hydroxyethyl methyl) ammonio propylperfluorobutane sulfonamide	SPr-EtOHAm-Pr-FBSA	C13H21O6S2N2F9	N-Sulfo Propyl (Hydroxyethyl Methyl) Ammonio Propyl perFluoroAlkane SulfonAmide	SPr-EtOHAm-Pr-FASA
N-sulfopropyl (hydroxyethyl methyl) ammonio propylperfluoropentane sulfonamide	SPr-EtOHAm-Pr-FPeSA	C14H21O6S2N2F11	N-Sulfo Propyl (Hydroxyethyl Methyl) Ammonio Propyl perFluoroAlkane SulfonAmide	SPr-EtOHAm-Pr-FASA
N-sulfopropyl (hydroxyethyl methyl) ammonio propylperfluorohexane sulfonamide	SPr-EtOHAm-Pr-FHxSA	C15H21O6S2N2F13	N-Sulfo Propyl (Hydroxyethyl Methyl) Ammonio Propyl perFluoroAlkane SulfonAmide	SPr-EtOHAm-Pr-FASA
N-sulfopropyl (hydroxyethyl methyl) ammonio propylperfluoroheptane sulfonamide	SPr-EtOHAm-Pr-FHpSA	C16H21O6S2N2F15	N-Sulfo Propyl (Hydroxyethyl Methyl) Ammonio Propyl perFluoroAlkane SulfonAmide	SPr-EtOHAm-Pr-FASA
N-sulfopropyl (hydroxyethyl methyl) ammonio propylperfluorooctane sulfonamide	SPr-EtOHAm-Pr-FOSA	C17H21O6S2N2F17	N-Sulfo Propyl (Hydroxyethyl Methyl) Ammonio Propyl perFluoroAlkane SulfonAmide	SPr-EtOHAm-Pr-FASA
N-sulfopropyl (hydroxyethyl methyl) ammonio propylperfluorononane sulfonamide	SPr-EtOHAm-Pr-FNSA	C18H21O6S2N2F19	N-Sulfo Propyl (Hydroxyethyl Methyl) Ammonio Propyl perFluoroAlkane SulfonAmide	SPr-EtOHAm-Pr-FASA
N-sulfopropyl (hydroxyethyl methyl) ammonio propylperfluorodecane sulfonamide	SPr-EtOHAm-Pr-FDSA	C19H21O6S2N2F21	N-Sulfo Propyl (Hydroxyethyl Methyl) Ammonio Propyl perFluoroAlkane SulfonAmide	SPr-EtOHAm-Pr-FASA
N-sulfopropyl (hydroxyethyl methyl) ammonio propylperfluoroundecane sulfonamide	SPr-EtOHAm-Pr-FUdSA	C20H21O6S2N2F23	N-Sulfo Propyl (Hydroxyethyl Methyl) Ammonio Propyl perFluoroAlkane SulfonAmide	SPr-EtOHAm-Pr-FASA
N-sulfopropyl (hydroxyethyl methyl) ammonio propylperfluorododecane sulfonamide	SPr-EtOHAm-Pr-FDoSA	C21H21O6S2N2F25	N-Sulfo Propyl (Hydroxyethyl Methyl) Ammonio Propyl perFluoroAlkane SulfonAmide	SPr-EtOHAm-Pr-FASA

N-sulfo hydroxypropyl dimethylammonio propyl perfluoroethane sulfonamide	S-OHPrAmPr-FEtSA	C10H19O6S2N2F5	N-SulfohydroxyPropyl dimethyl Ammonio Propyl perFluoroAlkaneSulfonamide	SOHPrAmPr-FASA
N-sulfo hydroxypropyl dimethylammonio propyl perfluoropropane sulfonamide	S-OHPrAmPr-FPrSA	C11H19O6S2N2F7	N-SulfohydroxyPropyl dimethyl Ammonio Propyl perFluoroAlkaneSulfonamide	SOHPrAmPr-FASA
N-sulfo hydroxypropyl dimethylammonio propyl perfluorobutane sulfonamide	S-OHPrAmPr-FBSA	C12H19O6S2N2F9	N-SulfohydroxyPropyl dimethyl Ammonio Propyl perFluoroAlkaneSulfonamide	SOHPrAmPr-FASA
N-sulfo hydroxypropyl dimethylammonio propyl perfluoropentane sulfonamide	S-OHPrAmPr-FPeSA	C13H19O6S2N2F11	N-SulfohydroxyPropyl dimethyl Ammonio Propyl perFluoroAlkaneSulfonamide	SOHPrAmPr-FASA
N-sulfo hydroxypropyl dimethylammonio propyl perfluorohexane sulfonamide	S-OHPrAmPr-FHxSA	C14H19O6S2N2F13	N-SulfohydroxyPropyl dimethyl Ammonio Propyl perFluoroAlkaneSulfonamide	SOHPrAmPr-FASA
N-sulfo hydroxypropyl dimethylammonio propyl perfluoroheptane sulfonamide	S-OHPrAmPr-FHpSA	C15H19O6S2N2F15	N-SulfohydroxyPropyl dimethyl Ammonio Propyl perFluoroAlkaneSulfonamide	SOHPrAmPr-FASA
N-sulfo hydroxypropyl dimethylammonio propyl perfluorooctane sulfonamide	S-OHPrAmPr-FOSA	C16H19O6S2N2F17	N-SulfohydroxyPropyl dimethyl Ammonio Propyl perFluoroAlkaneSulfonamide	SOHPrAmPr-FASA
N-sulfo hydroxypropyl dimethylammonio propyl perfluorononane sulfonamide	S-OHPrAmPr-FNSA	C17H19O6S2N2F19	N-SulfohydroxyPropyl dimethyl Ammonio Propyl perFluoroAlkaneSulfonamide	SOHPrAmPr-FASA
N-sulfo hydroxypropyl dimethylammonio propyl perfluorodecane sulfonamide	S-OHPrAmPr-FDSA	C18H19O6S2N2F21	N-SulfohydroxyPropyl dimethyl Ammonio Propyl perFluoroAlkaneSulfonamide	SOHPrAmPr-FASA
N-sulfo hydroxypropyl dimethylammonio propyl perfluoroundecane sulfonamide	S-OHPrAmPr-FUdSA	C19H19O6S2N2F23	N-SulfohydroxyPropyl dimethyl Ammonio Propyl perFluoroAlkaneSulfonamide	SOHPrAmPr-FASA
N-sulfo hydroxypropyl dimethylammonio propyl perfluorododecane sulfonamide	S-OHPrAmPr-FDoSA	C20H19O6S2N2F25	N-SulfohydroxyPropyl dimethyl Ammonio Propyl perFluoroAlkaneSulfonamide	SOHPrAmPr-FASA
N-sulfohydroxypropyl dimethylammoniopropyl perfluoroethane sulfonamido acetic acid	S-OHPrAmPr-FEtSAA	C12H21O8S2N2F5	N-SulfohydroxyPropyl dimethyl AmmonioPropyl perFluoroAlkaneSulfonamido Acetic Acid	S-OHPrAmPr-FASAA
N-sulfohydroxypropyl dimethylammoniopropyl perfluoropropane sulfonamido acetic acid	S-OHPrAmPr-FPrSAA	C13H21O8S2N2F7	N-SulfohydroxyPropyl dimethyl AmmonioPropyl perFluoroAlkaneSulfonamido Acetic Acid	S-OHPrAmPr-FASAA
N-sulfohydroxypropyl dimethylammoniopropyl perfluorobutane sulfonamido acetic acid	S-OHPrAmPr-FBSAA	C14H21O8S2N2F9	N-SulfohydroxyPropyl dimethyl AmmonioPropyl perFluoroAlkaneSulfonamido Acetic Acid	S-OHPrAmPr-FASAA
N-sulfohydroxypropyl dimethylammoniopropyl perfluoropentane sulfonamido acetic acid	S-OHPrAmPr-FPeSAA	C15H21O8S2N2F11	N-SulfohydroxyPropyl dimethyl AmmonioPropyl perFluoroAlkaneSulfonamido Acetic Acid	S-OHPrAmPr-FASAA
N-sulfohydroxypropyl dimethylammoniopropyl perfluorohexane sulfonamido acetic acid	S-OHPrAmPr-FHxSAA	C16H21O8S2N2F13	N-SulfohydroxyPropyl dimethyl AmmonioPropyl perFluoroAlkaneSulfonamido Acetic Acid	S-OHPrAmPr-FASAA
N-sulfohydroxypropyl dimethylammoniopropyl perfluoroheptane sulfonamido acetic acid	S-OHPrAmPr-FHpSAA	C17H21O8S2N2F15	N-SulfohydroxyPropyl dimethyl AmmonioPropyl perFluoroAlkaneSulfonamido Acetic Acid	S-OHPrAmPr-FASAA
N-sulfohydroxypropyl dimethylammoniopropyl perfluorooctane sulfonamido acetic acid	S-OHPrAmPr-FOSAA	C18H21O8S2N2F17	N-SulfohydroxyPropyl dimethyl AmmonioPropyl perFluoroAlkaneSulfonamido Acetic Acid	S-OHPrAmPr-FASAA
N-sulfohydroxypropyl dimethylammoniopropyl perfluorononane sulfonamido acetic acid	S-OHPrAmPr-FNSAA	C19H21O8S2N2F19	N-SulfohydroxyPropyl dimethyl AmmonioPropyl perFluoroAlkaneSulfonamido Acetic Acid	S-OHPrAmPr-FASAA
N-sulfohydroxypropyl dimethylammoniopropyl perfluorodecane sulfonamido acetic acid	S-OHPrAmPr-FDSAA	C20H21O8S2N2F21	N-SulfohydroxyPropyl dimethyl AmmonioPropyl perFluoroAlkaneSulfonamido Acetic Acid	S-OHPrAmPr-FASAA
N-sulfohydroxypropyl dimethylammoniopropyl perfluoroundecane sulfonamido acetic acid	S-OHPrAmPr-FUdSAA	C21H21O8S2N2F23	N-SulfohydroxyPropyl dimethyl AmmonioPropyl perFluoroAlkaneSulfonamido Acetic Acid	S-OHPrAmPr-FASAA

N-sulfohydroxypropyl dimethylammoniopropyl perfluorododecane sulfonamido acetic acid	S-OHPrAmPr-FDoSAA	C22H21O8S2N2F25	N-SulfohydroxyPropyl dimethyl AmmonioPropyl perFluoroAlkaneSulfonamido Acetic Acid	S-OHPrAmPr-FASAA
N-sulfohydroxy propyl dimethylammonio propyl perfluoroethane sulfonamido hydroxy propyl sulfonate	S-OHPrAmPr-FEtSA-OHPrS	C13H25O10S3N2F5	N-SulfohydroxyPropyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamidohydroxypropyl Sulfonate	S-OHPrAmPr-FASA-OHPrS
N-sulfohydroxypropyl dimethylammonio propyl perfluoropropane sulfonamido hydroxy propyl sulfonate	S-OHPrAmPr-FPrSA-OHPrS	C14H25O10S3N2F7	N-SulfohydroxyPropyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamidohydroxypropyl Sulfonate	S-OHPrAmPr-FASA-OHPrS
N-sulfohydroxypropyl dimethylammonio propyl perfluorobutane sulfonamido hydroxy propyl sulfonate	S-OHPrAmPr-FBSA-OHPrS	C15H25O10S3N2F9	N-SulfohydroxyPropyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamidohydroxypropyl Sulfonate	S-OHPrAmPr-FASA-OHPrS
N-sulfohydroxypropyl dimethylammonio propyl perfluoropentane sulfonamido hydroxy propyl sulfonate	S-OHPrAmPr-FPeSA-OHPrS	C16H25O10S3N2F11	N-SulfohydroxyPropyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamidohydroxypropyl Sulfonate	S-OHPrAmPr-FASA-OHPrS
N-sulfohydroxypropyl dimethylammonio propyl perfluorohexane sulfonamido hydroxy propyl sulfonate	S-OHPrAmPr-FHxSA-OHPrS	C17H25O10S3N2F13	N-SulfohydroxyPropyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamidohydroxypropyl Sulfonate	S-OHPrAmPr-FASA-OHPrS
N-sulfohydroxypropyl dimethylammonio propyl perfluoroheptane sulfonamido hydroxy propyl sulfonate	S-OHPrAmPr-FHpSA-OHPrS	C18H25O10S3N2F15	N-SulfohydroxyPropyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamidohydroxypropyl Sulfonate	S-OHPrAmPr-FASA-OHPrS
N-sulfohydroxypropyl dimethylammonio propyl perfluorooctane sulfonamido hydroxy propyl sulfonate	S-OHPrAmPr-FOSA-OHPrS	C19H25O10S3N2F17	N-SulfohydroxyPropyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamidohydroxypropyl Sulfonate	S-OHPrAmPr-FASA-OHPrS
N-sulfohydroxypropyl dimethylammonio propyl perfluorononane sulfonamido hydroxy propyl sulfonate	S-OHPrAmPr-FNSA-OHPrS	C20H25O10S3N2F19	N-SulfohydroxyPropyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamidohydroxypropyl Sulfonate	S-OHPrAmPr-FASA-OHPrS
N-sulfohydroxypropyl dimethylammonio propyl perfluorodecane sulfonamido hydroxy propyl sulfonate	S-OHPrAmPr-FDSA-OHPrS	C21H25O10S3N2F21	N-SulfohydroxyPropyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamidohydroxypropyl Sulfonate	S-OHPrAmPr-FASA-OHPrS
N-sulfohydroxypropyl dimethylammonio propyl perfluoroundecane sulfonamido hydroxy propyl sulfonate	S-OHPrAmPr-FUdSA-OHPrS	C22H25O10S3N2F23	N-SulfohydroxyPropyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamidohydroxypropyl Sulfonate	S-OHPrAmPr-FASA-OHPrS
N-sulfohydroxypropyl dimethylammonio propyl perfluorododecane sulfonamido hydroxy propyl sulfonate	S-OHPrAmPr-FDoSA-OHPrS	C23H25O10S3N2F25	N-SulfohydroxyPropyl dimethylAmmonio Propyl perFluoroAlkaneSulfonamidohydroxypropyl Sulfonate	S-OHPrAmPr-FASA-OHPrS
N-Trimethylammoniopropyl perfluoroethane sulfonamide	TAmPr-FEtSA	C8H15O2SN2F5	N-TrimethylAmmonioPropyl perFluoroAlkaneSulfonamide	TAmPr-FASA
N-Trimethylammoniopropyl perfluoropropane sulfonamide	TAmPr-FPrSA	C9H15O2SN2F7	N-TrimethylAmmonioPropyl perFluoroAlkaneSulfonamide	TAmPr-FASA
N-Trimethylammoniopropyl perfluorobutane sulfonamide	TAmPr-FBSA	C10H15O2SN2F9	N-TrimethylAmmonioPropyl perFluoroAlkaneSulfonamide	TAmPr-FASA
N-Trimethylammoniopropyl perfluoropentane sulfonamide	TAmPr-FPeSA	C11H15O2SN2F11	N-TrimethylAmmonioPropyl perFluoroAlkaneSulfonamide	TAmPr-FASA
N-Trimethylammoniopropyl perfluorohexane sulfonamide	TAmPr-FHxSA	C12H15O2SN2F13	N-TrimethylAmmonioPropyl perFluoroAlkaneSulfonamide	TAmPr-FASA
N-Trimethylammoniopropyl perfluoroheptane sulfonamide	TAmPr-FHpSA	C13H15O2SN2F15	N-TrimethylAmmonioPropyl perFluoroAlkaneSulfonamide	TAmPr-FASA
N-Trimethylammoniopropyl perfluorooctane sulfonamide	TAmPr-FOSA	C14H15O2SN2F17	N-TrimethylAmmonioPropyl perFluoroAlkaneSulfonamide	TAmPr-FASA
N-Trimethylammoniopropyl perfluorononane sulfonamide	TAmPr-FNSA	C15H15O2SN2F19	N-TrimethylAmmonioPropyl perFluoroAlkaneSulfonamide	TAmPr-FASA
N-Trimethylammoniopropyl perfluorodecane sulfonamide	TAmPr-FDSA	C16H15O2SN2F21	N-TrimethylAmmonioPropyl perFluoroAlkaneSulfonamide	TAmPr-FASA

N-Trimethylammoniopropyl perfluoroundecane sulfonamide	TAmPr-FUdSA	C17H15O2SN2F23	N-TrimethylAmmonioPropyl perFluoroAlkaneSulfonamide	TAmPr-FASA
N-Trimethylammoniopropyl perfluorododecane sulfonamide	TAmPr-FDoSA	C18H15O2SN2F25	N-TrimethylAmmonioPropyl perFluoroAlkaneSulfonamide	TAmPr-FASA
N-trimethylammoniopropyl perfluoroethane sulfonamido propanoic acid	TAmPr-FEtSAPrA	C11H19O4SN2F5	N-TrimethylAmmonioPropyl perFluoroAlkaneSulfonAmido Propanoic acid	TAmPr-FASAPrA
N-trimethylammoniopropyl perfluoropropane sulfonamido propanoic acid	TAmPr-FPrSAPrA	C12H19O4SN2F7	N-TrimethylAmmonioPropyl perFluoroAlkaneSulfonAmido Propanoic acid	TAmPr-FASAPrA
N-trimethylammoniopropyl perfluorobutane sulfonamido propanoic acid	TAmPr-FBSAPrA	C13H19O4SN2F9	N-TrimethylAmmonioPropyl perFluoroAlkaneSulfonAmido Propanoic acid	TAmPr-FASAPrA
N-trimethylammoniopropyl perfluoropentane sulfonamido propanoic acid	TAmPr-FPeSAPrA	C14H19O4SN2F11	N-TrimethylAmmonioPropyl perFluoroAlkaneSulfonAmido Propanoic acid	TAmPr-FASAPrA
N-trimethylammoniopropyl perfluorohexane sulfonamido propanoic acid	TAmPr-FHxSAPrA	C15H19O4SN2F13	N-TrimethylAmmonioPropyl perFluoroAlkaneSulfonAmido Propanoic acid	TAmPr-FASAPrA
N-trimethylammoniopropyl perfluoroheptane sulfonamido propanoic acid	TAmPr-FHpSAPrA	C16H19O4SN2F15	N-TrimethylAmmonioPropyl perFluoroAlkaneSulfonAmido Propanoic acid	TAmPr-FASAPrA
N-trimethylammoniopropyl perfluorooctane sulfonamido propanoic acid	TAmPr-FOSAPrA	C17H19O4SN2F17	N-TrimethylAmmonioPropyl perFluoroAlkaneSulfonAmido Propanoic acid	TAmPr-FASAPrA
N-trimethylammoniopropyl perfluorononane sulfonamido propanoic acid	TAmPr-FNSAPrA	C18H19O4SN2F19	N-TrimethylAmmonioPropyl perFluoroAlkaneSulfonAmido Propanoic acid	TAmPr-FASAPrA
N-trimethylammoniopropyl perfluorodecane sulfonamido propanoic acid	TAmPr-FDSAPrA	C19H19O4SN2F21	N-TrimethylAmmonioPropyl perFluoroAlkaneSulfonAmido Propanoic acid	TAmPr-FASAPrA
N-trimethylammoniopropyl perfluoroundecane sulfonamido propanoic acid	TAmPr-FUdSAPrA	C20H19O4SN2F23	N-TrimethylAmmonioPropyl perFluoroAlkaneSulfonAmido Propanoic acid	TAmPr-FASAPrA
N-trimethylammoniopropyl perfluorododecane sulfonamido propanoic acid	TAmPr-FDoSAPrA	C21H19O4SN2F25	N-TrimethylAmmonioPropyl perFluoroAlkaneSulfonAmido Propanoic acid	TAmPr-FASAPrA
N-trimethylammoniopropyl N-methylperfluoroethanesulfonamide	TAmPr-N-MeFEtSA	C9H17O2SN2F5	N-TrimethylAmmonioPropyl N-Methyl perFluoroAlkaneSulfonamide	TAmPr-N-MeFASA
N-trimethylammoniopropyl N-methylperfluoropropanesulfonamide	TAmPr-N-MeFPrSA	C10H17O2SN2F7	N-TrimethylAmmonioPropyl N-Methyl perFluoroAlkaneSulfonamide	TAmPr-N-MeFASA
N-trimethylammoniopropyl N-methylperfluorobutanesulfonamide	TAmPr-N-MeFBSA	C11H17O2SN2F9	N-TrimethylAmmonioPropyl N-Methyl perFluoroAlkaneSulfonamide	TAmPr-N-MeFASA
N-trimethylammoniopropyl N-methylperfluoropentanesulfonamide	TAmPr-N-MeFPeSA	C12H17O2SN2F11	N-TrimethylAmmonioPropyl N-Methyl perFluoroAlkaneSulfonamide	TAmPr-N-MeFASA
N-trimethylammoniopropyl N-methylperfluorohexanesulfonamide	TAmPr-N-MeFHxSA	C13H17O2SN2F13	N-TrimethylAmmonioPropyl N-Methyl perFluoroAlkaneSulfonamide	TAmPr-N-MeFASA
N-trimethylammoniopropyl N-methylperfluoroheptanesulfonamide	TAmPr-N-MeFHpSA	C14H17O2SN2F15	N-TrimethylAmmonioPropyl N-Methyl perFluoroAlkaneSulfonamide	TAmPr-N-MeFASA
N-trimethylammoniopropyl N-methylperfluorooctanesulfonamide	TAmPr-N-MeFOSA	C15H17O2SN2F17	N-TrimethylAmmonioPropyl N-Methyl perFluoroAlkaneSulfonamide	TAmPr-N-MeFASA
N-trimethylammoniopropyl N-methylperfluorononanesulfonamide	TAmPr-N-MeFNSA	C16H17O2SN2F19	N-TrimethylAmmonioPropyl N-Methyl perFluoroAlkaneSulfonamide	TAmPr-N-MeFASA

N-trimethylammoniopropyl N-methylperfluorodecanesulfonamide	TAmPr-N-MeFDSA	C17H17O2SN2F21	N-TrimethylAmmonioPropyl N-Methyl perFluoroAlkaneSulfonamide	TAmPr-N-MeFASA
N-trimethylammoniopropyl N-methylperfluoroundecanesulfonamide	TAmPr-N-MeFUdSA	C18H17O2SN2F23	N-TrimethylAmmonioPropyl N-Methyl perFluoroAlkaneSulfonamide	TAmPr-N-MeFASA
N-trimethylammoniopropyl N-methylperfluorododecanesulfonamide	TAmPr-N-MeFDoSA	C19H17O2SN2F25	N-TrimethylAmmonioPropyl N-Methyl perFluoroAlkaneSulfonamide	TAmPr-N-MeFASA
N-dimethyl ammonio propyl-perfluoroethane amide	AmPr-FEtAd	C7H13ON2F3	N-dimethylammonio propyl-perfluoroalkaneamide	AmPr-FAAd
N-dimethyl ammonio propyl-perfluoropropane amide	AmPr-FPrAd	C8H13ON2F5	N-dimethylammonio propyl-perfluoroalkaneamide	AmPr-FAAd
N-dimethyl ammonio propyl-perfluorobutane amide	AmPr-FBAd	C9H13ON2F7	N-dimethylammonio propyl-perfluoroalkaneamide	AmPr-FAAd
N-dimethyl ammonio propyl-perfluoropentane amide	AmPr-FPeAd	C10H13ON2F9	N-dimethylammonio propyl-perfluoroalkaneamide	AmPr-FAAd
N-dimethyl ammonio propyl-perfluorohexane amide	AmPr-FHxAd	C11H13ON2F11	N-dimethylammonio propyl-perfluoroalkaneamide	AmPr-FAAd
N-dimethyl ammonio propyl-perfluoroheptane amide	AmPr-FHpAd	C12H13ON2F13	N-dimethylammonio propyl-perfluoroalkaneamide	AmPr-FAAd
N-dimethyl ammonio propyl-perfluorooctane amide	AmPr-FOAd	C13H13ON2F15	N-dimethylammonio propyl-perfluoroalkaneamide	AmPr-FAAd
N-dimethyl ammonio propyl-perfluorononane amide	AmPr-FNAd	C14H13ON2F17	N-dimethylammonio propyl-perfluoroalkaneamide	AmPr-FAAd
N-dimethyl ammonio propyl-perfluorodecane amide	AmPr-FDAd	C15H13ON2F19	N-dimethylammonio propyl-perfluoroalkaneamide	AmPr-FAAd
N-dimethyl ammonio propyl-perfluoroundecane amide	AmPr-FUdAd	C16H13ON2F21	N-dimethylammonio propyl-perfluoroalkaneamide	AmPr-FAAd
N-dimethyl ammonio propyl-perfluorododecane amide	AmPr-FDoAd	C17H13ON2F23	N-dimethylammonio propyl-perfluoroalkaneamide	AmPr-FAAd
N-dimethyl ammonio propyl-perfluorotridecane amide	AmPr-FTrDAd	C18H13ON2F25	N-dimethylammonio propyl-perfluoroalkaneamide	AmPr-FAAd
N-dimethyl ammonio propyl-perfluorotetradecane amide	AmPr-FTeDAd	C19H13ON2F27	N-dimethylammonio propyl-perfluoroalkaneamide	AmPr-FAAd
N-dimethyl ammonio propyl-perfluoropentadecane amide	AmPr-FPeDAd	C20H13ON2F29	N-dimethylammonio propyl-perfluoroalkaneamide	AmPr-FAAd
N-betaine propyl perfluoroethane amide	BPr-FEtAd	C9H15O3N2F3	N-betaine propyl perfluoroalkane amide	BPr-FAAd
N-betaine propyl perfluoropropane amide	BPr-FPrAd	C10H15O3N2F5	N-betaine propyl perfluoroalkane amide	BPr-FAAd
N-betaine propyl perfluorobutane amide	BPr-FBAd	C11H15O3N2F7	N-betaine propyl perfluoroalkane amide	BPr-FAAd
N-betaine propyl perfluoropentane amide	BPr-FPeAd	C12H15O3N2F9	N-betaine propyl perfluoroalkane amide	BPr-FAAd
N-betaine propyl perfluorohexane amide	BPr-FHxAd	C13H15O3N2F11	N-betaine propyl perfluoroalkane amide	BPr-FAAd
N-betaine propyl perfluoroheptane amide	BPr-FHpAd	C14H15O3N2F13	N-betaine propyl perfluoroalkane amide	BPr-FAAd
N-betaine propyl perfluorooctane amide	BPr-FOAd	C15H15O3N2F15	N-betaine propyl perfluoroalkane amide	BPr-FAAd
N-betaine propyl perfluorononane amide	BPr-FNAd	C16H15O3N2F17	N-betaine propyl perfluoroalkane amide	BPr-FAAd
N-betaine propyl perfluorodecane amide	BPr-FDAd	C17H15O3N2F19	N-betaine propyl perfluoroalkane amide	BPr-FAAd
N-betaine propyl perfluoroundecane amide	BPr-FUdAd	C18H15O3N2F21	N-betaine propyl perfluoroalkane amide	BPr-FAAd
N-betaine propyl perfluorododecane amide	BPr-FDoAd	C19H15O3N2F23	N-betaine propyl perfluoroalkane amide	BPr-FAAd
N-betaine propyl perfluorotridecane amide	BPr-FTrDAd	C20H15O3N2F25	N-betaine propyl perfluoroalkane amide	BPr-FAAd
N-betaine propyl perfluorotetradecane amide	BPr-FTeDAd	C21H15O3N2F27	N-betaine propyl perfluoroalkane amide	BPr-FAAd
N-betaine propyl perfluoropentadecane amide	BPr-FPeDAd	C22H15O3N2F29	N-betaine propyl perfluoroalkane amide	BPr-FAAd
N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluoroethane amide	MeEtCMeAmPr-FEtAd	C12H21O3N2F3	N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluoroalkane amide	MeEtCMeAmPr-FAAd
N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluoropropane amide	MeEtCMeAmPr-FPrAd	C13H21O3N2F5	N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluoroalkane amide	MeEtCMeAmPr-FAAd

N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluorobutane amide	MeEtCMeAmPr-FBAd	C14H21O3N2F7	N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluoroalkane amide	MeEtCMeAmPr-FAAd
N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluoropentane amide	MeEtCMeAmPr-FPeAd	C15H21O3N2F9	N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluoroalkane amide	MeEtCMeAmPr-FAAd
N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluorohexane amide	MeEtCMeAmPr-FHxAd	C16H21O3N2F11	N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluoroalkane amide	MeEtCMeAmPr-FAAd
N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluoroheptane amide	MeEtCMeAmPr-FHpAd	C17H21O3N2F13	N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluoroalkane amide	MeEtCMeAmPr-FAAd
N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluorooctane amide	MeEtCMeAmPr-FOAd	C18H21O3N2F15	N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluoroalkane amide	MeEtCMeAmPr-FAAd
N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluorononane amide	MeEtCMeAmPr-FNAd	C19H21O3N2F17	N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluoroalkane amide	MeEtCMeAmPr-FAAd
N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluorodecane amide	MeEtCMeAmPr-FDAd	C20H21O3N2F19	N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluoroalkane amide	MeEtCMeAmPr-FAAd
N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluoroundecane amide	MeEtCMeAmPr-FUdAd	C21H21O3N2F21	N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluoroalkane amide	MeEtCMeAmPr-FAAd
N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluorododecane amide	MeEtCMeAmPr-FDoAd	C22H21O3N2F23	N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluoroalkane amide	MeEtCMeAmPr-FAAd
N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluorotridecane amide	MeEtCMeAmPr-FTrDAd	C23H21O3N2F25	N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluoroalkane amide	MeEtCMeAmPr-FAAd
N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluorotetradecane amide	MeEtCMeAmPr-FTeDAd	C24H21O3N2F27	N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluoroalkane amide	MeEtCMeAmPr-FAAd
N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluoropentadecane amide	MeEtCMeAmPr-FPeDAd	C25H21O3N2F29	N-methylethyl-carboxymethyl dimethyl ammonio propyl perfluoroalkane amide	MeEtCMeAmPr-FAAd
hexafluoropropylene oxide dimer acid *(GenX)*	HFPO-DA	C6HF11O3	perfluoropropoxy propanoic acids	HFPO-DA
trifluoromethoxy propoxy propanoate (*Adona 3M)*	ADONA	C7H2O4F12	ADONA	ADONA
perfluoroethoxy ethoxy acetate *(Asahi product)*	PFEt-O-Ace	C6HO4F11	PFEt-O-Ace	PFEt-O-Ace
1:1 perfluoroethane sulfonate	1:1 PFEtS	C2H3O3SF3	X:1 PerFluoroAlkaneSulfonate	X:1 PFAS
2:1 perfluoropropane sulfonate	2:1 PFPrS	C3H3O3SF5	X:1 PerFluoroAlkaneSulfonate	X:1 PFAS
3:1 perfluorobutane sulfonate	3:1 PFBS	C4H3O3SF7	X:1 PerFluoroAlkaneSulfonate	X:1 PFAS
4:1 perfluoropentane sulfonate	4:1 PFPeS	C5H3O3SF9	X:1 PerFluoroAlkaneSulfonate	X:1 PFAS
5:1 perfluorohexane sulfonate	5:1 PFHxS	C6H3O3SF11	X:1 PerFluoroAlkaneSulfonate	X:1 PFAS
6:1 perfluoroheptane sulfonate	6:1 PFHpS	C7H3O3SF13	X:1 PerFluoroAlkaneSulfonate	X:1 PFAS
7:1 perfluorooctane sulfonate	7:1 PFOS	C8H3O3SF15	X:1 PerFluoroAlkaneSulfonate	X:1 PFAS
8:1 perfluorononane sulfonate	8:1 PFNS	C9H3O3SF17	X:1 PerFluoroAlkaneSulfonate	X:1 PFAS
9:1 perfluorodecane sulfonate	9:1 PFDS	C10H3O3SF19	X:1 PerFluoroAlkaneSulfonate	X:1 PFAS
10:1 perfluoroundecane sulfonate	10:1 PFUdS	C11H3O3SF21	X:1 PerFluoroAlkaneSulfonate	X:1 PFAS
11:1 perfluorododecane sulfonate	11:1 PFDoS	C12H3O3SF23	X:1 PerFluoroAlkaneSulfonate	X:1 PFAS
12:1 perfluorotridecane sulfonate	12:1 PFTrDS	C13H3O3SF25	X:1 PerFluoroAlkaneSulfonate	X:1 PFAS
13:3 perfluorotetradecane sulfonate	13:1 PFTeDS	C14H3O3SF27	X:1 PerFluoroAlkaneSulfonate	X:1 PFAS

1:1 fluorotelomer amino ethyl trimethyl ammonium	1:1 FTA-EtTAm	C7H15N2F3	X:1 fluorotelomer amino ethyl trimethyl ammonium	X:1 FTA-EtTAm
2:1 fluorotelomer amino ethyl trimethyl ammonium	2:1 FTA-EtTAm	C8H15N2F5	X:1 fluorotelomer amino ethyl trimethyl ammonium	X:1 FTA-EtTAm
3:1 fluorotelomer amino ethyl trimethyl ammonium	3:1 FTA-EtTAm	C9H15N2F7	X:1 fluorotelomer amino ethyl trimethyl ammonium	X:1 FTA-EtTAm
4:1 fluorotelomer amino ethyl trimethyl ammonium	4:1 FTA-EtTAm	C10H15N2F9	X:1 fluorotelomer amino ethyl trimethyl ammonium	X:1 FTA-EtTAm
5:1 fluorotelomer amino ethyl trimethyl ammonium	5:1 FTA-EtTAm	C11H15N2F11	X:1 fluorotelomer amino ethyl trimethyl ammonium	X:1 FTA-EtTAm
6:1 fluorotelomer amino ethyl trimethyl ammonium	6:1 FTA-EtTAm	C12H15N2F13	X:1 fluorotelomer amino ethyl trimethyl ammonium	X:1 FTA-EtTAm
7:1 fluorotelomer amino ethyl trimethyl ammonium	7:1 FTA-EtTAm	C13H15N2F15	X:1 fluorotelomer amino ethyl trimethyl ammonium	X:1 FTA-EtTAm
8:1 fluorotelomer amino ethyl trimethyl ammonium	8:1 FTA-EtTAm	C14H15N2F17	X:1 fluorotelomer amino ethyl trimethyl ammonium	X:1 FTA-EtTAm
9:1 fluorotelomer amino ethyl trimethyl ammonium	9:1 FTA-EtTAm	C15H15N2F19	X:1 fluorotelomer amino ethyl trimethyl ammonium	X:1 FTA-EtTAm
10:1 fluorotelomer amino ethyl trimethyl ammonium	10:1 FTA-EtTAm	C16H15N2F21	X:1 fluorotelomer amino ethyl trimethyl ammonium	X:1 FTA-EtTAm
11:1 fluorotelomer amino ethyl trimethyl ammonium	11:1 FTA-EtTAm	C17H15N2F23	X:1 fluorotelomer amino ethyl trimethyl ammonium	X:1 FTA-EtTAm
12:1 fluorotelomer amino ethyl trimethyl ammonium	12:1 FTA-EtTAm	C18H15N2F25	X:1 fluorotelomer amino ethyl trimethyl ammonium	X:1 FTA-EtTAm
13:1 fluorotelomer amino ethyl trimethyl ammonium	13:1 FTA-EtTAm	C19H15N2F27	X:1 fluorotelomer amino ethyl trimethyl ammonium	X:1 FTA-EtTAm
14:1 fluorotelomer amino ethyl trimethyl ammonium	14:1 FTA-EtTAm	C20H15N2F29	X:1 fluorotelomer amino ethyl trimethyl ammonium	X:1 FTA-EtTAm
1:1 hydrido-fluorotelomer trimethyl ammonium	1:1 H-FT-TAm	C5H11NF2	X:1 hydrido-fluorotelomer trimethyl ammonium	X:1 H-FT-TAm
2:1 hydrido-fluorotelomer trimethyl ammonium	2:1 H-FT-TAm	C6H11NF4	X:1 hydrido-fluorotelomer trimethyl ammonium	X:1 H-FT-TAm
3:1 hydrido-fluorotelomer trimethyl ammonium	3:1 H-FT-TAm	C7H11NF6	X:1 hydrido-fluorotelomer trimethyl ammonium	X:1 H-FT-TAm
4:1 hydrido-fluorotelomer trimethyl ammonium	4:1 H-FT-TAm	C8H11NF8	X:1 hydrido-fluorotelomer trimethyl ammonium	X:1 H-FT-TAm
5:1 hydrido-fluorotelomer trimethyl ammonium	5:1 H-FT-TAm	C9H11NF10	X:1 hydrido-fluorotelomer trimethyl ammonium	X:1 H-FT-TAm
6:1 hydrido-fluorotelomer trimethyl ammonium	6:1 H-FT-TAm	C10H11NF12	X:1 hydrido-fluorotelomer trimethyl ammonium	X:1 H-FT-TAm
7:1 hydrido-fluorotelomer trimethyl ammonium	7:1 H-FT-TAm	C11H11NF14	X:1 hydrido-fluorotelomer trimethyl ammonium	X:1 H-FT-TAm
8:1 hydrido-fluorotelomer trimethyl ammonium	8:1 H-FT-TAm	C12H11NF16	X:1 hydrido-fluorotelomer trimethyl ammonium	X:1 H-FT-TAm
9:1 hydrido-fluorotelomer trimethyl ammonium	9:1 H-FT-TAm	C13H11NF18	X:1 hydrido-fluorotelomer trimethyl ammonium	X:1 H-FT-TAm
10:1 hydrido-fluorotelomer trimethyl ammonium	10:1 H-FT-TAm	C14H11NF20	X:1 hydrido-fluorotelomer trimethyl ammonium	X:1 H-FT-TAm
11:1 hydrido-fluorotelomer trimethyl ammonium	11:1 H-FT-TAm	C15H11NF22	X:1 hydrido-fluorotelomer trimethyl ammonium	X:1 H-FT-TAm
12:1 hydrido-fluorotelomer trimethyl ammonium	12:1 H-FT-TAm	C16H11NF24	X:1 hydrido-fluorotelomer trimethyl ammonium	X:1 H-FT-TAm
13:1 hydrido-fluorotelomer trimethyl ammonium	13:1 H-FT-TAm	C17H11NF26	X:1 hydrido-fluorotelomer trimethyl ammonium	X:1 H-FT-TAm
14:1 hydrido-fluorotelomer trimethyl ammonium	14:1 H-FT-TAm	C18H11NF28	X:1 hydrido-fluorotelomer trimethyl ammonium	X:1 H-FT-TAm
2:1 hydrido-fluorotelomer dimethyl ammonio butane	2:1 H-FT-AmBu	C9H17NF4	X:1 hydrido-fluorotelomer dimethyl ammonio butane	X:1 H-FT-AmBu
4:1 hydrido-fluorotelomer dimethyl ammonio butane	4:1 H-FT-AmBu	C11H17NF8	X:1 hydrido-fluorotelomer dimethyl ammonio butane	X:1 H-FT-AmBu
6:1 hydrido-fluorotelomer dimethyl ammonio butane	6:1 H-FT-AmBu	C13H17NF12	X:1 hydrido-fluorotelomer dimethyl ammonio butane	X:1 H-FT-AmBu
8:1 hydrido-fluorotelomer dimethyl ammonio butane	8:1 H-FT-AmBu	C15H17NF16	X:1 hydrido-fluorotelomer dimethyl ammonio butane	X:1 H-FT-AmBu
10:1 hydrido-fluorotelomer dimethyl ammonio butane	10:1 H-FT-AmBu	C17H17NF20	X:1 hydrido-fluorotelomer dimethyl ammonio butane	X:1 H-FT-AmBu
12:1 hydrido-fluorotelomer dimethyl ammonio butane	12:1 H-FT-AmBu	C19H17NF24	X:1 hydrido-fluorotelomer dimethyl ammonio butane	X:1 H-FT-AmBu
14:1 hydrido-fluorotelomer dimethyl ammonio butane	14:1 H-FT-AmBu	C21H17NF28	X:1 hydrido-fluorotelomer dimethyl ammonio butane	X:1 H-FT-AmBu
1:1 hydrido-fluorotelomer dimethyl ammonio ethane	1:1 H-FT-AmEt	C6H13NF2	X:1 hydrido-fluorotelomer dimethyl ammonio ethane	X:1 H-FT-AmEt
2:1 hydrido-fluorotelomer dimethyl ammonio ethane	2:1 H-FT-AmEt	C7H13NF4	X:1 hydrido-fluorotelomer dimethyl ammonio ethane	X:1 H-FT-AmEt

3:1 hydrido-fluorotelomer dimethyl ammonio ethane	3:1 H-FT-AmEt	C8H13NF6	X:1 hydrido-fluorotelomer dimethyl ammonio ethane	X:1 H-FT-AmEt
4:1 hydrido-fluorotelomer dimethyl ammonio ethane	4:1 H-FT-AmEt	C9H13NF8	X:1 hydrido-fluorotelomer dimethyl ammonio ethane	X:1 H-FT-AmEt
5:1 hydrido-fluorotelomer dimethyl ammonio ethane	5:1 H-FT-AmEt	C10H13NF10	X:1 hydrido-fluorotelomer dimethyl ammonio ethane	X:1 H-FT-AmEt
6:1 hydrido-fluorotelomer dimethyl ammonio ethane	6:1 H-FT-AmEt	C11H13NF12	X:1 hydrido-fluorotelomer dimethyl ammonio ethane	X:1 H-FT-AmEt
7:1 hydrido-fluorotelomer dimethyl ammonio ethane	7:1 H-FT-AmEt	C12H13NF14	X:1 hydrido-fluorotelomer dimethyl ammonio ethane	X:1 H-FT-AmEt
8:1 hydrido-fluorotelomer dimethyl ammonio ethane	8:1 H-FT-AmEt	C13H13NF16	X:1 hydrido-fluorotelomer dimethyl ammonio ethane	X:1 H-FT-AmEt
9:1 hydrido-fluorotelomer dimethyl ammonio ethane	9:1 H-FT-AmEt	C14H13NF18	X:1 hydrido-fluorotelomer dimethyl ammonio ethane	X:1 H-FT-AmEt
10:1 hydrido-fluorotelomer dimethyl ammonio ethane	10:1 H-FT-AmEt	C15H13NF20	X:1 hydrido-fluorotelomer dimethyl ammonio ethane	X:1 H-FT-AmEt
11:1 hydrido-fluorotelomer dimethyl ammonio ethane	11:1 H-FT-AmEt	C16H13NF22	X:1 hydrido-fluorotelomer dimethyl ammonio ethane	X:1 H-FT-AmEt
12:1 hydrido-fluorotelomer dimethyl ammonio ethane	12:1 H-FT-AmEt	C17H13NF24	X:1 hydrido-fluorotelomer dimethyl ammonio ethane	X:1 H-FT-AmEt
13:1 hydrido-fluorotelomer dimethyl ammonio ethane	13:1 H-FT-AmEt	C18H13NF26	X:1 hydrido-fluorotelomer dimethyl ammonio ethane	X:1 H-FT-AmEt
14:1 hydrido-fluorotelomer dimethyl ammonio ethane	14:1 H-FT-AmEt	C19H13NF28	X:1 hydrido-fluorotelomer dimethyl ammonio ethane	X:1 H-FT-AmEt
2:1 hydrido-fluorotelomer dimethyl ammonio propane	2:1 H-FT-AmPr	C8H15NF4	X:1 hydrido-fluorotelomer dimethyl ammonio propane	X:1 H-FT-AmPr
4:1 hydrido-fluorotelomer dimethyl ammonio propane	4:1 H-FT-AmPr	C10H15NF8	X:1 hydrido-fluorotelomer dimethyl ammonio propane	X:1 H-FT-AmPr
6:1 hydrido-fluorotelomer dimethyl ammonio propane	6:1 H-FT-AmPr	C12H15NF12	X:1 hydrido-fluorotelomer dimethyl ammonio propane	X:1 H-FT-AmPr
8:1 hydrido-fluorotelomer dimethyl ammonio propane	8:1 H-FT-AmPr	C14H15NF16	X:1 hydrido-fluorotelomer dimethyl ammonio propane	X:1 H-FT-AmPr
10:1 hydrido-fluorotelomer dimethyl ammonio propane	10:1 H-FT-AmPr	C16H15NF20	X:1 hydrido-fluorotelomer dimethyl ammonio propane	X:1 H-FT-AmPr
12:1 hydrido-fluorotelomer dimethyl ammonio propane	12:1 H-FT-AmPr	C18H15NF24	X:1 hydrido-fluorotelomer dimethyl ammonio propane	X:1 H-FT-AmPr
14:1 hydrido-fluorotelomer dimethyl ammonio propane	14:1 H-FT-AmPr	C20H15NF28	X:1 hydrido-fluorotelomer dimethyl ammonio propane	X:1 H-FT-AmPr
2:1 hydrido-fluorotelomer betaine	2:1 H-FTB	C7H11O2NF4	X:1 hydrido-fluorotelomer betaine	X:1 H-FTB
3:1 hydrido-fluorotelomer betaine	3:1 H-FTB	C8H11O2NF6	X:1 hydrido-fluorotelomer betaine	X:1 H-FTB
4:1 hydrido-fluorotelomer betaine	4:1 H-FTB	C9H11O2NF8	X:1 hydrido-fluorotelomer betaine	X:1 H-FTB
5:1 hydrido-fluorotelomer betaine	5:1 H-FTB	C10H11O2NF10	X:1 hydrido-fluorotelomer betaine	X:1 H-FTB
6:1 hydrido-fluorotelomer betaine	6:1 H-FTB	C11H11O2NF12	X:1 hydrido-fluorotelomer betaine	X:1 H-FTB
7:1 hydrido-fluorotelomer betaine	7:1 H-FTB	C12H11O2NF14	X:1 hydrido-fluorotelomer betaine	X:1 H-FTB
8:1 hydrido-fluorotelomer betaine	8:1 H-FTB	C13H11O2NF16	X:1 hydrido-fluorotelomer betaine	X:1 H-FTB
9:1 hydrido-fluorotelomer betaine	9:1 H-FTB	C14H11O2NF18	X:1 hydrido-fluorotelomer betaine	X:1 H-FTB
10:1 hydrido-fluorotelomer betaine	10:1 H-FTB	C15H11O2NF20	X:1 hydrido-fluorotelomer betaine	X:1 H-FTB
11:1 hydrido-fluorotelomer betaine	11:1 H-FTB	C16H11O2NF22	X:1 hydrido-fluorotelomer betaine	X:1 H-FTB
12:1 hydrido-fluorotelomer betaine	12:1 H-FTB	C17H11O2NF24	X:1 hydrido-fluorotelomer betaine	X:1 H-FTB
13:1 hydrido-fluorotelomer betaine	13:1 H-FTB	C18H11O2NF26	X:1 hydrido-fluorotelomer betaine	X:1 H-FTB
14:1 hydrido-fluorotelomer betaine	14:1 H-FTB	C19H11O2NF28	X:1 hydrido-fluorotelomer betaine	X:1 H-FTB
15:1 hydrido-fluorotelomer betaine	15:1 H-FTB	C20H11O2NF30	X:1 hydrido-fluorotelomer betaine	X:1 H-FTB
1:2 fluorotelomer carboxylic acid	1:2 FTCA	C3H3O2F3	X:2 fluorotelomer carboxylic acid	X:2 FTCA
2:2 fluorotelomer carboxylic acid	2:2 FTCA	C4H3O2F5	X:2 fluorotelomer carboxylic acid	X:2 FTCA
3:2 fluorotelomer carboxylic acid	3:2 FTCA	C5H3O2F7	X:2 fluorotelomer carboxylic acid	X:2 FTCA
4:2 fluorotelomer carboxylic acid	4:2 FTCA	C6H3O2F9	X:2 fluorotelomer carboxylic acid	X:2 FTCA

5:2 fluorotelomer carboxylic acid	5:2 FTCA	C7H3O2F11	X:2 fluorotelomer carboxylic acid	X:2 FTCA
6:2 fluorotelomer carboxylic acid	6:2 FTCA	C8H3O2F13	X:2 fluorotelomer carboxylic acid	X:2 FTCA
7:2 fluorotelomer carboxylic acid	7:2 FTCA	C9H3O2F15	X:2 fluorotelomer carboxylic acid	X:2 FTCA
8:2 fluorotelomer carboxylic acid	8:2 FTCA	C10H3O2F17	X:2 fluorotelomer carboxylic acid	X:2 FTCA
9:2 fluorotelomer carboxylic acid	9:2 FTCA	C11H3O2F19	X:2 fluorotelomer carboxylic acid	X:2 FTCA
10:2 fluorotelomer carboxylic acid	10:2 FTCA	C12H3O2F21	X:2 fluorotelomer carboxylic acid	X:2 FTCA
11:2 fluorotelomer carboxylic acid	11:2 FTCA	C13H3O2F23	X:2 fluorotelomer carboxylic acid	X:2 FTCA
12:2 fluorotelomer carboxylic acid	12:2 FTCA	C14H3O2F25	X:2 fluorotelomer carboxylic acid	X:2 FTCA
13:2 fluorotelomer carboxylic acid	13:2 FTCA	C15H3O2F27	X:2 fluorotelomer carboxylic acid	X:2 FTCA
14:2 fluorotelomer carboxylic acid	14:2 FTCA	C16H3O2F29	X:2 fluorotelomer carboxylic acid	X:2 FTCA
2:2 fluorotelomer sulfonate	2:2 FTS	C4H5O3SF5	X:2 FluoroTelomer Sulfonate	X:2 FTS
4:2 fluorotelomer sulfonate	4:2 FTS	C6H5O3SF9	X:2 FluoroTelomer Sulfonate	X:2 FTS
6:2 fluorotelomer sulfonate	6:2 FTS	C8H5O3SF13	X:2 FluoroTelomer Sulfonate	X:2 FTS
8:2 fluorotelomer sulfonate	8:2 FTS	C10H5O3SF17	X:2 FluoroTelomer Sulfonate	X:2 FTS
10:2 fluorotelomer sulfonate	10:2 FTS	C12H5O3SF21	X:2 FluoroTelomer Sulfonate	X:2 FTS
12:2 fluorotelomer sulfonate	12:2 FTS	C14H5O3SF25	X:2 FluoroTelomer Sulfonate	X:2 FTS
14:2 fluorotelomer sulfonate	14:2 FTS	C16H5O3SF29	X:2 FluoroTelomer Sulfonate	X:2 FTS
16:2 fluorotelomer sulfonate	16:2 FTS	C18H5O3SF33	X:2 FluoroTelomer Sulfonate	X:2 FTS
18:2 fluorotelomer sulfonate	18:2 FTS	C20H5O3SF37	X:2 FluoroTelomer Sulfonate	X:2 FTS
20:2 fluorotelomer sulfonate	20:2 FTS	C22H5O3SF41	X:2 FluoroTelomer Sulfonate	X:2 FTS
1:2 unsaturated fluorotelomer carboxylic acid	1:2 UFTCA	C3H2O2F2	X:2 unsaturated fluorotelomer carboxylic acid	X:2 UFTCA
2:2 unsaturated fluorotelomer carboxylic acid	2:2 UFTCA	C4H2O2F4	X:2 unsaturated fluorotelomer carboxylic acid	X:2 UFTCA
3:2 unsaturated fluorotelomer carboxylic acid	3:2 UFTCA	C5H2O2F6	X:2 unsaturated fluorotelomer carboxylic acid	X:2 UFTCA
4:2 unsaturated fluorotelomer carboxylic acid	4:2 UFTCA	C6H2O2F8	X:2 unsaturated fluorotelomer carboxylic acid	X:2 UFTCA
5:2 unsaturated fluorotelomer carboxylic acid	5:2 UFTCA	C7H2O2F10	X:2 unsaturated fluorotelomer carboxylic acid	X:2 UFTCA
6:2 unsaturated fluorotelomer carboxylic acid	6:2 UFTCA	C8H2O2F12	X:2 unsaturated fluorotelomer carboxylic acid	X:2 UFTCA
7:2 unsaturated fluorotelomer carboxylic acid	7:2 UFTCA	C9H2O2F14	X:2 unsaturated fluorotelomer carboxylic acid	X:2 UFTCA
8:2 unsaturated fluorotelomer carboxylic acid	8:2 UFTCA	C10H2O2F16	X:2 unsaturated fluorotelomer carboxylic acid	X:2 UFTCA
9:2 unsaturated fluorotelomer carboxylic acid	9:2 UFTCA	C11H2O2F18	X:2 unsaturated fluorotelomer carboxylic acid	X:2 UFTCA
10:2 unsaturated fluorotelomer carboxylic acid	10:2 UFTCA	C12H2O2F20	X:2 unsaturated fluorotelomer carboxylic acid	X:2 UFTCA
11:2 unsaturated fluorotelomer carboxylic acid	11:2 UFTCA	C13H2O2F22	X:2 unsaturated fluorotelomer carboxylic acid	X:2 UFTCA
12:2 unsaturated fluorotelomer carboxylic acid	12:2 UFTCA	C14H2O2F24	X:2 unsaturated fluorotelomer carboxylic acid	X:2 UFTCA
13:2 unsaturated fluorotelomer carboxylic acid	13:2 UFTCA	C15H2O2F26	X:2 unsaturated fluorotelomer carboxylic acid	X:2 UFTCA
14:2 unsaturated fluorotelomer carboxylic acid	14:2 UFTCA	C16H2O2F28	X:2 unsaturated fluorotelomer carboxylic acid	X:2 UFTCA
1:2 fluorotelomer ketone sulfonate*	1:2 FTKS	C4H5O4SF3	X:2 fluorotelomer ketone sulfonate	X:2 FTKS
2:2 fluorotelomer ketone sulfonate*	2:2 FTKS	C5H5O4SF5	X:2 fluorotelomer ketone sulfonate	X:2 FTKS
3:2 fluorotelomer ketone sulfonate*	3:2 FTKS	C6H5O4SF7	X:2 fluorotelomer ketone sulfonate	X:2 FTKS

4:2 fluorotelomer ketone sulfonate*	4:2 FTKS	C7H5O4SF9	X:2 fluorotelomer ketone sulfonate	X:2 FTKS
5:2 fluorotelomer ketone sulfonate*	5:2 FTKS	C8H5O4SF11	X:2 fluorotelomer ketone sulfonate	X:2 FTKS
6:2 fluorotelomer ketone sulfonate*	6:2 FTKS	C9H5O4SF13	X:2 fluorotelomer ketone sulfonate	X:2 FTKS
7:2 fluorotelomer ketone sulfonate*	7:2 FTKS	C10H5O4SF15	X:2 fluorotelomer ketone sulfonate	X:2 FTKS
8:2 fluorotelomer ketone sulfonate*	8:2 FTKS	C11H5O4SF17	X:2 fluorotelomer ketone sulfonate	X:2 FTKS
9:2 fluorotelomer ketone sulfonate*	9:2 FTKS	C12H5O4SF19	X:2 fluorotelomer ketone sulfonate	X:2 FTKS
10:2 fluorotelomer ketone sulfonate*	10:2 FTKS	C13H5O4SF21	X:2 fluorotelomer ketone sulfonate	X:2 FTKS
11:2 fluorotelomer ketone sulfonate*	11:2 FTKS	C14H5O4SF23	X:2 fluorotelomer ketone sulfonate	X:2 FTKS
12:2 fluorotelomer ketone sulfonate*	12:2 FTKS	C15H5O4SF25	X:2 fluorotelomer ketone sulfonate	X:2 FTKS
13:2 fluorotelomer ketone sulfonate*	13:2 FTKS	C16H5O4SF27	X:2 fluorotelomer ketone sulfonate	X:2 FTKS
14:2 fluorotelomer ketone sulfonate*	14:2 FTKS	C17H5O4SF29	X:2 fluorotelomer ketone sulfonate	X:2 FTKS
2:2 fluorotelomer sulfate	2:2 FTOS	C4H5O4SF5	X:2 fluorotelomer sulfate	X:2 FTOS
4:2 fluorotelomer sulfate	4:2 FTOS	C6H5O4SF9	X:2 fluorotelomer sulfate	X:2 FTOS
6:2 fluorotelomer sulfate	6:2 FTOS	C8H5O4SF13	X:2 fluorotelomer sulfate	X:2 FTOS
8:2 fluorotelomer sulfate	8:2 FTOS	C10H5O4SF17	X:2 fluorotelomer sulfate	X:2 FTOS
10:2 fluorotelomer sulfate	10:2 FTOS	C12H5O4SF21	X:2 fluorotelomer sulfate	X:2 FTOS
12:2 fluorotelomer sulfate	12:2 FTOS	C14H5O4SF25	X:2 fluorotelomer sulfate	X:2 FTOS
14:2 fluorotelomer sulfate	14:2 FTOS	C16H5O4SF29	X:2 fluorotelomer sulfate	X:2 FTOS
2:2 fluorotelomer sulfinate	2:2 FTSi	C4H5O2SF5	X:2 fluorotelomer sulfinate	X:2 FTSi
4:2 fluorotelomer sulfinate	4:2 FTSi	C6H5O2SF9	X:2 fluorotelomer sulfinate	X:2 FTSi
6:2 fluorotelomer sulfinate	6:2 FTSi	C8H5O2SF13	X:2 fluorotelomer sulfinate	X:2 FTSi
8:2 fluorotelomer sulfinate	8:2 FTSi	C10H5O2SF17	X:2 fluorotelomer sulfinate	X:2 FTSi
10:2 fluorotelomer sulfinate	10:2 FTSi	C12H5O2SF21	X:2 fluorotelomer sulfinate	X:2 FTSi
12:2 fluorotelomer sulfinate	12:2 FTSi	C14H5O2SF25	X:2 fluorotelomer sulfinate	X:2 FTSi
14:2 fluorotelomer sulfinate	14:2 FTSi	C16H5O2SF29	X:2 fluorotelomer sulfinate	X:2 FTSi
1-hydroxy-2:2 fluorotelomer sulfonate	1OH-2:2 FTS	C4H5O4SF5	1-hydroxy-X:2 FluoroTelomer Sulfonate	1OH-X:2 FTS
1-hydroxy-3:2 fluorotelomer sulfonate	1OH-3:2 FTS	C5H5O4SF7	1-hydroxy-X:2 FluoroTelomer Sulfonate	1OH-X:2 FTS
1-hydroxy-4:2 fluorotelomer sulfonate	1OH-4:2 FTS	C6H5O4SF9	1-hydroxy-X:2 FluoroTelomer Sulfonate	1OH-X:2 FTS
1-hydroxy-5:2 fluorotelomer sulfonate	1OH-5:2 FTS	C7H5O4SF11	1-hydroxy-X:2 FluoroTelomer Sulfonate	1OH-X:2 FTS
1-hydroxy-6:2 fluorotelomer sulfonate	1OH-6:2 FTS	C8H5O4SF13	1-hydroxy-X:2 FluoroTelomer Sulfonate	1OH-X:2 FTS
1-hydroxy-7:2 fluorotelomer sulfonate	1OH-7:2 FTS	C9H5O4SF15	1-hydroxy-X:2 FluoroTelomer Sulfonate	1OH-X:2 FTS
1-hydroxy-8:2 fluorotelomer sulfonate	1OH-8:2 FTS	C10H5O4SF17	1-hydroxy-X:2 FluoroTelomer Sulfonate	1OH-X:2 FTS
1-hydroxy-9:2 fluorotelomer sulfonate	1OH-9:2 FTS	C11H5O4SF19	1-hydroxy-X:2 FluoroTelomer Sulfonate	1OH-X:2 FTS
1-hydroxy-10:2 fluorotelomer sulfonate	1OH-10:2 FTS	C12H5O4SF21	1-hydroxy-X:2 FluoroTelomer Sulfonate	1OH-X:2 FTS
1-hydroxy-11:2 fluorotelomer sulfonate	1OH-11:2 FTS	C13H5O4SF23	1-hydroxy-X:2 FluoroTelomer Sulfonate	1OH-X:2 FTS
1-hydroxy-12:2 fluorotelomer sulfonate	1OH-12:2 FTS	C14H5O4SF25	1-hydroxy-X:2 FluoroTelomer Sulfonate	1OH-X:2 FTS
1-hydroxy-14:2 fluorotelomer sulfonate	1OH-14:2 FTS	C16H5O4SF29	1-hydroxy-X:2 FluoroTelomer Sulfonate	1OH-X:2 FTS

1-hydroxy-16:2 fluorotelomer sulfonate	1OH-16:2 FTS	C18H5O4SF33	1-hydroxy-X:2 FluoroTelomer Sulfonate	1OH-X:2 FTS
1-hydroxy-18:2 fluorotelomer sulfonate	1OH-18:2 FTS	C20H5O4SF37	1-hydroxy-X:2 FluoroTelomer Sulfonate	1OH-X:2 FTS
1:2 unsaturated fluorotelomer sulfonate	1:2 UFTS	C3H4O3SF2	X:2 unsaturated fluorotelomer sulfonate	X:2 UFTS
2:2 unsaturated fluorotelomer sulfonate	2:2 UFTS	C4H4O3SF4	X:2 unsaturated fluorotelomer sulfonate	X:2 UFTS
3:2 unsaturated fluorotelomer sulfonate	3:2 UFTS	C5H4O3SF6	X:2 unsaturated fluorotelomer sulfonate	X:2 UFTS
4:2 unsaturated fluorotelomer sulfonate	4:2 UFTS	C6H4O3SF8	X:2 unsaturated fluorotelomer sulfonate	X:2 UFTS
5:2 unsaturated fluorotelomer sulfonate	5:2 UFTS	C7H4O3SF10	X:2 unsaturated fluorotelomer sulfonate	X:2 UFTS
6:2 unsaturated fluorotelomer sulfonate	6:2 UFTS	C8H4O3SF12	X:2 unsaturated fluorotelomer sulfonate	X:2 UFTS
7:2 unsaturated fluorotelomer sulfonate	7:2 UFTS	C9H4O3SF14	X:2 unsaturated fluorotelomer sulfonate	X:2 UFTS
8:2 unsaturated fluorotelomer sulfonate	8:2 UFTS	C10H4O3SF16	X:2 unsaturated fluorotelomer sulfonate	X:2 UFTS
9:2 unsaturated fluorotelomer sulfonate	9:2 UFTS	C11H4O3SF18	X:2 unsaturated fluorotelomer sulfonate	X:2 UFTS
10:2 unsaturated fluorotelomer sulfonate	10:2 UFTS	C12H4O3SF20	X:2 unsaturated fluorotelomer sulfonate	X:2 UFTS
11:2 unsaturated fluorotelomer sulfonate	11:2 UFTS	C13H4O3SF22	X:2 unsaturated fluorotelomer sulfonate	X:2 UFTS
12:2 unsaturated fluorotelomer sulfonate	12:2 UFTS	C14H4O3SF24	X:2 unsaturated fluorotelomer sulfonate	X:2 UFTS
13:2 unsaturated fluorotelomer sulfonate	13:2 UFTS	C15H4O3SF26	X:2 unsaturated fluorotelomer sulfonate	X:2 UFTS
14:2 unsaturated fluorotelomer sulfonate	14:2 UFTS	C16H4O3SF28	X:2 unsaturated fluorotelomer sulfonate	X:2 UFTS
2:2 fluorotelomer dimethyl ammonio ethane	2:2 FT-AmEt	C8H14NF5	X:2 fluorotelomer dimethyl ammonio ethane	X:2 FT-AmEt
4:2 fluorotelomer dimethyl ammonio ethane	4:2 FT-AmEt	C10H14NF9	X:2 fluorotelomer dimethyl ammonio ethane	X:2 FT-AmEt
6:2 fluorotelomer dimethyl ammonio ethane	6:2 FT-AmEt	C12H14NF13	X:2 fluorotelomer dimethyl ammonio ethane	X:2 FT-AmEt
8:2 fluorotelomer dimethyl ammonio ethane	8:2 FT-AmEt	C14H14NF17	X:2 fluorotelomer dimethyl ammonio ethane	X:2 FT-AmEt
10:2 fluorotelomer dimethyl ammonio ethane	10:2 FT-AmEt	C16H14NF21	X:2 fluorotelomer dimethyl ammonio ethane	X:2 FT-AmEt
12:2 fluorotelomer dimethyl ammonio ethane	12:2 FT-AmEt	C18H14NF25	X:2 fluorotelomer dimethyl ammonio ethane	X:2 FT-AmEt
14:2 fluorotelomer dimethyl ammonio ethane	14:2 FT-AmEt	C20H14NF29	X:2 fluorotelomer dimethyl ammonio ethane	X:2 FT-AmEt
2:2 fluorotelomer sulfonamide	2:2 FTSA	C4H6O2NSF5	X:2 fluorotelomer sulfonamide	X:2 FTSA
4:2 fluorotelomer sulfonamide	4:2 FTSA	C6H6O2NSF9	X:2 fluorotelomer sulfonamide	X:2 FTSA
6:2 fluorotelomer sulfonamide	6:2 FTSA	C8H6O2NSF13	X:2 fluorotelomer sulfonamide	X:2 FTSA
8:2 fluorotelomer sulfonamide	8:2 FTSA	C10H6O2NSF17	X:2 fluorotelomer sulfonamide	X:2 FTSA
10:2 fluorotelomer sulfonamide	10:2 FTSA	C12H6O2NSF21	X:2 fluorotelomer sulfonamide	X:2 FTSA
12:2 fluorotelomer sulfonamide	12:2 FTSA	C14H6O2NSF25	X:2 fluorotelomer sulfonamide	X:2 FTSA
14:2 fluorotelomer sulfonamide	14:2 FTSA	C16H6O2NSF29	X:2 fluorotelomer sulfonamide	X:2 FTSA
2:2 fluorotelomer sulfonamido propyl amine	2:2 FTSA-PrAn	C7H13O2N2SF5	X:2 fluorotelomer sulfonamido propyl amine	X:2 FTSA-PrAn
4:2 fluorotelomer sulfonamido propyl amine	4:2 FTSA-PrAn	C9H13O2N2SF9	X:2 fluorotelomer sulfonamido propyl amine	X:2 FTSA-PrAn
6:2 fluorotelomer sulfonamido propyl amine	6:2 FTSA-PrAn	C11H13O2N2SF13	X:2 fluorotelomer sulfonamido propyl amine	X:2 FTSA-PrAn
8:2 fluorotelomer sulfonamido propyl amine	8:2 FTSA-PrAn	C13H13O2N2SF17	X:2 fluorotelomer sulfonamido propyl amine	X:2 FTSA-PrAn
10:2 fluorotelomer sulfonamido propyl amine	10:2 FTSA-PrAn	C15H13O2N2SF21	X:2 fluorotelomer sulfonamido propyl amine	X:2 FTSA-PrAn
12:2 fluorotelomer sulfonamido propyl amine	12:2 FTSA-PrAn	C17H13O2N2SF25	X:2 fluorotelomer sulfonamido propyl amine	X:2 FTSA-PrAn
14:2 fluorotelomer sulfonamido propyl amine	14:2 FTSA-PrAn	C19H13O2N2SF29	X:2 fluorotelomer sulfonamido propyl amine	X:2 FTSA-PrAn

2:2 fluorotelomer sulfonamido propyl methyl amine	2:2 FTSA-Pr-MeAn	C8H15O2N2SF5	X:2 fluorotelomer sulfonamido propyl methyl amine	X:2 FTSA-Pr-MeAn
4:2 fluorotelomer sulfonamido propyl methyl amine	4:2 FTSA-Pr-MeAn	C10H15O2N2SF9	X:2 fluorotelomer sulfonamido propyl methyl amine	X:2 FTSA-Pr-MeAn
6:2 fluorotelomer sulfonamido propyl methyl amine	6:2 FTSA-Pr-MeAn	C12H15O2N2SF13	X:2 fluorotelomer sulfonamido propyl methyl amine	X:2 FTSA-Pr-MeAn
8:2 fluorotelomer sulfonamido propyl methyl amine	8:2 FTSA-Pr-MeAn	C14H15O2N2SF17	X:2 fluorotelomer sulfonamido propyl methyl amine	X:2 FTSA-Pr-MeAn
10:2 fluorotelomer sulfonamido propyl methyl amine	10:2 FTSA-Pr-MeAn	C16H15O2N2SF21	X:2 fluorotelomer sulfonamido propyl methyl amine	X:2 FTSA-Pr-MeAn
12:2 fluorotelomer sulfonamido propyl methyl amine	12:2 FTSA-Pr-MeAn	C18H15O2N2SF25	X:2 fluorotelomer sulfonamido propyl methyl amine	X:2 FTSA-Pr-MeAn
14:2 fluorotelomer sulfonamido propyl methyl amine	14:2 FTSA-Pr-MeAn	C20H15O2N2SF29	X:2 fluorotelomer sulfonamido propyl methyl amine	X:2 FTSA-Pr-MeAn
2:2 fluorotelomer sulfonamido propyl dimethyl amine	2:2 FTSAPr-DiMeAn	C9H17O2N2SF5	X:2 fluorotelomer sulfonamido propyl dimethyl amine	X:2 FTSAPr-DiMeAn
4:2 fluorotelomer sulfonamido propyl dimethyl amine	4:2 FTSAPr-DiMeAn	C11H17O2N2SF9	X:2 fluorotelomer sulfonamido propyl dimethyl amine	X:2 FTSAPr-DiMeAn
6:2 fluorotelomer sulfonamido propyl dimethyl amine	6:2 FTSAPr-DiMeAn	C13H17O2N2SF13	X:2 fluorotelomer sulfonamido propyl dimethyl amine	X:2 FTSAPr-DiMeAn
8:2 fluorotelomer sulfonamido propyl dimethyl amine	8:2 FTSAPr-DiMeAn	C15H17O2N2SF17	X:2 fluorotelomer sulfonamido propyl dimethyl amine	X:2 FTSAPr-DiMeAn
10:2 fluorotelomer sulfonamido propyl dimethyl amine	10:2 FTSAPr-DiMeAn	C17H17O2N2SF21	X:2 fluorotelomer sulfonamido propyl dimethyl amine	X:2 FTSAPr-DiMeAn
12:2 fluorotelomer sulfonamido propyl dimethyl amine	12:2 FTSAPr-DiMeAn	C19H17O2N2SF25	X:2 fluorotelomer sulfonamido propyl dimethyl amine	X:2 FTSAPr-DiMeAn
14:2 fluorotelomer sulfonamido propyl dimethyl amine	14:2 FTSAPr-DiMeAn	C21H17O2N2SF29	X:2 fluorotelomer sulfonamido propyl dimethyl amine	X:2 FTSAPr-DiMeAn
2:2 fluorotelomer sulfonamido propyl methyl amino acetic acid	2:2 FTSA-Pr-MeAA	C10H17O4N2SF5	X:2 fluorotelomer sulfonamido propyl methyl amino acetic acid	X:2 FTSA-Pr-MeAA
4:2 fluorotelomer sulfonamido propyl methyl amino acetic acid	4:2 FTSA-Pr-MeAA	C12H17O4N2SF9	X:2 fluorotelomer sulfonamido propyl methyl amino acetic acid	X:2 FTSA-Pr-MeAA
6:2 fluorotelomer sulfonamido propyl methyl amino acetic acid	6:2 FTSA-Pr-MeAA	C14H17O4N2SF13	X:2 fluorotelomer sulfonamido propyl methyl amino acetic acid	X:2 FTSA-Pr-MeAA
8:2 fluorotelomer sulfonamido propyl methyl amino acetic acid	8:2 FTSA-Pr-MeAA	C16H17O4N2SF17	X:2 fluorotelomer sulfonamido propyl methyl amino acetic acid	X:2 FTSA-Pr-MeAA
10:2 fluorotelomer sulfonamido propyl methyl amino acetic acid	10:2 FTSA-Pr-MeAA	C18H17O4N2SF21	X:2 fluorotelomer sulfonamido propyl methyl amino acetic acid	X:2 FTSA-Pr-MeAA
12:2 fluorotelomer sulfonamido propyl methyl amino acetic acid	12:2 FTSA-Pr-MeAA	C20H17O4N2SF25	X:2 fluorotelomer sulfonamido propyl methyl amino acetic acid	X:2 FTSA-Pr-MeAA
14:2 fluorotelomer sulfonamido propyl methyl amino acetic acid	14:2 FTSA-Pr-MeAA	C22H17O4N2SF29	X:2 fluorotelomer sulfonamido propyl methyl amino acetic acid	X:2 FTSA-Pr-MeAA
2:2 fluorotelomer sulfinyl ethanamido propyl trimethyl ammonium	2:2 FTSO-EtAdPrTAm	C12H21O2N2SF5	X:2 fluorotelomer sulfinyl ethanamido propyl trimethyl ammonium	X:2 FTSO-EtAdPrTAm
4:2 fluorotelomer sulfinyl ethanamido propyl trimethyl ammonium	4:2 FTSO-EtAdPrTAm	C14H21O2N2SF9	X:2 fluorotelomer sulfinyl ethanamido propyl trimethyl ammonium	X:2 FTSO-EtAdPrTAm
6:2 fluorotelomer sulfinyl ethanamido propyl trimethyl ammonium	6:2 FTSO-EtAdPrTAm	C16H21O2N2SF13	X:2 fluorotelomer sulfinyl ethanamido propyl trimethyl ammonium	X:2 FTSO-EtAdPrTAm
8:2 fluorotelomer sulfinyl ethanamido propyl trimethyl ammonium	8:2 FTSO-EtAdPrTAm	C18H21O2N2SF17	X:2 fluorotelomer sulfinyl ethanamido propyl trimethyl ammonium	X:2 FTSO-EtAdPrTAm
10:2 fluorotelomer sulfinyl ethanamido propyl trimethyl ammonium	10:2 FTSO-EtAdPrTAm	C20H21O2N2SF21	X:2 fluorotelomer sulfinyl ethanamido propyl trimethyl ammonium	X:2 FTSO-EtAdPrTAm
12:2 fluorotelomer sulfinyl ethanamido propyl trimethyl ammonium	12:2 FTSO-EtAdPrTAm	C22H21O2N2SF25	X:2 fluorotelomer sulfinyl ethanamido propyl trimethyl ammonium	X:2 FTSO-EtAdPrTAm

14:2 fluorotelomer sulfinyl ethanamido propyl trimethyl ammonium	14:2 FTSO-EtAdPrTAm	C24H21O2N2SF29	X:2 fluorotelomer sulfinyl ethanamido propyl trimethyl ammonium	X:2 FTSO-EtAdPrTAm
2:2 fluorotelomer sulfinyl hydroxypropyl trimethyl ammonium	2:2 FTSO-OHPrTAm	C10H18O2NSF5	X:2 fluorotelomer sulfinyl hydroxypropyl trimethyl ammonium	X:2 FTSO-OHPrTAm
4:2 fluorotelomer sulfinyl hydroxypropyl trimethyl ammonium	4:2 FTSO-OHPrTAm	C12H18O2NSF9	X:2 fluorotelomer sulfinyl hydroxypropyl trimethyl ammonium	X:2 FTSO-OHPrTAm
6:2 fluorotelomer sulfinyl hydroxypropyl trimethyl ammonium	6:2 FTSO-OHPrTAm	C14H18O2NSF13	X:2 fluorotelomer sulfinyl hydroxypropyl trimethyl ammonium	X:2 FTSO-OHPrTAm
8:2 fluorotelomer sulfinyl hydroxypropyl trimethyl ammonium	8:2 FTSO-OHPrTAm	C16H18O2NSF17	X:2 fluorotelomer sulfinyl hydroxypropyl trimethyl ammonium	X:2 FTSO-OHPrTAm
10:2 fluorotelomer sulfinyl hydroxypropyl trimethyl ammonium	10:2 FTSO-OHPrTAm	C18H18O2NSF21	X:2 fluorotelomer sulfinyl hydroxypropyl trimethyl ammonium	X:2 FTSO-OHPrTAm
12:2 fluorotelomer sulfinyl hydroxypropyl trimethyl ammonium	12:2 FTSO-OHPrTAm	C20H18O2NSF25	X:2 fluorotelomer sulfinyl hydroxypropyl trimethyl ammonium	X:2 FTSO-OHPrTAm
14:2 fluorotelomer sulfinyl hydroxypropyl trimethyl ammonium	14:2 FTSO-OHPrTAm	C22H18O2NSF29	X:2 fluorotelomer sulfinyl hydroxypropyl trimethyl ammonium	X:2 FTSO-OHPrTAm
2:2 fluorotelomer sulfinyl propanoic acid	2:2 FTSO-PrA	C7H9O3SF5	X:2 fluorotelomer sulfinyl propanoic acid	X:2 FTSO-PrA
4:2 fluorotelomer sulfinyl propanoic acid	4:2 FTSO-PrA	C9H9O3SF9	X:2 fluorotelomer sulfinyl propanoic acid	X:2 FTSO-PrA
6:2 fluorotelomer sulfinyl propanoic acid	6:2 FTSO-PrA	C11H9O3SF13	X:2 fluorotelomer sulfinyl propanoic acid	X:2 FTSO-PrA
8:2 fluorotelomer sulfinyl propanoic acid	8:2 FTSO-PrA	C13H9O3SF17	X:2 fluorotelomer sulfinyl propanoic acid	X:2 FTSO-PrA
10:2 fluorotelomer sulfinyl propanoic acid	10:2 FTSO-PrA	C15H9O3SF21	X:2 fluorotelomer sulfinyl propanoic acid	X:2 FTSO-PrA
12:2 fluorotelomer sulfinyl propanoic acid	12:2 FTSO-PrA	C17H9O3SF25	X:2 fluorotelomer sulfinyl propanoic acid	X:2 FTSO-PrA
14:2 fluorotelomer sulfinyl propanoic acid	14:2 FTSO-PrA	C19H9O3SF29	X:2 fluorotelomer sulfinyl propanoic acid	X:2 FTSO-PrA
2:2 fluorotelomersulfonyl propanoic acid	2:2 FTSO2PrA	C7H9O4SF5	X:2 FluoroTelomerSulfonyl Propanoic Acid	X:2 FTSO2PrA
4:2 fluorotelomersulfonyl propanoic acid	4:2 FTSO2PrA	C9H9O4SF9	X:2 FluoroTelomerSulfonyl Propanoic Acid	X:2 FTSO2PrA
6:2 fluorotelomersulfonyl propanoic acid	6:2 FTSO2PrA	C11H9O4SF13	X:2 FluoroTelomerSulfonyl Propanoic Acid	X:2 FTSO2PrA
8:2 fluorotelomersulfonyl propanoic acid	8:2 FTSO2PrA	C13H9O4SF17	X:2 FluoroTelomerSulfonyl Propanoic Acid	X:2 FTSO2PrA
10:2 fluorotelomersulfonyl propanoic acid	10:2 FTSO2PrA	C15H9O4SF21	X:2 FluoroTelomerSulfonyl Propanoic Acid	X:2 FTSO2PrA
12:2 fluorotelomersulfonyl propanoic acid	12:2 FTSO2PrA	C17H9O4SF25	X:2 FluoroTelomerSulfonyl Propanoic Acid	X:2 FTSO2PrA
14:2 fluorotelomersulfonyl propanoic acid	14:2 FTSO2PrA	C19H9O4SF29	X:2 FluoroTelomerSulfonyl Propanoic Acid	X:2 FTSO2PrA
2:2 fluorotelomer sulfonyl ethano amido propyl trimethyl ammonium	2:2 FTSO2-EtAdPrTAm	C12H21O3N2SF5	X:2 fluorotelomer sulfonyl ethano amido propyl trimethyl ammonium	X:2 FTSO2-EtAdPrTAm
4:2 fluorotelomer sulfonyl ethano amido propyl trimethyl ammonium	4:2 FTSO2-EtAdPrTAm	C14H21O3N2SF9	X:2 fluorotelomer sulfonyl ethano amido propyl trimethyl ammonium	X:2 FTSO2-EtAdPrTAm
6:2 fluorotelomer sulfonyl ethano amido propyl trimethyl ammonium	6:2 FTSO2-EtAdPrTAm	C16H21O3N2SF13	X:2 fluorotelomer sulfonyl ethano amido propyl trimethyl ammonium	X:2 FTSO2-EtAdPrTAm
8:2 fluorotelomer sulfonyl ethano amido propyl trimethyl ammonium	8:2 FTSO2-EtAdPrTAm	C18H21O3N2SF17	X:2 fluorotelomer sulfonyl ethano amido propyl trimethyl ammonium	X:2 FTSO2-EtAdPrTAm
10:2 fluorotelomer sulfonyl ethano amido propyl trimethyl ammonium	10:2 FTSO2-EtAdPrTAm	C20H21O3N2SF21	X:2 fluorotelomer sulfonyl ethano amido propyl trimethyl ammonium	X:2 FTSO2-EtAdPrTAm

12:2 fluorotelomer sulfonyl ethano amido propyl trimethyl ammonium	12:2 FTSO2-EtAdPrTAm	C22H21O3N2SF25	X:2 fluorotelomer sulfonyl ethano amido propyl trimethyl ammonium	X:2 FTSO2-EtAdPrTAm
14:2 fluorotelomer sulfonyl ethano amido propyl trimethyl ammonium	14:2 FTSO2-EtAdPrTAm	C24H21O3N2SF29	X:2 fluorotelomer sulfonyl ethano amido propyl trimethyl ammonium	X:2 FTSO2-EtAdPrTAm
2:2 fluorotelomer sulfinyl propanamido dimethyl ethyl sulfonate	2:2 FTSO-PrAd-DiMePrS	C11H18O5NS2F5	X:2 fluorotelomer sulfinyl propanamido dimethyl ethyl sulfonate	X:2 FTSO-PrAd-DiMePrS
4:2 fluorotelomer sulfinyl propanamido dimethyl ethyl sulfonate	4:2 FTSO-PrAd-DiMePrS	C13H18O5NS2F9	X:2 fluorotelomer sulfinyl propanamido dimethyl ethyl sulfonate	X:2 FTSO-PrAd-DiMePrS
6:2 fluorotelomer sulfinyl propanamido dimethyl ethyl sulfonate	6:2 FTSO-PrAd-DiMePrS	C15H18O5NS2F13	X:2 fluorotelomer sulfinyl propanamido dimethyl ethyl sulfonate	X:2 FTSO-PrAd-DiMePrS
8:2 fluorotelomer sulfinyl propanamido dimethyl ethyl sulfonate	8:2 FTSO-PrAd-DiMePrS	C17H18O5NS2F17	X:2 fluorotelomer sulfinyl propanamido dimethyl ethyl sulfonate	X:2 FTSO-PrAd-DiMePrS
10:2 fluorotelomer sulfinyl propanamido dimethyl ethyl sulfonate	10:2 FTSO-PrAd-DiMePrS	C19H18O5NS2F21	X:2 fluorotelomer sulfinyl propanamido dimethyl ethyl sulfonate	X:2 FTSO-PrAd-DiMePrS
12:2 fluorotelomer sulfinyl propanamido dimethyl ethyl sulfonate	12:2 FTSO-PrAd-DiMePrS	C21H18O5NS2F25	X:2 fluorotelomer sulfinyl propanamido dimethyl ethyl sulfonate	X:2 FTSO-PrAd-DiMePrS
14:2 fluorotelomer sulfinyl propanamido dimethyl ethyl sulfonate	14:2 FTSO-PrAd-DiMePrS	C23H18O5NS2F29	X:2 fluorotelomer sulfinyl propanamido dimethyl ethyl sulfonate	X:2 FTSO-PrAd-DiMePrS
2:2 fluorotelomer sulfonyl propanoamido-dimethylethyl sulfonate	2:2 FTSO2PrAd-DiMeEtS	C11H18O6NS2F5	X:2 Fluorotelomer Sulfonyl PropanoAmido-Dimethyl ethyl sulfonate	X:2 FTSO2PrAd-DiMeEtS
4:2 fluorotelomer sulfonyl propanoamido-dimethylethyl sulfonate	4:2 FTSO2PrAd-DiMeEtS	C13H18O6NS2F9	X:2 Fluorotelomer Sulfonyl PropanoAmido-Dimethyl ethyl sulfonate	X:2 FTSO2PrAd-DiMeEtS
6:2 fluorotelomer sulfonyl propanoamido-dimethylethyl sulfonate	6:2 FTSO2PrAd-DiMeEtS	C15H18O6NS2F13	X:2 Fluorotelomer Sulfonyl PropanoAmido-Dimethyl ethyl sulfonate	X:2 FTSO2PrAd-DiMeEtS
8:2 fluorotelomer sulfonyl propanoamido-dimethylethyl sulfonate	8:2 FTSO2PrAd-DiMeEtS	C17H18O6NS2F17	X:2 Fluorotelomer Sulfonyl PropanoAmido-Dimethyl ethyl sulfonate	X:2 FTSO2PrAd-DiMeEtS
10:2 fluorotelomer sulfonyl propanoamido-dimethylethyl sulfonate	10:2 FTSO2PrAd-DiMeEtS	C19H18O6NS2F21	X:2 Fluorotelomer Sulfonyl PropanoAmido-Dimethyl ethyl sulfonate	X:2 FTSO2PrAd-DiMeEtS
12:2 fluorotelomer sulfonyl propanoamido-dimethylethyl sulfonate	12:2 FTSO2PrAd-DiMeEtS	C21H18O6NS2F25	X:2 Fluorotelomer Sulfonyl PropanoAmido-Dimethyl ethyl sulfonate	X:2 FTSO2PrAd-DiMeEtS
14:2 fluorotelomer sulfonyl propanoamido-dimethylethyl sulfonate	14:2 FTSO2PrAd-DiMeEtS	C23H18O6NS2F29	X:2 Fluorotelomer Sulfonyl PropanoAmido-Dimethyl ethyl sulfonate	X:2 FTSO2PrAd-DiMeEtS
2:2 fluorotelomer sulfonyl hydroxypropyl trimethyl ammonium	2:2 FTSO2-OHPrTAm	C10H18O3NSF5	X:2 fluorotelomer sulfonyl hydroxypropyl trimethyl ammonium	X:2 FTSO2-OHPrTAm
4:2 fluorotelomer sulfonyl hydroxypropyl trimethyl ammonium	4:2 FTSO2-OHPrTAm	C12H18O3NSF9	X:2 fluorotelomer sulfonyl hydroxypropyl trimethyl ammonium	X:2 FTSO2-OHPrTAm
6:2 fluorotelomer sulfonyl hydroxypropyl trimethyl ammonium	6:2 FTSO2-OHPrTAm	C14H18O3NSF13	X:2 fluorotelomer sulfonyl hydroxypropyl trimethyl ammonium	X:2 FTSO2-OHPrTAm
8:2 fluorotelomer sulfonyl hydroxypropyl trimethyl ammonium	8:2 FTSO2-OHPrTAm	C16H18O3NSF17	X:2 fluorotelomer sulfonyl hydroxypropyl trimethyl ammonium	X:2 FTSO2-OHPrTAm
10:2 fluorotelomer sulfonyl hydroxypropyl trimethyl ammonium	10:2 FTSO2-OHPrTAm	C18H18O3NSF21	X:2 fluorotelomer sulfonyl hydroxypropyl trimethyl ammonium	X:2 FTSO2-OHPrTAm

12:2 fluorotelomer sulfonyl hydroxypropyl trimethyl ammonium	12:2 FTSO2-OHPrTAm	C20H18O3NSF25	X:2 fluorotelomer sulfonyl hydroxypropyl trimethyl ammonium	X:2 FTSO2-OHPrTAm
14:2 fluorotelomer sulfonyl hydroxypropyl trimethyl ammonium	14:2 FTSO2-OHPrTAm	C22H18O3NSF29	X:2 fluorotelomer sulfonyl hydroxypropyl trimethyl ammonium	X:2 FTSO2-OHPrTAm
2:2 fluorotelomer thiol	2:2 FTSH	C4H5SF5	X:2 fluorotelomer thiol	X:2 FTSH
4:2 fluorotelomer thiol	4:2 FTSH	C6H5SF9	X:2 fluorotelomer thiol	X:2 FTSH
6:2 fluorotelomer thiol	6:2 FTSH	C8H5SF13	X:2 fluorotelomer thiol	X:2 FTSH
8:2 fluorotelomer thiol	8:2 FTSH	C10H5SF17	X:2 fluorotelomer thiol	X:2 FTSH
10:2 fluorotelomer thiol	10:2 FTSH	C12H5SF21	X:2 fluorotelomer thiol	X:2 FTSH
12:2 fluorotelomer thiol	12:2 FTSH	C14H5SF25	X:2 fluorotelomer thiol	X:2 FTSH
14:2 fluorotelomer thiol	14:2 FTSH	C16H5SF29	X:2 fluorotelomer thiol	X:2 FTSH
2:2 fluorotelomer thia acetic acid	2:2 FTThA	C6H7O2SF5	X:2 fluorotelomer thia acetic acid	X:2 FTThA
4:2 fluorotelomer thia acetic acid	4:2 FTThA	C8H7O2SF9	X:2 fluorotelomer thia acetic acid	X:2 FTThA
6:2 fluorotelomer thia acetic acid	6:2 FTThA	C10H7O2SF13	X:2 fluorotelomer thia acetic acid	X:2 FTThA
8:2 fluorotelomer thia acetic acid	8:2 FTThA	C12H7O2SF17	X:2 fluorotelomer thia acetic acid	X:2 FTThA
10:2 fluorotelomer thia acetic acid	10:2 FTThA	C14H7O2SF21	X:2 fluorotelomer thia acetic acid	X:2 FTThA
12:2 fluorotelomer thia acetic acid	12:2 FTThA	C16H7O2SF25	X:2 fluorotelomer thia acetic acid	X:2 FTThA
14:2 fluorotelomer thia acetic acid	14:2 FTThA	C18H7O2SF29	X:2 fluorotelomer thia acetic acid	X:2 FTThA
2:2 fluorotelomer thia propanoic acid	2:2 FTThPrA	C7H9O2SF5	X:2 fluorotelomer thia propanoic acid	X:2 FTThPrA
4:2 fluorotelomer thia propanoic acid	4:2 FTThPrA	C9H9O2SF9	X:2 fluorotelomer thia propanoic acid	X:2 FTThPrA
6:2 fluorotelomer thia propanoic acid	6:2 FTThPrA	C11H9O2SF13	X:2 fluorotelomer thia propanoic acid	X:2 FTThPrA
8:2 fluorotelomer thia propanoic acid	8:2 FTThPrA	C13H9O2SF17	X:2 fluorotelomer thia propanoic acid	X:2 FTThPrA
10:2 fluorotelomer thia propanoic acid	10:2 FTThPrA	C15H9O2SF21	X:2 fluorotelomer thia propanoic acid	X:2 FTThPrA
12:2 fluorotelomer thia propanoic acid	12:2 FTThPrA	C17H9O2SF25	X:2 fluorotelomer thia propanoic acid	X:2 FTThPrA
14:2 fluorotelomer thia propanoic acid	14:2 FTThPrA	C19H9O2SF29	X:2 fluorotelomer thia propanoic acid	X:2 FTThPrA
2:2 fluorotelomer thia amido hexyl aldehyde	2:2 FTTh-AdHxOCH	C11H16O2NSF5	X:2 fluorotelomer thia amido hexyl aldehyde	X:2 FTTh-AdHxOCH
4:2 fluorotelomer thia amido hexyl aldehyde	4:2 FTTh-AdHxOCH	C13H16O2NSF9	X:2 fluorotelomer thia amido hexyl aldehyde	X:2 FTTh-AdHxOCH
6:2 fluorotelomer thia amido hexyl aldehyde	6:2 FTTh-AdHxOCH	C15H16O2NSF13	X:2 fluorotelomer thia amido hexyl aldehyde	X:2 FTTh-AdHxOCH
8:2 fluorotelomer thia amido hexyl aldehyde	8:2 FTTh-AdHxOCH	C17H16O2NSF17	X:2 fluorotelomer thia amido hexyl aldehyde	X:2 FTTh-AdHxOCH
10:2 fluorotelomer thia amido hexyl aldehyde	10:2 FTTh-AdHxOCH	C19H16O2NSF21	X:2 fluorotelomer thia amido hexyl aldehyde	X:2 FTTh-AdHxOCH
12:2 fluorotelomer thia amido hexyl aldehyde	12:2 FTTh-AdHxOCH	C21H16O2NSF25	X:2 fluorotelomer thia amido hexyl aldehyde	X:2 FTTh-AdHxOCH
14:2 fluorotelomer thia amido hexyl aldehyde	14:2 FTTh-AdHxOCH	C23H16O2NSF29	X:2 fluorotelomer thia amido hexyl aldehyde	X:2 FTTh-AdHxOCH
2:2 fluorotelomer thia amido pentanoic acid	2:2 FTTh-AdPeA	C10H14O3NSF5	X:2 fluorotelomer thia amido pentanoic acid	X:2 FTTh-AdPeA
4:2 fluorotelomer thia amido pentanoic acid	4:2 FTTh-AdPeA	C12H14O3NSF9	X:2 fluorotelomer thia amido pentanoic acid	X:2 FTTh-AdPeA
6:2 fluorotelomer thia amido pentanoic acid	6:2 FTTh-AdPeA	C14H14O3NSF13	X:2 fluorotelomer thia amido pentanoic acid	X:2 FTTh-AdPeA
8:2 fluorotelomer thia amido pentanoic acid	8:2 FTTh-AdPeA	C16H14O3NSF17	X:2 fluorotelomer thia amido pentanoic acid	X:2 FTTh-AdPeA
10:2 fluorotelomer thia amido pentanoic acid	10:2 FTTh-AdPeA	C18H14O3NSF21	X:2 fluorotelomer thia amido pentanoic acid	X:2 FTTh-AdPeA

12:2 fluorotelomer thia amido pentanoic acid	12:2 FTTh-AdPeA	C20H14O3NSF25	X:2 fluorotelomer thia amido pentanoic acid	X:2 FTTh-AdPeA
14:2 fluorotelomer thia amido pentanoic acid	14:2 FTTh-AdPeA	C22H14O3NSF29	X:2 fluorotelomer thia amido pentanoic acid	X:2 FTTh-AdPeA
2:2 fluorotelomer thia amido propano amido pentanoic acid	2:2 FTTh-AdPrAdPeA	C13H19O4N2SF5	X:2 fluorotelomer thia amido propano amido pentanoic acid	X:2 FTTh-AdPrAdPeA
4:2 fluorotelomer thia amido propano amido pentanoic acid	4:2 FTTh-AdPrAdPeA	C15H19O4N2SF9	X:2 fluorotelomer thia amido propano amido pentanoic acid	X:2 FTTh-AdPrAdPeA
6:2 fluorotelomer thia amido propano amido pentanoic acid	6:2 FTTh-AdPrAdPeA	C17H19O4N2SF13	X:2 fluorotelomer thia amido propano amido pentanoic acid	X:2 FTTh-AdPrAdPeA
8:2 fluorotelomer thia amido propano amido pentanoic acid	8:2 FTTh-AdPrAdPeA	C19H19O4N2SF17	X:2 fluorotelomer thia amido propano amido pentanoic acid	X:2 FTTh-AdPrAdPeA
10:2 fluorotelomer thia amido propano amido pentanoic acid	10:2 FTTh-AdPrAdPeA	C21H19O4N2SF21	X:2 fluorotelomer thia amido propano amido pentanoic acid	X:2 FTTh-AdPrAdPeA
12:2 fluorotelomer thia amido propano amido pentanoic acid	12:2 FTTh-AdPrAdPeA	C23H19O4N2SF25	X:2 fluorotelomer thia amido propano amido pentanoic acid	X:2 FTTh-AdPrAdPeA
14:2 fluorotelomer thia amido propano amido pentanoic acid	14:2 FTTh-AdPrAdPeA	C25H19O4N2SF29	X:2 fluorotelomer thia amido propano amido pentanoic acid	X:2 FTTh-AdPrAdPeA
2:2 fluorotelomer thia carboxy propanoamido propyl dimethyl ammonium	2:2 FTTh-CPrAd-PrAm	C13H21O3N2SF5	X:2 fluorotelomer thia carboxy propanoamido propyl dimethyl ammonium	X:2 FTTh-CPrAd-PrAm
4:2 fluorotelomer thia carboxy propanoamido propyl dimethyl ammonium	4:2 FTTh-CPrAd-PrAm	C15H21O3N2SF9	X:2 fluorotelomer thia carboxy propanoamido propyl dimethyl ammonium	X:2 FTTh-CPrAd-PrAm
6:2 fluorotelomer thia carboxy propanoamido propyl dimethyl ammonium	6:2 FTTh-CPrAd-PrAm	C17H21O3N2SF13	X:2 fluorotelomer thia carboxy propanoamido propyl dimethyl ammonium	X:2 FTTh-CPrAd-PrAm
8:2 fluorotelomer thia carboxy propanoamido propyl dimethyl ammonium	8:2 FTTh-CPrAd-PrAm	C19H21O3N2SF17	X:2 fluorotelomer thia carboxy propanoamido propyl dimethyl ammonium	X:2 FTTh-CPrAd-PrAm
10:2 fluorotelomer thia carboxy propanoamido propyl dimethyl ammonium	10:2 FTTh-CPrAd-PrAm	C21H21O3N2SF21	X:2 fluorotelomer thia carboxy propanoamido propyl dimethyl ammonium	X:2 FTTh-CPrAd-PrAm
12:2 fluorotelomer thia carboxy propanoamido propyl dimethyl ammonium	12:2 FTTh-CPrAd-PrAm	C23H21O3N2SF25	X:2 fluorotelomer thia carboxy propanoamido propyl dimethyl ammonium	X:2 FTTh-CPrAd-PrAm
14:2 fluorotelomer thia carboxy propanoamido propyl dimethyl ammonium	14:2 FTTh-CPrAd-PrAm	C25H21O3N2SF29	X:2 fluorotelomer thia carboxy propanoamido propyl dimethyl ammonium	X:2 FTTh-CPrAd-PrAm
2:2 fluorotelomer thia ethanamido propyl dimethyl ammonium	2:2 FTTh-EtAdPrAm	C11H19ON2SF5	X:2 fluorotelomer thia ethanamido propyl dimethyl ammonium	X:2 FTTh-EtAdPrAm
4:2 fluorotelomer thia ethanamido propyl dimethyl ammonium	4:2 FTTh-EtAdPrAm	C13H19ON2SF9	X:2 fluorotelomer thia ethanamido propyl dimethyl ammonium	X:2 FTTh-EtAdPrAm
6:2 fluorotelomer thia ethanamido propyl dimethyl ammonium	6:2 FTTh-EtAdPrAm	C15H19ON2SF13	X:2 fluorotelomer thia ethanamido propyl dimethyl ammonium	X:2 FTTh-EtAdPrAm
8:2 fluorotelomer thia ethanamido propyl dimethyl ammonium	8:2 FTTh-EtAdPrAm	C17H19ON2SF17	X:2 fluorotelomer thia ethanamido propyl dimethyl ammonium	X:2 FTTh-EtAdPrAm
10:2 fluorotelomer thia ethanamido propyl dimethyl ammonium	10:2 FTTh-EtAdPrAm	C19H19ON2SF21	X:2 fluorotelomer thia ethanamido propyl dimethyl ammonium	X:2 FTTh-EtAdPrAm
12:2 fluorotelomer thia ethanamido propyl dimethyl ammonium	12:2 FTTh-EtAdPrAm	C21H19ON2SF25	X:2 fluorotelomer thia ethanamido propyl dimethyl ammonium	X:2 FTTh-EtAdPrAm

14:2 fluorotelomer thia ethanamido propyl dimethyl ammonium	14:2 FTTh-EtAdPrAm	C23H19ON2SF29	X:2 fluorotelomer thia ethanamido propyl dimethyl ammonium	X:2 FTTh-EtAdPrAm
2:2 fluorotelomer thia ethanamido propyl trimethyl ammonium	2:2 FTTh-EtAdPrTAm	C12H21ON2SF5	X:2 fluorotelomer thia ethanamido propyl trimethyl ammonium	X:2 FTTh-EtAdPrTAm
4:2 fluorotelomer thia ethanamido propyl trimethyl ammonium	4:2 FTTh-EtAdPrTAm	C14H21ON2SF9	X:2 fluorotelomer thia ethanamido propyl trimethyl ammonium	X:2 FTTh-EtAdPrTAm
6:2 fluorotelomer thia ethanamido propyl trimethyl ammonium	6:2 FTTh-EtAdPrTAm	C16H21ON2SF13	X:2 fluorotelomer thia ethanamido propyl trimethyl ammonium	X:2 FTTh-EtAdPrTAm
8:2 fluorotelomer thia ethanamido propyl trimethyl ammonium	8:2 FTTh-EtAdPrTAm	C18H21ON2SF17	X:2 fluorotelomer thia ethanamido propyl trimethyl ammonium	X:2 FTTh-EtAdPrTAm
10:2 fluorotelomer thia ethanamido propyl trimethyl ammonium	10:2 FTTh-EtAdPrTAm	C20H21ON2SF21	X:2 fluorotelomer thia ethanamido propyl trimethyl ammonium	X:2 FTTh-EtAdPrTAm
12:2 fluorotelomer thia ethanamido propyl trimethyl ammonium	12:2 FTTh-EtAdPrTAm	C22H21ON2SF25	X:2 fluorotelomer thia ethanamido propyl trimethyl ammonium	X:2 FTTh-EtAdPrTAm
14:2 fluorotelomer thia ethanamido propyl trimethyl ammonium	14:2 FTTh-EtAdPrTAm	C24H21ON2SF29	X:2 fluorotelomer thia ethanamido propyl trimethyl ammonium	X:2 FTTh-EtAdPrTAm
2:2 fluorotelomer thia propanoamido dimethyl ethyl sulfonate	2:2 FTTh-PrAd-DiMeEtS	C11H18O4NS2F5	X:2 fluorotelomer thia propanoamido dimethyl ethyl sulfonate	X:2 FTTh-PrAd-DiMeEtS
4:2 fluorotelomer thia propanoamido dimethyl ethyl sulfonate	4:2 FTTh-PrAd-DiMeEtS	C13H18O4NS2F9	X:2 fluorotelomer thia propanoamido dimethyl ethyl sulfonate	X:2 FTTh-PrAd-DiMeEtS
6:2 fluorotelomer thia propanoamido dimethyl ethyl sulfonate	6:2 FTTh-PrAd-DiMeEtS	C15H18O4NS2F13	X:2 fluorotelomer thia propanoamido dimethyl ethyl sulfonate	X:2 FTTh-PrAd-DiMeEtS
8:2 fluorotelomer thia propanoamido dimethyl ethyl sulfonate	8:2 FTTh-PrAd-DiMeEtS	C17H18O4NS2F17	X:2 fluorotelomer thia propanoamido dimethyl ethyl sulfonate	X:2 FTTh-PrAd-DiMeEtS
10:2 fluorotelomer thia propanoamido dimethyl ethyl sulfonate	10:2 FTTh-PrAd-DiMeEtS	C19H18O4NS2F21	X:2 fluorotelomer thia propanoamido dimethyl ethyl sulfonate	X:2 FTTh-PrAd-DiMeEtS
12:2 fluorotelomer thia propanoamido dimethyl ethyl sulfonate	12:2 FTTh-PrAd-DiMeEtS	C21H18O4NS2F25	X:2 fluorotelomer thia propanoamido dimethyl ethyl sulfonate	X:2 FTTh-PrAd-DiMeEtS
14:2 fluorotelomer thia propanoamido dimethyl ethyl sulfonate	14:2 FTTh-PrAd-DiMeEtS	C23H18O4NS2F29	X:2 fluorotelomer thia propanoamido dimethyl ethyl sulfonate	X:2 FTTh-PrAd-DiMeEtS
2:2 fluorotelomer thia hydroxy propanoic acid	2:2 FTTh-OHPrA	C7H9O3SF5	X:2 fluorotelomer thia hydroxy propanoic acid	X:2 FTTh-OHPrA
4:2 fluorotelomer thia hydroxy propanoic acid	4:2 FTTh-OHPrA	C9H9O3SF9	X:2 fluorotelomer thia hydroxy propanoic acid	X:2 FTTh-OHPrA
6:2 fluorotelomer thia hydroxy propanoic acid	6:2 FTTh-OHPrA	C11H9O3SF13	X:2 fluorotelomer thia hydroxy propanoic acid	X:2 FTTh-OHPrA
8:2 fluorotelomer thia hydroxy propanoic acid	8:2 FTTh-OHPrA	C13H9O3SF17	X:2 fluorotelomer thia hydroxy propanoic acid	X:2 FTTh-OHPrA
10:2 fluorotelomer thia hydroxy propanoic acid	10:2 FTTh-OHPrA	C15H9O3SF21	X:2 fluorotelomer thia hydroxy propanoic acid	X:2 FTTh-OHPrA
12:2 fluorotelomer thia hydroxy propanoic acid	12:2 FTTh-OHPrA	C17H9O3SF25	X:2 fluorotelomer thia hydroxy propanoic acid	X:2 FTTh-OHPrA
14:2 fluorotelomer thia hydroxy propanoic acid	14:2 FTTh-OHPrA	C19H9O3SF29	X:2 fluorotelomer thia hydroxy propanoic acid	X:2 FTTh-OHPrA
2:2 fluorotelomer thia hydroxy propyl trimethyl ammonium	2:2 FTTh-OHPrTAm	C10H18ONSF5	X:2 fluorotelomer thia hydroxy propyl trimethyl ammonium	X:2 FTTh-OHPrTAm
4:2 fluorotelomer thia hydroxy propyl trimethyl ammonium	4:2 FTTh-OHPrTAm	C12H18ONSF9	X:2 fluorotelomer thia hydroxy propyl trimethyl ammonium	X:2 FTTh-OHPrTAm

6:2 fluorotelomer thia hydroxy propyl trimethyl ammonium	6:2 FTTh-OHPrTAm	C14H18ONSF13	X:2 fluorotelomer thia hydroxy propyl trimethyl ammonium	X:2 FTTh-OHPrTAm
8:2 fluorotelomer thia hydroxy propyl trimethyl ammonium	8:2 FTTh-OHPrTAm	C16H18ONSF17	X:2 fluorotelomer thia hydroxy propyl trimethyl ammonium	X:2 FTTh-OHPrTAm
10:2 fluorotelomer thia hydroxy propyl trimethyl ammonium	10:2 FTTh-OHPrTAm	C18H18ONSF21	X:2 fluorotelomer thia hydroxy propyl trimethyl ammonium	X:2 FTTh-OHPrTAm
12:2 fluorotelomer thia hydroxy propyl trimethyl ammonium	12:2 FTTh-OHPrTAm	C20H18ONSF25	X:2 fluorotelomer thia hydroxy propyl trimethyl ammonium	X:2 FTTh-OHPrTAm
14:2 fluorotelomer thia hydroxy propyl trimethyl ammonium	14:2 FTTh-OHPrTAm	C22H18ONSF29	X:2 fluorotelomer thia hydroxy propyl trimethyl ammonium	X:2 FTTh-OHPrTAm
2:2 fluorotelomer betaine	2:2 FTB	C8H12O2NF5	X:2 fluorotelomer betaine	X:2 FTB
4:2 fluorotelomer betaine	4:2 FTB	C10H12O2NF9	X:2 fluorotelomer betaine	X:2 FTB
6:2 fluorotelomer betaine	6:2 FTB	C12H12O2NF13	X:2 fluorotelomer betaine	X:2 FTB
8:2 fluorotelomer betaine	8:2 FTB	C14H12O2NF17	X:2 fluorotelomer betaine	X:2 FTB
10:2 fluorotelomer betaine	10:2 FTB	C16H12O2NF21	X:2 fluorotelomer betaine	X:2 FTB
12:2 fluorotelomer betaine	12:2 FTB	C18H12O2NF25	X:2 fluorotelomer betaine	X:2 FTB
14:2 fluorotelomer betaine	14:2 FTB	C20H12O2NF29	X:2 fluorotelomer betaine	X:2 FTB
2:2 hydrido-fluorotelomer betaine	2:2 H-FTB	C8H13O2NF4	X:2 hydrido-fluorotelomer betaine	X:2 H-FTB
3:2 hydrido-fluorotelomer betaine	3:2 H-FTB	C9H13O2NF6	X:2 hydrido-fluorotelomer betaine	X:2 H-FTB
4:2 hydrido-fluorotelomer betaine	4:2 H-FTB	C10H13O2NF8	X:2 hydrido-fluorotelomer betaine	X:2 H-FTB
5:2 hydrido-fluorotelomer betaine	5:2 H-FTB	C11H13O2NF10	X:2 hydrido-fluorotelomer betaine	X:2 H-FTB
6:2 hydrido-fluorotelomer betaine	6:2 H-FTB	C12H13O2NF12	X:2 hydrido-fluorotelomer betaine	X:2 H-FTB
7:2 hydrido-fluorotelomer betaine	7:2 H-FTB	C13H13O2NF14	X:2 hydrido-fluorotelomer betaine	X:2 H-FTB
8:2 hydrido-fluorotelomer betaine	8:2 H-FTB	C14H13O2NF16	X:2 hydrido-fluorotelomer betaine	X:2 H-FTB
9:2 hydrido-fluorotelomer betaine	9:2 H-FTB	C15H13O2NF18	X:2 hydrido-fluorotelomer betaine	X:2 H-FTB
10:2 hydrido-fluorotelomer betaine	10:2 H-FTB	C16H13O2NF20	X:2 hydrido-fluorotelomer betaine	X:2 H-FTB
11:2 hydrido-fluorotelomer betaine	11:2 H-FTB	C17H13O2NF22	X:2 hydrido-fluorotelomer betaine	X:2 H-FTB
12:2 hydrido-fluorotelomer betaine	12:2 H-FTB	C18H13O2NF24	X:2 hydrido-fluorotelomer betaine	X:2 H-FTB
13:2 hydrido-fluorotelomer betaine	13:2 H-FTB	C19H13O2NF26	X:2 hydrido-fluorotelomer betaine	X:2 H-FTB
14:2 hydrido-fluorotelomer betaine	14:2 H-FTB	C20H13O2NF28	X:2 hydrido-fluorotelomer betaine	X:2 H-FTB
15:2 hydrido-fluorotelomer betaine	15:2 H-FTB	C21H13O2NF30	X:2 hydrido-fluorotelomer betaine	X:2 H-FTB
16:2 hydrido-fluorotelomer betaine	16:2 H-FTB	C22H13O2NF32	X:2 hydrido-fluorotelomer betaine	X:2 H-FTB
2:2 fluorotelomer sulfonamido propyl betaine	2:2 FTSA-PrB	C11H19O4N2SF5	X:2 fluorotelomer sulfonamido propyl betaine	X:2 FTSA-PrB
4:2 fluorotelomer sulfonamido propyl betaine	4:2 FTSA-PrB	C13H19O4N2SF9	X:2 fluorotelomer sulfonamido propyl betaine	X:2 FTSA-PrB
6:2 fluorotelomer sulfonamido propyl betaine	6:2 FTSA-PrB	C15H19O4N2SF13	X:2 fluorotelomer sulfonamido propyl betaine	X:2 FTSA-PrB
8:2 fluorotelomer sulfonamido propyl betaine	8:2 FTSA-PrB	C17H19O4N2SF17	X:2 fluorotelomer sulfonamido propyl betaine	X:2 FTSA-PrB
10:2 fluorotelomer sulfonamido propyl betaine	10:2 FTSA-PrB	C19H19O4N2SF21	X:2 fluorotelomer sulfonamido propyl betaine	X:2 FTSA-PrB
12:2 fluorotelomer sulfonamido propyl betaine	12:2 FTSA-PrB	C21H19O4N2SF25	X:2 fluorotelomer sulfonamido propyl betaine	X:2 FTSA-PrB

14:2 fluorotelomer sulfonamido propyl betaine	14:2 FTSA-PrB	C23H19O4N2SF29	X:2 fluorotelomer sulfonamido propyl betaine	X:2 FTSA-PrB
16:2 fluorotelomer sulfonamido propyl betaine	16:2 FTSA-PrB	C25H19O4N2SF33	X:2 fluorotelomer sulfonamido propyl betaine	X:2 FTSA-PrB
2:2 fluorotelomer thia ethanoamido propyl betaine	2:2 FTTh-EtAdPrB	C13H21O3N2SF5	X:2 fluorotelomer thia ethanoamido propyl betaine	X:2 FTTh-EtAdPrB
4:2 fluorotelomer thia ethanoamido propyl betaine	4:2 FTTh-EtAdPrB	C15H21O3N2SF9	X:2 fluorotelomer thia ethanoamido propyl betaine	X:2 FTTh-EtAdPrB
6:2 fluorotelomer thia ethanoamido propyl betaine	6:2 FTTh-EtAdPrB	C17H21O3N2SF13	X:2 fluorotelomer thia ethanoamido propyl betaine	X:2 FTTh-EtAdPrB
8:2 fluorotelomer thia ethanoamido propyl betaine	8:2 FTTh-EtAdPrB	C19H21O3N2SF17	X:2 fluorotelomer thia ethanoamido propyl betaine	X:2 FTTh-EtAdPrB
10:2 fluorotelomer thia ethanoamido propyl betaine	10:2 FTTh-EtAdPrB	C21H21O3N2SF21	X:2 fluorotelomer thia ethanoamido propyl betaine	X:2 FTTh-EtAdPrB
12:2 fluorotelomer thia ethanoamido propyl betaine	12:2 FTTh-EtAdPrB	C23H21O3N2SF25	X:2 fluorotelomer thia ethanoamido propyl betaine	X:2 FTTh-EtAdPrB
14:2 fluorotelomer thia ethanoamido propyl betaine	14:2 FTTh-EtAdPrB	C25H21O3N2SF29	X:2 fluorotelomer thia ethanoamido propyl betaine	X:2 FTTh-EtAdPrB
2:2 1-hydroxy 2-hydroxymethyl fluorotelomer thia propanoic acid	2:2 OH-MeOH-FTTh-PrA	C8H11O4SF5	X:2 1-hydroxy 2-hydroxymethyl fluorotelomer thia propanoic acid	X:2 OH-MeOH-FTTh-PrA
4:2 1-hydroxy 2-hydroxymethyl fluorotelomer thia propanoic acid	4:2 OH-MeOH-FTTh-PrA	C10H11O4SF9	X:2 1-hydroxy 2-hydroxymethyl fluorotelomer thia propanoic acid	X:2 OH-MeOH-FTTh-PrA
6:2 1-hydroxy 2-hydroxymethyl fluorotelomer thia propanoic acid	6:2 OH-MeOH-FTTh-PrA	C12H11O4SF13	X:2 1-hydroxy 2-hydroxymethyl fluorotelomer thia propanoic acid	X:2 OH-MeOH-FTTh-PrA
8:2 1-hydroxy 2-hydroxymethyl fluorotelomer thia propanoic acid	8:2 OH-MeOH-FTTh-PrA	C14H11O4SF17	X:2 1-hydroxy 2-hydroxymethyl fluorotelomer thia propanoic acid	X:2 OH-MeOH-FTTh-PrA
10:2 1-hydroxy 2-hydroxymethyl fluorotelomer thia propanoic acid	10:2 OH-MeOH-FTTh-PrA	C16H11O4SF21	X:2 1-hydroxy 2-hydroxymethyl fluorotelomer thia propanoic acid	X:2 OH-MeOH-FTTh-PrA
12:2 1-hydroxy 2-hydroxymethyl fluorotelomer thia propanoic acid	12:2 OH-MeOH-FTTh-PrA	C18H11O4SF25	X:2 1-hydroxy 2-hydroxymethyl fluorotelomer thia propanoic acid	X:2 OH-MeOH-FTTh-PrA
14:2 1-hydroxy 2-hydroxymethyl fluorotelomer thia propanoic acid	14:2 OH-MeOH-FTTh-PrA	C20H11O4SF29	X:2 1-hydroxy 2-hydroxymethyl fluorotelomer thia propanoic acid	X:2 OH-MeOH-FTTh-PrA
2:2 1,2-di(hydroxymethyl) fluorotelomer thia propanoic acid	2:2 di(MeOH)-FTTh-PrA	C9H13O4SF5	X:2 1,2-di(hydroxymethyl) fluorotelomer thia propanoic acid	X:2 di(MeOH)-FTTh-PrA
4:2 1,2-di(hydroxymethyl) fluorotelomer thia propanoic acid	4:2 di(MeOH)-FTTh-PrA	C11H13O4SF9	X:2 1,2-di(hydroxymethyl) fluorotelomer thia propanoic acid	X:2 di(MeOH)-FTTh-PrA
6:2 1,2-di(hydroxymethyl) fluorotelomer thia propanoic acid	6:2 di(MeOH)-FTTh-PrA	C13H13O4SF13	X:2 1,2-di(hydroxymethyl) fluorotelomer thia propanoic acid	X:2 di(MeOH)-FTTh-PrA
8:2 1,2-di(hydroxymethyl) fluorotelomer thia propanoic acid	8:2 di(MeOH)-FTTh-PrA	C15H13O4SF17	X:2 1,2-di(hydroxymethyl) fluorotelomer thia propanoic acid	X:2 di(MeOH)-FTTh-PrA
10:2 1,2-di(hydroxymethyl) fluorotelomer thia propanoic acid	10:2 di(MeOH)-FTTh-PrA	C17H13O4SF21	X:2 1,2-di(hydroxymethyl) fluorotelomer thia propanoic acid	X:2 di(MeOH)-FTTh-PrA
12:2 1,2-di(hydroxymethyl) fluorotelomer thia propanoic acid	12:2 di(MeOH)-FTTh-PrA	C19H13O4SF25	X:2 1,2-di(hydroxymethyl) fluorotelomer thia propanoic acid	X:2 di(MeOH)-FTTh-PrA
14:2 1,2-di(hydroxymethyl) fluorotelomer thia propanoic acid	14:2 di(MeOH)-FTTh-PrA	C21H13O4SF29	X:2 1,2-di(hydroxymethyl) fluorotelomer thia propanoic acid	X:2 di(MeOH)-FTTh-PrA
1:3 fluorotelomer carboxylic acid	1:3 FTCA	C4H5O2F3	X:3 fluorotelomer carboxylic acid	X:3 FTCA
2:3 fluorotelomer carboxylic acid	2:3 FTCA	C5H5O2F5	X:3 fluorotelomer carboxylic acid	X:3 FTCA
3:3 fluorotelomer carboxylic acid	3:3 FTCA	C6H5O2F7	X:3 fluorotelomer carboxylic acid	X:3 FTCA

4:3 fluorotelomer carboxylic acid	4:3 FTCA	C7H5O2F9	X:3 fluorotelomer carboxylic acid	X:3 FTCA
5:3 fluorotelomer carboxylic acid	5:3 FTCA	C8H5O2F11	X:3 fluorotelomer carboxylic acid	X:3 FTCA
6:3 fluorotelomer carboxylic acid	6:3 FTCA	C9H5O2F13	X:3 fluorotelomer carboxylic acid	X:3 FTCA
7:3 fluorotelomer carboxylic acid	7:3 FTCA	C10H5O2F15	X:3 fluorotelomer carboxylic acid	X:3 FTCA
8:3 fluorotelomer carboxylic acid	8:3 FTCA	C11H5O2F17	X:3 fluorotelomer carboxylic acid	X:3 FTCA
9:3 fluorotelomer carboxylic acid	9:3 FTCA	C12H5O2F19	X:3 fluorotelomer carboxylic acid	X:3 FTCA
10:3 fluorotelomer carboxylic acid	10:3 FTCA	C13H5O2F21	X:3 fluorotelomer carboxylic acid	X:3 FTCA
11:3 fluorotelomer carboxylic acid	11:3 FTCA	C14H5O2F23	X:3 fluorotelomer carboxylic acid	X:3 FTCA
12:3 fluorotelomer carboxylic acid	12:3 FTCA	C15H5O2F25	X:3 fluorotelomer carboxylic acid	X:3 FTCA
13:3 fluorotelomer carboxylic acid	13:3 FTCA	C16H5O2F27	X:3 fluorotelomer carboxylic acid	X:3 FTCA
14:3 fluorotelomer carboxylic acid	14:3 FTCA	C17H5O2F29	X:3 fluorotelomer carboxylic acid	X:3 FTCA
1:3 fluorotelomer sulfonate	1:3 FTS	C4H7O3SF3	X:3 fluorotelomer sulfonate	X:3 FTS
2:3 fluorotelomer sulfonate	2:3 FTS	C5H7O3SF5	X:3 fluorotelomer sulfonate	X:3 FTS
3:3 fluorotelomer sulfonate	3:3 FTS	C6H7O3SF7	X:3 fluorotelomer sulfonate	X:3 FTS
4:3 fluorotelomer sulfonate	4:3 FTS	C7H7O3SF9	X:3 fluorotelomer sulfonate	X:3 FTS
5:3 fluorotelomer sulfonate	5:3 FTS	C8H7O3SF11	X:3 fluorotelomer sulfonate	X:3 FTS
6:3 fluorotelomer sulfonate	6:3 FTS	C9H7O3SF13	X:3 fluorotelomer sulfonate	X:3 FTS
7:3 fluorotelomer sulfonate	7:3 FTS	C10H7O3SF15	X:3 fluorotelomer sulfonate	X:3 FTS
8:3 fluorotelomer sulfonate	8:3 FTS	C11H7O3SF17	X:3 fluorotelomer sulfonate	X:3 FTS
9:3 fluorotelomer sulfonate	9:3 FTS	C12H7O3SF19	X:3 fluorotelomer sulfonate	X:3 FTS
10:3 fluorotelomer sulfonate	10:3 FTS	C13H7O3SF21	X:3 fluorotelomer sulfonate	X:3 FTS
11:3 fluorotelomer sulfonate	11:3 FTS	C14H7O3SF23	X:3 fluorotelomer sulfonate	X:3 FTS
12:3 fluorotelomer sulfonate	12:3 FTS	C15H7O3SF25	X:3 fluorotelomer sulfonate	X:3 FTS
13:3 fluorotelomer sulfonate	13:3 FTS	C16H7O3SF27	X:3 fluorotelomer sulfonate	X:3 FTS
14:3 fluorotelomer sulfonate	14:3 FTS	C17H7O3SF29	X:3 fluorotelomer sulfonate	X:3 FTS
1:3 keto-fluorotelomer thia keto-ethanol	1:3 K-FTTh-K-EtOH	C6H7O3SF3	X:3 keto-fluorotelomer thia keto-ethanol	X:3 K-FTTh-K-EtOH
2:3 keto-fluorotelomer thia keto-ethanol	2:3 K-FTTh-K-EtOH	C7H7O3SF5	X:3 keto-fluorotelomer thia keto-ethanol	X:3 K-FTTh-K-EtOH
3:3 keto-fluorotelomer thia keto-ethanol	3:3 K-FTTh-K-EtOH	C8H7O3SF7	X:3 keto-fluorotelomer thia keto-ethanol	X:3 K-FTTh-K-EtOH
4:3 keto-fluorotelomer thia keto-ethanol	4:3 K-FTTh-K-EtOH	C9H7O3SF9	X:3 keto-fluorotelomer thia keto-ethanol	X:3 K-FTTh-K-EtOH
5:3 keto-fluorotelomer thia keto-ethanol	5:3 K-FTTh-K-EtOH	C10H7O3SF11	X:3 keto-fluorotelomer thia keto-ethanol	X:3 K-FTTh-K-EtOH
6:3 keto-fluorotelomer thia keto-ethanol	6:3 K-FTTh-K-EtOH	C11H7O3SF13	X:3 keto-fluorotelomer thia keto-ethanol	X:3 K-FTTh-K-EtOH
7:3 keto-fluorotelomer thia keto-ethanol	7:3 K-FTTh-K-EtOH	C12H7O3SF15	X:3 keto-fluorotelomer thia keto-ethanol	X:3 K-FTTh-K-EtOH
8:3 keto-fluorotelomer thia keto-ethanol	8:3 K-FTTh-K-EtOH	C13H7O3SF17	X:3 keto-fluorotelomer thia keto-ethanol	X:3 K-FTTh-K-EtOH
9:3 keto-fluorotelomer thia keto-ethanol	9:3 K-FTTh-K-EtOH	C14H7O3SF19	X:3 keto-fluorotelomer thia keto-ethanol	X:3 K-FTTh-K-EtOH
10:3 keto-fluorotelomer thia keto-ethanol	10:3 K-FTTh-K-EtOH	C15H7O3SF21	X:3 keto-fluorotelomer thia keto-ethanol	X:3 K-FTTh-K-EtOH
11:3 keto-fluorotelomer thia keto-ethanol	11:3 K-FTTh-K-EtOH	C16H7O3SF23	X:3 keto-fluorotelomer thia keto-ethanol	X:3 K-FTTh-K-EtOH
12:3 keto-fluorotelomer thia keto-ethanol	12:3 K-FTTh-K-EtOH	C17H7O3SF25	X:3 keto-fluorotelomer thia keto-ethanol	X:3 K-FTTh-K-EtOH

1:3 keto-fluorotelomer thia 2-hydroxy propanoic acid	1:3 K-FTTh-OH-PrA	C7H9O4SF3	X:3 keto-fluorotelomer thia 2-hydroxy propanoic acid	X:3 K-FTTh-OH-PrA
2:3 keto-fluorotelomer thia 2-hydroxy propanoic acid	2:3 K-FTTh-OH-PrA	C8H9O4SF5	X:3 keto-fluorotelomer thia 2-hydroxy propanoic acid	X:3 K-FTTh-OH-PrA
3:3 keto-fluorotelomer thia 2-hydroxy propanoic acid	3:3 K-FTTh-OH-PrA	C9H9O4SF7	X:3 keto-fluorotelomer thia 2-hydroxy propanoic acid	X:3 K-FTTh-OH-PrA
4:3 keto-fluorotelomer thia 2-hydroxy propanoic acid	4:3 K-FTTh-OH-PrA	C10H9O4SF9	X:3 keto-fluorotelomer thia 2-hydroxy propanoic acid	X:3 K-FTTh-OH-PrA
5:3 keto-fluorotelomer thia 2-hydroxy propanoic acid	5:3 K-FTTh-OH-PrA	C11H9O4SF11	X:3 keto-fluorotelomer thia 2-hydroxy propanoic acid	X:3 K-FTTh-OH-PrA
6:3 keto-fluorotelomer thia 2-hydroxy propanoic acid	6:3 K-FTTh-OH-PrA	C12H9O4SF13	X:3 keto-fluorotelomer thia 2-hydroxy propanoic acid	X:3 K-FTTh-OH-PrA
7:3 keto-fluorotelomer thia 2-hydroxy propanoic acid	7:3 K-FTTh-OH-PrA	C13H9O4SF15	X:3 keto-fluorotelomer thia 2-hydroxy propanoic acid	X:3 K-FTTh-OH-PrA
8:3 keto-fluorotelomer thia 2-hydroxy propanoic acid	8:3 K-FTTh-OH-PrA	C14H9O4SF17	X:3 keto-fluorotelomer thia 2-hydroxy propanoic acid	X:3 K-FTTh-OH-PrA
9:3 keto-fluorotelomer thia 2-hydroxy propanoic acid	9:3 K-FTTh-OH-PrA	C15H9O4SF19	X:3 keto-fluorotelomer thia 2-hydroxy propanoic acid	X:3 K-FTTh-OH-PrA
10:3 keto-fluorotelomer thia 2-hydroxy propanoic acid	10:3 K-FTTh-OH-PrA	C16H9O4SF21	X:3 keto-fluorotelomer thia 2-hydroxy propanoic acid	X:3 K-FTTh-OH-PrA
11:3 keto-fluorotelomer thia 2-hydroxy propanoic acid	11:3 K-FTTh-OH-PrA	C17H9O4SF23	X:3 keto-fluorotelomer thia 2-hydroxy propanoic acid	X:3 K-FTTh-OH-PrA
12:3 keto-fluorotelomer thia 2-hydroxy propanoic acid	12:3 K-FTTh-OH-PrA	C18H9O4SF25	X:3 keto-fluorotelomer thia 2-hydroxy propanoic acid	X:3 K-FTTh-OH-PrA
1:3 keto-fluorotelomer thia keto 2-hydroxy propanoic acid	1:3 K-FTTh-K-OH-PrA	C7H7O5SF3	X:3 keto-fluorotelomer thia keto 2-hydroxy propanoic acid	X:3 K-FTTh-K-OH-PrA
2:3 keto-fluorotelomer thia keto 2-hydroxy propanoic acid	2:3 K-FTTh-K-OH-PrA	C8H7O5SF5	X:3 keto-fluorotelomer thia keto 2-hydroxy propanoic acid	X:3 K-FTTh-K-OH-PrA
3:3 keto-fluorotelomer thia keto 2-hydroxy propanoic acid	3:3 K-FTTh-K-OH-PrA	C9H7O5SF7	X:3 keto-fluorotelomer thia keto 2-hydroxy propanoic acid	X:3 K-FTTh-K-OH-PrA
4:3 keto-fluorotelomer thia keto 2-hydroxy propanoic acid	4:3 K-FTTh-K-OH-PrA	C10H7O5SF9	X:3 keto-fluorotelomer thia keto 2-hydroxy propanoic acid	X:3 K-FTTh-K-OH-PrA
5:3 keto-fluorotelomer thia keto 2-hydroxy propanoic acid	5:3 K-FTTh-K-OH-PrA	C11H7O5SF11	X:3 keto-fluorotelomer thia keto 2-hydroxy propanoic acid	X:3 K-FTTh-K-OH-PrA
6:3 keto-fluorotelomer thia keto 2-hydroxy propanoic acid	6:3 K-FTTh-K-OH-PrA	C12H7O5SF13	X:3 keto-fluorotelomer thia keto 2-hydroxy propanoic acid	X:3 K-FTTh-K-OH-PrA
7:3 keto-fluorotelomer thia keto 2-hydroxy propanoic acid	7:3 K-FTTh-K-OH-PrA	C13H7O5SF15	X:3 keto-fluorotelomer thia keto 2-hydroxy propanoic acid	X:3 K-FTTh-K-OH-PrA
8:3 keto-fluorotelomer thia keto 2-hydroxy propanoic acid	8:3 K-FTTh-K-OH-PrA	C14H7O5SF17	X:3 keto-fluorotelomer thia keto 2-hydroxy propanoic acid	X:3 K-FTTh-K-OH-PrA
9:3 keto-fluorotelomer thia keto 2-hydroxy propanoic acid	9:3 K-FTTh-K-OH-PrA	C15H7O5SF19	X:3 keto-fluorotelomer thia keto 2-hydroxy propanoic acid	X:3 K-FTTh-K-OH-PrA
10:3 keto-fluorotelomer thia keto 2-hydroxy propanoic acid	10:3 K-FTTh-K-OH-PrA	C16H7O5SF21	X:3 keto-fluorotelomer thia keto 2-hydroxy propanoic acid	X:3 K-FTTh-K-OH-PrA
11:3 keto-fluorotelomer thia keto 2-hydroxy propanoic acid	11:3 K-FTTh-K-OH-PrA	C17H7O5SF23	X:3 keto-fluorotelomer thia keto 2-hydroxy propanoic acid	X:3 K-FTTh-K-OH-PrA
12:3 keto-fluorotelomer thia keto 2-hydroxy propanoic acid	12:3 K-FTTh-K-OH-PrA	C18H7O5SF25	X:3 keto-fluorotelomer thia keto 2-hydroxy propanoic acid	X:3 K-FTTh-K-OH-PrA
2:3 2-ester fluorotelomer dimethylammonio ethano-ketone	2:3 OCO-FTAm-EtK	C10H14O3NF5	X:3 2-ester fluorotelomer dimethylammonium ethano-ketone	X:3 OCO-FTAm-EtK
4:3 2-ester fluorotelomer dimethylammonio ethano-ketone	4:3 OCO-FTAm-EtK	C12H14O3NF9	X:3 2-ester fluorotelomer dimethylammonium ethano-ketone	X:3 OCO-FTAm-EtK

6:3 2-ester fluorotelomer dimethylammonio ethano-ketone	6:3 OCO-FTAm-EtK	C14H14O3NF13	X:3 2-ester fluorotelomer dimethylammonium ethano-ketone	X:3 OCO-FTAm-EtK
8:3 2-ester fluorotelomer dimethylammonio ethano-ketone	8:3 OCO-FTAm-EtK	C16H14O3NF17	X:3 2-ester fluorotelomer dimethylammonium ethano-ketone	X:3 OCO-FTAm-EtK
10:3 2-ester fluorotelomer dimethylammonio ethano-ketone	10:3 OCO-FTAm-EtK	C18H14O3NF21	X:3 2-ester fluorotelomer dimethylammonium ethano-ketone	X:3 OCO-FTAm-EtK
12:3 2-ester fluorotelomer dimethylammonio ethano-ketone	12:3 OCO-FTAm-EtK	C20H14O3NF25	X:3 2-ester fluorotelomer dimethylammonium ethano-ketone	X:3 OCO-FTAm-EtK
14:3 2-ester fluorotelomer dimethylammonio ethano-ketone	14:3 OCO-FTAm-EtK	C22H14O3NF29	X:3 2-ester fluorotelomer dimethylammonium ethano-ketone	X:3 OCO-FTAm-EtK
16:3 2-ester fluorotelomer dimethylammonio ethano-ketone	16:3 OCO-FTAm-EtK	C24H14O3NF33	X:3 2-ester fluorotelomer dimethylammonium ethano-ketone	X:3 OCO-FTAm-EtK
18:3 2-ester fluorotelomer dimethylammonio ethano-ketone	18:3 OCO-FTAm-EtK	C26H14O3NF37	X:3 2-ester fluorotelomer dimethylammonium ethano-ketone	X:3 OCO-FTAm-EtK
2:3 2-methylester fluorotelomer dimethyl ammonio propanoic acid	2:3 MeOCO-FTAm-PrA	C12H18O4NF5	X:3 2-methylester fluorotelomer dimethyl ammonio propanoic acid	X:3 MeOCO-FTAm-PrA
4:3 2-methylester fluorotelomer dimethyl ammonio propanoic acid	4:3 MeOCO-FTAm-PrA	C14H18O4NF9	X:3 2-methylester fluorotelomer dimethyl ammonio propanoic acid	X:3 MeOCO-FTAm-PrA
6:3 2-methylester fluorotelomer dimethyl ammonio propanoic acid	6:3 MeOCO-FTAm-PrA	C16H18O4NF13	X:3 2-methylester fluorotelomer dimethyl ammonio propanoic acid	X:3 MeOCO-FTAm-PrA
8:3 2-methylester fluorotelomer dimethyl ammonio propanoic acid	8:3 MeOCO-FTAm-PrA	C18H18O4NF17	X:3 2-methylester fluorotelomer dimethyl ammonio propanoic acid	X:3 MeOCO-FTAm-PrA
10:3 2-methylester fluorotelomer dimethyl ammonio propanoic acid	10:3 MeOCO-FTAm-PrA	C20H18O4NF21	X:3 2-methylester fluorotelomer dimethyl ammonio propanoic acid	X:3 MeOCO-FTAm-PrA
12:3 2-methylester fluorotelomer dimethyl ammonio propanoic acid	12:3 MeOCO-FTAm-PrA	C22H18O4NF25	X:3 2-methylester fluorotelomer dimethyl ammonio propanoic acid	X:3 MeOCO-FTAm-PrA
14:3 2-methylester fluorotelomer dimethyl ammonio propanoic acid	14:3 MeOCO-FTAm-PrA	C24H18O4NF29	X:3 2-methylester fluorotelomer dimethyl ammonio propanoic acid	X:3 MeOCO-FTAm-PrA
16:3 2-methylester fluorotelomer dimethyl ammonio propanoic acid	16:3 MeOCO-FTAm-PrA	C26H18O4NF33	X:3 2-methylester fluorotelomer dimethyl ammonio propanoic acid	X:3 MeOCO-FTAm-PrA
18:3 2-methylester fluorotelomer dimethyl ammonio propanoic acid	18:3 MeOCO-FTAm-PrA	C28H18O4NF37	X:3 2-methylester fluorotelomer dimethyl ammonio propanoic acid	X:3 MeOCO-FTAm-PrA
2:3 1-ester 2-oxamethanol fluorotelomer dimethyl amine	2:3 OCO-OMeOH-FT-DiMeAn	C9H14O4NF5	X:3 1-ester 2-oxamethanol fluorotelomer dimethyl amine	X:3 OCO-OMeOH-FT-DiMeAn
4:3 1-ester 2-oxamethanol fluorotelomer dimethyl amine	4:3 OCO-OMeOH-FT-DiMeAn	C11H14O4NF9	X:3 1-ester 2-oxamethanol fluorotelomer dimethyl amine	X:3 OCO-OMeOH-FT-DiMeAn
6:3 1-ester 2-oxamethanol fluorotelomer dimethyl amine	6:3 OCO-OMeOH-FT-DiMeAn	C13H14O4NF13	X:3 1-ester 2-oxamethanol fluorotelomer dimethyl amine	X:3 OCO-OMeOH-FT-DiMeAn
8:3 1-ester 2-oxamethanol fluorotelomer dimethyl amine	8:3 OCO-OMeOH-FT-DiMeAn	C15H14O4NF17	X:3 1-ester 2-oxamethanol fluorotelomer dimethyl amine	X:3 OCO-OMeOH-FT-DiMeAn
10:3 1-ester 2-oxamethanol fluorotelomer dimethyl amine	10:3 OCO-OMeOH-FT-DiMeAn	C17H14O4NF21	X:3 1-ester 2-oxamethanol fluorotelomer dimethyl amine	X:3 OCO-OMeOH-FT-DiMeAn

12:3 1-ester 2-oxamethanol fluorotelomer dimethyl amine	12:3 OCO-OMeOH-FT-DiMeAn	C19H14O4NF25	X:3 1-ester 2-oxamethanol fluorotelomer dimethyl amine	X:3 OCO-OMeOH-FT-DiMeAn
14:3 1-ester 2-oxamethanol fluorotelomer dimethyl amine	14:3 OCO-OMeOH-FT-DiMeAn	C21H14O4NF29	X:3 1-ester 2-oxamethanol fluorotelomer dimethyl amine	X:3 OCO-OMeOH-FT-DiMeAn
16:3 1-ester 2-oxamethanol fluorotelomer dimethyl amine	16:3 OCO-OMeOH-FT-DiMeAn	C23H14O4NF33	X:3 1-ester 2-oxamethanol fluorotelomer dimethyl amine	X:3 OCO-OMeOH-FT-DiMeAn
18:3 1-ester 2-oxamethanol fluorotelomer dimethyl amine	18:3 OCO-OMeOH-FT-DiMeAn	C25H14O4NF37	X:3 1-ester 2-oxamethanol fluorotelomer dimethyl amine	X:3 OCO-OMeOH-FT-DiMeAn
2:3 2-hydroxy fluorotelomer methylamine	2:3 OH-FT-MeAn	C6H10ONF5	X:3 2-hydroxy fluorotelomer methylamine	X:3 OH-FT-MeAn
4:3 2-hydroxy fluorotelomer methylamine	4:3 OH-FT-MeAn	C8H10ONF9	X:3 2-hydroxy fluorotelomer methylamine	X:3 OH-FT-MeAn
6:3 2-hydroxy fluorotelomer methylamine	6:3 OH-FT-MeAn	C10H10ONF13	X:3 2-hydroxy fluorotelomer methylamine	X:3 OH-FT-MeAn
8:3 2-hydroxy fluorotelomer methylamine	8:3 OH-FT-MeAn	C12H10ONF17	X:3 2-hydroxy fluorotelomer methylamine	X:3 OH-FT-MeAn
10:3 2-hydroxy fluorotelomer methylamine	10:3 OH-FT-MeAn	C14H10ONF21	X:3 2-hydroxy fluorotelomer methylamine	X:3 OH-FT-MeAn
12:3 2-hydroxy fluorotelomer methylamine	12:3 OH-FT-MeAn	C16H10ONF25	X:3 2-hydroxy fluorotelomer methylamine	X:3 OH-FT-MeAn
14:3 2-hydroxy fluorotelomer methylamine	14:3 OH-FT-MeAn	C18H10ONF29	X:3 2-hydroxy fluorotelomer methylamine	X:3 OH-FT-MeAn
16:3 2-hydroxy fluorotelomer methylamine	16:3 OH-FT-MeAn	C20H10ONF33	X:3 2-hydroxy fluorotelomer methylamine	X:3 OH-FT-MeAn
18:3 2-hydroxy fluorotelomer methylamine	18:3 OH-FT-MeAn	C22H10ONF37	X:3 2-hydroxy fluorotelomer methylamine	X:3 OH-FT-MeAn
2:3 2-hydroxy fluorotelomer dimethylamine	2:3 OH-FT-DiMeAn	C7H12ONF5	X:3 2-hydroxy fluorotelomer dimethylamine	X:3 OH-FT-DiMeAn
4:3 2-hydroxy fluorotelomer dimethylamine	4:3 OH-FT-DiMeAn	C9H12ONF9	X:3 2-hydroxy fluorotelomer dimethylamine	X:3 OH-FT-DiMeAn
6:3 2-hydroxy fluorotelomer dimethylamine	6:3 OH-FT-DiMeAn	C11H12ONF13	X:3 2-hydroxy fluorotelomer dimethylamine	X:3 OH-FT-DiMeAn
8:3 2-hydroxy fluorotelomer dimethylamine	8:3 OH-FT-DiMeAn	C13H12ONF17	X:3 2-hydroxy fluorotelomer dimethylamine	X:3 OH-FT-DiMeAn
10:3 2-hydroxy fluorotelomer dimethylamine	10:3 OH-FT-DiMeAn	C15H12ONF21	X:3 2-hydroxy fluorotelomer dimethylamine	X:3 OH-FT-DiMeAn
12:3 2-hydroxy fluorotelomer dimethylamine	12:3 OH-FT-DiMeAn	C17H12ONF25	X:3 2-hydroxy fluorotelomer dimethylamine	X:3 OH-FT-DiMeAn
14:3 2-hydroxy fluorotelomer dimethylamine	14:3 OH-FT-DiMeAn	C19H12ONF29	X:3 2-hydroxy fluorotelomer dimethylamine	X:3 OH-FT-DiMeAn
16:3 2-hydroxy fluorotelomer dimethylamine	16:3 OH-FT-DiMeAn	C21H12ONF33	X:3 2-hydroxy fluorotelomer dimethylamine	X:3 OH-FT-DiMeAn
18:3 2-hydroxy fluorotelomer dimethylamine	18:3 OH-FT-DiMeAn	C23H12ONF37	X:3 2-hydroxy fluorotelomer dimethylamine	X:3 OH-FT-DiMeAn
2:3 2-hydroxy fluorotelomer trimethylammonium	2:3 OH-FT-TAm	C8H14ONF5	X:3 2-hydroxy fluorotelomer trimethylammonium	X:3 OH-FT-TAm
4:3 2-hydroxy fluorotelomer trimethylammonium	4:3 OH-FT-TAm	C10H14ONF9	X:3 2-hydroxy fluorotelomer trimethylammonium	X:3 OH-FT-TAm
6:3 2-hydroxy fluorotelomer trimethylammonium	6:3 OH-FT-TAm	C12H14ONF13	X:3 2-hydroxy fluorotelomer trimethylammonium	X:3 OH-FT-TAm
8:3 2-hydroxy fluorotelomer trimethylammonium	8:3 OH-FT-TAm	C14H14ONF17	X:3 2-hydroxy fluorotelomer trimethylammonium	X:3 OH-FT-TAm
10:3 2-hydroxy fluorotelomer trimethylammonium	10:3 OH-FT-TAm	C16H14ONF21	X:3 2-hydroxy fluorotelomer trimethylammonium	X:3 OH-FT-TAm
12:3 2-hydroxy fluorotelomer trimethylammonium	12:3 OH-FT-TAm	C18H14ONF25	X:3 2-hydroxy fluorotelomer trimethylammonium	X:3 OH-FT-TAm
14:3 2-hydroxy fluorotelomer trimethylammonium	14:3 OH-FT-TAm	C20H14ONF29	X:3 2-hydroxy fluorotelomer trimethylammonium	X:3 OH-FT-TAm
16:3 2-hydroxy fluorotelomer trimethylammonium	16:3 OH-FT-TAm	C22H14ONF33	X:3 2-hydroxy fluorotelomer trimethylammonium	X:3 OH-FT-TAm
18:3 2-hydroxy fluorotelomer trimethylammonium	18:3 OH-FT-TAm	C24H14ONF37	X:3 2-hydroxy fluorotelomer trimethylammonium	X:3 OH-FT-TAm
2:3 2-hydroxy fluorotelomer dimethylammonio carboxylic acid	2:3 OH-FTAmCA	C8H12O3NF5	X:3 2-hydroxy fluorotelomer dimethylammonio carboxylic acid	X:3 OH-FTAmCA

4:3 2-hydroxy fluorotelomer dimethylammonio carboxylic acid	4:3 OH-FTAmCA	C10H12O3NF9	X:3 2-hydroxy fluorotelomer dimethylammonio carboxylic acid	X:3 OH-FTAmCA
6:3 2-hydroxy fluorotelomer dimethylammonio carboxylic acid	6:3 OH-FTAmCA	C12H12O3NF13	X:3 2-hydroxy fluorotelomer dimethylammonio carboxylic acid	X:3 OH-FTAmCA
8:3 2-hydroxy fluorotelomer dimethylammonio carboxylic acid	8:3 OH-FTAmCA	C14H12O3NF17	X:3 2-hydroxy fluorotelomer dimethylammonio carboxylic acid	X:3 OH-FTAmCA
10:3 2-hydroxy fluorotelomer dimethylammonio carboxylic acid	10:3 OH-FTAmCA	C16H12O3NF21	X:3 2-hydroxy fluorotelomer dimethylammonio carboxylic acid	X:3 OH-FTAmCA
12:3 2-hydroxy fluorotelomer dimethylammonio carboxylic acid	12:3 OH-FTAmCA	C18H12O3NF25	X:3 2-hydroxy fluorotelomer dimethylammonio carboxylic acid	X:3 OH-FTAmCA
14:3 2-hydroxy fluorotelomer dimethylammonio carboxylic acid	14:3 OH-FTAmCA	C20H12O3NF29	X:3 2-hydroxy fluorotelomer dimethylammonio carboxylic acid	X:3 OH-FTAmCA
16:3 2-hydroxy fluorotelomer dimethylammonio carboxylic acid	16:3 OH-FTAmCA	C22H12O3NF33	X:3 2-hydroxy fluorotelomer dimethylammonio carboxylic acid	X:3 OH-FTAmCA
18:3 2-hydroxy fluorotelomer dimethylammonio carboxylic acid	18:3 OH-FTAmCA	C24H12O3NF37	X:3 2-hydroxy fluorotelomer dimethylammonio carboxylic acid	X:3 OH-FTAmCA
2:3 2-hydroxy unsaturated fluorotelomer dimethylamine	2:3 OH-UFT-DiMeAn	C7H11ONF4	X:3 2-hydroxy unsaturated fluorotelomer dimethylamine	X:3 OH-UFT-DiMeAn
4:3 2-hydroxy unsaturated fluorotelomer dimethylamine	4:3 OH-UFT-DiMeAn	C9H11ONF8	X:3 2-hydroxy unsaturated fluorotelomer dimethylamine	X:3 OH-UFT-DiMeAn
6:3 2-hydroxy unsaturated fluorotelomer dimethylamine	6:3 OH-UFT-DiMeAn	C11H11ONF12	X:3 2-hydroxy unsaturated fluorotelomer dimethylamine	X:3 OH-UFT-DiMeAn
8:3 2-hydroxy unsaturated fluorotelomer dimethylamine	8:3 OH-UFT-DiMeAn	C13H11ONF16	X:3 2-hydroxy unsaturated fluorotelomer dimethylamine	X:3 OH-UFT-DiMeAn
10:3 2-hydroxy unsaturated fluorotelomer dimethylamine	10:3 OH-UFT-DiMeAn	C15H11ONF20	X:3 2-hydroxy unsaturated fluorotelomer dimethylamine	X:3 OH-UFT-DiMeAn
12:3 2-hydroxy unsaturated fluorotelomer dimethylamine	12:3 OH-UFT-DiMeAn	C17H11ONF24	X:3 2-hydroxy unsaturated fluorotelomer dimethylamine	X:3 OH-UFT-DiMeAn
14:3 2-hydroxy unsaturated fluorotelomer dimethylamine	14:3 OH-UFT-DiMeAn	C19H11ONF28	X:3 2-hydroxy unsaturated fluorotelomer dimethylamine	X:3 OH-UFT-DiMeAn
16:3 2-hydroxy unsaturated fluorotelomer dimethylamine	16:3 OH-UFT-DiMeAn	C21H11ONF32	X:3 2-hydroxy unsaturated fluorotelomer dimethylamine	X:3 OH-UFT-DiMeAn
18:3 2-hydroxy unsaturated fluorotelomer dimethylamine	18:3 OH-UFT-DiMeAn	C23H11ONF36	X:3 2-hydroxy unsaturated fluorotelomer dimethylamine	X:3 OH-UFT-DiMeAn
2:3 2-hydroxy fluorotelomer dimethylammonio propanoic acid	2:3 OH-FTAm-PrA	C10H16O3NF5	X:3 2-hydroxy fluorotelomer dimethylammonio propanoic acid	X:3 OH-FTAm-PrA
4:3 2-hydroxy fluorotelomer dimethylammonio propanoic acid	4:3 OH-FTAm-PrA	C12H16O3NF9	X:3 2-hydroxy fluorotelomer dimethylammonio propanoic acid	X:3 OH-FTAm-PrA
6:3 2-hydroxy fluorotelomer dimethylammonio propanoic acid	6:3 OH-FTAm-PrA	C14H16O3NF13	X:3 2-hydroxy fluorotelomer dimethylammonio propanoic acid	X:3 OH-FTAm-PrA
8:3 2-hydroxy fluorotelomer dimethylammonio propanoic acid	8:3 OH-FTAm-PrA	C16H16O3NF17	X:3 2-hydroxy fluorotelomer dimethylammonio propanoic acid	X:3 OH-FTAm-PrA

10:3 2-hydroxy fluorotelomer dimethylammonio propanoic acid	10:3 OH-FTAm-PrA	C18H16O3NF21	X:3 2-hydroxy fluorotelomer dimethylammonio propanoic acid	X:3 OH-FTAm-PrA
12:3 2-hydroxy fluorotelomer dimethylammonio propanoic acid	12:3 OH-FTAm-PrA	C20H16O3NF25	X:3 2-hydroxy fluorotelomer dimethylammonio propanoic acid	X:3 OH-FTAm-PrA
14:3 2-hydroxy fluorotelomer dimethylammonio propanoic acid	14:3 OH-FTAm-PrA	C22H16O3NF29	X:3 2-hydroxy fluorotelomer dimethylammonio propanoic acid	X:3 OH-FTAm-PrA
16:3 2-hydroxy fluorotelomer dimethylammonio propanoic acid	16:3 OH-FTAm-PrA	C24H16O3NF33	X:3 2-hydroxy fluorotelomer dimethylammonio propanoic acid	X:3 OH-FTAm-PrA
18:3 2-hydroxy fluorotelomer dimethylammonio propanoic acid	18:3 OH-FTAm-PrA	C26H16O3NF37	X:3 2-hydroxy fluorotelomer dimethylammonio propanoic acid	X:3 OH-FTAm-PrA
1:3 fluorotelomer betaine	1:3 FTB	C8H14O2NF3	X:3 fluorotelomer betaine	X:3 FTB
2:3 fluorotelomer betaine	2:3 FTB	C9H14O2NF5	X:3 fluorotelomer betaine	X:3 FTB
3:3 fluorotelomer betaine	3:3 FTB	C10H14O2NF7	X:3 fluorotelomer betaine	X:3 FTB
4:3 fluorotelomer betaine	4:3 FTB	C11H14O2NF9	X:3 fluorotelomer betaine	X:3 FTB
5:3 fluorotelomer betaine	5:3 FTB	C12H14O2NF11	X:3 fluorotelomer betaine	X:3 FTB
6:3 fluorotelomer betaine	6:3 FTB	C13H14O2NF13	X:3 fluorotelomer betaine	X:3 FTB
7:3 fluorotelomer betaine	7:3 FTB	C14H14O2NF15	X:3 fluorotelomer betaine	X:3 FTB
8:3 fluorotelomer betaine	8:3 FTB	C15H14O2NF17	X:3 fluorotelomer betaine	X:3 FTB
9:3 fluorotelomer betaine	9:3 FTB	C16H14O2NF19	X:3 fluorotelomer betaine	X:3 FTB
10:3 fluorotelomer betaine	10:3 FTB	C17H14O2NF21	X:3 fluorotelomer betaine	X:3 FTB
11:3 fluorotelomer betaine	11:3 FTB	C18H14O2NF23	X:3 fluorotelomer betaine	X:3 FTB
12:3 fluorotelomer betaine	12:3 FTB	C19H14O2NF25	X:3 fluorotelomer betaine	X:3 FTB
13:3 fluorotelomer betaine	13:3 FTB	C20H14O2NF27	X:3 fluorotelomer betaine	X:3 FTB
14:3 fluorotelomer betaine	14:3 FTB	C21H14O2NF29	X:3 fluorotelomer betaine	X:3 FTB
15:3 fluorotelomer betaine	15:3 FTB	C22H14O2NF31	X:3 fluorotelomer betaine	X:3 FTB
2:3 2-hydroxy fluorotelomer betaine	2:3 OH-FTB	C9H14O3NF5	X:3 2-hydroxy fluorotelomer betaine	X:3 OH-FTB
4:3 2-hydroxy fluorotelomer betaine	4:3 OH-FTB	C11H14O3NF9	X:3 2-hydroxy fluorotelomer betaine	X:3 OH-FTB
6:3 2-hydroxy fluorotelomer betaine	6:3 OH-FTB	C13H14O3NF13	X:3 2-hydroxy fluorotelomer betaine	X:3 OH-FTB
8:3 2-hydroxy fluorotelomer betaine	8:3 OH-FTB	C15H14O3NF17	X:3 2-hydroxy fluorotelomer betaine	X:3 OH-FTB
10:3 2-hydroxy fluorotelomer betaine	10:3 OH-FTB	C17H14O3NF21	X:3 2-hydroxy fluorotelomer betaine	X:3 OH-FTB
12:3 2-hydroxy fluorotelomer betaine	12:3 OH-FTB	C19H14O3NF25	X:3 2-hydroxy fluorotelomer betaine	X:3 OH-FTB
14:3 2-hydroxy fluorotelomer betaine	14:3 OH-FTB	C21H14O3NF29	X:3 2-hydroxy fluorotelomer betaine	X:3 OH-FTB
16:3 2-hydroxy fluorotelomer betaine	16:3 OH-FTB	C23H14O3NF33	X:3 2-hydroxy fluorotelomer betaine	X:3 OH-FTB
18:3 2-hydroxy fluorotelomer betaine	18:3 OH-FTB	C25H14O3NF37	X:3 2-hydroxy fluorotelomer betaine	X:3 OH-FTB
2:3 2-hydroxy unsaturated fluorotelomer betaine	2:3 OH-UFTB	C9H13O3NF4	X:3 2-hydroxy unsaturated fluorotelomer betaine	X:3 OH-UFTB
4:3 2-hydroxy unsaturated fluorotelomer betaine	4:3 OH-UFTB	C11H13O3NF8	X:3 2-hydroxy unsaturated fluorotelomer betaine	X:3 OH-UFTB
6:3 2-hydroxy unsaturated fluorotelomer betaine	6:3 OH-UFTB	C13H13O3NF12	X:3 2-hydroxy unsaturated fluorotelomer betaine	X:3 OH-UFTB
8:3 2-hydroxy unsaturated fluorotelomer betaine	8:3 OH-UFTB	C15H13O3NF16	X:3 2-hydroxy unsaturated fluorotelomer betaine	X:3 OH-UFTB

10:3 2-hydroxy unsaturated fluorotelomer betaine	10:3 OH-UFTB	C17H13O3NF20	X:3 2-hydroxy unsaturated fluorotelomer betaine	X:3 OH-UFTB
12:3 2-hydroxy unsaturated fluorotelomer betaine	12:3 OH-UFTB	C19H13O3NF24	X:3 2-hydroxy unsaturated fluorotelomer betaine	X:3 OH-UFTB
14:3 2-hydroxy unsaturated fluorotelomer betaine	14:3 OH-UFTB	C21H13O3NF28	X:3 2-hydroxy unsaturated fluorotelomer betaine	X:3 OH-UFTB
16:3 2-hydroxy unsaturated fluorotelomer betaine	16:3 OH-UFTB	C23H13O3NF32	X:3 2-hydroxy unsaturated fluorotelomer betaine	X:3 OH-UFTB
18:3 2-hydroxy unsaturated fluorotelomer betaine	18:3 OH-UFTB	C25H13O3NF36	X:3 2-hydroxy unsaturated fluorotelomer betaine	X:3 OH-UFTB
2:3 2-methylester-fluorotelomer betaine	2:3 MeOCO-FTB	C11H16O4NF5	X:3 2-methylester-fluorotelomer betaine	X:3 MeOCO-FTB
4:3 2-methylester-fluorotelomer betaine	4:3 MeOCO-FTB	C13H16O4NF9	X:3 2-methylester-fluorotelomer betaine	X:3 MeOCO-FTB
6:3 2-methylester-fluorotelomer betaine	6:3 MeOCO-FTB	C15H16O4NF13	X:3 2-methylester-fluorotelomer betaine	X:3 MeOCO-FTB
8:3 2-methylester-fluorotelomer betaine	8:3 MeOCO-FTB	C17H16O4NF17	X:3 2-methylester-fluorotelomer betaine	X:3 MeOCO-FTB
10:3 2-methylester-fluorotelomer betaine	10:3 MeOCO-FTB	C19H16O4NF21	X:3 2-methylester-fluorotelomer betaine	X:3 MeOCO-FTB
12:3 2-methylester-fluorotelomer betaine	12:3 MeOCO-FTB	C21H16O4NF25	X:3 2-methylester-fluorotelomer betaine	X:3 MeOCO-FTB
14:3 2-methylester-fluorotelomer betaine	14:3 MeOCO-FTB	C23H16O4NF29	X:3 2-methylester-fluorotelomer betaine	X:3 MeOCO-FTB
16:3 2-methylester-fluorotelomer betaine	16:3 MeOCO-FTB	C25H16O4NF33	X:3 2-methylester-fluorotelomer betaine	X:3 MeOCO-FTB
18:3 2-methylester-fluorotelomer betaine	18:3 MeOCO-FTB	C27H16O4NF37	X:3 2-methylester-fluorotelomer betaine	X:3 MeOCO-FTB
2:3 fluorotelomer 1-methanol, 2-methylester, 3-hydroxy betaine	2:3 MeOH-MeOCO-OH-FTB	C12H18O6NF5	X:3 fluorotelomer 1-methanol, 2-methylester, 3-hydroxy betaine	X:3 MeOH-MeOCO-OH-FTB
4:3 fluorotelomer 1-methanol, 2-methylester, 3-hydroxy betaine	4:3 MeOH-MeOCO-OH-FTB	C14H18O6NF9	X:3 fluorotelomer 1-methanol, 2-methylester, 3-hydroxy betaine	X:3 MeOH-MeOCO-OH-FTB
6:3 fluorotelomer 1-methanol, 2-methylester, 3-hydroxy betaine	6:3 MeOH-MeOCO-OH-FTB	C16H18O6NF13	X:3 fluorotelomer 1-methanol, 2-methylester, 3-hydroxy betaine	X:3 MeOH-MeOCO-OH-FTB
8:3 fluorotelomer 1-methanol, 2-methylester, 3-hydroxy betaine	8:3 MeOH-MeOCO-OH-FTB	C18H18O6NF17	X:3 fluorotelomer 1-methanol, 2-methylester, 3-hydroxy betaine	X:3 MeOH-MeOCO-OH-FTB
10:3 fluorotelomer 1-methanol, 2-methylester, 3-hydroxy betaine	10:3 MeOH-MeOCO-OH-FTB	C20H18O6NF21	X:3 fluorotelomer 1-methanol, 2-methylester, 3-hydroxy betaine	X:3 MeOH-MeOCO-OH-FTB
12:3 fluorotelomer 1-methanol, 2-methylester, 3-hydroxy betaine	12:3 MeOH-MeOCO-OH-FTB	C22H18O6NF25	X:3 fluorotelomer 1-methanol, 2-methylester, 3-hydroxy betaine	X:3 MeOH-MeOCO-OH-FTB
14:3 fluorotelomer 1-methanol, 2-methylester, 3-hydroxy betaine	14:3 MeOH-MeOCO-OH-FTB	C24H18O6NF29	X:3 fluorotelomer 1-methanol, 2-methylester, 3-hydroxy betaine	X:3 MeOH-MeOCO-OH-FTB
16:3 fluorotelomer 1-methanol, 2-methylester, 3-hydroxy betaine	16:3 MeOH-MeOCO-OH-FTB	C26H18O6NF33	X:3 fluorotelomer 1-methanol, 2-methylester, 3-hydroxy betaine	X:3 MeOH-MeOCO-OH-FTB
18:3 fluorotelomer 1-methanol, 2-methylester, 3-hydroxy betaine	18:3 MeOH-MeOCO-OH-FTB	C28H18O6NF37	X:3 fluorotelomer 1-methanol, 2-methylester, 3-hydroxy betaine	X:3 MeOH-MeOCO-OH-FTB
2:3 fluorotelomer 1,3-methanol, 2-methylester betaine	2:3 di(MeOH) MeOCO-FTB	C13H20O6NF5	X:3 fluorotelomer 1,3-methanol, 2-methylester betaine	X:3 di(MeOH) MeOCO-FTB
4:3 fluorotelomer 1,3-methanol, 2-methylester betaine	4:3 di(MeOH) MeOCO-FTB	C15H20O6NF9	X:3 fluorotelomer 1,3-methanol, 2-methylester betaine	X:3 di(MeOH) MeOCO-FTB
6:3 fluorotelomer 1,3-methanol, 2-methylester betaine	6:3 di(MeOH) MeOCO-FTB	C17H20O6NF13	X:3 fluorotelomer 1,3-methanol, 2-methylester betaine	X:3 di(MeOH) MeOCO-FTB
8:3 fluorotelomer 1,3-methanol, 2-methylester betaine	8:3 di(MeOH) MeOCO-FTB	C19H20O6NF17	X:3 fluorotelomer 1,3-methanol, 2-methylester betaine	X:3 di(MeOH) MeOCO-FTB

10:3 fluorotelomer 1,3-methanol, 2-methylester betaine	10:3 di(MeOH) MeOCO-FTB	C21H20O6NF21	X:3 fluorotelomer 1,3-methanol, 2-methylester betaine	X:3 di(MeOH) MeOCO-FTB
12:3 fluorotelomer 1,3-methanol, 2-methylester betaine	12:3 di(MeOH) MeOCO-FTB	C23H20O6NF25	X:3 fluorotelomer 1,3-methanol, 2-methylester betaine	X:3 di(MeOH) MeOCO-FTB
14:3 fluorotelomer 1,3-methanol, 2-methylester betaine	14:3 di(MeOH) MeOCO-FTB	C25H20O6NF29	X:3 fluorotelomer 1,3-methanol, 2-methylester betaine	X:3 di(MeOH) MeOCO-FTB
16:3 fluorotelomer 1,3-methanol, 2-methylester betaine	16:3 di(MeOH) MeOCO-FTB	C27H20O6NF33	X:3 fluorotelomer 1,3-methanol, 2-methylester betaine	X:3 di(MeOH) MeOCO-FTB
18:3 fluorotelomer 1,3-methanol, 2-methylester betaine	18:3 di(MeOH) MeOCO-FTB	C29H20O6NF37	X:3 fluorotelomer 1,3-methanol, 2-methylester betaine	X:3 di(MeOH) MeOCO-FTB
2:4 fluorotelomer betaine	2:4 FTB	C10H16O2NF5	X:4 fluorotelomer betaine	X:4 FTB
4:4 fluorotelomer betaine	4:4 FTB	C12H16O2NF9	X:4 fluorotelomer betaine	X:4 FTB
6:4 fluorotelomer betaine	6:4 FTB	C14H16O2NF13	X:4 fluorotelomer betaine	X:4 FTB
8:4 fluorotelomer betaine	8:4 FTB	C16H16O2NF17	X:4 fluorotelomer betaine	X:4 FTB
10:4 fluorotelomer betaine	10:4 FTB	C18H16O2NF21	X:4 fluorotelomer betaine	X:4 FTB
12:4 fluorotelomer betaine	12:4 FTB	C20H16O2NF25	X:4 fluorotelomer betaine	X:4 FTB
14:4 fluorotelomer betaine	14:4 FTB	C22H16O2NF29	X:4 fluorotelomer betaine	X:4 FTB
16:4 fluorotelomer betaine	16:4 FTB	C24H16O2NF33	X:4 fluorotelomer betaine	X:4 FTB
18:4 fluorotelomer betaine	18:4 FTB	C26H16O2NF37	X:4 fluorotelomer betaine	X:4 FTB
Class 19 (no structure, just mass; confidence level 4)	B-H Class 19 a	C10H15O2SN2F5	B-H Class 19	B-H Class 19
Class 19 (no structure, just mass; confidence level 4)	B-H Class 19 b	C12H15O2SN2F9	B-H Class 19	B-H Class 19
Class 19 (no structure, just mass; confidence level 4)	B-H Class 19 c	C14H15O2SN2F13	B-H Class 19	B-H Class 19
Class 19 (no structure, just mass; confidence level 4)	B-H Class 19 d	C16H15O2SN2F17	B-H Class 19	B-H Class 19
Class 19 (no structure, just mass; confidence level 4)	B-H Class 19 e	C18H15O2SN2F21	B-H Class 19	B-H Class 19
Class 19 (no structure, just mass; confidence level 4)	B-H Class 19 f	C20H15O2SN2F25	B-H Class 19	B-H Class 19
Class 38 (no structure, just mass; Confidence Level 4)	B-H Class 38 a	C11H21O2SN2F5	B-H Class 38	B-H Class 38
Class 38 (no structure, just mass; Confidence Level 4)	B-H Class 38 b	C12H21O2SN2F7	B-H Class 38	B-H Class 38
Class 38 (no structure, just mass; Confidence Level 4)	B-H Class 38 c	C13H21O2SN2F9	B-H Class 38	B-H Class 38
Class 38 (no structure, just mass; Confidence Level 4)	B-H Class 38 d	C14H21O2SN2F11	B-H Class 38	B-H Class 38
Class 38 (no structure, just mass; Confidence Level 4)	B-H Class 38 e	C15H21O2SN2F13	B-H Class 38	B-H Class 38
Class 38 (no structure, just mass; Confidence Level 4)	B-H Class 38 f	C16H21O2SN2F15	B-H Class 38	B-H Class 38
Class 38 (no structure, just mass; Confidence Level 4)	B-H Class 38 g	C17H21O2SN2F17	B-H Class 38	B-H Class 38
Class 38 (no structure, just mass; Confidence Level 4)	B-H Class 38 h	C18H21O2SN2F19	B-H Class 38	B-H Class 38
Class 38 (no structure, just mass; Confidence Level 4)	B-H Class 38 I	C19H21O2SN2F21	B-H Class 38	B-H Class 38
Class 38 (no structure, just mass; Confidence Level 4)	B-H Class 38 j	C20H21O2SN2F23	B-H Class 38	B-H Class 38

Appendix D

Lab Data Comparison

Appendix D

Analytical Comparison

1. Overview of Comparison

Analysis from the Colorado School of CSM

The Colorado School of Mines (CSM) performed per-and polyfluoroalkyl substances (PFAS) analysis throughout the course of the project. Prior to analyzing samples, CSM developed an analytical confirmation white paper that compared the PFAS composition of a groundwater sample as measured by CSM and a commercial lab (SGS AXYS Analytical Services). This report was submitted to SEMS. To verify PFAS results generated by CSM during the project, split samples were sent to Pace Analytical (Pace) and CSM for PFAS analysis. A comparison of these results is provided in the sections below.

CSM submitted a PFAS analytical standard operating procedure (SOP) to the U.S. Department of Defense (DoD) through the SERDP & ESTCP Management System (SEMS) at the beginning of the project that details analytical procedures used by CSM. In summary, CSM uses a validated modified method of USEPA 537.1. This method is characterized by whole-sample collection, preparation, and analysis of selected PFASs in unfiltered low-volume (3 to 7 milliliters) water samples. CSM's analytical method differs from USEPA 537.1 as it utilizes large volume injection as opposed to solid phase extraction, elution, and injection. In addition to the analytical SOP submitted to the DoD through SEMS, an analyte list was also submitted.

Analysis from Pace

Sample receipt, sample analysis, and data review have been performed in accordance with the most current approved standards from The NELAC Institute (TNI), the Pace[1] laboratory quality manual, SOPs, and Pace policies. Additionally, the DoD Quality Service Manual, version 5.3, has been followed for these samples, and specifically, Table B-15 was followed for all PFAS samples.

Pace's PFAS by Isotope Dilution test method, developed for non-potable water, solids, biota, and biosolids, follows all the rigorous quality control standards outlined in DoD Quality Service Manual Table B-15. Because of its ability to quantitate 40 PFAS compounds, this method is widely applicable to both DoD and commercial/industrial applications. Furthermore, Pace has been audited and certified to the accreditation standards of the DoD, TNI, and state accreditation bodies.

2. Evaluated Samples and Collection Method

Table 1 below lists the samples split between CSM and Pace and includes the date and time the samples were collected as well as the volume of water processed through the treatment system. Three sample

[1] Pace Analytical Services, LLC (formerly Shealy Environmental Services, Inc.) at 106 Vantage Point Drive, West Columbia, SC 29172; telephone: 803-791-9700; fax: 803-791-9111; www.Pacelabs.com.

point sources were collected: (1) feed to Train A, (2) Train A effluent, and (3) Train B effluent. The raw feed water was sourced from Horsham Air National Guard base Storm Water Outfall Number 9. The raw feed water fed treatment Train A directly at a feed rate of 1 liter per minute. The effluent from Train A was used as the feed to Train B, effectively constituting the 'in series' flow path.

Feed water was sourced from Storm Water Outfall Number 9 at the Air National Guard base in Horsham, Pennsylvania, during the pilot test period from February 4, 2021, to February 20, 2021. The effluent samples were collected from the treatment system using an automatic sample collection unit (ISCO 9300), which collected 1 liter of effluent sample per day. Effluent samples collected daily were split between CSM and Pace (refer to Table 1 for a list of samples). Three samples were collected: (1) feed (FT11), (2) Train A effluent (TAT11), and (3) Train B effluent (TBT11). The treatment system for this test (i.e., Test 11) was operated in series (lead/lag) configuration; Train A processed the influent feed water, whereas Train B was fed Train A effluent as its feed stream. The treatment system influent flow path residence time was 100 minutes prior to sample collection, which is reflected in Table 1 in the Time Collected column.

Table 1: List of Samples Sent to Both CSM and Pace (Split from Same Source)

Sample Source		Samples sent to commercial lab (Shealy/PACE) and split to Mines by I.D.	Volume Processed (L)	Date Collected	Time Collected	Source Water Location
Raw Feed (feed to Train A)		FT11	90	2/4/21	16:20	Storm water outfall no. 9 (ANG)
		FT11	2713	2/6/21	16:20	
		FT11	5186	2/8/21	16:20	
		FT11	7323	2/10/21	16:20	
		FT11	9935	2/12/21	16:20	
		FT11	12360	2/14/21	16:20	
In Series operation Untreated Feed ->Train A effluent (as feed) -> Train B	Train B Effluent	TBT11	75	2/4/21	18:00	
		TBT11	1739	2/6/21	18:00	
		TBT11	3236	2/8/21	18:00	
		TBT11	4417	2/10/21	18:00	
		TBT11	6013	2/12/21	18:00	
		TBT11	7242	2/14/21	18:00	
	Train A effluent (as feed to Train B)	TAT11	183	2/4/21	18:00	
		TAT11	2806	2/6/21	18:00	
		TAT11	5276	2/8/21	18:00	
		TAT11	7415	2/10/21	18:00	
		TAT11	10028	2/12/21	18:00	
		TAT11	12452	2/14/21	18:00	

3. Analysis of Split PFAS Sample Results

Table 2 is a summary of the PFAS species detected by each of the laboratories (i.e., CSM and Pace) in the source water. Those analytes undetected in the feed water were at the limit of quantitation (LOQ) as reported by the lab. In the case of analytes 4:2 FTS and 8:2 FTS, CSM reported these as LOQ (i.e., the LOQ is 15 nanograms per liter [ng/L]) in the feed sample; therefore, these compounds can be assumed to be less than 15 ng/L in the sample. All other analytes not detected in the feed water are also assumed to be lower than the LOQ reported by each lab.

Table 2: List of Analytes Detected in Source Water (CSM versus Pace)

Analytes Evaluated	Detected in Feed	
	Mines	Pace Lab
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9Cl-PF3ONS)	no	no
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3OUdS	no	no
1H, 1H, 2H, 2H-perfluorodecane sulfonic acid (8:2 FTS)	no	yes
1H, 1H, 2H, 2H-perfluorooctane sulfonic acid (6:2 FTS)	yes	yes
1H,1H,2H,2H-perfluorododecane sulfonic acid (10:2 FTS)	no	no
1H,1H,2H,2H-perfluorohexane sulfonic acid (4:2 FTS)	no	yes
Hexafluoropropylene oxide dimer acid (GenX)	no	yes
4,8-dioxa-3H-perfluorononanoic acid (ADONA)	no	no
N-ethylperfluoro-1-octanesulfonamide (EtFOSA)	no	no
N-ethylperfluoro-1-octanesulfonamidoacetic acid (EtFOSAA)	no	no
2-N-ethylperfluoro-1-octanesulfonamido-ethanol (EtFOSE)	no	no
N-methylperfluoro-1-octanesulfonamide (MeFOSA)	no	no
N-methylperfluoro-1-octanesulfonamidoacetic acid (MeFOSAA)	no	no
2-N-methylperfluoro-1-octanesulfonamido-ethanol (MeFOSE)	no	no
Perfluoro-1-butanesulfonic acid (PFBS)	yes	yes
Perfluoro-1-decanesulfonic acid (PFDS)	no	no
Perfluoro-1-heptanesulfonic acid (PFHpS)	yes	yes
Perfluoro-1-nonanesulfonic acid (PFNS)	no	yes
Perfluoro-1-octanesulfonamide (PFOSA)	no	yes
Perfluoro-1-pentanesulfonic acid (PFPeS)	yes	yes
Perfluorohexanesulfonic acid (PFHxS)	yes	yes
Perfluoro-n-butanoic acid (PFBA)	yes	yes
Perfluoro-n-decanoic acid (PFDA)	no	yes
Perfluoro-n-dodecanoic acid (PFDoA)	no	no
Perfluoro-n-heptanoic acid (PFHpA)	yes	yes
Perfluoro-n-hexanoic acid (PFHxA)	yes	yes
Perfluoro-n-nonanoic acid (PFNA)	no	yes
Perfluoro-n-octanoic acid (PFOA)	yes	yes
Perfluoro-n-pentanoic acid (PFPeA)	yes	yes
Perfluoro-n-tetradecanoic acid (PFTeDA)	no	no
Perfluoro-n-tridecanoic acid (PFTrDA)	no	no
Perfluoro-n-undecanoic acid (PFUdA)	no	no
Perfluorooctanesulfonic acid (PFOS)	yes	yes
Perfluoropropane sulfonic acid (PFPrS)	yes	n/a

Note:
1. Blue highlighted rows indicate compounds on the UCMR3 list.
UCMR3 = third Unregulated Contaminant Monitoring Rule

3.1. Method for Data Comparison

Six samples per point source (i.e., feed, Train A, and Train B; 18 samples split to two labs, totaling 36) were analyzed independently by both CSM and Pace. Then a statistical comparison of the obtained results from CSM and Pace was conducted using linear regression to assess the reproducibility of the laboratory results. The performance objectives of the regression analysis were set to a slope between 0.8 and 1.2, an R^2 value greater than 0.8, and a relative percent difference of less than or equal to 30%. Finally, results from the regression analysis were compared to the performance objectives to assess the similarity between data obtained from the two labs. For regression analysis, CSM data was plotted on the X-axis and Pace data on the Y-axis. The scatter plots with the regression analysis are presented below. A slope of 1 indicates 100% agreement between lab results, whereas a slope less than 1 indicates a positive bias toward the CSM data. The R^2 gives the variance of the data from the model, and the closer the value is to 1, the better the data fits the model.

3.2. Statistical Metrics (Linear Regression and Percent Difference)

A comparison analysis for the UCMR3 group of PFAS species (i.e., perfluorooctanesulfonic acid [PFOS], perfluorooctanoic acid [PFOA], perfluoroheptanoic acid [PFHpA], perfluorononanoic acid [PFNA], perfluorobutane sulfonic acid [PFBS], and perfluorohexane sulfonate [PFHxS] shows positive correlation between CSM and Pace as depicted in scatter plots presented as Figures 1 through 5 (PFNA was not quantified in samples by either lab). The R^2 values of all the analyzed UCMR3 PFAS species were between the performance objective of values of 0.8 and 1.2, indicating the regression model fits the data well. The slopes obtained for PFOA (Figure 2) and PFHpA (Figure 4) are close to 1, indicating a high level of agreement between the CSM and Pace data. However, the slopes of the remaining UCMR3 PFASs were slightly less than 0.8, indicating a positive bias toward the CSM data. As discussed in the main report, this positive bias of some of the PFASs in the CSM data might be due to differences in sample preparation between the two labs. Scatter plots for the UCMR3 (excluding PFNA) using linear regression are shown in the figures below.

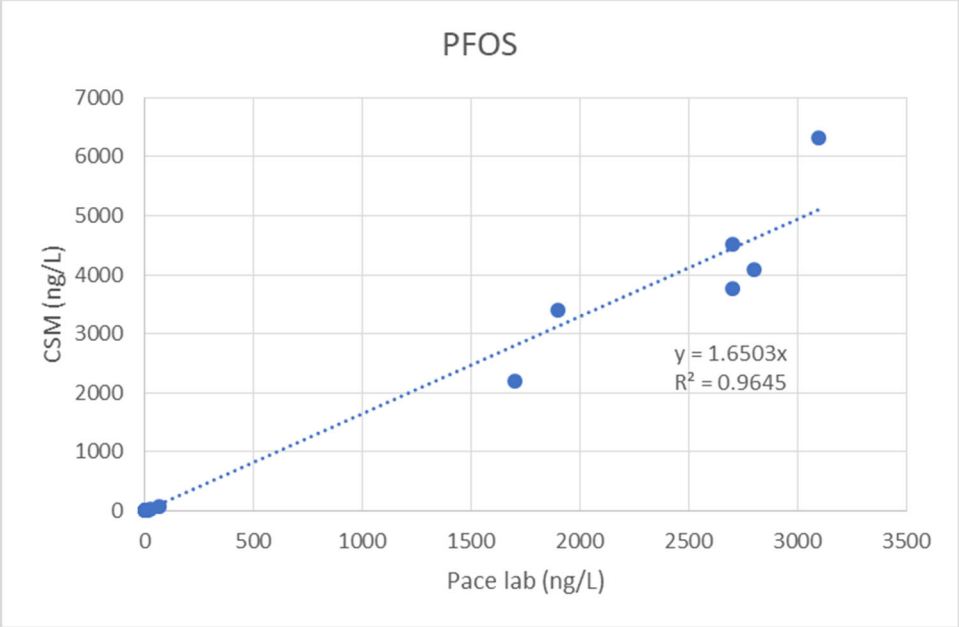

Figure 1: PFOS Lab Data Correlation

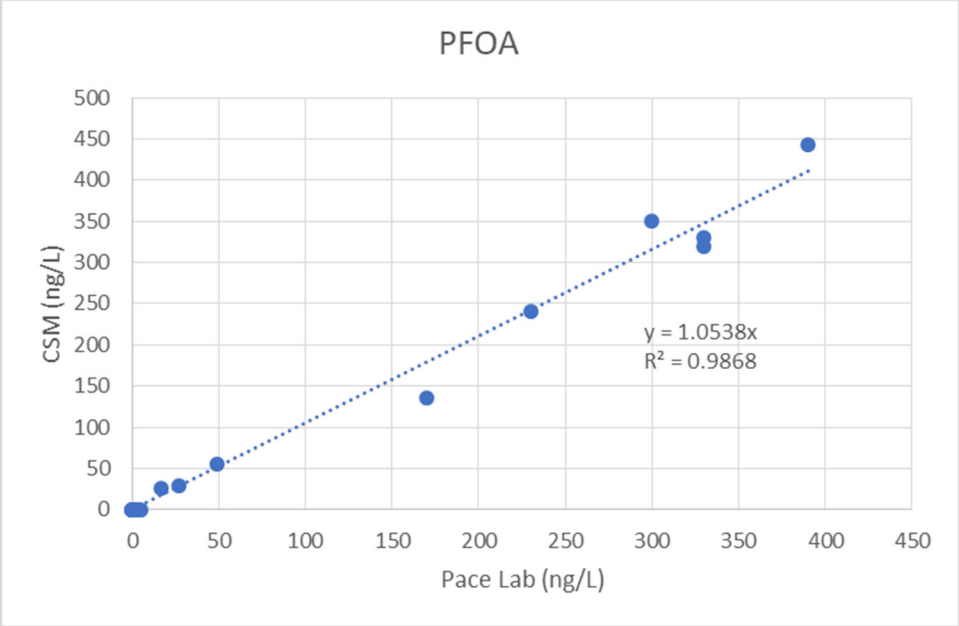

Figure 2: PFOA Lab Data Correlation

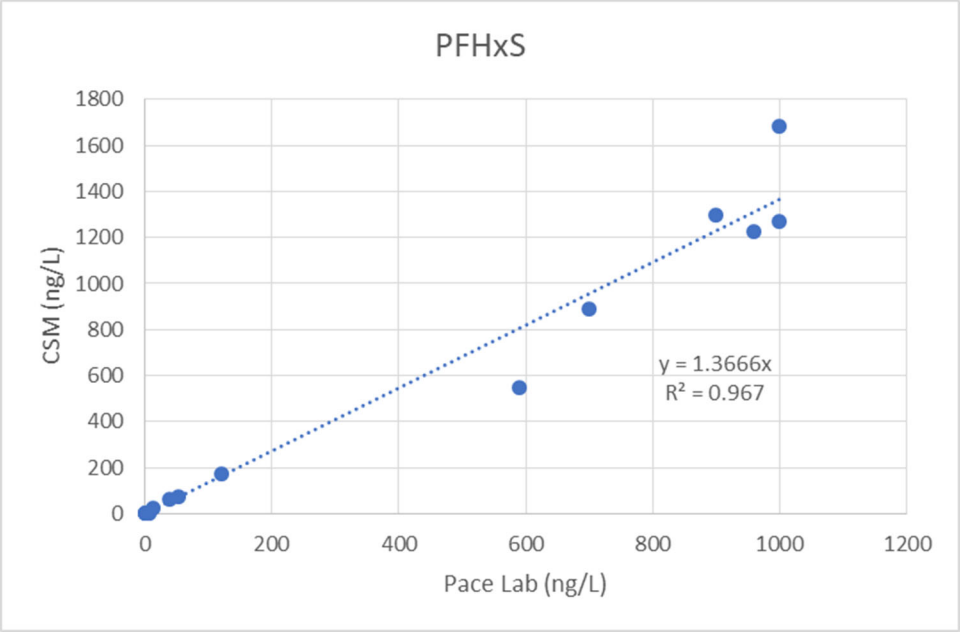

Figure 3: PFHxS Lab Data Correlation

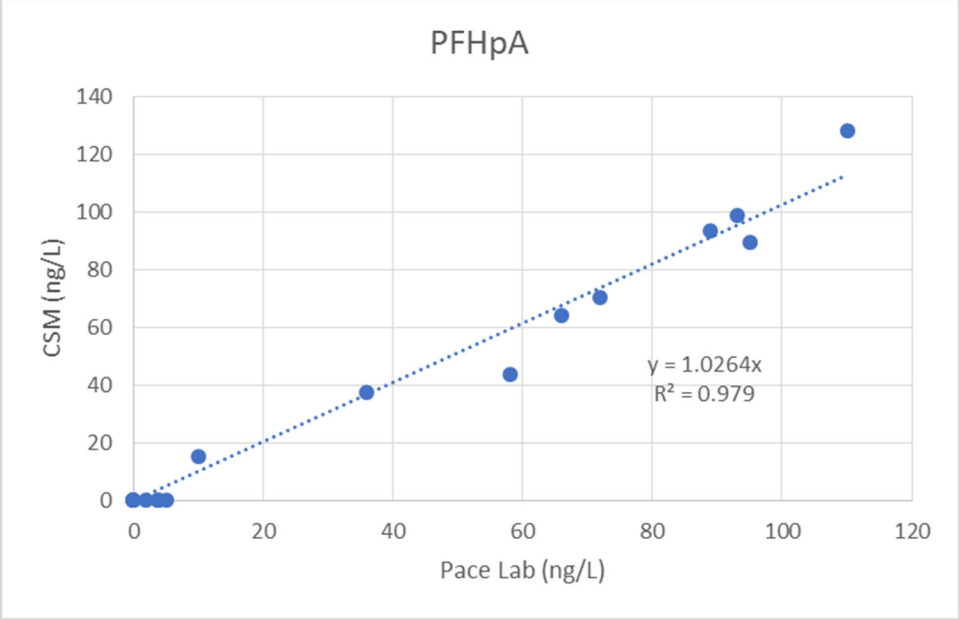

Figure 4: PFHpA Lab Data Correlation

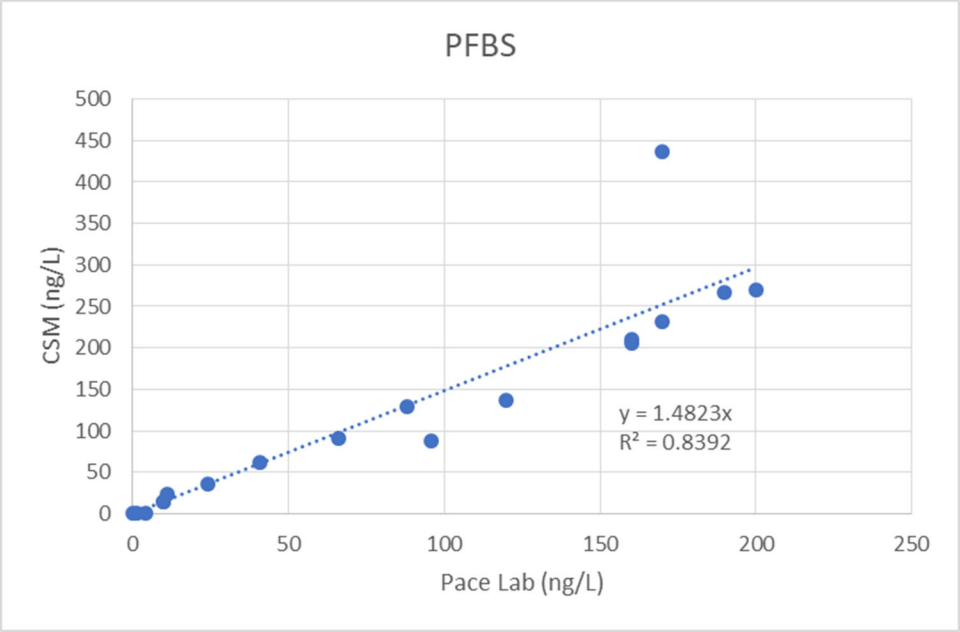

Figure 5: PFBS Lab Data Correlation

Appendix E

Horsham AGS Test Site Data Summary

Appendix E

Horsham ANG Test Data Summary

Thirteen tests were conducted at the Horsham, Pennsylvania, Air National Guard (ANG) (HAGS) base to evaluate the AquaPRS for per-and polyfluoroalkyl substances (PFAS) removal. The tests were conducted from June 2020 to April 2021. Each test was conducted for an average of 3 weeks with varying operating conditions. The purpose and scope of these tests was to demonstrate and validate the application of superfine powdered activated carbon (SPAC) and ceramic membrane filtration (CMF) in the treatment approach to reduce the total life cycle cost of PFAS-impacted groundwater treatment. The validation was accomplished by (1) evaluating broad spectrum and short-chain PFAS treatment selectivity, (2) evaluating the PFAS treatment performance in the presence of co-contaminants common at U.S. Department of Defense (DoD) impacted sites, and (3) evaluating the cost and performance requirements related to concentration and treatment of the retentate. All tests were conducted at the HAGS base test site with feed water sourced from Storm Water Outfall Number 9.

1. Test 1

Test 1 was conducted from June 23, 2020, to June 26, 2020, at the HAGS test site, with Trains A and B operated in parallel. The shortened test duration was due to poor influent feed quality (i.e., high influent solids) and inadequate pretreatment. The objective for Test 1 was to evaluate PFAS removal efficiency with the system operating conditions previously determined from Aqua-Aerobic Systems, Inc. (AASI) research and development laboratory trials. With the AquaPRS system having dual operation capability, two tests (operated in parallel) were set up with the same feed source and pretreatment (i.e., prefiltration by 20-micron and 5-micron pleated cartridge filters in series). The objective of this test was to evaluate system performance at two different sorbent concentrations (i.e., a high and a low). Table 1 details the operating conditions for Test 1.

Table 1: HAGS Test 1 Operational Parameters

Operational Parameter	Train A	Train B	Units
Membrane flux rate	100	100	Lmh
Recycle flow rate	6.7	6.7	L/minute
Permeate flow rate	0.67	0.67	L/minute
Filtration cycle duration (backwash frequency)	15	15	Minutes
Sorption reactor detention time	60	60	Minutes
Sorption reactor volume	40	40	L
Sorbent concentration	500	250	mg/L as C

Notes:
Green highlighted cells on the table indicate the operating parameter that was evaluated.
L = liter
Lmh = liter per square meter hour
L/minute = liter per minute
mg/L as C = milligrams per liter as carbon

The following data tables and graphs represent the analytical data generated during Test 1 at HAGS. Table 2 lists the PFAS analytical data as measured from the Colorado School of Mines (CSM) laboratory. The grey columns represent the third Unregulated Contaminant Monitoring Rule (UCMR3) compounds. The blue columns represent summed data for perfluorooctanesulfonic acid (PFOS) and perfluorooctanoic acid (PFOA), total PFAS, and the UCMR3 compounds.

Table 2: HAGS Test 1 PFAS Removal Data

Train A

			PFOA + PFOS		UCMR3		Total PFAS		PFOS		PFOA		PFNA		PFHxS		PFHpA		PFBS		PFBA		PFPeA		PFHxA		PFPrS		PFPeS		PFHpS	
Volume (L)	Calendar Time (days)	Operating Time (days)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
1403	2	1.45	9408	6703	12652	9942	14336	11874	8878	6154	530	549	26	16	2636	2633	172	163	410	427	28	17	605	604	415	721	175	188	405	430	231	161

Train B

			PFOA + PFOS		UCMR3		Total PFAS		PFOS		PFOA		PFNA		PFHxS		PFHpA		PFBS		PFBA		PFPeA		PFHxA		PFPrS		PFPeS		PFHpS	
Volume (L)	Calendar Time (days)	Operating Time (days)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
1561	2	1.61	9497	4160	12947	6931	14713	8473	8928	3773	568	388	19	12	2836	2171	171	178	424	410	15	58	544	565	369	332	180	180	423	408	234	121

Figure 1 displays the total organic carbon (TOC) data as analyzed by the CSM laboratory for Test 1. The chart shows the relative feed water TOC averaging 1.58 milligrams per liter (mg/L). Train A permeate TOC averaged 1.45 mg/L, and Train B permeate averaged 2.3 mg/L.

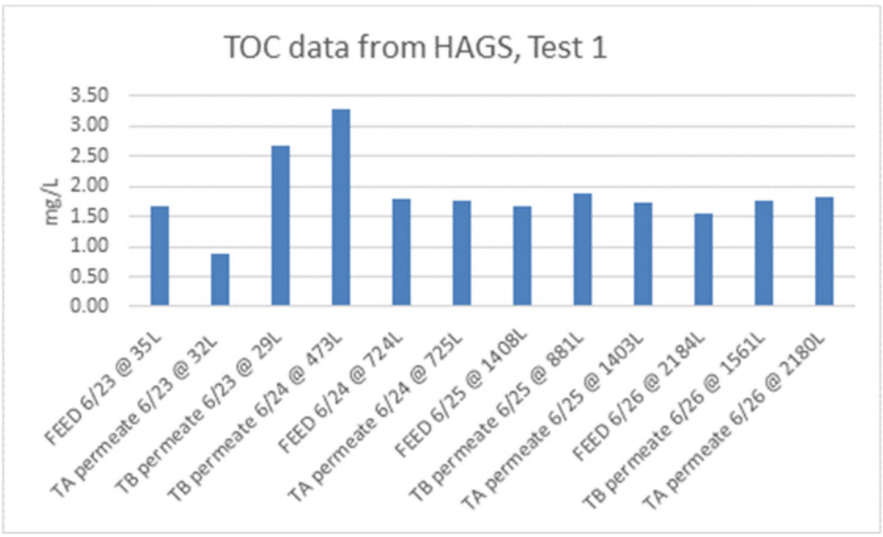

Figure 1: HAGS Test 1 TOC Data

Figures 2 and 3 show Test 1 PFAS data in bar chart form for comparison between feed and permeate PFAS levels. PFAS data is limited for Test 1 because of operational issues (i.e., inadequate pretreatment/premature membrane fouling), causing the test to end earlier than planned.

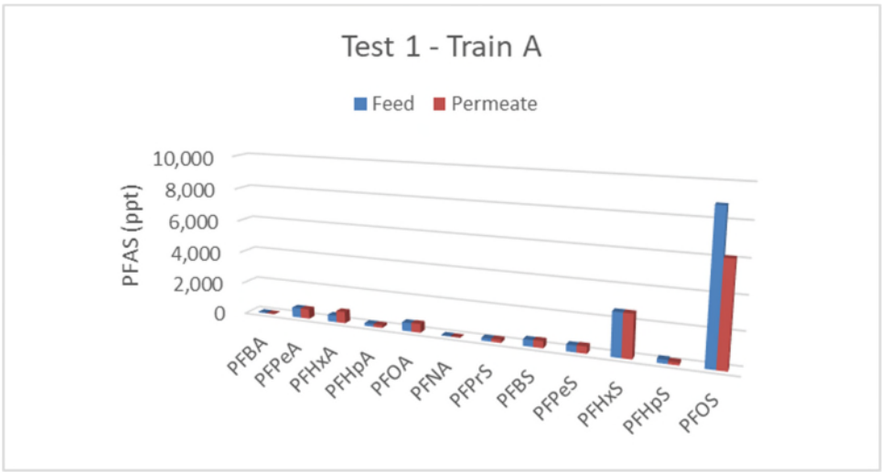

Figure 2: HAGS Test 1 Train A PFAS Data

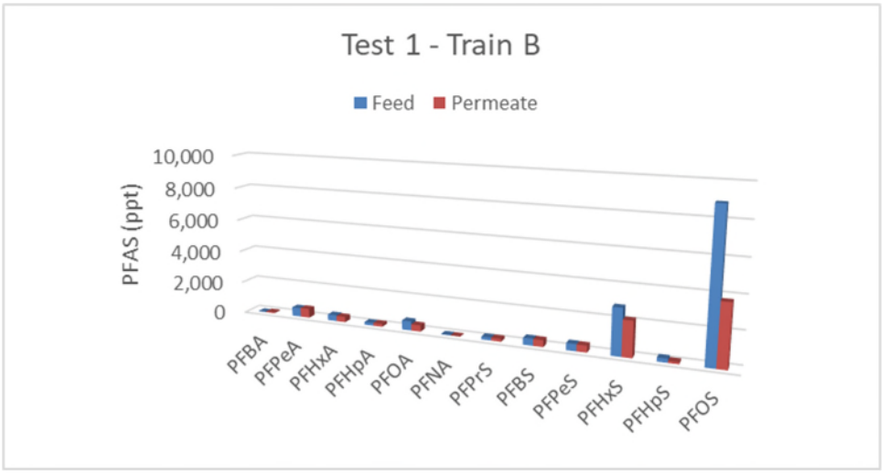

Figure 3: HAGS Test 1 Train B PFAS Data

2. Test 2

Test 2 was conducted from July 8, 2020, to July 23, 2020, at the HAGS test site, with Trains A and B operated in parallel. The objective for Test 2 was to repeat Test 1 with reduced recycle flow rate. Test 1 was operated with the recycle rate at 6.7 L/min., whereas Test 2 was conducted with the recycle flow rate at 3.5 L/min. This was done in response to the poor operating condition of Test 1 and to reduce the operating feed pressure; all other operating parameters were kept the same initially (see Table 3 note for explanation). Table 3 lists the operating parameters for Test 2.

Table 3: HAGS Test 2 Operational Parameters

Operational Parameter	Train A	Train B	Units
Membrane flux rate	100* (reduced to 50 on July 9, 2020)	100* (reduced to 75 on July 9, 2020)	Lmh
Recycle flow rate	3.5	3.5	L/minute
Permeate flow rate	0.67 (reduced to 0.33 on July 9, 2020)[a]	0.67 (reduced to 0.5 on July 9, 2020)[a]	L/minute
Filtration cycle duration (backwash frequency)	20	20	Minutes
Sorption reactor detention time	60 (increased to 120 on July 9, 2020)[a]	60 (increased to 80 on July 9, 2020)[a]	Minutes
Sorption reactor volume	40	40	L
Sorbent concentration[b]	500	250	mg/L as C

Notes:

[a] Train A flux was reduced to 50 Lmh and Train B to 75 Lmh on July 9, 2020, because of high transmembrane pressure (TMP) caused by storm weather runoff into the outfall (which increases turbidity/solids loading onto the membrane). As a result, other parameters were reduced, such as permeate flow and recycle rate to 0.33 L/min and 0.5 L/min, respectively.

[b] Green highlighted cells in the table indicate the operating parameter that was evaluated.

*Membrane flux rate was reduced on July 9, 2020

The following data tables and graphs represent the analytical data generated during Test 2 at HAGS. Figure 4 displays the TOC data as analyzed by the CSM laboratory for Test 2. The feed water TOC was measured at 4 mg/L. Train A permeate TOC averaged 1.84 mg/L, and Train B permeate averaged 1.96 mg/L. Table 4 lists the PFAS analytical data as measured from the CSM laboratory. The grey columns represent the UCMR3 compounds. The blue columns represent summed data for PFOS and PFOA, total PFAS, and the UCMR3 compounds.

Figures 5 and 6 show Test 2 PFAS data in bar chart form for comparison between feed and permeate PFAS levels. The data displayed on the charts were taken from the data found in Table 4 below. Figure 7 displays the metals water quality analysis of the feed water from the analysis on July 10, 2020, by the Pace Analytical laboratory.

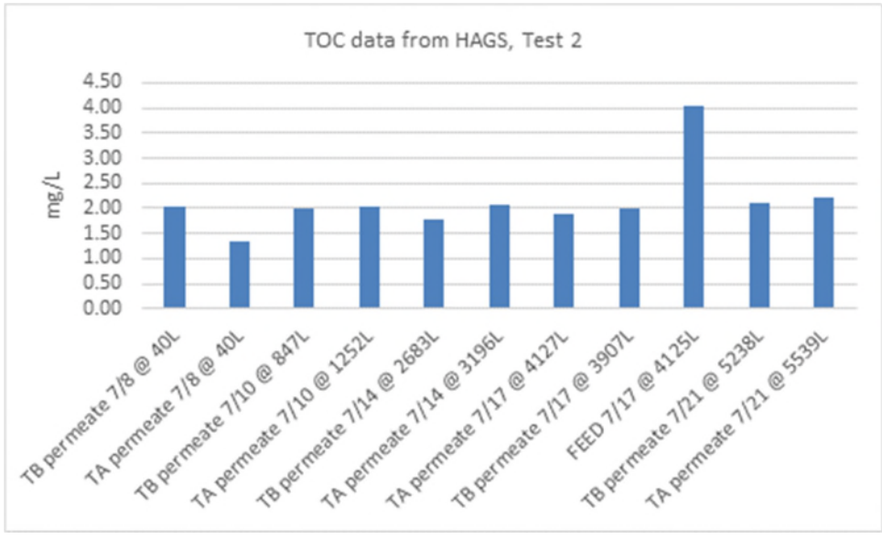

Figure 4: HAGS Test 2 TOC Data

Table 4: HAGS Test 2 PFAS Removal Data

Train A

			PFOA + PFOS		UCMR3		Total PFAS		PFOS		PFOA		PFNA		PFHxS		PFHpA		PFBS		PFBA		PFPeA		PFHxA		PFPrS		PFPeS		PFHpS	
Volume (L)	Calendar Time (days)	Operating Time (days)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
40	1	0.04	9641	76	12501	198	14243	880	9215	68	426	8	ND		2433	37	112	4	314	82	ND		388	381	610	220	87	60	349	18	308	3
1252	4	3	9641	5112	12501	8232	14243	10163	9215	4670	426	442	ND		2433	2649	112	137	314	333	ND		388	505	610	731	87	109	349	427	308	159
3196	8	7	9641	9645	12501	12187	14243	13746	9215	9290	426	355	ND		2433	2168	112	110	314	264	ND		388	448	610	642	87	89	349	224	308	155
4124	10	9	9089	11710	11798	14936	13558	16821	8733	11275	356	435	ND		2322	2782	110	116	278	327	ND		446	546	687	772	75	104	376	265	175	197

Train B

			PFOA + PFOS		UCMR3		Total PFAS		PFOS		PFOA		PFNA		PFHxS		PFHpA		PFBS		PFBA		PFPeA		PFHxA		PFPrS		PFPeS		PFHpS	
Volume (L)	Calendar Time (days)	Operating Time (days)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
40	1	0.04	9641	44	12501	351	14243	1290	9215	23	426	21	ND		2433	121	112	39	314	146	ND		388	406	610	387	87	60	349	84	308	3
847	2	1	9641	7740	12501	10742	14243	12615	9215	7371	426	369	ND		2433	2585	112	115	314	302	ND		388	509	610	712	87	70	349	416	308	166
2836	5	4	9641	9565	12501	12192	14243	13931	9215	9227	426	338	ND		2433	2231	112	118	314	278	ND		388	465	610	689	87	95	349	339	308	151
3907	6	5	9089	11749	11798	14438	13558	16245	8733	11397	356	352	ND		2322	2293	110	109	278	286	ND		446	455	687	708	75	96	376	371	175	177

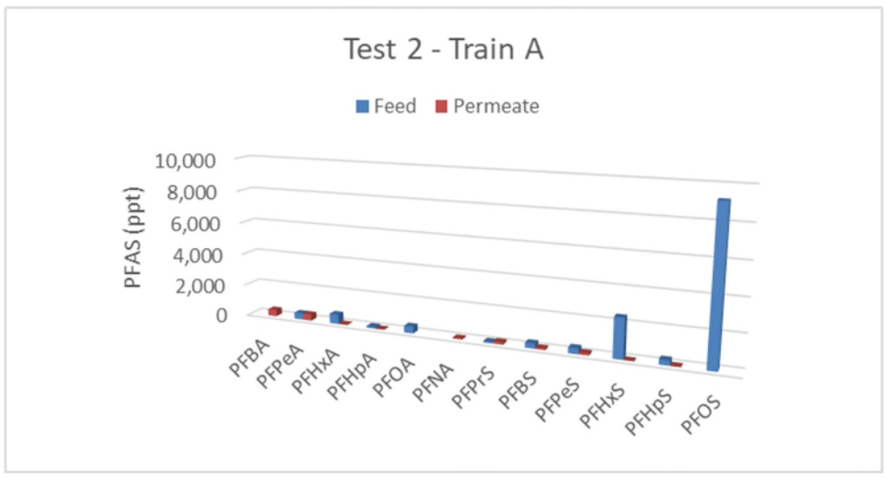

Figure 5: HAGS Test 2 Train A PFAS Data

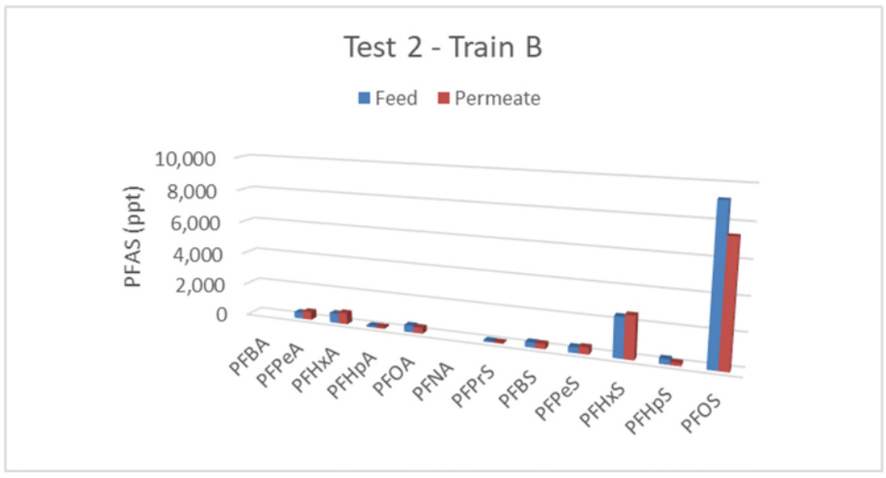

Figure 6: HAGS Test 2 Train B PFAS Data

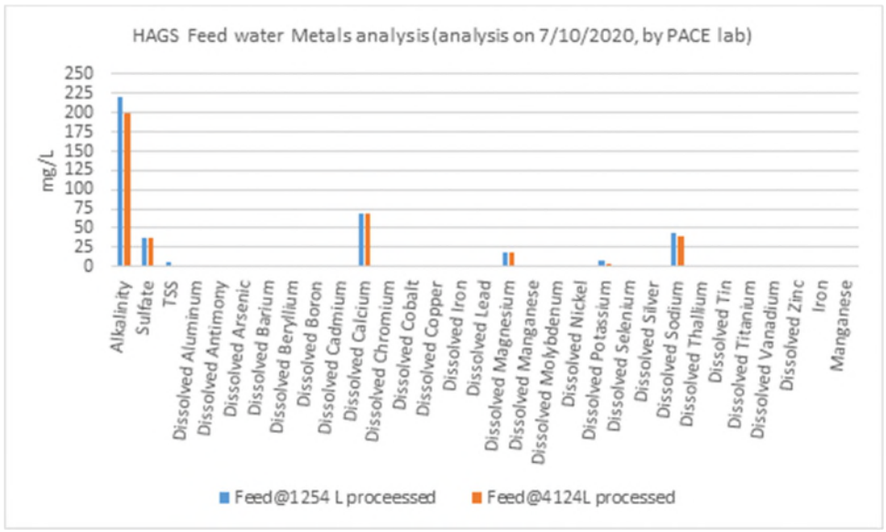

Figure 7: HAGS Feed Water—Metals Analysis July 10, 2020, by PACE Laboratory

3. Test 3

Test 3 was conducted from July 23, 2020, to August 1, 2020, at the HAGS test site with Trains A and B operated in parallel. The objective for Test 3 was to compare high and low operating membrane fluxes (Train A = 50 Lmh, Train B = 100 Lmh) with both trains' sorbent concentration at 500 mg/L as C. All other

parameters were kept the same. Test 3 operating parameters are listed on Table 5. This test was ended early because of high TMP (greater than 20 pounds per square inch) from backwash malfunction. As a result, no PFAS data were measured.

Table 5: HAGS Test 3 Operational Parameters

Operational Parameter	Train A	Train B	Units
Membrane flux rate	50	100	Lmh
Recycle flow rate	3.3	6.7	L/minute
Permeate flow rate	0.33	0.67	L/minute
Filtration cycle duration (backwash frequency)	30	30	Minutes
Sorption reactor detention time	60	60	Minutes
Sorption reactor volume	21.2	40	L
Sorbent concentration	500	500	mg/L as C

Note:
Green highlighted cells on the table indicate the operating parameter that was evaluated.

Figure 8 shows the TOC data as measured from feed and permeate samples collected during Test 3.

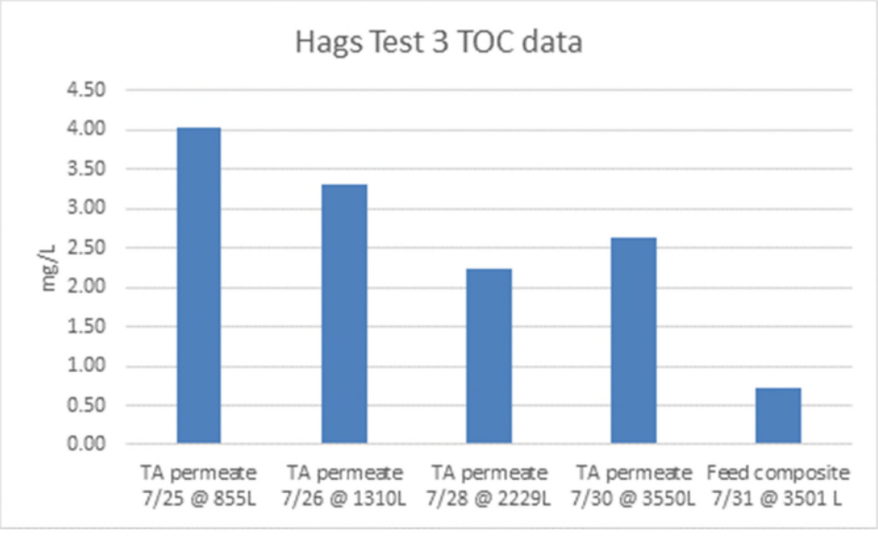

Figure 8: HAGS Test 3 TOC Data

4. Test 4

Test 4 was conducted from August 6, 2020, to August 31, 2020, at the HAGS test site with Trains A and B operated in parallel. The objective for Test 4 was to compare high and low sorbent detention times (30 minutes for Train A and 15 minutes for Train B) with both trains' sorbent concentration at 3,500 mg/L as C. All other parameters were kept the same. The operating parameters are listed in Table 6. Test 4 introduced the cloth media filtration system (5-micron filter) used as pretreatment to the AquaPRS. Samples for PFAS analysis were taken to show the cloth media filter system did not remove PFAS; results are shown in Section 5.

Table 6: HAGS Test 4 Operational Parameters

Operational Parameter	Train A	Train B	Units
Membrane flux rate	100	100	Lmh
Recycle flow rate	6.7	6.7	L/minute
Permeate flow rate	0.67	0.67	L/minute
Filtration cycle duration (backwash frequency)	30	30	Minutes
Sorption reactor detention time	30	15	Minutes
Sorption reactor volume	20	10	L
Sorbent concentration	3,500	3,500	mg/L as C

Note:
Green highlighted cells on the table indicate the operating parameter that was evaluated.

The following data tables and graphs represent the analytical data generated during Test 4 at the HAGS test site. Figure 9 shows TOC data (from the CSM laboratory) as measured from feed and permeate samples. Table 7 lists the PFAS data from Trains A and B as analyzed by the CSM laboratory. The grey columns represent the UCMR3 compounds. The blue columns represent summed data for PFOS and PFOA, total PFAS, and the UCMR3 compounds.

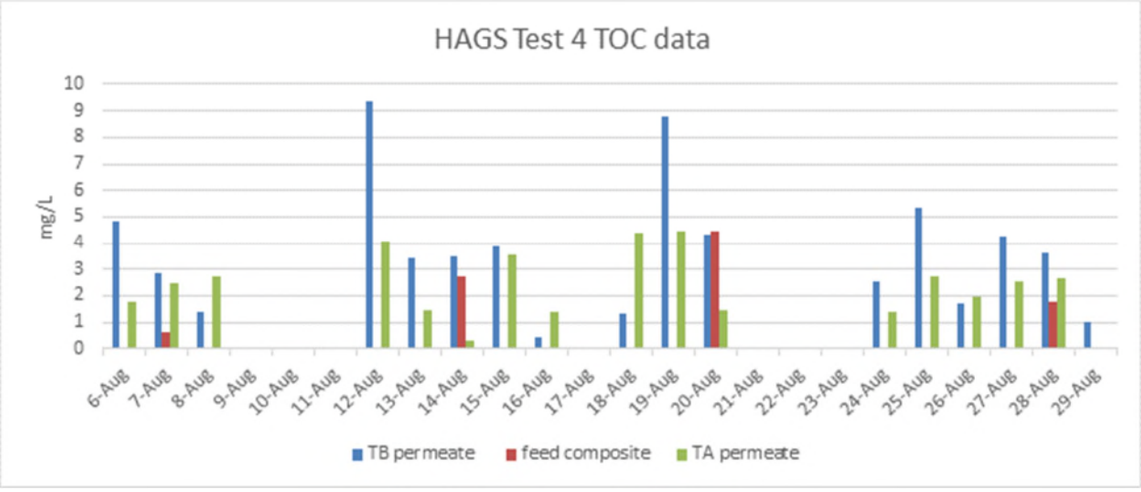

Figure 9: HAGS Test 4 TOC Data

Table 7: HAGS Test 4 PFAS Removal Data

Train A *Blank cells were sample error and/or 1.5xIQR. Cells in italics are either averages or values with sample error removed

	PFOA + PFOS		UCMR3		Total PFAS		PFOS (LOQ=10)		PFOA		PFNA (LOQ=1.0)		PFHxS		PFHpA		PFBS		PFBA		PFPeA		PFHxA		PFPrS		PFPeS		PFHpS (LOQ=0.1)		4:2 FTS (LOQ=0.5)		6:2 FTS		8:2 FTS (LOQ=2)	
Volume (L)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)
472	4,256	*2*	7,007	*67*	10,573	*1,105*	3,900		356	2	sLOQ	sLOQ	2,259	12	188	4	304	45	203	368	647	418	888	187	140	79	373	7	149	1	sLOQ	sLOQ	1,151	12	16	sLOQ
552	4,256	3	7,007	128	10,573	1,277	3,900	1	356	2	sLOQ	sLOQ	2,259	10	188	9	304	107	203	17	647	596	888	392	140	118	373	16	149	sLOQ	sLOQ	sLOQ	1,151	10	16	sLOQ
1,436	4,256	22	7,007	465	10,573	2,342	3,900	1	356	21	sLOQ	sLOQ	2,259	72	188	79	304	293	203	31	647	684	888	909	140	132	373	111	149	sLOQ	sLOQ	sLOQ	1,151	10	16	sLOQ
1,716	4,256	29	7,007	585	10,573	2,492	3,900	1	356	28	sLOQ	sLOQ	2,259	132	188	100	304	323	203	39	647	610	888	944	140	135	373	166	149	1	sLOQ	sLOQ	1,151	13	16	sLOQ
1,979	4,256	15	7,007	403	10,573	2,346	3,900	1	356	14	sLOQ	sLOQ	2,259	66	188	64	304	258	203	279	647	605	888	824	140	126	373	95	149	1	sLOQ	sLOQ	1,151	13	16	1
2,339	4,256	124	7,007	1189	10,573	3,266	3,900	30	356	95	sLOQ	sLOQ	2,259	553	188	200	304	311	203	13	647	616	888	893	140	127	373	329	149	9	sLOQ	sLOQ	1,151	90	16	sLOQ
2,408	4,256	131	7,007	1152	10,573	3,082	3,900	29	356	102	sLOQ	sLOQ	2,259	525	188	205	304	290	203	56	647	536	888	872	140	122	373	297	149	9	sLOQ	sLOQ	1,151	37	16	sLOQ
2,446	4,256	122	7,007	1062	10,573	2,979	3,900	32	356	90	sLOQ	sLOQ	2,259	481	188	175	304	283	203	29	647	568	888	827	140	116	373	294	149	9	sLOQ	sLOQ	1,151	73	16	sLOQ
3,071	4,256	401	7,007	2226	10,573	4,493	3,900	185	356	216	sLOQ	sLOQ	2,259	1310	188	227	304	289	203	2	647	549	888	861	140	130	373	377	149	30	sLOQ	sLOQ	1,151	318	16	sLOQ
3,980	4,256	820	7,007	3157	10,573	5,694	3,900	517	356	303	sLOQ	sLOQ	2,259	1829	188	214	304	295	203	2	647	562	888	827	140	133	373	373	149	57	sLOQ	sLOQ	1,151	582	16	1
4,852	4,256	1129	7,007	2994	10,573	4,844	3,900	865	356	264	sLOQ	sLOQ	2,259	1579	188	135	304	151	203	2	647	292	888	453	140	72	373	214	149	71	sLOQ	sLOQ	1,151	743	16	3
5,723	4,256	2759	7,007	5425	10,573	8,507	3,900	2386	356	373	sLOQ	sLOQ	2,259	2210	188	181	304	274	203	2	647	583	888	768	140	121	373	351	149	125	sLOQ	sLOQ	1,151	1123	16	8
6,337	4,256	3343	7,007	6023	10,573	9,303	3,900	2943	356	401	sLOQ	sLOQ	2,259	2210	188	187	304	282	203	2	647	566	888	828	140	136	373	349	149	139	sLOQ	sLOQ	1,151	1247	16	13
6,556	4,256	3633	7,007	6349	10,573	9,738	3,900	3213	356	420	sLOQ	sLOQ	2,259	2237	188	190	304	289	203	86	647	566	888	842	140	142	373	342	149	139	sLOQ	sLOQ	1,151	1254	16	19
6,707	4,256	3212	7,007	6253	10,573	9,625	3,900	2800	356	412	sLOQ	sLOQ	2,259	2519	188	223	304	300	203	40	647	612	888	846	140	135	373	411	149	145	sLOQ	sLOQ	1,151	1170	16	14

Train B *Blank cells were sample error and/or 1.5xIQR. Cells in italics are either averages or values with sample error removed

	PFOA + PFOS		UCMR3		Total PFAS		PFOS		PFOA		PFNA (LOQ=1.0)		PFHxS		PFHpA		PFBS		PFBA		PFPeA		PFHxA		PFPrS		PFPeS		PFHpS (LOQ=0.1)		4:2 FTS (LOQ=0.5)		6:2 FTS		8:2 FTS (LOQ=2)	
Volume (L)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)	Influent (ngL)	Effluent (ngL)
88	4,256	*37*	7,007	*447*	10,573	*4527*	3,900		356	30	sLOQ	sLOQ	2,259	89	188	13	304	16	203	2	647	142	888	64	140	27	373	17	149	9	sLOQ	sLOQ	1,151	36	16	3
491	4,256	80	7,007	706	10,573	2,260	3,900	33	356	47	sLOQ	sLOQ	2,259	240	188	134	304	252	203	2	647	510	888	706	140	107	373	206	149	3	sLOQ	sLOQ	1,151	19	16	sLOQ
1,259	4,256	75	7,007	682	10,573	2,236	3,900	30	356	46	sLOQ	sLOQ	2,259	232	188	140	304	235	203	2	647	464	888	758	140	99	373	208	149	4	sLOQ	sLOQ	1,151	17	16	1
2,145	4,256	334	7,007	2,198	10,573	4,388	3,900	99	356	235	sLOQ	sLOQ	2,259	1,380	188	205	304	278	203	2	647	584	888	847	140	129	373	347	149	27	sLOQ	sLOQ	1,151	254	16	sLOQ
2,423	4,256	513	7,007	2,723	10,573	5,023	3,900	225	356	288	sLOQ	sLOQ	2,259	1,759	188	178	304	274	203	9	647	576	888	782	140	126	373	369	149	44	sLOQ	sLOQ	1,151	394	16	1
2,679	4,256	372	7,007	2,281	10,573	4,606	3,900	144	356	228	sLOQ	sLOQ	2,259	1,387	188	216	304	306	203	22	647	615	888	860	140	140	373	373	149	28	sLOQ	sLOQ	1,151	287	16	sLOQ
2,971	4,256	1,246	7,007	4,205	10,573	7,242	3,900	840	356	406	sLOQ	sLOQ	2,259	2,427	188	212	304	320	203	13	647	683	888	976	140	153	373	379	149	85	sLOQ	sLOQ	1,151	746	16	1
3,035	4,256	1,303	7,007	3,976	10,573	6,700	3,900	887	356	416	sLOQ	sLOQ	2,259	2,198	188	200	304	275	203	37	647	537	888	827	140	126	373	342	149	83	sLOQ	sLOQ	1,151	770	16	1
3,064	4,256	1,221	7,007	3,959	10,573	6,574	3,900	844	356	377	sLOQ	sLOQ	2,259	2,257	188	195	304	286	203	15	647	591	888	837	140	135	373	358	149	87	sLOQ	sLOQ	1,151	592	16	1
3,637	4,256	2,236	7,007	5,325	10,573	8,845	3,900	1,836	356	399	sLOQ	sLOQ	2,259	2,517	188	239	304	333	203	2	647	679	888	926	140	160	373	407	149	115	sLOQ	sLOQ	1,151	1,225	16	7
4,504	4,256	4,507	7,007	7,719	10,573	11,462	3,900	4,069	356	438	sLOQ	sLOQ	2,259	2,690	188	201	304	320	203	2	647	639	888	903	140	167	373	406	149	181	sLOQ	sLOQ	1,151	1,422	16	23
5,093	4,256	4,526	7,007	6,646	10,573	9,096	3,900	4,230	356	296	sLOQ	sLOQ	2,259	1,836	188	123	304	161	203	2	647	321	888	523	140	87	373	220	149	133	sLOQ	sLOQ	1,151	1,126	16	40
5,334	4,256	5,150	7,007	8,326	10,573	11,766	3,900	4,736	356	414	sLOQ	sLOQ	2,259	2,690	188	189	304	297	203	2	647	591	888	790	140	155	373	359	149	171	sLOQ	sLOQ	1,151	1,342	16	28
5,501	4,256	5,240	7,007	8,190	10,573	11,740	3,900	4,803	356	437	sLOQ	sLOQ	2,259	2,449	188	203	304	298	203	9	647	592	888	879	140	139	373	385	149	159	sLOQ	sLOQ	1,151	1,352	16	35
5,608	4,256	4,063	7,007	7,096	10,573	10,693	3,900	3,677	356	386	sLOQ	sLOQ	2,259	2,543	188	190	304	300	203	273	647	640	888	870	140	138	373	394	149	165	sLOQ	sLOQ	1,151	1,101	16	17

Figures 10 to 15 show Test 4 PFAS removal data expressed as concentration per volume treated (i.e., gallons per pound of sorbent). The data displayed on the graphs were taken from the data found in Table 7 above.

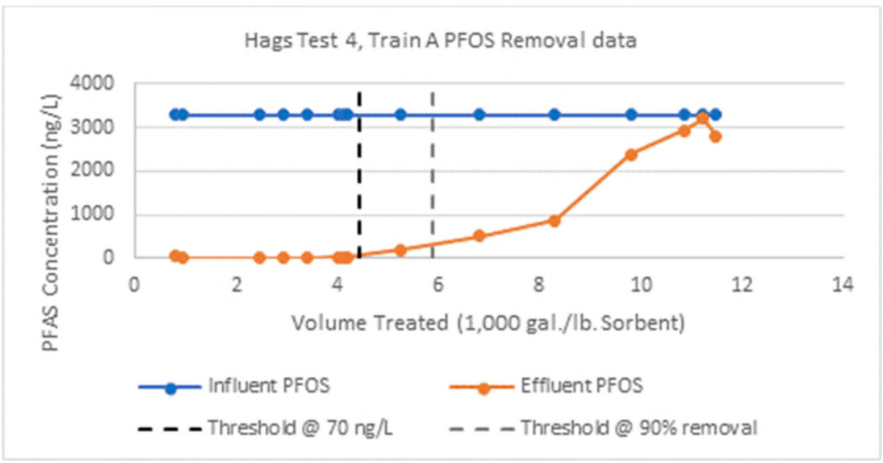

Figure 10: HAGS Test 4, Train A PFOS Removal Data

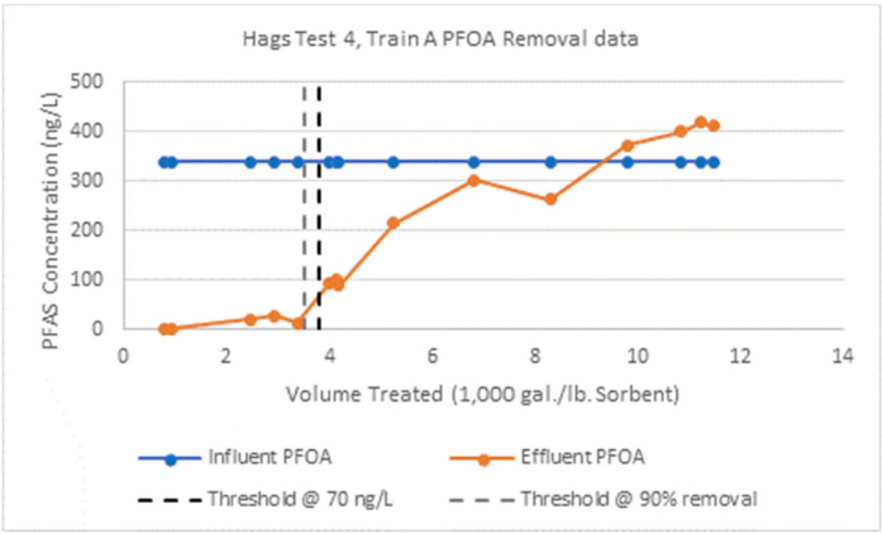

Figure 11: HAGS Test 4, Train A PFOA Removal Data

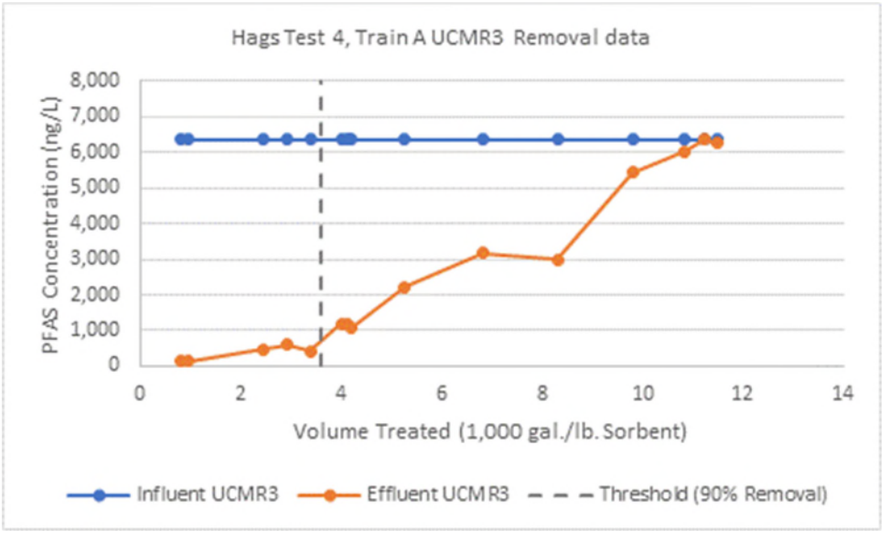

Figure 12: HAGS Test 4, Train A UCMR3 Removal Data

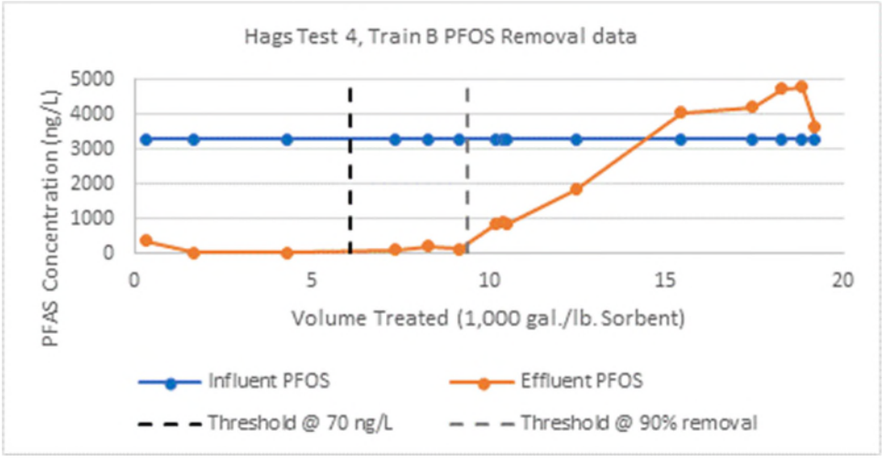

Figure 13: HAGS Test 4, Train B PFOS Removal Data

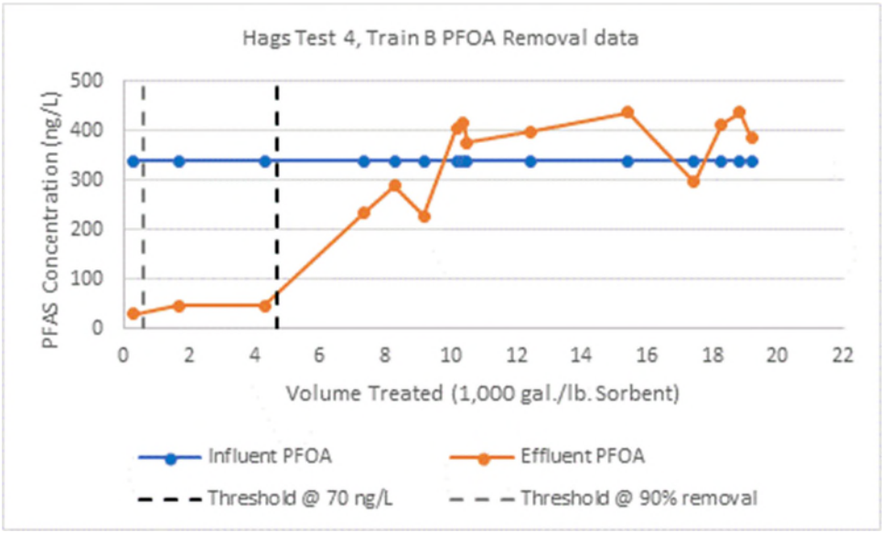

Figure 14: HAGS Test 4, Train B PFOA Removal Data

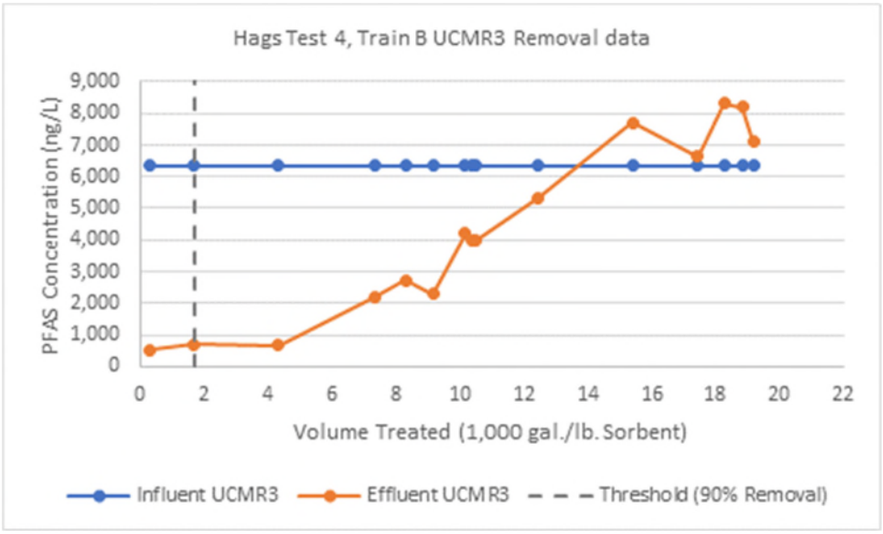

Figure 15: HAGS Test 4, Train B UCMR3 Removal Data

5. Test 5

Test 5 was conducted from September 1, 2020, to September 25, 2020, at the HAGS test site with Trains A and B operated in parallel. The objective for Test 5 was to compare high and low sorbent

concentrations (3,500 mg/L for Train A and 2,000 mg/L for Train B). All other parameters were kept the same. The operating parameters are listed in Table 8.

Table 8: HAGS Test 5 Operational Parameters

Operational Parameter	Train A	Train B	Units
Membrane flux rate	100	100	Lmh
Recycle flow rate	3.5	3.5	L/minute
Permeate flow rate	0.67	0.67	L/minute
Filtration cycle duration (backwash frequency)	30	30	Minutes
Sorption reactor detention time	30	30	Minutes
Sorption reactor volume	20	20	L
Sorbent concentration	3,500	2,000	mg/L as C

Note:
Green highlighted cells on the table indicate the operating parameter that was evaluated.

The following data tables and graphs represent the analytical data generated during Test 5 at the HAGS test site. Tables 9 and 10 list the PFAS analytical data as measured from the CSM laboratory for Trains A and B, respectively. The grey columns represent the UCMR3 compounds. The blue columns represent summed data for PFOS and PFOA, total PFAS, and the UCMR3 compounds.

Table 9: HAGS Test 5, Train A PFAS removal data

*Blank cells were sample error and/or 1.5x IQR. Cells in italics are either averages or values with sample error removed

Train A

**Other = SUM(FOSA, FBSA, PFN)

	PFOA + PFOS (LOQ=10.1)		UCMR3		Total PFAS		PFOS (LOQ=10)		PFOA (LOQ=0.1)		PFNA (LOQ=1.0)		PFHxS (LOQ=1.0)		PFHpA (LOQ=0.5)		PFBS (LOQ=0.5)		PFBA		PFPeA		PFHxA (LOQ=0.5)		PFPrS		PFPeS		PFHpS (LOQ=0.5)		4:2 FTS (LOQ=0.5)		**Other (LOQ=3)		8:2 FTS (LOQ=2)	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
20	5,037		7,780	*≤LOQ*	11,160	*64*	*4,656*		*382*		*11*	≤LOQ	*2,260*	≤LOQ	*161*	≤LOQ	*321*	≤LOQ	*42*	16	*590*	34	*155*	≤LOQ	*146*	9	*320*	2	*102*	3	*12*	≤LOQ	*1,401*	≤LOQ	*13*	≤LOQ
171	5,037		7,780	*39*	11,160	*466*	*4,656*		*382*		*11*	≤LOQ	*2,260*		*161*		*321*	39	*42*	61	*590*	34	*155*	112	*146*	41	*320*	35	*102*	30	*12*		*1,401*	117	*13*	≤LOQ
240	5,037		7,780	*16*	11,160	*554*	*4,656*		*382*		*11*	≤LOQ	*2,260*		*161*	≤LOQ	*321*	16	*42*	48	*590*	327	*155*	29	*146*	61	*320*	5	*102*	4	*12*	≤LOQ	*1,401*	65	*13*	≤LOQ
275	5,037	≤LOQ	7,942	*19*	18,213	*434*	4,656		382	≤LOQ	11	≤LOQ	2,399	≤LOQ	171	≤LOQ	334	19	34	43	590	184	787	37	156	67	425	2	53	≤LOQ	14	≤LOQ		82	0	≤LOQ
552	5,037		7,780	*64*	11,160	*860*	*4,656*		*382*		*11*	≤LOQ	*2,260*	≤LOQ	*161*	≤LOQ	*321*	64	*42*	53	*590*	266	*155*	129	*146*	133	*320*	7	*102*	3	*12*	≤LOQ	*1,401*	226	*13*	≤LOQ
388	5,037		7,780	*144*	11,160	*1,776*	*4,656*		*382*	≤LOQ	*11*	≤LOQ	*2,260*	≤LOQ	*161*	7	*321*	137	*42*	30	*590*	568	*155*	348	*146*	108	*320*	20	*102*	1	*12*	≤LOQ	*1,401*	557	*13*	≤LOQ
1,137	5,037	2	7,780	195	11,160	*1,622*	*4,656*	≤LOQ	*382*	2	*11*	≤LOQ	*2,260*	≤LOQ	*161*	12	*321*	180	*42*	64	*590*	434	*155*	472	*146*	110	*320*	36	*102*	≤LOQ	*12*	3	*1,401*	508	*13*	≤LOQ
2,294	5,037	112	7,780	619	11,160	2,931	*4,656*	69	*382*	44	*11*	≤LOQ	*2,260*	114	*161*	78	*321*	315	*42*	48	*590*	467	*155*	741	*146*	149	*320*	136	*102*	2	*12*	9	*1,401*	760	*13*	≤LOQ
3,137	5,037	251	7,780	1189	11,160	4,247	*4,656*	107	*382*	144	*11*	≤LOQ	*2,260*	334	*161*	152	*321*	392	*42*	79	*590*	549	*155*	921	*146*	167	*320*	262	*102*	5	*12*	16	*1,401*	1061	*13*	≤LOQ
3,709	5,037	381	7,780	2002	11,160	5,142	*4,656*	157	*382*	224	*11*	≤LOQ	*2,260*	1019	*161*	133	*321*	403	*42*	42	*590*	671	*155*	975	*146*	178	*320*	346	*102*	10	*12*	15	*1,401*	902	*13*	≤LOQ
4,244	5,037	534	7,780	2566	11,160	5,718	*4,656*	283	*382*	311	*11*	≤LOQ	*2,260*	1389	*161*	199	*321*	385	*42*	60	*590*	717	*155*	923	*146*	176	*320*	369	*102*	33	*12*	16	*1,401*	856	*13*	≤LOQ
4,519	5,037	441	7,780	2310	11,160	5,762	*4,656*	253	*382*	189	*11*	≤LOQ	*2,260*	1300	*161*	200	*321*	368	*42*	65	*590*	689	*155*	903	*146*	151	*320*	356	*102*	13	*12*	16	*1,401*	1259	*13*	≤LOQ
4,739	5,037	737	7,780	2804	11,160	5,703	*4,656*	378	*382*	358	*11*	5	*2,260*	1537	*161*	183	*321*	348	*42*	69	*590*	655	*155*	817	*146*	159	*320*	337	*102*	24	*12*	15	*1,401*	821	*13*	≤LOQ
5,174	5,037	1360	7,780	3327	11,160	7,453	*4,656*	902	*382*	458	*11*	7	*2,260*	2074	*161*	177	*321*	315	*42*	40	*590*	633	*155*	739	*146*	137	*320*	368	*102*	28	*12*	14	*1,401*	1568	*13*	≤LOQ
5,444	5,037	1607	7,780	3856	11,160	6,443	*4,656*	1262	*382*	345	*11*	9	*2,260*	1864	*161*	140	*321*	245	*42*	49	*590*	527	*155*	611	*146*	107	*320*	259	*102*	76	*12*	11	*1,401*	347	*13*	≤LOQ
5,645	5,037	2275	7,780	4776	11,160	11,853	*4,656*	1836	*382*	439	*11*	≤LOQ	*2,260*	2062	*161*	163	*321*	275	*42*	52	*590*	447	*155*	649	*146*	122	*320*	341	*102*	25	*12*	10	*1,401*	5431	*13*	≤LOQ
6,044	5,037	2794	7,780	5062	11,160	27,033	*4,656*	2354	*382*	440	*11*	≤LOQ	*2,260*	1892	*161*	140	*321*	236	*42*	39	*590*	518	*155*	564	*146*	104	*320*	317	*102*	15	*12*	12	*1,401*	20401	*13*	≤LOQ
6,372	4,296	2580	7,070	5330	10,520	3,258	3,869	2084	427	495	11	9	2,232	2261	160	172	323	317	42	25	620	471	781	764	145	141	343	349	93	52	12	12	*1,401*	2114	14	≤LOQ
6,807	4,296	1642	7,038	4250	10,418	7,387	*3,869*	1198	*427*	444	*11*	11	*2,260*	2114	*161*	168	*321*	326	*42*	64	*590*	603	*155*	767	*146*	148	*320*	310	*102*	64	*12*	13	*1,401*	1167	*13*	≤LOQ
7,239	4,296	3614	7,113	6695	11,713	10,038	3,869	3099	427	515	11	17	2,320	2510	176	200	322	371	51	35	643	607	760	876	154	173	397	358	77	100	12	13	2,486	1181	18	≤LOQ
7,674	4,296	7189	7,038	9312	10,418	12,088	*3,869*	6817	*427*	371	*11*	≤LOQ	*2,260*	2229	*161*	173	*321*	322	*42*	59	*590*	701	*155*	768	*146*	149	*320*	473	*102*	13	*12*	12	*1,401*	≤LOQ	*13*	≤LOQ
8,105	4,296	2800	7,038	5650	10,418	12,297	*3,869*	2392	*427*	407	*11*	7	*2,260*	2347	*161*	171	*321*	332	*42*	54	*590*	615	*155*	789	*146*	153	*320*	349	*102*	64	*12*	12	*1,401*	4610	*13*	≤LOQ
8,542	3,813	2169	6,428	4342	9,107	7,739	3,368	1703	450	466	11	15	2,146	2286	157	167	307	320	45	57	565	663	750	738	144	150	293	309	117	108	9	13	743	819	12	≤LOQ
8,921	4,050	2747	6,712	5688	10,067	13,725	3,612	2183	438	564	11	≤LOQ	2,179	2435	163	169	320	337	43	42	590	599	746	824	145	155	298	427	111	37	11	14	1,401	11938	11	≤LOQ
9,352	4,050	5176	6,793	7841	10,173	23,722	*3,612*	4774	*438*	402	*11*	≤LOQ	*2,260*	2192	*161*	158	*321*	315	*42*	62	*590*	632	*155*	743	*146*	150	*320*	368	*102*	50	*12*	10	*1,401*	13867	*13*	≤LOQ
9,783	4,050	5311	6,793	8583	10,173	14,530	*3,612*	5545	*438*	366	*11*	7	*2,260*	2217	*161*	157	*321*	304	*42*	56	*590*	565	*155*	750	*146*	148	*320*	346	*102*	79	*12*	10	*1,401*	4047	*13*	≤LOQ
10,218	4,050	3224	6,793	5759	10,173	8,703	*3,612*	2782	*438*	442	*11*	11	*2,260*	2079	*161*	150	*321*	305	*42*	54	*590*	573	*155*	697	*146*	138	*320*	281	*102*	108	*12*	10	*1,401*	1081	*13*	≤LOQ
10,650	4,050	4901	6,793	7503	10,173	10,307	*3,612*	4443	*438*	458	*11*	16	*2,260*	2136	*161*	166	*321*	307	*42*	84	*590*	568	*155*	734	*146*	143	*320*	286	*102*	112	*12*	12	*1,401*	860	*13*	≤LOQ
11,081	4,315	3966	7,016	6727	3,725	3,516	3,860	3568	455	397	11	14	2,228	2259	155	168	318	334	26	60	554	580	742	756	147	151	298	321	127	105	3	10	788	808	17	≤LOQ
11,518	4,315	3580	7,016	6511	3,725	3,487	3,860	3163	455	417	11	18	2,228	2407	155	179	318	346	26	74	554	570	742	805	147	160	298	323	127	126	3	13	788	893	17	12
11,351	5,110	3275	7,853	5941	11,233	8,741	*4,656*	2831	*455*	444	*11*	14	*2,260*	2184	*161*	164	*321*	318	*42*	48	*590*	663	*155*	745	*146*	144	*320*	307	*102*	116	*12*	11	*1,401*	767	*13*	≤LOQ

Table 10: HAGS Test 5, Train B PFAS removal data

*Blank cells were sample error and/or 1.5xIQR. Cells in italics are either averages or values with sample error removed

Train B **Other = SUM(FOSA, FBSA, PFN)

	PFOA + PFOS (LOQ=10.1)		UCMR3 (LOQ=13.1)		Total PFAS		PFOS (LOQ=10)		PFOA (LOQ=0.1)		PFNA (LOQ=1.0)		PFHxS (LOQ=1.0)		PFHpA (LOQ=0.5)		PFBS (LOQ=0.5)		PFBA		PFPeA		PFHxA (LOQ=0.5)		PFPrS		PFPeS		PFHpS (LOQ=0.5)		4:2 FTS (LOQ=0.5)		*Other (LOQ=3)		8:2 FTS (LOQ=2)	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
20	5,037		7,840		11,220	*222*	*4,656*		*442*	≤LOQ	*14*	≤LOQ	*2,260*	≤LOQ	*161*	≤LOQ	*321*	≤LOQ	*42*	40	*590*	79	*755*	≤LOQ	*146*	14	*320*	79	*102*	1	*12*	≤LOQ	*1,401*	10	*15*	≤LOQ
165	5,037		7,840	*53*	11,220	*2,391*	*4,656*		*442*		*14*	≤LOQ	*2,260*		*161*		*321*	53	*42*	55	*590*	384	*755*	118	*146*	103	*320*	384	*102*	5	*12*	2	*1,401*	1,286	*15*	≤LOQ
233	5,037		7,842	*70*	18,213	*1,736*	4,656		382		≤LOQ	≤LOQ	2,339	≤LOQ	171	≤LOQ	334	70	34	42	590	565	787	162	156	136	425	565	53	2	14	≤LOQ	8,212	256	0	≤LOQ
271	5,037	≤LOQ	7,842	*74*	18,213	*3,629*	4,656	≤LOQ	382	≤LOQ	≤LOQ	≤LOQ	2,339	≤LOQ	171	≤LOQ	334	74	34	54	590	562	787	196	156	125	425	562	53	≤LOQ	14	≤LOQ	8,212	8,256	0	≤LOQ
549	5,037	*1*	7,842	*32*	18,213	*2,502*	4,656		382	1	≤LOQ	≤LOQ	2,339	17	171	14	334		34	68	590	623	787	482	156	154	425	623	53	1	14	3	8,212	532	0	≤LOQ
930	5,037		7,840		11,220	*2,065*	*4,656*		*442*		*14*	≤LOQ	*2,260*		*161*		*321*		*42*	58	*590*	397	*755*	563	*146*	102	*320*	397	*102*	3	*12*	7	*1,401*	561	*15*	≤LOQ
1,143	5,037	3	7,840	33	11,220	488	*4,656*	≤LOQ	*442*	3	*14*	≤LOQ	*2,260*	10	*161*	3	*321*	16	*42*	18	*590*	143	*755*	30	*146*	31	*320*	143	*102*	1	*12*	≤LOQ	*1,401*	78	*15*	≤LOQ
1,429	5,037	2	7,840	202	11,220	3,501	*4,656*	≤LOQ	*442*	2	*14*	≤LOQ	*2,260*	41	*161*	20	*321*	139	*42*	32	*590*	438	*755*	362	*146*	110	*320*	438	*102*	≤LOQ	*12*	4	*1,401*	7,316	*15*	≤LOQ
2,308	5,037	56	7,840	651	11,220	14,848	*4,656*	≤LOQ	*442*	56	*14*	≤LOQ	*2,260*	203	*161*	77	*321*	310	*42*	33	*590*	643	*755*	782	*146*	161	*320*	643	*102*	1	*12*	10	*1,401*	11,324	*15*	≤LOQ
2,959	5,037	136	7,840	1,077	11,220	5,098	*4,656*	66	*442*	70	*14*	≤LOQ	*2,260*	430	*161*	140	*321*	371	*42*	52	*590*	711	*755*	932	*146*	167	*320*	711	*102*	3	*12*	12	*1,401*	1,433	*15*	≤LOQ
3,209	5,037	264	7,840	1,223	11,220	26,029	*4,656*	101	*442*	162	*14*	≤LOQ	*2,260*	396	*161*	165	*321*	393	*42*	43	*590*	706	*755*	950	*146*	165	*320*	706	*102*	3	*12*	15	*1,401*	22,212	*15*	≤LOQ
3,410	5,037	345	7,840	1,717	11,220	6,442	*4,656*	165	*442*	180	*14*	≤LOQ	*2,260*	775	*161*	194	*321*	402	*42*	41	*590*	732	*755*	1,001	*146*	169	*320*	732	*102*	6	*12*	15	*1,401*	2,028	*15*	≤LOQ
3,524	5,037	303	7,840	1,812	11,220	5,450	*4,656*	93	*442*	203	*14*	≤LOQ	*2,260*	316	*161*	200	*321*	393	*42*	62	*590*	686	*755*	940	*146*	159	*320*	686	*102*	16	*12*	17	*1,401*	1,072	*15*	≤LOQ
3,743	5,037	535	7,840	2,292	11,220	22,442	*4,656*	224	*442*	311	*14*	≤LOQ	*2,260*	1,207	*161*	181	*321*	369	*42*	37	*590*	684	*755*	900	*146*	162	*320*	684	*102*	5	*12*	17	*1,401*	17,661	*15*	≤LOQ
4,185	5,037	573	7,840	2,748	11,220	5,775	*4,656*	282	*442*	290	*14*	≤LOQ	*2,260*	1,684	*161*	194	*321*	297	*42*	58	*590*	513	*755*	710	*146*	127	*320*	513	*102*	43	*12*	12	*1,401*	1,051	*15*	≤LOQ
4,462	5,037	1,072	7,840	3,078	11,220	5,226	*4,656*	714	*442*	358	*14*	5	*2,260*	1,636	*161*	137	*321*	233	*42*	41	*590*	446	*755*	552	*146*	105	*320*	446	*102*	39	*12*	10	*1,401*	510	*15*	≤LOQ
4,662	5,037	1,133	7,840	3,113	11,220	6,042	*4,656*	788	*442*	351	*14*	≤LOQ	*2,260*	1,593	*161*	139	*321*	242	*42*	36	*590*	450	*755*	593	*146*	116	*320*	450	*102*	25	*12*	9	*1,401*	1,252	*15*	≤LOQ
5,061	5,083	1,154	7,858	3,333	9,307	5,032	4,656	822	427	332	11	7	2,232	1,800	160	142	323	243	42	41	620	440	781	584	145	121	343	440	93	56	12	12	*1,401*	674	14	≤LOQ
5,333	5,083	1,124	7,858	3,663	9,307	5,637	4,656	754	427	371	11	8	2,232	2,066	160	163	323	309	42	40	620	589	781	735	145	146	343	589	93	62	12	14	*1,401*	1,463	14	≤LOQ
5,826	5,101	1,275	7,919	3,776	12,518	6,845	4,656	862	445	412	14	10	2,320	2,024	176	163	322	314	51	65	643	628	760	754	154	143	397	628	77	65	12	13	2,486	766	18	≤LOQ
6,261	4,314	1,312	7,132	4,584	11,731	7,805	3,863	1,444	445	467	14	13	2,320	2,173	176	171	322	322	51	35	643	651	760	828	154	156	397	651	77	84	12	12	2,486	804	18	≤LOQ
6,693	4,266	2,965	7,008	7,671	10,388	15,741	*3,624*	*2,431*	*442*	534	*14*	9	*2,260*	3,932	*161*	194	*321*	580	*42*	56	*590*	694	*755*	891	*146*	254	*320*	694	*102*	98	*12*	11	*1,401*	5,373	*15*	≤LOQ
7,124	4,266	2,767	7,008	5,561	10,388	3,705	*3,624*	2,283	*442*	479	*14*	18	*2,260*	2,315	*161*	162	*321*	317	*42*	54	*590*	611	*755*	780	*146*	146	*320*	611	*102*	71	*12*	12	*1,401*	1,860	*15*	≤LOQ
7,554	4,262	4,225	6,324	7,051	10,279	15,340	3,624	3,689	438	535	14	6	2,179	2,323	163	171	320	326	43	43	590	632	746	777	145	155	298	632	111	37	11	13	1,401	6,001	11	≤LOQ
7,911	4,262	3,697	6,324	6,741	10,279	12,839	3,624	3,404	438	434	14	14	2,179	2,344	163	180	320	319	43	51	590	654	746	788	145	159	298	654	111	47	11	13	1,401	3,732	11	≤LOQ
8,344	3,810	2,680	6,553	5,295	9,933	13,556	*3,366*	2,231	*442*	449	*14*	11	*2,260*	2,146	*161*	157	*321*	313	*42*	78	*590*	582	*755*	743	*146*	147	*320*	582	*102*	41	*12*	10	*1,401*	6,078	*15*	≤LOQ
8,782	4,054	3,133	6,736	5,843	10,177	8,351	*3,612*	2,682	*442*	451	*14*	17	*2,260*	2,223	*161*	165	*321*	322	*42*	55	*590*	610	*755*	755	*146*	153	*320*	610	*102*	146	*12*	11	*1,401*	768	*15*	≤LOQ
9,213	4,054	3,117	6,736	5,838	10,177	13,177	*3,612*	2,719	*442*	398	*14*	≤LOQ	*2,260*	2,231	*161*	168	*321*	322	*42*	55	*590*	625	*755*	756	*146*	157	*320*	625	*102*	52	*12*	10	*1,401*	5,060	*15*	≤LOQ
9,644	4,054	4,217	6,736	7,279	10,177	16,388	*3,612*	3,632	*442*	524	*14*	17	*2,260*	2,526	*161*	184	*321*	352	*42*	42	*590*	710	*755*	864	*146*	176	*320*	710	*102*	55	*12*	11	*1,401*	6,542	*15*	≤LOQ
10,074	4,067	5,032	6,768	7,719	9,477	19,717	3,612	4,647	455	386	14	≤LOQ	2,228	2,193	155	170	318	324	26	58	554	593	742	760	147	152	298	593	127	31	9	9	788	9,784	17	17
10,503	4,067	6,335	6,768	9,345	9,477	20,700	3,612	6,416	455	519	14	5	2,228	2,462	155	186	318	362	26	50	554	688	742	844	147	173	298	688	127	51	9	13	788	8,247	17	≤LOQ

Figures 16 to 21 show Test 5 PFAS removal data expressed as concentration per volume treated (i.e., gallons per pound of sorbent). The data displayed on the graphs were taken from the data found in Tables 9 and 10 above. Figure 22 shows the cloth media filter (used as pretreatment to the membrane system) does not remove any PFAS. Table 11 lists the PFAS data measured from pretreatment filter samples to verify no PFAS was removed from the pre-filters.

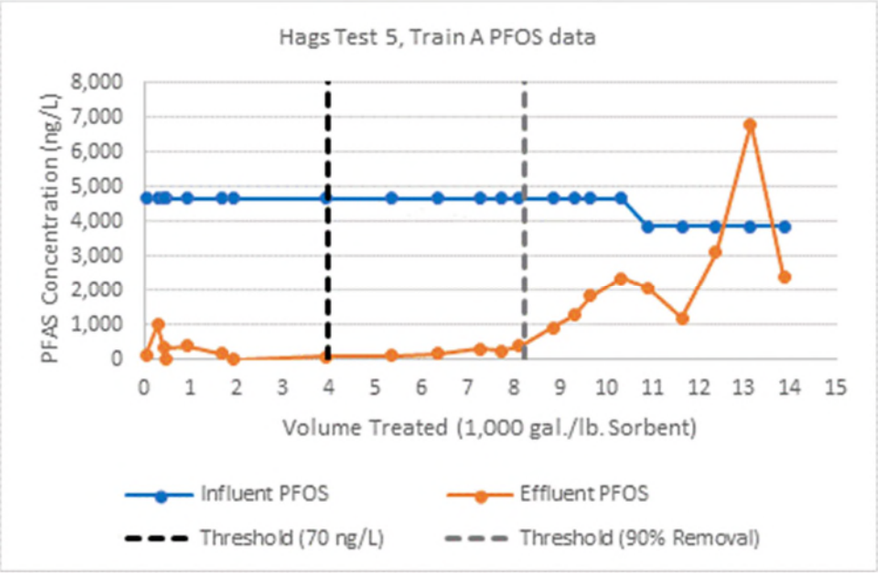

Figure 16: HAGS Test 5, Train A PFOS Removal Data

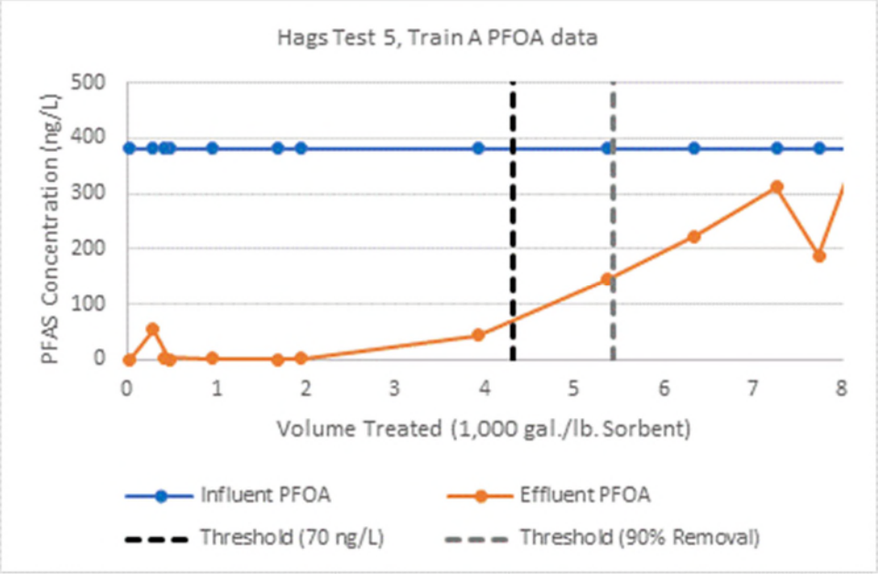

Figure 17: HAGS Test 5, Train A PFOA Removal Data

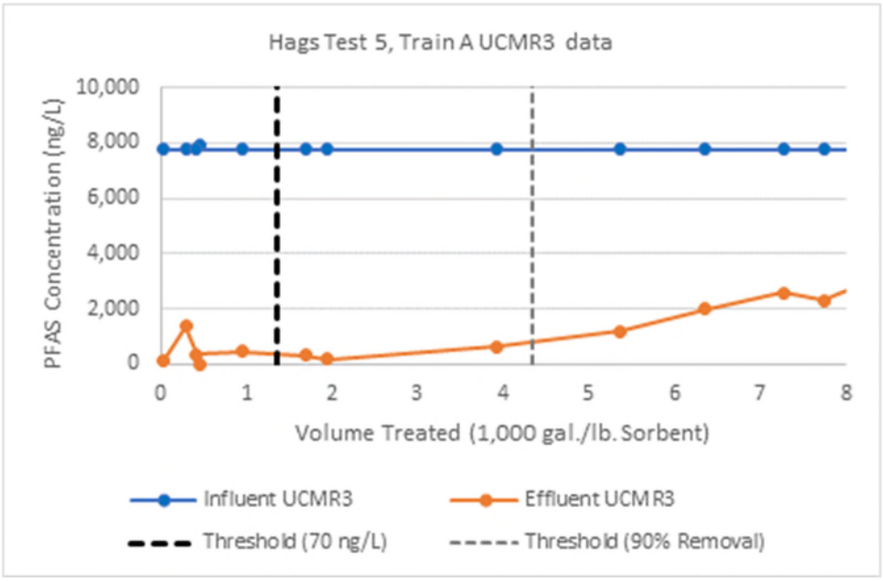

Figure 18: HAGS Test 5, Train A UCMR3 Removal Data

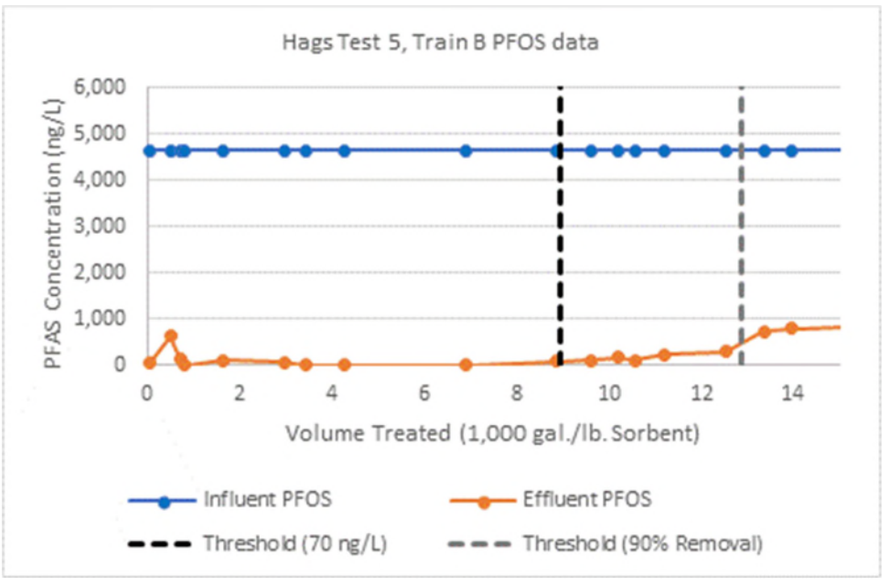

Figure 19: HAGS Test 5, Train B PFOS Removal Data

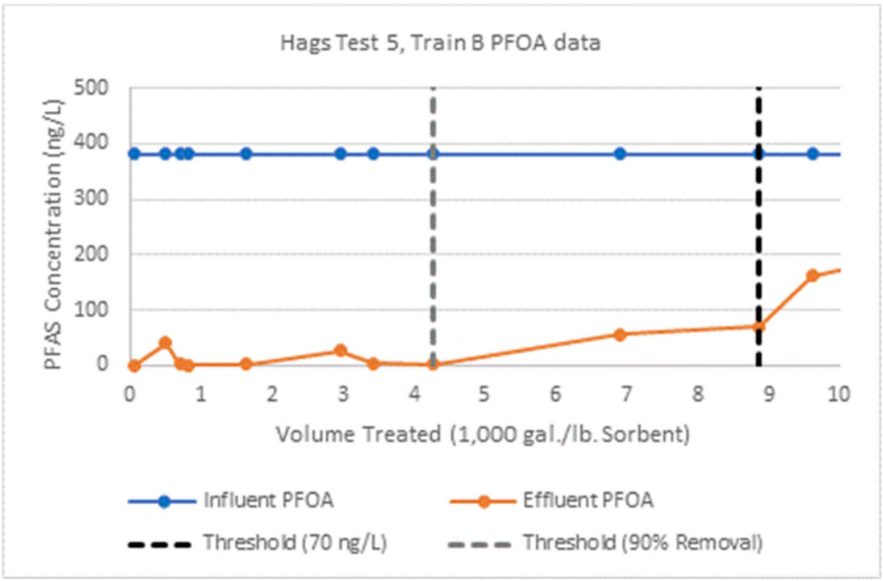

Figure 20: HAGS Test 5, Train B PFOA Removal data

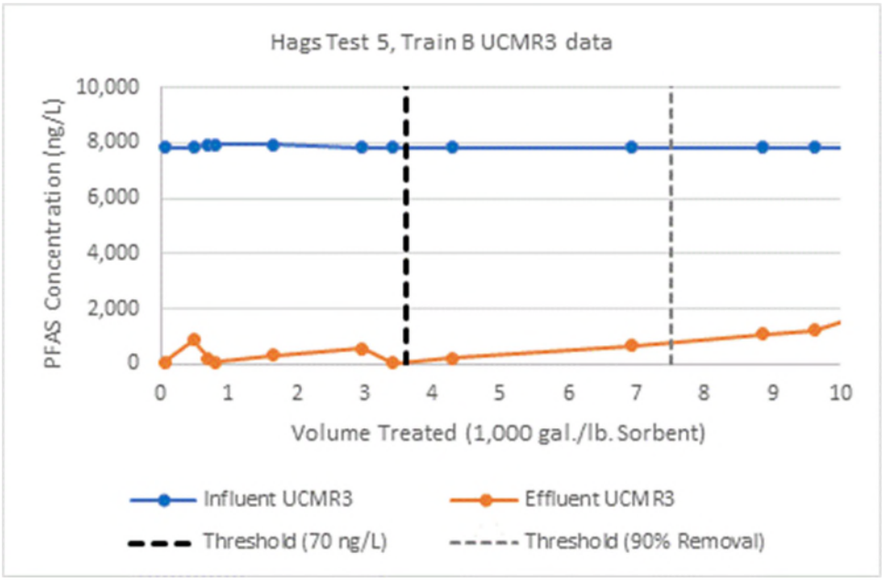

Figure 21: HAGS Test 5, Train B UCMR3 Removal Data

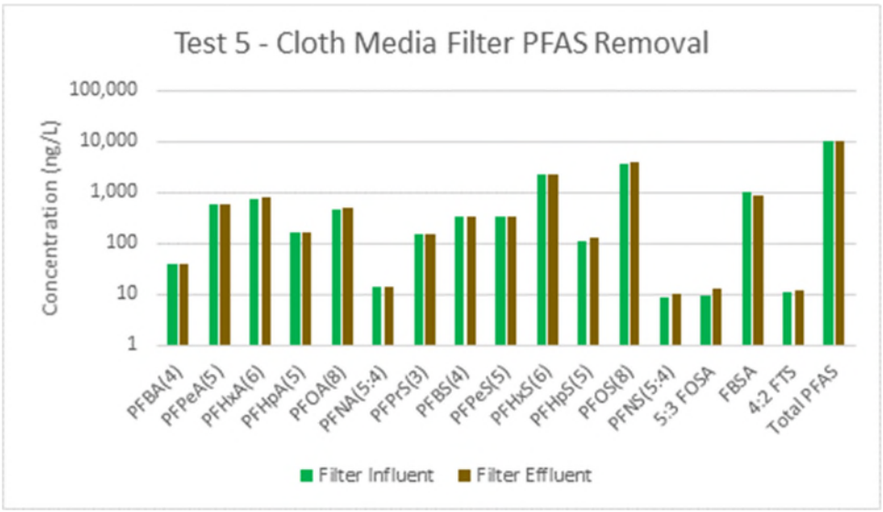

Figure 22: HAGS Test 5 Cloth Media Filter PFAS Removal Test

Table 11: HAGS Test 5 Pretreatment PFAS Data

	Hags Test 5																	
	Pretreatment to the AquaPRS	**PFBA**	**PFPeA**	**PFHxA**	**PFHpA**	**PFOA**	**PFNA**	**PFPrS**	**PFBS**	**PFPeS**	**PFHxS**	**PFHpS**	**PFOS**	**PFNS**	**FOSA**	**FBSA**	**4:2 FTS**	**8:2 FTS**
3-Sep	5um cartridge prefilter effluent	33.8	590.1	787.1	171.3	381.58	0.00	155.7	333.9	425.4	2399	53.4	4655.76	0.0	8.2	8203	14.4	0
18-Sep	cloth media (5um) influent	69.2	587.8	725.0	163.0	441.68	14.44	149.4	339.2	316.4	2247	120.5	3678.55	9.6	12.9	864	8.5	14
21-Sep	cloth media (5um) influent	63.6	631.1	833.1	181.2	528.50	9.11	165.2	363.2	469.7	2486	42.5	3797.57	0.0	0.0	10930	15.8	0
24-Sep	cloth media (5um) influent	81.9	604.7	840.0	177.0	485.18	13.34	164.7	363.5	339.5	2430	173.0	4015.99	12.2	13.4	950	15.1	19
18-Sep	cloth media (5um) effluent	55.3	586.4	772.5	164.0	479.26	11.88	154.8	336.5	302.6	2280	130.7	4144.13	15.5	15.3	0	10.5	11
21-Sep	cloth media (5um) effluent	35.6	650.3	835.8	180.4	508.44	14.33	166.6	363.9	339.2	2425	183.0	4027.39	11.9	13.9	910	14.2	11
24-Sep	cloth media (5um) effluent	33.1	575.5	819.4	169.8	503.42	17.16	157.8	353.6	403.0	2426	88.4	3908.83	3.8	9.8	1828	11.6	0

6. Test 6

Test 6 was conducted from October 14, 2020, to October 30, 2020, at the HAGS test site with Trains A and B operated in parallel. The objective for Test 6 was to compare removals at high and low membrane flux operation with both trains at high sorbent concentration. All other parameters were kept the same. The operating parameters are listed in Table 12.

Table 12: HAGS Test 6 Operational Parameters

Operational Parameter	Train A	Train B	Units
Membrane flux rate	100	150	Lmh
Recycle flow rate	10	10	L/minute
Permeate flow rate	0.67	1	L/minute
Filtration cycle duration (backwash frequency)	30	30	Minutes
Sorption reactor detention time	60	40	Minutes
Sorption reactor volume	40	40	L
Sorbent concentration	5,000	5,000	mg/L as C

Note:
Green highlighted cells on the table indicate the operating parameter that was evaluated.

The following data tables and graphs represent the analytical data generated during Test 6 at the HAGS test site. Tables 13 and 14 list the PFAS analytical data as measured from the CSM laboratory for Trains A and B, respectively. The grey columns represent the UCMR3 compounds. The blue columns represent summed data for PFOS and PFOA, total PFAS, and the UCMR3 compounds.

Table 13: HAGS Test 6, Train A PFAS Removal Data

Train A *Blank cells were sample error and/or 1.5x10R. Cells in italics are either averages or values with sample error removed

	PFOA + PFOS (LOQ=6)		UCMR3 (LOQ=18)		Total PFAS (LOQ=75)		PFOS (LOQ=3)		PFOA (LOQ=3)		PFNA (LOQ=1.0)		PFHxS (LOQ=3)		PFHpA (LOQ=6)		PFBS (LOQ=3)		PFBA (LOQ=30)		PFPeA (LOQ=3)		PFHxA (LOQ=15)		PFPrS (LOQ=3)		PFPeS (LOQ=3)		PFHpS (LOQ=3)		4:2 FTS		6:2 FTS		8:2 FTS	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
40	7,706	≤LOQ	10,563	≤LOQ	13,149	≤LOQ	7,104	≤LOQ	602	≤LOQ	n/a	n/a	2,282	≤LOQ	139	≤LOQ	376	≤LOQ	≤LOQ	≤LOQ	781	≤LOQ	1,010	≤LOQ	174	≤LOQ	347	≤LOQ	273	≤LOQ	n/a	n/a	n/a	n/a	n/a	n/a
138	7,706		10,563		13,149		7,104		602		n/a	n/a	2,282		139		376		≤LOQ	≤LOQ	781	425	1,010	425	174	71	347	243	273	18	n/a	n/a	n/a	n/a	n/a	n/a
720	6,880	≤LOQ	9,831	*54*	12,435	*1,056*	6,306	≤LOQ	573	≤LOQ	n/a	n/a	2,355	≤LOQ	203	≤LOQ	394	54	≤LOQ	≤LOQ	804	715	1,000	144	179	143	364	≤LOQ	257	≤LOQ	n/a	n/a	n/a	n/a	n/a	n/a
1,047	1,708	*456*	2,365	*632*	2,930	*1,516*	1,564	*450*	144	*86*	n/a	n/a	518	77	55	11	84	78	≤LOQ	≤LOQ	208	375	237	204	39	84	80	19	60	11	n/a	n/a	n/a	n/a	n/a	n/a
1,955	4,420	*834*	6,303	*1006*	7,896	*2,029*	4,080	*834*	339	≤LOQ	n/a	n/a	1,504	34	136	≤LOQ	243	138	≤LOQ	≤LOQ	471	524	620	347	111	117	226	36	166	≤LOQ	n/a	n/a	n/a	n/a	n/a	n/a
2,863	5,480	*147*	7,889	*443*	9,967	*1,993*	5,030	*159*	450	8	n/a	n/a	1,914	29	174	22	321	243	≤LOQ	≤LOQ	641	689	785	659	145	159	294	44	212	≤LOQ	n/a	n/a	n/a	n/a	n/a	n/a
3,770	5,664	*382*	8,203	*759*	10,370	*3,115*	5,185	*382*	479	≤LOQ	n/a	n/a	2,013	≤LOQ	185	54	341	322	≤LOQ	≤LOQ	643	761	834	880	154	168	306	547	231	≤LOQ	n/a	n/a	n/a	n/a	n/a	n/a
4,684	5,789	*≤LOQ*	8,312	*640*	10,510	*2,915*	5,331	≤LOQ	459	≤LOQ	n/a	n/a	2,012	207	177	95	334	338	≤LOQ	≤LOQ	673	699	833	886	152	169	309	520	232	≤LOQ	n/a	n/a	n/a	n/a	n/a	n/a
5,599	6,524	*450*	9,232	*2432*	11,608	*5,807*	6,015	≤LOQ	509	*450*	n/a	n/a	2,149	1402	193	186	365	394	≤LOQ	≤LOQ	720	771	923	1038	161	212	332	1207	241	148	n/a	n/a	n/a	n/a	n/a	n/a
6,507	6,089	≤LOQ	8,868	*1277*	11,234	*7,444*	5,581	≤LOQ	508	≤LOQ	n/a	n/a	2,220	858	191	≤LOQ	368	413	≤LOQ	≤LOQ	735	771	928	1064	170	234	342	4093	252	≤LOQ	n/a	n/a	n/a	n/a	n/a	n/a
7,423	5,853	≤LOQ	8,637	*636*	11,172	*8,207*	5,326	≤LOQ	527	≤LOQ	n/a	n/a	2,271	≤LOQ	189	211	384	425	≤LOQ	≤LOQ	741	767	954	1072	177	215	355	5518	248	≤LOQ	n/a	n/a	n/a	n/a	n/a	n/a
8,339	6,314	521	9,155	2106	11,659	4,547	5,782	238	532	282	n/a	n/a	2,249	935	197	211	395	440	≤LOQ	≤LOQ	750	813	978	1066	178	194	356	368	243	≤LOQ	n/a	n/a	n/a	n/a	n/a	n/a
9,247	5,839	898	8,542	2823	10,318	5,662	*5,331*	466	*506*	432	n/a	n/a	*2,149*	1286	*189*	213	*365*	426	≤LOQ	≤LOQ	*720*	809	*923*	1048	*161*	197	*332*	758	*241*	27	n/a	n/a	n/a	n/a	n/a	n/a
10,155	5,839	725	8,542	2728	10,318	4,550	*5,331*	261	*506*	464	n/a	n/a	*2,149*	1527	*189*	190	*365*	286	≤LOQ	≤LOQ	*720*	492	*923*	695	*161*	126	*332*	444	*241*	64	n/a	n/a	n/a	n/a	n/a	n/a
11,062	5,839	3715	8,542	6206	10,318	10,231	*5,331*	2835	*506*	880	n/a	n/a	*2,149*	1900	*189*	234	*365*	357	≤LOQ	≤LOQ	*720*	651	*923*	897	*161*	178	*332*	2236	*241*	≤LOQ	n/a	n/a	n/a	n/a	n/a	n/a
11,969	5,839	1708	8,542	4857	10,318	7,195	*5,331*	1159	*506*	543	n/a	n/a	*2,149*	2463	*189*	201	*365*	486	≤LOQ	≤LOQ	*720*	730	*923*	951	*161*	169	*332*	398	*241*	89	n/a	n/a	n/a	n/a	n/a	n/a
12,871	5,839	1584	8,542	3203	10,318	4,202	*5,331*	1242	*506*	342	n/a	n/a	*2,149*	1356	*189*	106	*365*	157	≤LOQ	≤LOQ	*720*	270	*923*	376	*161*	66	*332*	185	*241*	102	n/a	n/a	n/a	n/a	n/a	n/a

Table 14: HAGS Test 6, Train B PFAS Removal Data

Train B *Blank cells were sample error and/or 1.5x10R. Cells in italics are either averages or values with sample error removed

	PFOA + PFOS (LOQ=6)		UCMR3 (LOQ=18)		Total PFAS (LOQ=75)		PFOS (LOQ=3)		PFOA (LOQ=3)		PFNA (LOQ=1.0)		PFHxS (LOQ=3)		PFHpA (LOQ=6)		PFBS (LOQ=3)		PFBA (LOQ=30)		PFPeA (LOQ=3)		PFHxA (LOQ=15)		PFPrS (LOQ=3)		PFPeS (LOQ=3)		PFHpS (LOQ=3)		4:2 FTS		6:2 FTS		8:2 FTS	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
46	7,706	*465*	10,563	*478*	13,149	*510*	7,104	*457*	602	*27*	n/a	n/a	2,282	8	139	0	376	6	≤LOQ	≤LOQ	781	21	1,010	≤LOQ	174	10	347	≤LOQ	273	≤LOQ	n/a	n/a	n/a	n/a	n/a	n/a
197	7,706		10,563		13,149		7,104		602		n/a	n/a	2,282	419	139	33	376	103	≤LOQ	≤LOQ	781	365	1,010	243	174	76	347	163	273	17	n/a	n/a	n/a	n/a	n/a	n/a
1,052	6,880	*≤LOQ*	9,831	*82*	12,435	*1,264*	6,306	*≤LOQ*	573	≤LOQ	n/a	n/a	2,355	≤LOQ	203	≤LOQ	394	92	≤LOQ	≤LOQ	804	720	1,000	254	179	159	364	58	257	≤LOQ	n/a	n/a	n/a	n/a	n/a	n/a
1,280	1,708	*345*	2,365	*532*	2,930	*1,563*	1,564	*345*	144	≤LOQ	n/a	n/a	518	51	55	≤LOQ	84	136	≤LOQ	≤LOQ	208	503	237	358	39	120	80	50	60	≤LOQ	n/a	n/a	n/a	n/a	n/a	n/a
2,528	4,420	*262*	6,303	*511*	7,896	*1,638*	4,080	*262*	339	≤LOQ	n/a	n/a	1,504	39	136	24	243	187	≤LOQ	≤LOQ	471	591	620	530	111	142	226	64	166	≤LOQ	n/a	n/a	n/a	n/a	n/a	n/a
3,858	5,480	*362*	7,889	*634*	9,967	*2,705*	5,030	*269*	450	*55*	n/a	n/a	1,914	114	174	53	321	304	≤LOQ	≤LOQ	641	674	785	802	145	166	294	228	212	≤LOQ	n/a	n/a	n/a	n/a	n/a	n/a
4,815	5,664	*574*	8,203	*1,202*	10,370	*3,396*	5,185	*579*	479	≤LOQ	n/a	n/a	2,013	190	185	77	341	357	≤LOQ	≤LOQ	643	646	834	939	154	158	306	451	231	≤LOQ	n/a	n/a	n/a	n/a	n/a	n/a
5,547	5,789	*1,026*	8,312	*1,803*	10,510	*4,035*	5,331	*845*	459	*185*	n/a	n/a	2,012	232	177	107	334	377	≤LOQ	≤LOQ	673	675	833	960	152	165	309	431	232	≤LOQ	n/a	n/a	n/a	n/a	n/a	n/a
7,033	6,524	≤LOQ	9,232	1,155	11,608	4,480	6,015	≤LOQ	509	≤LOQ	n/a	n/a	2,149	603	193	154	365	398	≤LOQ	≤LOQ	720	720	923	1,008	161	180	332	1,418	241	≤LOQ	n/a	n/a	n/a	n/a	n/a	n/a
8,209	6,089	256	8,868	1,430	11,234	3,603	5,581	70	508	186	n/a	n/a	2,220	586	191	176	368	403	≤LOQ	≤LOQ	735	727	928	997	170	165	342	267	252	17	n/a	n/a	n/a	n/a	n/a	n/a
9,540	5,853	1,796	8,637	3,637	11,172	6,894	5,326	1,355	527	441	n/a	n/a	2,271	1,194	189	220	384	427	≤LOQ	≤LOQ	741	738	954	1,013	177	176	355	1,312	248	11	n/a	n/a	n/a	n/a	n/a	n/a
10,484	6,314	1,577	9,155	3,605	11,659	6,490	5,782	1,114	532	463	n/a	n/a	2,249	1,363	197	224	395	442	≤LOQ	≤LOQ	750	810	978	1,070	178	186	356	801	243	18	n/a	n/a	n/a	n/a	n/a	n/a
10,705	5,839	516	8,542	2,110	10,318	4,405	*5,331*	185	*506*	331	n/a	n/a	*2,149*	984	*189*	207	*365*	403	≤LOQ	≤LOQ	*720*	751	*923*	985	*161*	180	*332*	343	*241*	37	n/a	n/a	n/a	n/a	n/a	n/a
10,706	5,839	524	8,542	2,038	10,318	4,386	*5,331*	206	*506*	318	n/a	n/a	*2,149*	932	*189*	195	*365*	387	≤LOQ	≤LOQ	*720*	782	*923*	1,023	*161*	180	*332*	329	*241*	34	n/a	n/a	n/a	n/a	n/a	n/a
10,980	5,839	559	8,542	2,313	10,318	4,645	*5,331*	222	*506*	337	n/a	n/a	*2,149*	1,118	*189*	223	*365*	413	≤LOQ	≤LOQ	*720*	748	*923*	1,010	*161*	166	*332*	371	*241*	37	n/a	n/a	n/a	n/a	n/a	n/a
12,294	5,839	1,089	8,542	3,381	10,318	5,663	*5,331*	623	*506*	466	n/a	n/a	*2,149*	1,674	*189*	211	*365*	406	≤LOQ	≤LOQ	*720*	714	*923*	929	*161*	178	*332*	377	*241*	84	n/a	n/a	n/a	n/a	n/a	n/a
13,254	5,839	1,113	8,542	3,090	10,318	3,983	*5,331*	656	*506*	457	n/a	n/a	*2,149*	1,727	*189*	114	*365*	136	≤LOQ	≤LOQ	*720*	200	*923*	309	*161*	54	*332*	207	*241*	123	n/a	n/a	n/a	n/a	n/a	n/a

Figures 23 to 28 show Test 6 PFAS removal data expressed as concentration per volume treated (i.e., gallons per pound of sorbent). The data displayed on the graphs were taken from the data found in Tables 13 and 14 above.

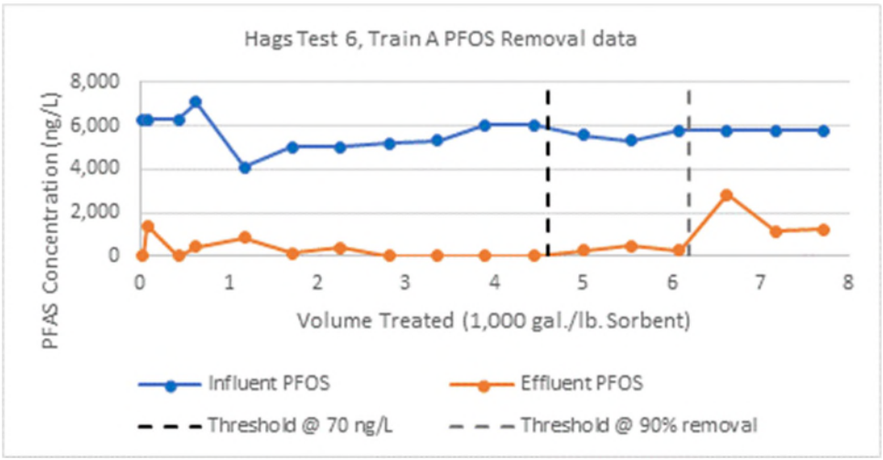

Figure 23: HAGS Test 6, Train A PFOS Removal Data

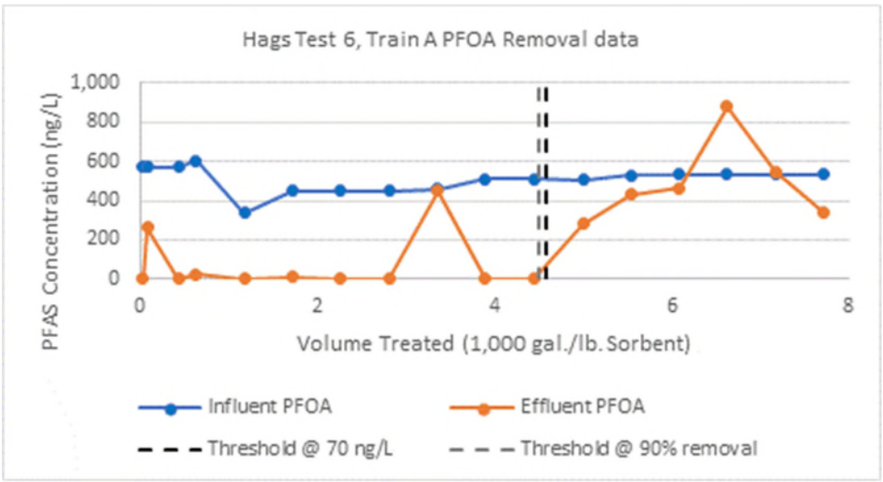

Figure 24: HAGS Test 6, Train A PFOA Removal Data

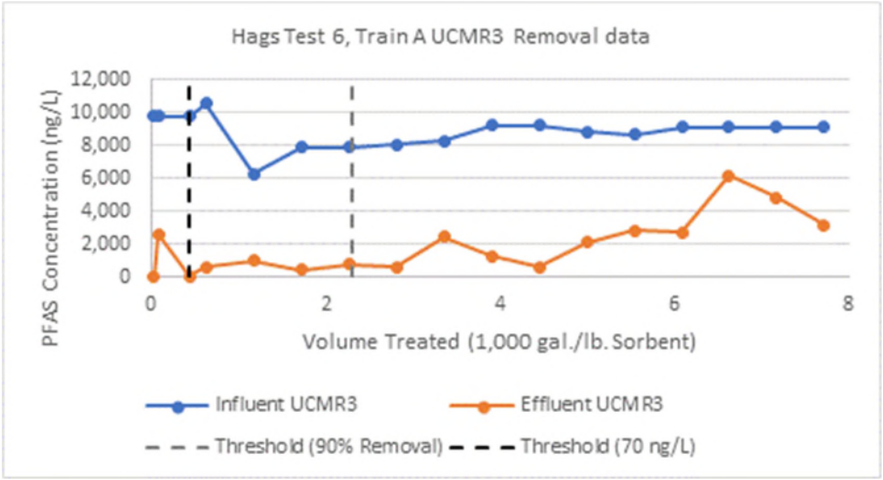

Figure 25: HAGS Test 6, Train A UCMR3 Removal Data

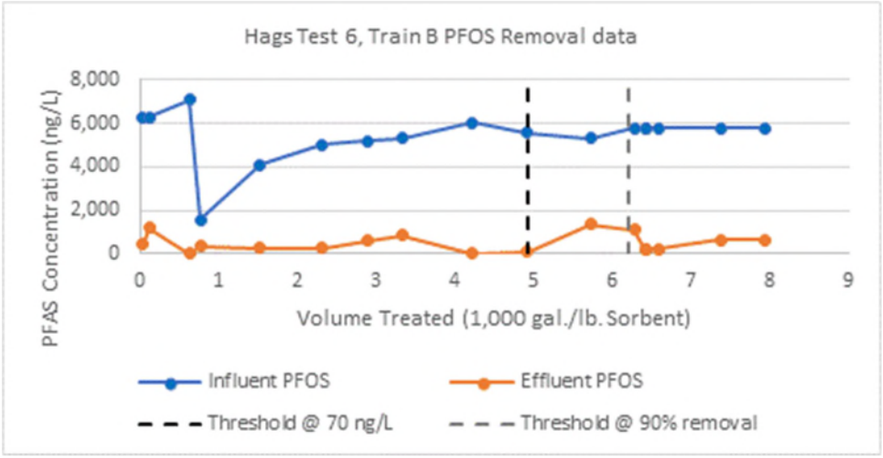

Figure 26: HAGS Test 6, Train B PFOS Removal Data

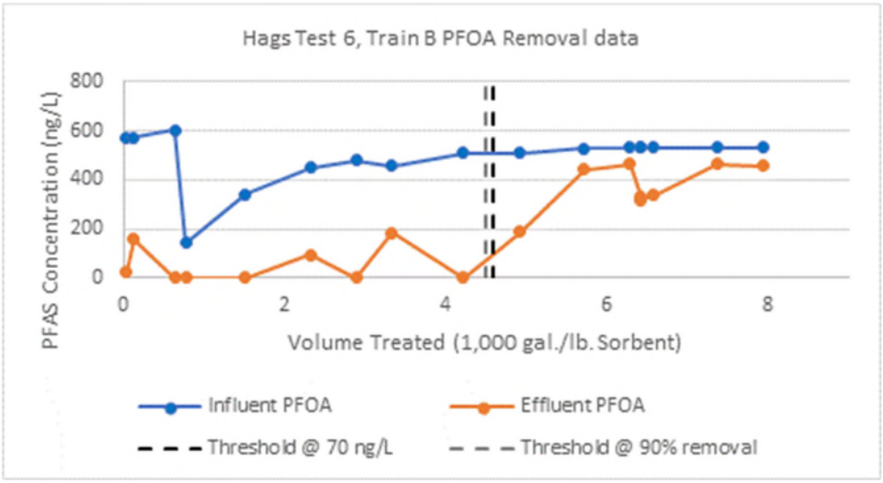

Figure 27: HAGS Test 6, Train B PFOA Removal Data

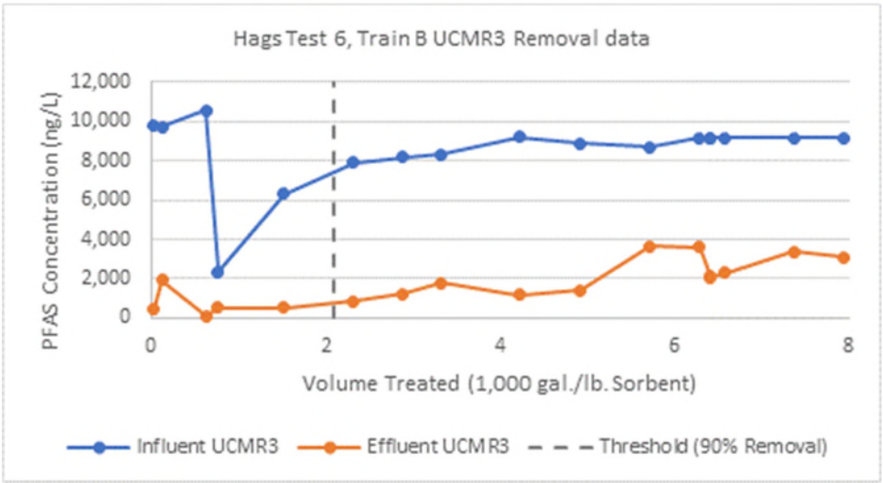

Figure 28: HAGS Test 6, Train B UCMR3 Removal Data

7. Test 7

Test 7 was conducted from December 1, 2020, to December 12, 2020, at the HAGS test site with Trains A and B operated in parallel. The objective for Test 7 was to compare removals at high and low sorption detention time with both trains at high sorbent concentrations. All other parameters were kept the same. The operating parameters are listed in Table 15.

Table 15: HAGS Test 7 Operational Parameters

Operational Parameter	Train A	Train B	Units
Membrane flux rate	150	150	Lmh
Recycle flow rate	10	10	L/minute
Permeate flow rate	1	1	L/minute
Filtration cycle duration (backwash frequency)	30	30	Minutes
Sorption reactor detention time	20	5	Minutes
Sorption reactor volume	20	5	L
Sorbent concentration	15,000	15,000	mg/L as C

Note:
Green highlighted cells on the table indicate the operating parameter that was evaluated.

The following data tables and graphs represent the analytical data generated during Test 7 at the HAGS test site. Tables 16 and 17 list the PFAS analytical data as measured from the CSM laboratory for Trains A and B, respectively. The grey columns represent the UCMR3 compounds. The blue columns represent summed data for PFOS and PFOA, total PFAS, and the UCMR3 compounds.

Table 16: HAGS Test 7, Train A PFAS Data

Train A *Blank cells were sample error and/or 1.5x10R. Cells in italics are either averages or values with sample error removed

	PFOA + PFOS (LOQ=20)		UCMR3 (LOQ=43)		Total PFAS (LOQ=51)		PFOS (LOQ=10)		PFOA (LOQ=10)		PFNA		PFHxS (LOQ=1.0)		PFHpA (LOQ=1.0)		PFBS (LOQ=20)		PFBA (LOQ=1.0)		PFPeA (LOQ=1.0)		PFHxA (LOQ=1.0)		PFPrS (LOQ=1.0)		PFPeS (LOQ=1.0)		PFHpS (LOQ=1.0)		4:2 FTS		6:2 FTS (LOQ=1.0)		8:2 FTS	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
24	6,373	≤LOQ	3,330	≤LOQ	12,327	≤LOQ	6,603	≤LOQ	376	≤LOQ	n/a	n/a	2,002	≤LOQ	125	≤LOQ	224	≤LOQ	64	≤LOQ	538	≤LOQ	782	≤LOQ	148	≤LOQ	339	≤LOQ	69	≤LOQ	n/a	n/a	1,658	≤LOQ	n/a	n/a
770	6,734	≤LOQ	8,746	≤LOQ	11,596	181	6,439	≤LOQ	355	≤LOQ	n/a	n/a	1,628	≤LOQ	75	≤LOQ	249	≤LOQ	48	66	436	81	659	16	133	17	333	≤LOQ	68	≤LOQ	n/a	n/a	1,171	≤LOQ	n/a	n/a
953	5,634	≤LOQ	7,420	≤LOQ	10,263	317	5,271	≤LOQ	363	≤LOQ	n/a	n/a	1,470	≤LOQ	117	≤LOQ	138	≤LOQ	68	18	499	174	638	86	116	40	221	≤LOQ	107	≤LOQ	n/a	n/a	1,135	≤LOQ	n/a	n/a
1,227	4,680	≤LOQ	5,875	≤LOQ	7,575	364	4,441	≤LOQ	239	≤LOQ	n/a	n/a	932	≤LOQ	73	≤LOQ	130	≤LOQ	4	79	266	138	421	44	74	42	206	≤LOQ	50	≤LOQ	n/a	n/a	680	≤LOQ	n/a	n/a
1,831	1,701	≤LOQ	2,128	≤LOQ	2,806	503	1,538	≤LOQ	104	≤LOQ	n/a	n/a	406	≤LOQ	1	≤LOQ	20	≤LOQ	4	51	122	294	166	34	31	63	90	≤LOQ	20	≤LOQ	n/a	n/a	246	≤LOQ	n/a	n/a
2,208	4,746	≤LOQ	6,587	≤LOQ	9,113	597	4,391	≤LOQ	355	≤LOQ	n/a	n/a	1,552	≤LOQ	123	≤LOQ	165	≤LOQ	35	43	483	378	699	93	122	82	337	≤LOQ	50	≤LOQ	n/a	n/a	800	≤LOQ	n/a	n/a
2,554	2,855	≤LOQ	3,744	≤LOQ	4,971	654	2,744	≤LOQ	111	≤LOQ	n/a	n/a	725	≤LOQ	59	≤LOQ	105	≤LOQ	14	94	237	380	310	89	57	91	156	≤LOQ	50	≤LOQ	n/a	n/a	402	≤LOQ	n/a	n/a
3,215	3,351	≤LOQ	5,503	≤LOQ	7,420	865	3,747	≤LOQ	204	≤LOQ	n/a	n/a	1,249	≤LOQ	100	≤LOQ	208	≤LOQ	3	52	370	462	492	227	104	125	260	≤LOQ	22	≤LOQ	n/a	n/a	661	≤LOQ	n/a	n/a
3,511	6,467	≤LOQ	8,301	≤LOQ	10,938	714	6,056	≤LOQ	411	≤LOQ	n/a	n/a	1,517	≤LOQ	93	≤LOQ	224	≤LOQ	15	29	443	440	630	116	122	130	310	≤LOQ	86	≤LOQ	n/a	n/a	1,026	≤LOQ	n/a	n/a
3,877	5,730	≤LOQ	7,655	≤LOQ	10,273	802	5,372	≤LOQ	418	≤LOQ	n/a	n/a	1,568	≤LOQ	96	≤LOQ	202	≤LOQ			411	436	633	237	123	128	334	≤LOQ	40	≤LOQ	n/a	n/a	1,078	≤LOQ	n/a	n/a
4,398	6,384	≤LOQ	8,803	≤LOQ	11,676	810	6,785	≤LOQ	198	≤LOQ	n/a	n/a	1,486	≤LOQ	127	≤LOQ	213	≤LOQ	40	32	441	375	701	257	126	134	320	12	31	≤LOQ	n/a	n/a	1,208	≤LOQ	n/a	n/a
4,435	6,685	≤LOQ	8,572	≤LOQ	11,348	755	6,411	≤LOQ	274	≤LOQ	n/a	n/a	1,549	≤LOQ	112	≤LOQ	225	≤LOQ			477	370	588	256	136	122	329	7	58	≤LOQ	n/a	n/a	1,189	≤LOQ	n/a	n/a
5,207	6,632	≤LOQ	8,591	≤LOQ	11,343	717	6,261	≤LOQ	371	≤LOQ	n/a	n/a	1,617	≤LOQ	101	≤LOQ	240	≤LOQ	27	27	377	337	599	253	122	100	270	≤LOQ	105	≤LOQ	n/a	n/a	1,858	≤LOQ	n/a	n/a
5,865	10,360	≤LOQ	12,147	31	14,343	839	10,032	≤LOQ	328	≤LOQ	n/a	n/a	1,504	≤LOQ	104	≤LOQ	178	31			442	421	652	261	128	110	333	16	47	≤LOQ	n/a	n/a	1,194	≤LOQ	n/a	n/a
6,268	8,364	≤LOQ	10,465	107	13,693	1,187	8,044	≤LOQ	320	≤LOQ	n/a	n/a	1,671	≤LOQ	145	≤LOQ	286	107	17	75	407	481	664	371	135	130	390	22	26	≤LOQ	n/a	n/a	1,587	≤LOQ	n/a	n/a
7,092	7,090	≤LOQ	9,036	105	11,787	1,269	6,793	≤LOQ	291	≤LOQ	n/a	n/a	1,578	≤LOQ	99	≤LOQ	269	105			445	453	762	520	140	140	392	50	29	≤LOQ	n/a	n/a	982	≤LOQ	n/a	n/a
7,721	7,431	≤LOQ	9,429	174	12,034	1,426	7,091	≤LOQ	340	≤LOQ	n/a	n/a	1,636	≤LOQ	108	≤LOQ	255	174			431	470	651	580	140	150	357	53	64	≤LOQ	n/a	n/a	1,021	≤LOQ	n/a	n/a
8,365	10,011	≤LOQ	12,259	≤LOQ	15,707	1,417	9,512	≤LOQ	499	≤LOQ	n/a	n/a	1,824	≤LOQ	134	≤LOQ	289	≤LOQ	37	60	466	445	832	622	158	146	430	145	89	≤LOQ	n/a	n/a	1,377	≤LOQ	n/a	n/a
9,010	6,683	≤LOQ	8,564	280	11,319	1,363	*6,336*	≤LOQ	*547*	≤LOQ	n/a	n/a	*1,560*	≤LOQ	*103*	≤LOQ	*218*	280	*37*	127	*440*	512	*645*	783	*127*	167	*333*	94	*50*	≤LOQ	n/a	n/a	*1,124*	≤LOQ	n/a	n/a
9,656	6,683	≤LOQ	8,564	279	11,319	1,320	*6,336*	≤LOQ	*547*	≤LOQ	n/a	n/a	*1,560*	≤LOQ	*103*	≤LOQ	*218*	279	*37*	90	*440*	466	*645*	829	*127*	149	*333*	108	*50*	≤LOQ	n/a	n/a	*1,124*	≤LOQ	n/a	n/a
9,343	6,683	≤LOQ	8,564	269	11,319	1,771	*6,336*	≤LOQ	*547*	≤LOQ	n/a	n/a	*1,560*	≤LOQ	*103*	28	*218*	241	*37*	18	*440*	475	*645*	779	*127*	150	*333*	80	*50*	≤LOQ	n/a	n/a	*1,124*	≤LOQ	n/a	n/a
9,343	6,683	≤LOQ	8,564	278	11,319	1,800	*6,336*	≤LOQ	*547*	≤LOQ	n/a	n/a	*1,560*	≤LOQ	*103*	24	*218*	254	*37*	60	*440*	462	*645*	758	*127*	144	*333*	97	*50*	≤LOQ	n/a	n/a	*1,124*	≤LOQ	n/a	n/a

Table 17: HAGS Test 7, Train B PFAS Data

Train B *Blank cells were sample error and/or 1.5x10R. Cells in italics are either averages or values with sample error removed

	PFOA + PFOS (LOQ=20)		UCMR3 (LOQ=43)		Total PFAS (LOQ=51)		PFOS (LOQ=10)		PFOA (LOQ=10)		PFNA		PFHxS (LOQ=1.0)		PFHpA (LOQ=1.0)		PFBS (LOQ=20)		PFBA (LOQ=1.0)		PFPeA (LOQ=1.0)		PFHxA (LOQ=1.0)		PFPrS (LOQ=1.0)		PFPeS (LOQ=1.0)		PFHpS (LOQ=1.0)		4:2 FTS		6:2 FTS (LOQ=1.0)		8:2 FTS	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
35	6,373	≤LOQ	3,330	≤LOQ	12,327	54	6,603	≤LOQ	376	≤LOQ	n/a	n/a	2,002	≤LOQ	125	≤LOQ	224	≤LOQ	64	17	538	16	782	21	148	≤LOQ	339	≤LOQ	69	≤LOQ	n/a	n/a	1,658	≤LOQ	n/a	n/a
191	6,734	≤LOQ	8,746	25	11,596	237	6,439	≤LOQ	355	≤LOQ	n/a	n/a	1,628	25	75	≤LOQ	249	≤LOQ	48	20	436	136	659	31	133	25	333	≤LOQ	68	≤LOQ	n/a	n/a	1,171	≤LOQ	n/a	n/a
738	5,634	≤LOQ	7,420	≤LOQ	10,263	661	5,271	≤LOQ	363	≤LOQ	n/a	n/a	1,470	≤LOQ	117	≤LOQ	138	≤LOQ	68	39	499	359	638	158	116	104	221	≤LOQ	107	≤LOQ	n/a	n/a	1,135	≤LOQ	n/a	n/a
759	5,634	≤LOQ	7,420	93	10,263	1,006	5,271	≤LOQ	363	≤LOQ	n/a	n/a	1,470	≤LOQ	117	≤LOQ	138	93	68	30	499	504	638	236	116	144	221	≤LOQ	107	≤LOQ	n/a	n/a	1,135	≤LOQ	n/a	n/a
1,076	4,680	≤LOQ	5,875	7	7,575	318	4,441	≤LOQ	239	≤LOQ	n/a	n/a	932	7	73	≤LOQ	130	≤LOQ	4	32	266	423	421	324	74	124	206	9	50	≤LOQ	n/a	n/a	680	≤LOQ	n/a	n/a
1,726	1,701	≤LOQ	2,128	149	2,806	1,262	1,538	≤LOQ	104	≤LOQ	n/a	n/a	406	≤LOQ	1	≤LOQ	20	149	4	34	122	393	166	520	31	124	90	42	20	≤LOQ	n/a	n/a	246	≤LOQ	n/a	n/a
2,036	4,746	≤LOQ	6,587	173	9,113	1,524	4,391	≤LOQ	355	≤LOQ	n/a	n/a	1,552	≤LOQ	123	≤LOQ	165	173	35	44	483	451	699	626	122	131	337	99	50	≤LOQ	n/a	n/a	800	≤LOQ	n/a	n/a
2,377	2,855	≤LOQ	3,744	243	5,010	1,614	2,744	≤LOQ	111	≤LOQ	n/a	n/a	725	43	59	≤LOQ	105	200	14	62	237	430	310	637	57	134	156	107	89	≤LOQ	n/a	n/a	402	≤LOQ	n/a	n/a
3,028	3,351	≤LOQ	5,503	203	7,420	1,323	3,747	≤LOQ	204	≤LOQ	n/a	n/a	1,249	74	100	22	208	107	3	14	370	367	492	541	104	121	260	77	22	≤LOQ	n/a	n/a	661	≤LOQ	n/a	n/a
3,332	6,467	≤LOQ	8,301	359	10,938	1,643	6,056	≤LOQ	411	≤LOQ	n/a	n/a	1,517	84	93	52	224	224	15	14	449	409	630	617	122	126	310	119	86	≤LOQ	n/a	n/a	1,026	≤LOQ	n/a	n/a
3,680	5,730	≤LOQ	7,655	323	10,273	1,574	5,372	≤LOQ	418	≤LOQ	n/a	n/a	1,568	136	96	37	202	149			411	410	633	585	123	144	334	112	40	≤LOQ	n/a	n/a	1,078	≤LOQ	n/a	n/a
4,055	6,384	≤LOQ	8,803	444	11,676	1,447	6,785	≤LOQ	198	≤LOQ	n/a	n/a	1,486	211	127	54	213	179	40		441	239	701	482	126	95	320	127	31	≤LOQ	n/a	n/a	1,208	≤LOQ	n/a	n/a
4,116	6,122		8,009	*559*	10,601	*1,643*	5,691		431		n/a	n/a	1,581	280	94	98	211	221			427	231	639	678	127	41	339	191	39	9	n/a	n/a	1,021	93	n/a	n/a
4,128	6,685	≤LOQ	8,572	786	11,348	2,645	6,411	≤LOQ	274	76	n/a	n/a	1,549	350	112	108	225	338			477	320	588	953	136	104	329	472	58	≤LOQ	n/a	n/a	1,189	≤LOQ	n/a	n/a
4,828	6,632	76	8,591	634	11,922	1,740	6,261	≤LOQ	371	76	n/a	n/a	1,617	259	101	107	240	131			377	204	599	643	122	41	270	143	105	10	n/a	n/a	1,858	58	n/a	n/a
5,475	10,360	232	12,147	1,084	14,958	2,634	10,032	93	328	140	n/a	n/a	1,504	525	104	123	178	205	16	25	442	381	652	627	128	99	333	309	47	≤LOQ	n/a	n/a	1,194	109	n/a	n/a
5,860	8,364	483	10,465	1,756	13,693	3,611	8,044	234	320	255	n/a	n/a	1,671	916	145	143	286	208	17	85	407	476	664	734	135	113	390	366	26	13	n/a	n/a	1,587	267	n/a	n/a
6,054	7,429	717	9,515	2,197	12,644	4,275	6,845	395	584	322	n/a	n/a	1,671	1,150	114	113	302	211	37	36	467	418	707	639	144	124	375	378	55	16	n/a	n/a	1,343	408	n/a	n/a
6,623	7,090	451	9,036	1,883	11,852	4,002	6,793	140	291	310	n/a	n/a	1,578	1,069	99	136	269	228	65	52	445	443	762	739	140	129	392	426	29	≤LOQ	n/a	n/a	982	329	n/a	n/a
7,151	7,431	473	9,429	2,314	12,034	4,445	7,091	139	340	334	n/a	n/a	1,636	1,438	108	132	255	271			431	413	651	637	140	130	357	381	64	≤LOQ	n/a	n/a	1,021	571	n/a	n/a
7,189	10,011	734	12,259	2,975	15,707	5,674	9,512	333	499	454	n/a	n/a	1,824	1,795	134	147	289	240	37	23	466	486	832	679	158	143	430	410	89	23	n/a	n/a	1,377	935	n/a	n/a
7,191	10,011	1,023	12,259	3,213	15,707	6,228	9,512	583	499	446	n/a	n/a	1,824	1,832	134	120	289	238	37	38	466	464	832	714	158	135	430	511	89	26	n/a	n/a	1,377	1,121	n/a	n/a

Figures 29 to 34 show Test 7 PFAS removal data expressed as concentration per volume treated (i.e., gallons per pound of sorbent). The data displayed on the graphs were taken from the data found in Tables 16 and 17 above.

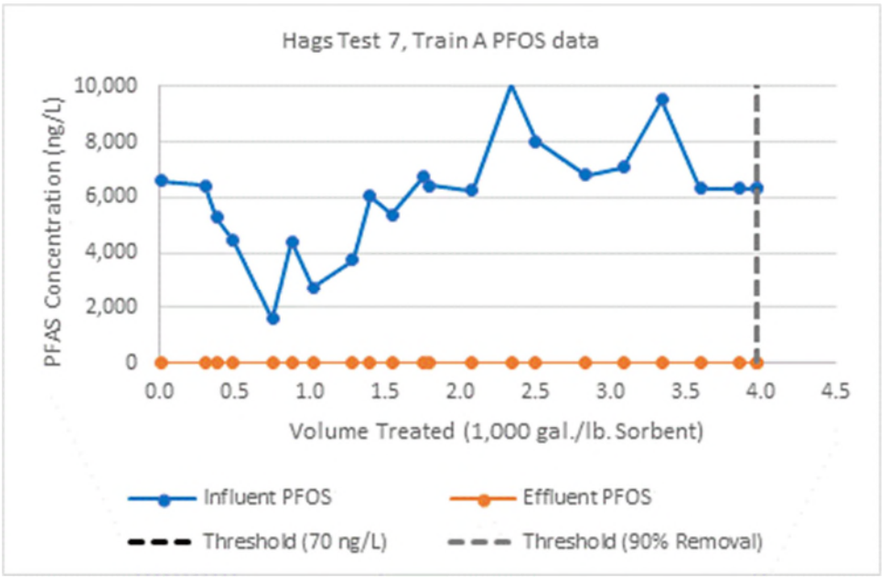

Figure 29: HAGS Test 7, Train A PFOS Data

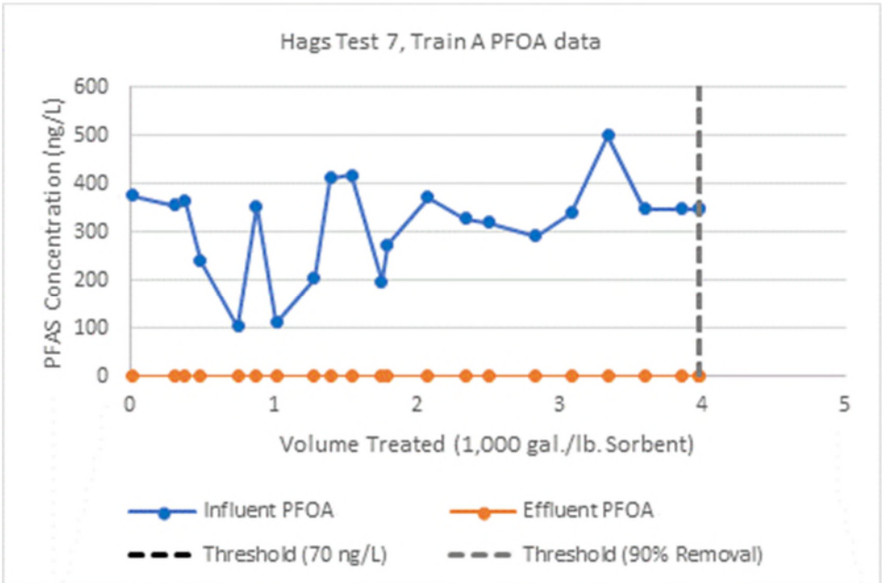

Figure 30: HAGS Test 7, Train A PFOA Data

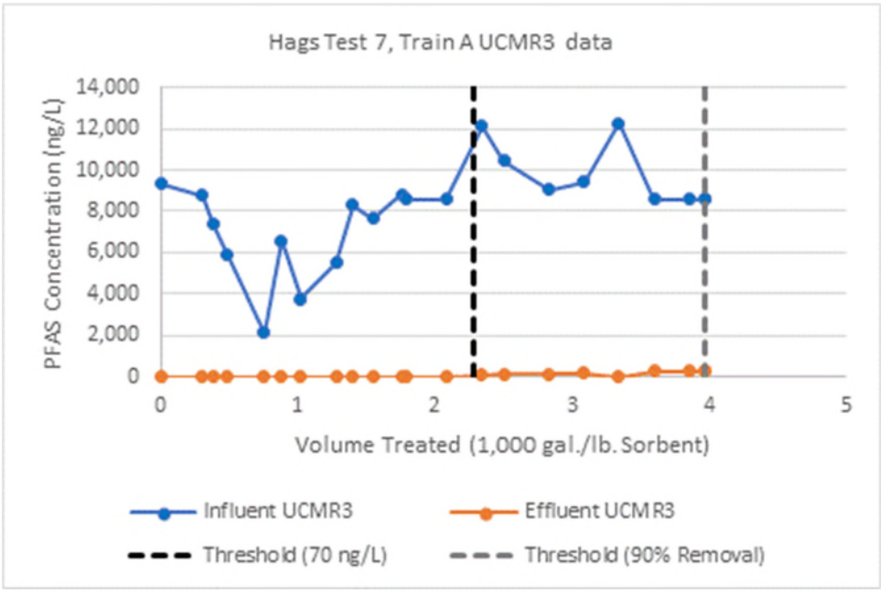

Figure 31: HAGS Test 7, Train A UCMR3 Data

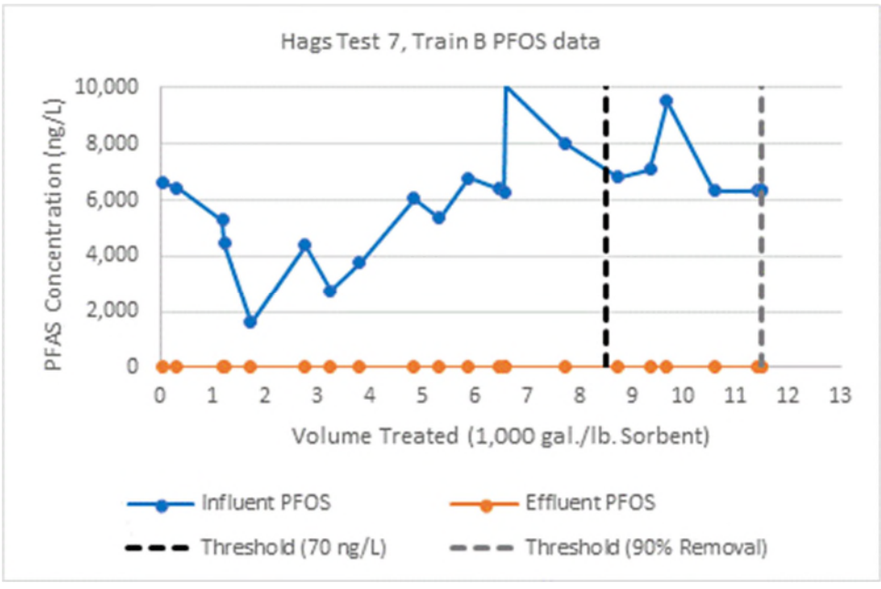

Figure 32: HAGS Test 7, Train B PFOS Data

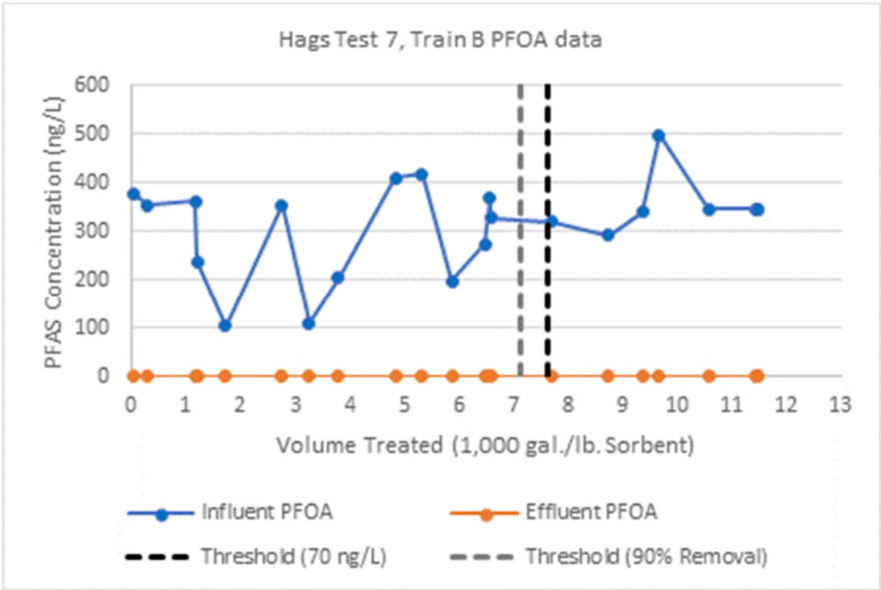

Figure 33: HAGS Test 7, Train B PFOA Data

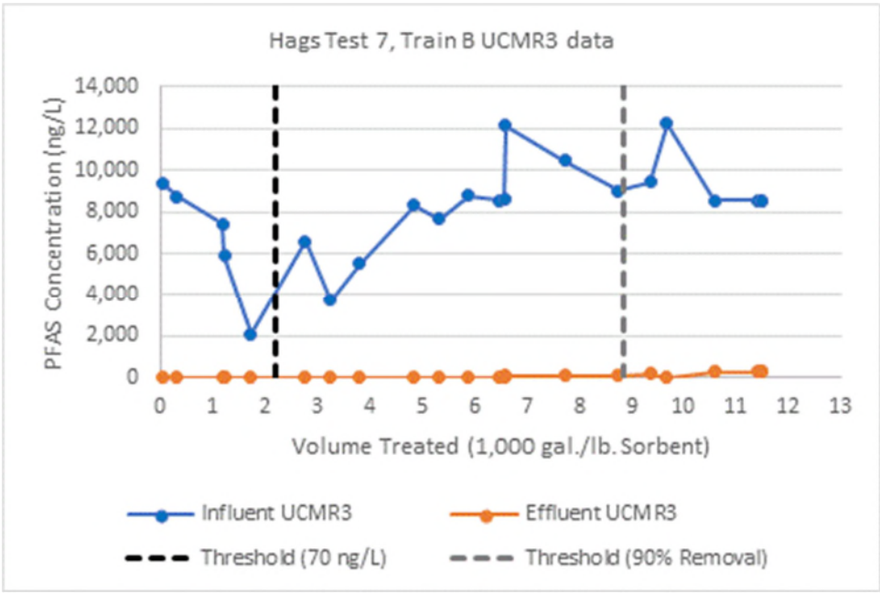

Figure 34: HAGS Test 7, Train B UCMR3 Data

8. Test 8

Test 8 was conducted from December 15, 2020, to December 18, 2020, at the HAGS test site with Trains A and B operated in parallel. The objective for Test 8 was to evaluate operation at high sorbent concentrations, with Train A at 21.25 grams per liter (g/L) and Train B at 86 g/L. However, this test was stopped early because of high feed pressure on the membrane as a result of membrane feed channel plugging (i.e., as a result of a highly concentrated sorbent level). The operating parameters are listed in Table 18.

Table 18: HAGS Test 8 Operational Parameters

Operational Parameter	Train A	Train B	Units
Membrane flux rate	100	100	Lmh
Recycle flow rate	10	10	L/minute
Permeate flow rate	1	1	L/minute
Filtration cycle duration (backwash frequency)	30	30	Minutes
Sorption reactor detention time	20	5	Minutes
Sorption reactor volume	20	5	L
Sorbent concentration	21,250	86,000	mg/L as C

Note:
Green highlighted cells on the table indicate the operating parameter that was evaluated.

No PFAS data was measured during Test 8 because of the AquaPRS operational problems, which occurred when it reached an operational limit with the high sorbent concentration.

9. Test 9

Test 9 was conducted from December 23, 2020, to January 19, 2020, at the HAGS test site with Trains A and B operated in parallel. The objective for Test 9 was to compare removals at high and low sorption concentration, with Train A at 10 g/L and Train B at 40 g/L. All other parameters were kept the same. The operating parameters are listed in Table 19. Train A operation was ended early because of a faulty valve on the recycle line rendering the test incomplete. Train B operation was not interrupted.

Table 19: HAGS Test 7 Operational Parameters

Operational Parameter	Train A	Train B	Units
Membrane flux rate	150	150	Lmh
Recycle flow rate	10	10	L/minute
Permeate flow rate	1	1	L/minute
Filtration cycle duration (backwash frequency)	15	15	Minutes
Sorption reactor detention time	20	5	Minutes
Sorption reactor volume	20	5	L
Sorbent concentration	10,000	40,000	mg/L as C

Note:
Green highlighted cells on the table indicate the operating parameter that was evaluated.

The following data tables and graphs represent the analytical data generated during Test 9 at the HAGS test site. Tables 20 and 21 list the PFAS analytical data as measured from the CSM laboratory for Trains A and B, respectively. The grey columns represent the UCMR3 compounds. The blue columns represent summed data for PFOS and PFOA, total PFAS, and the UCMR3 compounds.

Table 20: HAGS Test 9, Train A PFAS Data

Train A *Blank cells were sample error and/or 1.5x IQR. Cells in italics are either averages or values with sample error removed

	PFOA + PFOS (LOQ=6)		UCMR3		Total PFAS		PFOS (LOQ=1.0)		PFOA (LOQ=5)		PFNA (LOQ=1.0)		PFHxS		PFHpA (LOQ=1.0)		PFBS		PFBA (LOQ=1.0)		PFPeA (LOQ=1.0)		PFHxA (LOQ=1.0)		PFPrS		PFPeS		PFHpS (LOQ=1.0)		4:2 FTS (LOQ=1.0)		6:2 FTS (LOQ=1.0)		8:2 FTS (LOQ=1.0)	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
366	4,370	15	6,625	41	9,049	61	4,610	15	360	≤LOQ	n/a	n/a	1,322	12	113	≤LOQ	220	14	n/a	n/a	396	≤LOQ	506	≤LOQ	101	4	215	2	113	1	12	14	1,064	≤LOQ	17	≤LOQ
1,648	6,341	13	8,991	62	11,975	804	6,539	13	401	≤LOQ	n/a	n/a	1,637	7	140	≤LOQ	274	42	n/a	n/a	451	297	620	54	127	78	263	5	151	1	15	12	1,340	≤LOQ	16	≤LOQ
2,018	6,314	12	8,359	201	11,537	1,265	5,882	12	432	≤LOQ	n/a	n/a	1,638	26	137	17	270	146	n/a	n/a	455	293	611	357	128	82	267	27	111	≤LOQ	25	5	1,550	8	30	≤LOQ
2,029	5,482	9	7,386	193	10,336	1,215	5,052	9	430	≤LOQ	n/a	n/a	1,501	19	134	19	269	145	n/a	n/a	436	268	594	383	124	78	256	24	134	1	14	≤LOQ	1,368	≤LOQ	23	≤LOQ
2,197	5,572	51	7,641	440	10,774	1,608	5,103	15	469	35	n/a	n/a	1,637	104	143	78	290	208	n/a	n/a	497	232	645	495	132	68	306	106	90	2	15	19	1,424	15	24	≤LOQ
2,534	5,397	62	7,440	982	10,415	2,677	5,007	62	390	≤LOQ	n/a	n/a	1,612	574	133	117	298	230	n/a	n/a	515	355	664	529	136	100	276	200	110	6	34	18	1,221	131	18	≤LOQ
2,728	5,183	13	7,278	128	10,437	1,565	4,715	13	468	≤LOQ	n/a	n/a	1,658	9	136	10	302	96	n/a	n/a	471	484	653	314	138	127	277	11	104	1	25	10	1,470	5	21	≤LOQ
2,845	3,413	317	4,759	1517	6,889	3,589	3,113	83	300	234	n/a	n/a	1,036	808	112	138	198	253	n/a	n/a	411	407	518	606	104	107	177	242	78	8	23	25	809	269	10	≤LOQ

Table 21: HAGS Test 9, Train B PFAS Data

Train B *Blank cells were sample error and/or 1.5x IQR. Cells in italics are either averages or values with sample error removed

	PFOA + PFOS (LOQ=6)		UCMR3		Total PFAS		PFOS (LOQ=1.0)		PFOA (LOQ=5)		PFNA (LOQ=1.0)		PFHxS		PFHpA (LOQ=1.0)		PFBS		PFBA (LOQ=1.0)		PFPeA (LOQ=1.0)		PFHxA (LOQ=1.0)		PFPrS		PFPeS		PFHpS (LOQ=1.0)		4:2 FTS (LOQ=1.0)		6:2 FTS (LOQ=1.0)		8:2 FTS (LOQ=1.0)	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
369	4,370	16	6,625	43	9,049	162	4,610	16	360	≤LOQ	n/a	n/a	1,322	8	113	5	220	14	n/a	n/a	396	72	506	12	101	23	215	3	113	1	12	≤LOQ	1,064	8	17	≤LOQ
1,643	6,341	11	8,991	44	11,975	412	6,539	11	401	≤LOQ	n/a	n/a	1,637	10	140	≤LOQ	274	23	n/a	n/a	451	289	620	13	127	61	263	3	151	1	15	≤LOQ	1,340	≤LOQ	16	≤LOQ
2,014	6,314	13	8,359	69	11,537	733	5,882	13	432	≤LOQ	n/a	n/a	1,638	10	137	≤LOQ	270	46	n/a	n/a	455	465	611	65	128	111	267	5	111	1	25	17	1,550	≤LOQ	30	≤LOQ
2,015	5,482	17	7,386	72	10,336	812	5,052	17	430	≤LOQ	n/a	n/a	1,501	7	134	≤LOQ	269	49	n/a	n/a	436	520	594	78	124	125	256	5	134	1	14	10	1,368	≤LOQ	23	≤LOQ
2,025	5,451	18	7,459	75	10,577	809	5,075	18	376	≤LOQ	n/a	n/a	1,584	7	140	≤LOQ	285	49	n/a	n/a	476	503	652	85	134	121	266	5	133	1	16	20	1,421	≤LOQ	20	≤LOQ
2,163	5,572	17	7,641	108	10,774	1,139	5,103	17	469	≤LOQ	n/a	n/a	1,637	10	143	7	290	75	n/a	n/a	497	738	645	184	132	151	306	9	90	1	15	8	1,424	≤LOQ	24	≤LOQ
2,451	5,397	14	7,440	100	10,415	912	5,007	14	390	≤LOQ	n/a	n/a	1,612	10	133	7	298	69	n/a	n/a	515	491	664	178	136	115	276	8	110	1	34	15	1,221	5	18	≤LOQ
2,452	1,593	19	2,441	99	3,831	856	1,404	19	189	≤LOQ	n/a	n/a	631	8	72	6	145	66	n/a	n/a	251	469	326	166	72	107	122	8	42	1	11	7	558	≤LOQ	9	≤LOQ
3,816	6,518	7	8,521	223	11,721	1,354	6,133	7	385	≤LOQ	n/a	n/a	1,591	22	136	23	275	172	n/a	n/a	470	422	659	539	127	121	259	32	134	1	13	10	1,507	5	32	≤LOQ
4,012	6,068	15	8,068	240	10,953	1,339	5,622	15	445	≤LOQ	n/a	n/a	1,592	23	136	21	272	174	n/a	n/a	486	436	617	504	129	118	271	31	96	1	17	9	1,251	≤LOQ	17	≤LOQ
5,349	5,183	9	7,278	288	10,437	1,505	4,715	9	468	≤LOQ	n/a	n/a	1,658	39	136	32	302	207	n/a	n/a	471	431	653	600	138	117	277	44	104	1	25	25	1,470	≤LOQ	21	≤LOQ
5,886	5,691	9	7,692	376	10,712	1,654	*5,276*	9	*416*	≤LOQ	n/a	n/a	*1,591*	56	*135*	50	*274*	262	n/a	n/a	*456*	417	*632*	653	*127*	122	*365*	67	*106*	1	*16*	9	*1,395*	9	*21*	≤LOQ
5,889	5,691	52	7,692	464	10,712	1,738	*5,276*	18	*416*	35	n/a	n/a	*1,591*	90	*135*	64	*274*	258	n/a	n/a	*456*	383	*632*	643	*127*	117	*365*	84	*106*	2	*16*	22	*1,395*	23	*21*	≤LOQ
5,915	6,390	43	9,056	636	12,188	2,847	6,516	13	473	30	n/a	n/a	1,652	95	135	76	280	421	n/a	n/a	442	745	645	1,112	130	205	271	106	104	2	33	21	1,458	21	49	≤LOQ
6,723	5,691	84	7,692	679	10,712	2,214	*5,276*	18	*416*	66	n/a	n/a	*1,591*	169	*135*	102	*274*	324	n/a	n/a	*456*	459	*632*	728	*127*	133	*365*	145	*106*	3	*16*	23	*1,395*	45	*21*	≤LOQ
7,030	6,454	103	8,490	778	11,653	2,286	5,987	12	466	91	n/a	n/a	1,619	250	139	118	278	306	n/a	n/a	456	445	715	668	125	125	268	179	113	4	18	30	1,443	57	25	≤LOQ
7,287	6,678	150	8,743	976	11,971	2,651	6,206	25	472	125	n/a	n/a	1,649	346	140	140	277	341	n/a	n/a	488	454	694	741	130	132	266	240	113	5	25	29	1,487	73	26	≤LOQ
7,309	5,691	127	7,692	946	10,712	2,522	*5,276*	23	*416*	104	n/a	n/a	*1,591*	370	*135*	142	*274*	307	n/a	n/a	*456*	435	*632*	667	*127*	129	*365*	245	*106*	4	*16*	23	*1,395*	72	*21*	≤LOQ
8,536	5,691	309	7,692	1,381	10,712	3,053	*5,276*	107	*416*	202	n/a	n/a	*1,591*	612	*135*	152	*274*	309	n/a	n/a	*456*	412	*632*	652	*127*	130	*365*	283	*106*	14	*16*	28	*1,395*	154	*21*	≤LOQ
9,166	5,691	472	7,692	1,840	10,712	3,213	*5,276*	140	*416*	332	n/a	n/a	*1,591*	987	*135*	164	*274*	217	n/a	n/a	*456*	220	*632*	432	*127*	68	*365*	320	*106*	24	*16*	17	*1,395*	291	*21*	≤LOQ
9,776	5,691	356	7,692	1,680	10,712	3,162	*5,276*	69	*416*	287	n/a	n/a	*1,591*	964	*135*	133	*274*	227	n/a	n/a	*456*	314	*632*	488	*127*	93	*365*	260	*106*	18	*16*	12	*1,395*	297	*21*	≤LOQ
10,373	6,012	412	8,010	1,642	11,147	3,360	5,545	172	467	240	n/a	n/a	1,591	841	133	121	273	268	n/a	n/a	481	391	676	603	128	119	265	271	107	22	14	23	1,442	289	25	≤LOQ
10,970	5,691	396	7,692	2,876	10,712	5,108	*5,276*	544	*416*	451	n/a	n/a	*1,591*	1,439	*135*	144	*274*	298	n/a	n/a	*456*	430	*632*	650	*127*	133	*365*	293	*106*	61	*16*	17	*1,395*	648	*21*	≤LOQ
11,346	5,691	1,347	7,692	3,506	10,712	6,008	*5,276*	814	*416*	534	n/a	n/a	*1,591*	1,712	*135*	156	*274*	291	n/a	n/a	*456*	466	*632*	632	*127*	134	*365*	294	*106*	52	*16*	21	*1,395*	902	*21*	≤LOQ
11,355	5,691	1,784	7,692	4,088	10,712	6,687	*5,276*	1,146	*416*	637	n/a	n/a	*1,591*	1,858	*135*	154	*274*	292	n/a	n/a	*456*	461	*632*	656	*127*	130	*365*	301	*106*	66	*16*	24	*1,395*	961	*21*	≤LOQ

Figures 35 to 40 show Test 9 PFAS removal data expressed as concentration per volume treated (i.e., gallons per pound of sorbent). The data displayed on the graphs were taken from the data found in Tables 20 and 21 above.

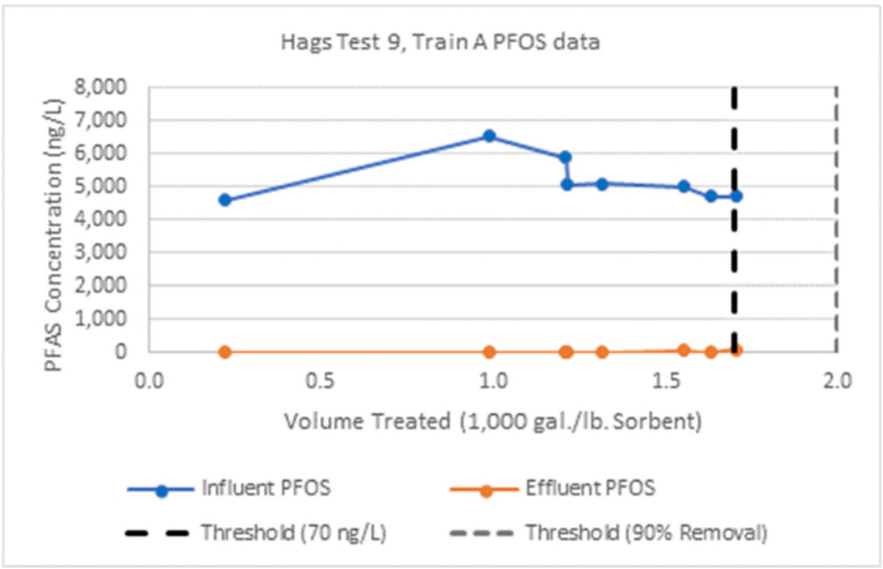

Figure 35: HAGS Test 9, Train A PFOS Data

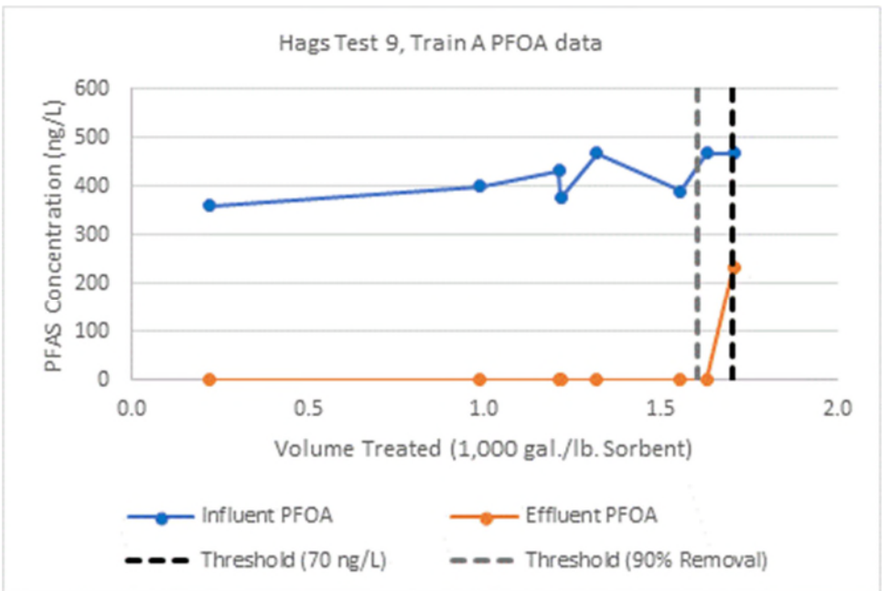

Figure 36: HAGS Test 9, Train A PFOA Data

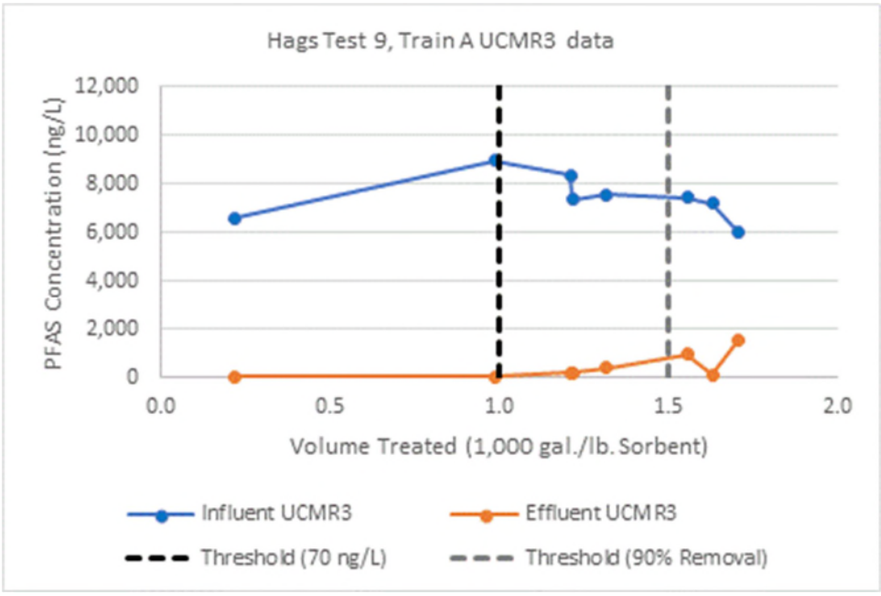

Figure 37: HAGS Test 9, Train A UCMR3 Data

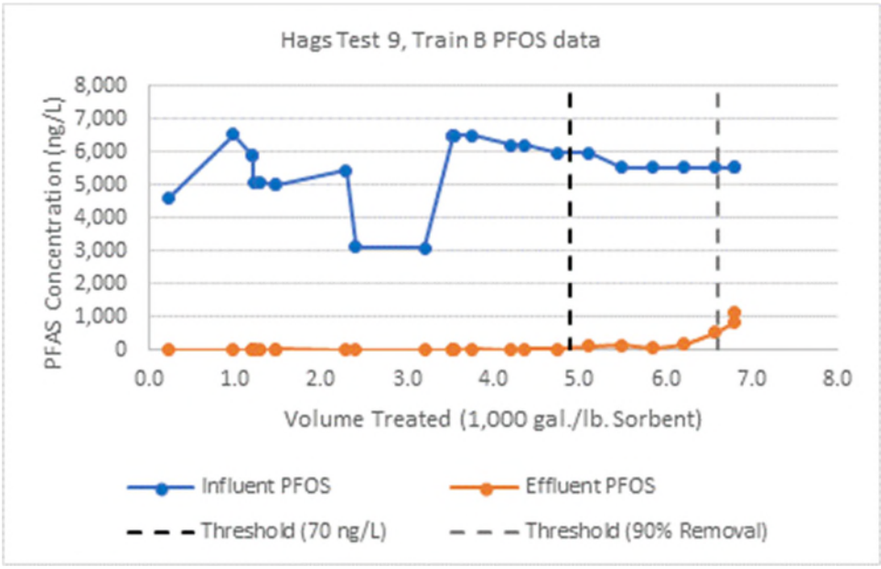

Figure 38: HAGS Test 9, Train B PFOS Data

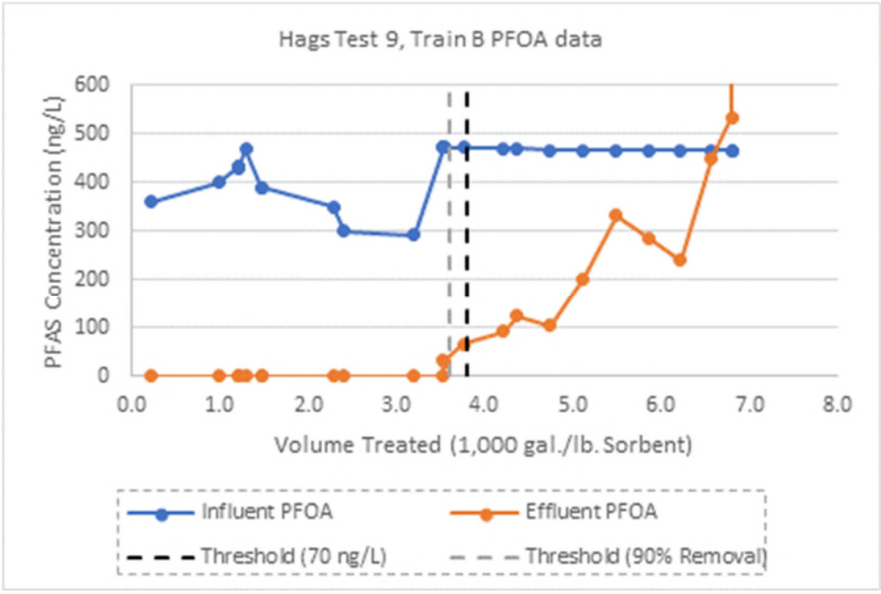

Figure 39: HAGS Test 9, Train B PFOA Data

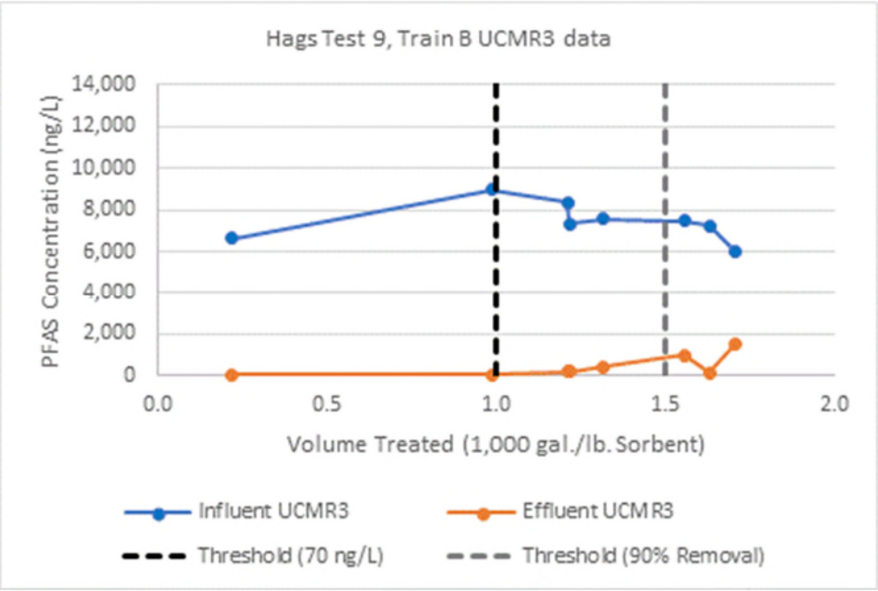

Figure 40: HAGS Test 9, Train B UCMR3 Data

10. Test 10

Test 10 was conducted from January 21, 2021, to February 2, 2021, at the HAGS test site with Trains A and B operated in parallel. The objective for Test 10 (a repeat of Test 9) was to compare removals at high and low sorption concentration, with Train A at 10 g/L and Train B at 40 g/L. All other parameters were kept the same. The operating parameters are listed in Table 22.

Table 22: HAGS Test 10 Operational Parameters

Operational Parameter	Train A	Train B	Units
Membrane flux rate	150	150	Lmh
Recycle flow rate	10	10	L/minute
Permeate flow rate	1	1	L/minute
Filtration cycle duration (backwash frequency)	15	15	Minutes
Sorption reactor detention time	20	5	Minutes
Sorption reactor volume	20	5	L
Sorbent concentration	10,000	40,000	mg/L as C

Note:
Green highlighted cells on the table indicate the operating parameter that was evaluated.

The following data tables and graphs represent the analytical data generated during Test 10 at the HAGS test site. Tables 23 and 24 list the PFAS analytical data as measured from the CSM laboratory for Trains A and B, respectively. The grey columns represent the UCMR3 compounds. The blue columns represent summed data for PFOS and PFOA, total PFAS, and the UCMR3 compounds.

Table 23: HAGS Test 10, Train A PFAS Data

Train A *Blank cells were sample error and/or 1.5xIQR. Cells in italics are either averages or values with sample error removed

	PFOA + PFOS (LOQ=2)		UCMR3		Total PFAS		PFOS (LOQ=1.0)		PFOA (LOQ=1.0)		PFNA (LOQ=1.0)		PFHxS (LOQ=1.0)		PFHpA (LOQ=1.0)		PFBS		PFBA (LOQ=1.0)		PFPeA (LOQ=1.0)		PFHxA (LOQ=2)		PFPrS (LOQ=1.0)		PFPeS		PFHpS (LOQ=1.0)		4:2 FTS (LOQ=1.0)		6:2 FTS (LOQ=1.0)		8:2 FTS (LOQ=1.0)	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
20	6,626		8,748		12,047		6,138		488	≤LOQ	n/a	n/a	1,689	5	139	≤LOQ	294	5	n/a	n/a	462	≤LOQ	632	≤LOQ	143	≤LOQ	297	1	141	1	34	≤LOQ	1,624	11	54	≤LOQ
32	5,681		7,819		10,940		*5,212*		*469*	≤LOQ	n/a	n/a	*1,696*	56	*144*	3	*339*	18	n/a	n/a	*459*	≤LOQ	*647*	15	*143*	6	*332*	12	*125*	4	*26*	12	*1,457*	31	*40*	≤LOQ
775	5,681	14	7,819	30	10,940	213	*5,212*	14	*469*	≤LOQ	n/a	n/a	*1,696*	6	*144*	≤LOQ	*339*	11	n/a	n/a	*459*	125	*647*	18	*143*	30	*332*	2	*125*	≤LOQ	*26*	13	*1,457*	≤LOQ	*40*	≤LOQ
2,044	5,681	14	7,819	43	10,940	409	*5,212*	14	*469*	≤LOQ	n/a	n/a	*1,696*	5	*144*	6	*339*	19	n/a	n/a	*459*	270	*647*	37	*143*	57	*332*	2	*125*	≤LOQ	*26*	≤LOQ	*1,457*	≤LOQ	*40*	≤LOQ
3,346	5,681	9	7,819	45	10,940	659	*5,212*	9	*469*	≤LOQ	n/a	n/a	*1,696*	≤LOQ	*144*	≤LOQ	*339*	36	n/a	n/a	*459*	449	*647*	56	*143*	99	*332*	4	*125*	≤LOQ	*26*	6	*1,457*	≤LOQ	*40*	≤LOQ
4,618	5,681	10	7,819	85	10,940	934	*5,212*	10	*469*	≤LOQ	n/a	n/a	*1,696*	8	*144*	≤LOQ	*339*	68	n/a	n/a	*459*	548	*647*	195	*143*	141	*332*	9	*125*	≤LOQ	*26*	17	*1,457*	≤LOQ	*40*	≤LOQ
5,903	5,681	10	7,819	144	10,940	1,169	*5,212*	10	*469*	≤LOQ	n/a	n/a	*1,696*	17	*144*	11	*339*	106	n/a	n/a	*459*	542	*647*	311	*143*	153	*332*	15	*125*	≤LOQ	*26*	8	*1,457*	5	*40*	≤LOQ
7,197	5,681	8	7,819	201	10,940	1,302	*5,212*	8	*469*	≤LOQ	n/a	n/a	*1,696*	19	*144*	16	*339*	157	n/a	n/a	*459*	429	*647*	484	*143*	146	*332*	23	*125*	≤LOQ	*26*	18	*1,457*	≤LOQ	*40*	≤LOQ
7,810	5,681	5	7,819	241	10,940	1,516	*5,212*	5	*469*	≤LOQ	n/a	n/a	*1,696*	24	*144*	21	*339*	191	n/a	n/a	*459*	520	*647*	551	*143*	149	*332*	31	*125*	≤LOQ	19	19	*1,457*	5	25	≤LOQ
9,206	5,571	8	7,712	294	10,929	1,672	5,112	8	459	≤LOQ	n/a	n/a	1,698	39	143	31	300	216	n/a	n/a	435	518	656	657	140	144	294	43	146	≤LOQ	12	16	1,486	16	17	≤LOQ
10,480	5,107	8	7,242	339	10,332	1,741	4,638	8	463	≤LOQ	n/a	n/a	1,634	51	144	40	297	240	n/a	n/a	448	487	681	707	142	147	289	52	112	≤LOQ	19	8	1,418	≤LOQ	19	≤LOQ
11,774	5,781	36	7,951	459	11,066	2,018	5,312	12	463	25	n/a	n/a	1,726	76	143	55	301	232	n/a	n/a	465	506	637	811	143	160	288	73	111	2	27	9	1,471	18	23	≤LOQ
13,066	5,895	50	8,158	514	11,238	1,962	5,394	11	501	39	n/a	n/a	1,814	101	149	61	300	302	n/a	n/a	455	428	678	770	146	149	302	91	116	2	17	10	1,443	19	30	≤LOQ
14,354	4,846	61	6,360	598	9,377	2,176	4,465	8	381	53	n/a	n/a	1,666	140	151	77	297	320	n/a	n/a	440	482	631	803	143	152	281	112	133	2	*17*	28	1,389	28	*40*	≤LOQ
15,541	5,681	88	7,819	729	10,940	2,333	*5,212*	9	*469*	79	n/a	n/a	*1,696*	137	*144*	92	*339*	352	n/a	n/a	*459*	468	*647*	802	*143*	157	*332*	166	*125*	3	*17*	17	*1,457*	52	*40*	≤LOQ

Table 24: HAGS Test 10, Train B PFAS Data

Train B *Blank cells were sample error and/or 1.5xIQR. Cells in italics are either averages or values with sample error removed

	PFOA + PFOS (LOQ=2)		UCMR3		Total PFAS		PFOS (LOQ=1.0)		PFOA (LOQ=1.0)		PFNA (LOQ=1.0)		PFHxS (LOQ=1.0)		PFHpA (LOQ=1.0)		PFBS		PFBA (LOQ=1.0)		PFPeA (LOQ=1.0)		PFHxA (LOQ=2)		PFPrS (LOQ=1.0)		PFPeS		PFHpS (LOQ=1.0)		4:2 FTS (LOQ=1.0)		6:2 FTS (LOQ=1.0)		8:2 FTS (LOQ=1.0)	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
12	6,626	≤LOQ	8,748	14	12,047	41	6,138	≤LOQ	488	≤LOQ	n/a	n/a	1,689	7	139	≤LOQ	294	7	n/a	n/a	462	≤LOQ	632	≤LOQ	143	≤LOQ	297	1	141	1	34	5	1,624	20	54	≤LOQ
722	5,681		7,819		10,940		*5,212*		*469*	≤LOQ	n/a	n/a	*1,696*		*144*	5	*339*	10	n/a	n/a	*459*	11	*647*	26	*143*	12	*332*	3	*125*	≤LOQ	*26*	≤LOQ	*1,457*	11	*40*	≤LOQ
1,045	5,681	≤LOQ	7,819	11	10,940	185	*5,212*	≤LOQ	*469*	≤LOQ	n/a	n/a	*1,696*	≤LOQ	*144*	≤LOQ	*339*	11	n/a	n/a	*459*	135	*647*	≤LOQ	*143*	31	*332*	1	*125*	≤LOQ	*26*	≤LOQ	*1,457*	7	*40*	≤LOQ
2,622	5,681	10	7,819	55	10,940	754	*5,212*	10	*469*	≤LOQ	n/a	n/a	*1,696*	≤LOQ	*144*	≤LOQ	*339*	46	n/a	n/a	*459*	482	*647*	83	*143*	118	*332*	5	*125*	≤LOQ	*26*	12	*1,457*	≤LOQ	*40*	≤LOQ
3,875	5,681	9	7,819	129	10,940	1,244	*5,212*	9	*469*	≤LOQ	n/a	n/a	*1,696*	7	*144*	8	*339*	105	n/a	n/a	*459*	620	*647*	312	*143*	163	*332*	14	*125*	≤LOQ	*26*	≤LOQ	*1,457*	7	*40*	≤LOQ
5,140	5,681	8	7,819	240	10,940	1,567	*5,212*	8	*469*	≤LOQ	n/a	n/a	*1,696*	30	*144*	19	*339*	184	n/a	n/a	*459*	591	*647*	515	*143*	160	*332*	32	*125*	≤LOQ	*26*	14	*1,457*	15	*40*	≤LOQ
6,412	5,681	49	7,819	503	10,940	2,018	*5,212*	16	*469*	33	n/a	n/a	*1,696*	89	*144*	53	*339*	312	n/a	n/a	*459*	352	*647*	919	*143*	127	*332*	82	*125*	2	*26*	14	*1,457*	18	*40*	≤LOQ
7,680	5,681	107	7,819	689	10,940	2,334	*5,212*	27	*469*	81	n/a	n/a	*1,696*	135	*144*	102	*339*	345	n/a	n/a	*459*	444	*647*	816	*143*	139	*332*	151	*125*	5	*26*	38	*1,457*	50	*40*	≤LOQ
8,312	5,571	96	7,712	885	10,929	2,698	5,112	23	459	73	n/a	n/a	1,698	308	143	125	300	355	n/a	n/a	435	550	656	829	140	152	294	189	146	6	19	32	1,486	55	25	≤LOQ
9,622	5,107	242	7,242	1,220	10,332	2,934	4,638	53	463	189	n/a	n/a	1,634	518	144	146	297	316	n/a	n/a	448	463	681	702	142	145	289	226	112	10	12	31	1,418	136	17	≤LOQ
10,873	5,781	440	7,351	1,816	11,066	3,842	5,312	190	469	250	n/a	n/a	1,726	899	143	155	301	322	n/a	n/a	465	500	637	694	143	152	288	286	111	30	19	33	1,471	331	19	≤LOQ
12,130	5,895	596	8,158	2,287	11,238	4,444	5,394	225	501	371	n/a	n/a	1,814	1,210	149	157	300	324	n/a	n/a	455	461	678	697	146	148	302	307	116	17	27	17	1,443	511	23	≤LOQ
13,368	4,846	1,153	6,360	3,145	9,377	5,744	4,465	754	381	393	n/a	n/a	1,666	1,514	151	155	297	323	n/a	n/a	440	471	631	706	143	148	281	320	133	75	17	22	1,389	857	30	≤LOQ
14,601	5,681	985	7,819	3,158	10,940	5,893	*5,212*	533	*469*	386	n/a	n/a	*1,696*	1,690	*144*	161	*339*	322	n/a	n/a	*459*	454	*647*	694	*143*	155	*332*	327	*125*	65	*17*	40	*1,457*	1,001	*40*	≤LOQ

Figures 41 to 46 show Test 10 PFAS removal data expressed as concentration per volume treated (i.e., gallons per pound of sorbent). The data displayed on the graphs were taken from the data found in Tables 23 and 24 above.

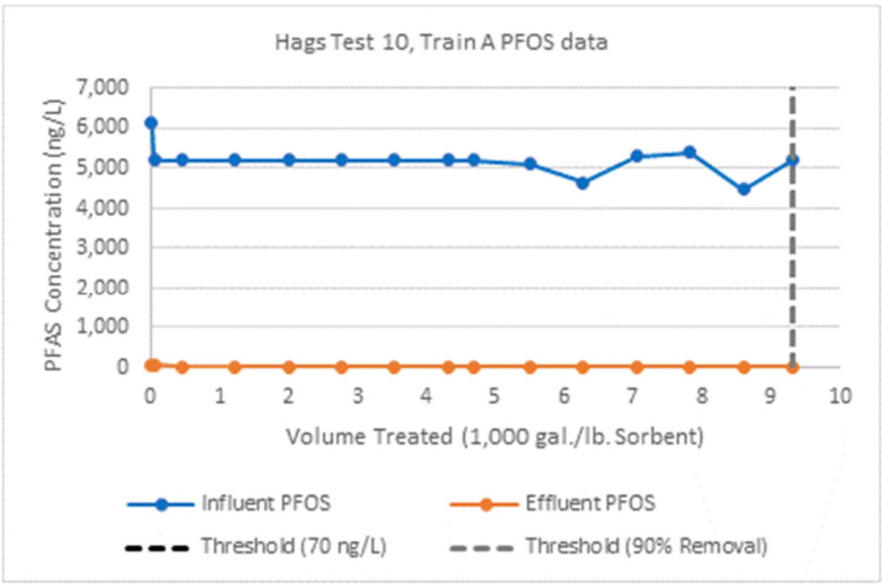

Figure 41: HAGS Test 10, Train A PFOS Data

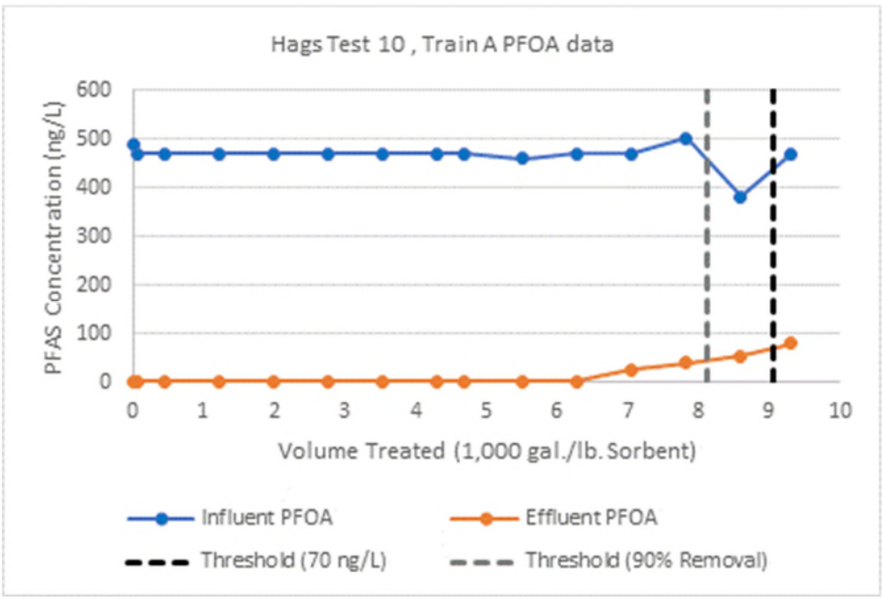

Figure 42: HAGS Test 10, Train A PFOA Data

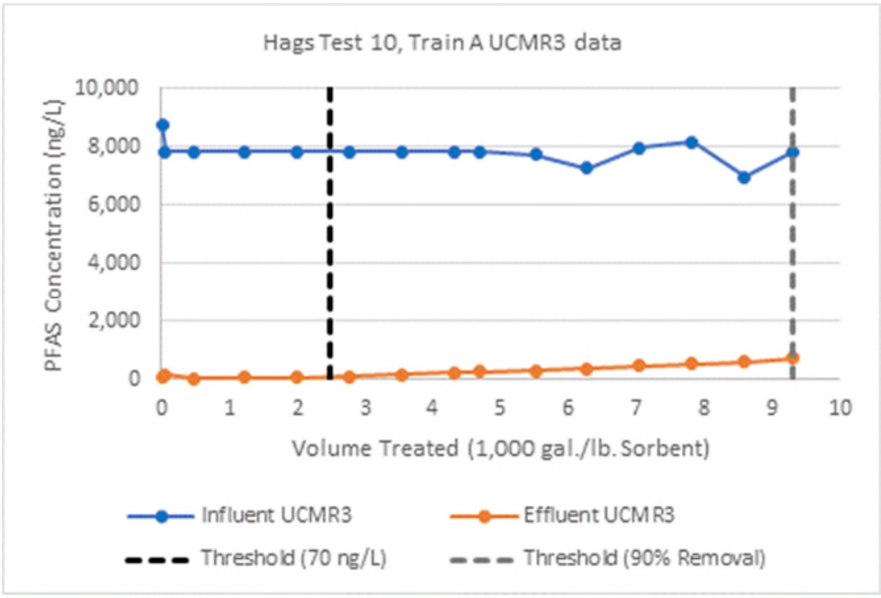

Figure 43: HAGS Test 10, Train A UCMR3 Data

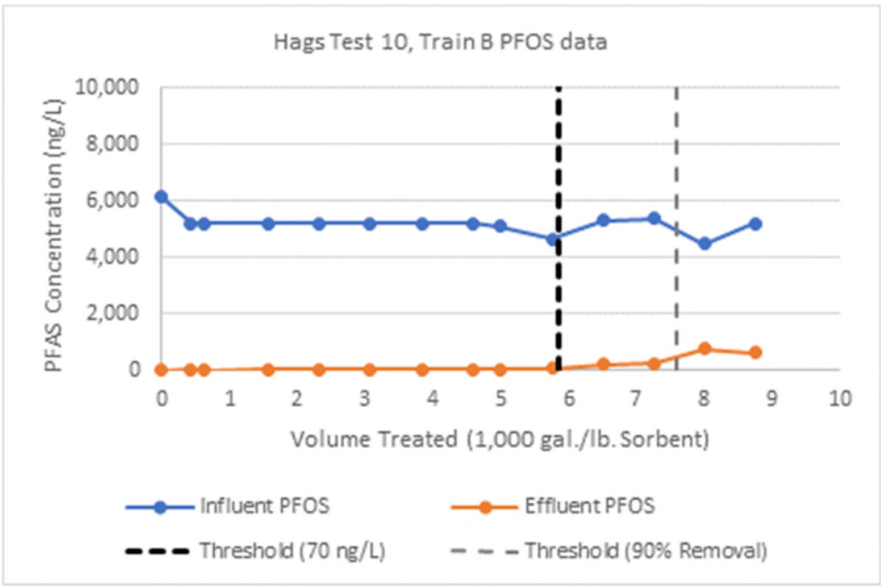

Figure 44: HAGS Test 10, Train B PFOS Data

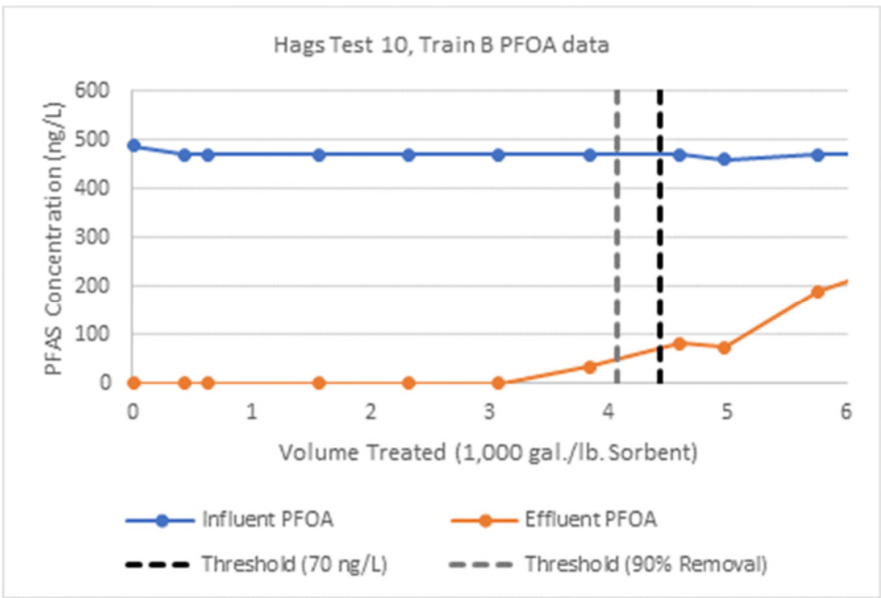

Figure 45: HAGS Test 10, Train B PFOA Data

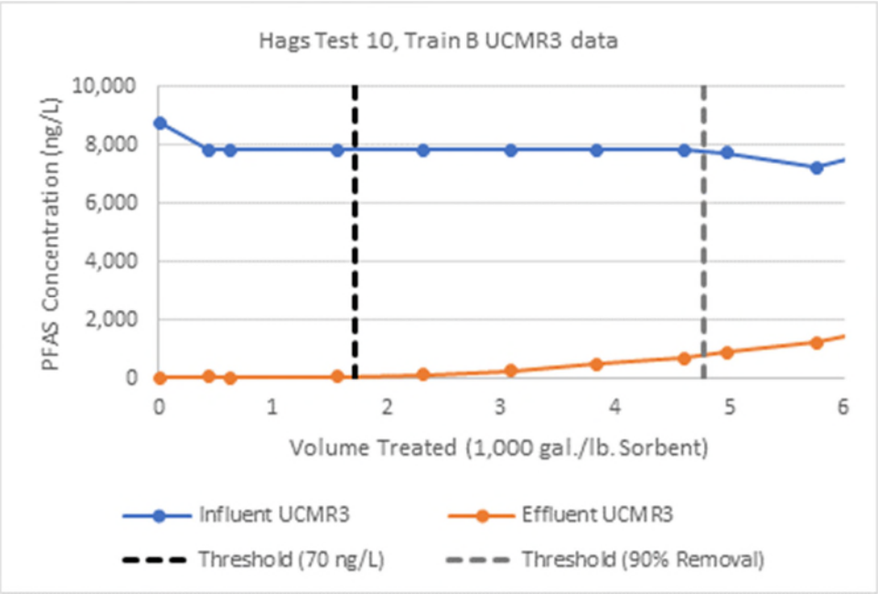

Figure 46: HAGS Test 10, Train B UCMR3 Data

11. Test 11

Test 11 was conducted from February 4, 2021, to February 20, 2021, at the HAGS test site with Trains A and B operated in series (i.e., Train A was the lead position, and Train B was the lag position). The objective for Test 11 was to evaluate PFAS removals when operating the AquaPRS in series (i.e., effluent from Train A was fed to Train B). The operating parameters are listed in Table 25.

Table 25: HAGS Test 11 Operational Parameters

Operational Parameter	Train A (lead, fresh sorbent)	Train B (lag, fresh sorbent)	Units
Membrane flux rate	150	100	Lmh
Recycle flow rate	10	6.7	L/minute
Permeate flow rate	1	0.67	L/minute
Filtration cycle duration (backwash frequency)	15	20	Minutes
Sorption reactor detention time	5	7.5	Minutes
Sorption reactor volume	5	5	L

Note:
Green highlighted cells on the table indicate the operating parameter that was evaluated.

The following data tables and graphs represent the analytical data generated during Test 11 at the HAGS test site. Tables 26 and 27 list the PFAS analytical data as measured from the CSM laboratory for Trains A and B, respectively. The grey columns represent the UCMR3 compounds. The blue columns represent summed data for PFOS and PFOA, total PFAS, and the UCMR3 compounds.

Table 26: HAGS Test 11, Train A (Lead Position) PFAS Data

*Blank cells were sample error and/or 1.5x10R. Cells in italics are either averages or values with sample error removed

Train A ***Other = sum of GenX, 4:2 FTS, 8:2 FTS, PFOSA, PFDA)

	PFOA + PFOS		UCMR3		Total PFAS		PFOS		PFOA (LOQ=3.5)		PFNA (LOQ=3.5)		PFHxS		PFHpA (LOQ=3.5)		PFBS		PFBA		PFPeA		PFHxA		PFPrS (LOQ=3.5)		PFPeS (LOQ=3.5)		PFHpS (LOQ=3.5)		4:2 FTS		6:2 FTS (LOQ=7)		***Other (LOQ=7)	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
183	3,430	10	4,800	31	6,931	101	3,100	5.4	330	4	13	≤LOQ	1,000	7	110	4	200	11	120	18	350	23	490	25	n/a	n/a	180	4	81	≤LOQ	n/a	n/a	320	≤LOQ	50	≤LOQ
2,806	1,870	2	2,614	12	3,640	335	1,700	1.5	170	≤LOQ	7	≤LOQ	530	1	58	≤LOQ	36	10	61	66	180	220	230	35	n/a	n/a	85	≤LOQ	41	≤LOQ	n/a	n/a	400	≤LOQ	29	2
5,276	2,130	3	3,022	52	4,270	540	1,900	1.2	230	1.7	8	≤LOQ	700	5	72	4	120	41	73	71	210	270	270	140	n/a	n/a	110	4	46	≤LOQ	n/a	n/a	520	≤LOQ	19	3
7,415	3,030	6	4,245	117	5,934	791	2,700	1.6	330	4.6	11	≤LOQ	360	13	35	10	160	88	39	81	280	300	400	280	n/a	n/a	150	10	69	≤LOQ	n/a	n/a	720	≤LOQ	31	3
10,028	3,130	38	4,393	297	6,166	1,279	2,800	11	330	27	11	≤LOQ	1,000	53	33	36	170	170	39	100	300	360	420	470	n/a	n/a	150	40	63	≤LOQ	n/a	n/a	710	6	31	6
12,452	3,100	75	4,249	451	5,839	1,345	2,800	26	300	49	11	≤LOQ	300	120	89	66	160	130	94	88	270	230	360	430	n/a	n/a	140	66	60	≤LOQ	n/a	n/a	700	15	26	5

Table 27: HAGS Test 11, Train B (Lag Position) PFAS Data

*Blank cells were sample error and/or 1.5x10R. Cells in italics are either averages or values with sample error removed

Train B ***Other = sum of GenX, 4:2 FTS, 8:2 FTS, PFOSA, PFDA)

	PFOA + PFOS (LOQ=7)		UCMR3 (LOQ=21)		Total PFAS (LOQ=63)		PFOS (LOQ=3.5)		PFOA (LOQ=3.5)		PFNA (LOQ=3.5)		PFHxS (LOQ=3.5)		PFHpA (LOQ=3.5)		PFBS (LOQ=3.5)		PFBA (LOQ=3.5)		PFPeA (LOQ=3.5)		PFHxA (LOQ=3.5)		PFPrS (LOQ=3.5)		PFPeS (LOQ=3.5)		PFHpS (LOQ=3.5)		4:2 FTS		6:2 FTS (LOQ=7)		Other (LOQ=7)	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
75	10	≤LOQ	31	≤LOQ	101	≤LOQ	5.4	≤LOQ	4	≤LOQ	≤LOQ	≤LOQ	7	≤LOQ	4	≤LOQ	11	≤LOQ	18	≤LOQ	23	≤LOQ	25	≤LOQ	n/a	n/a	4	≤LOQ	≤LOQ	≤LOQ	n/a	n/a	≤LOQ	≤LOQ	≤LOQ	≤LOQ
1,739	1.5	4.2	12	5.8	335	110	1.5	4.2	≤LOQ	≤LOQ	≤LOQ	≤LOQ	1	1.6	≤LOQ	≤LOQ	10	≤LOQ	66	81	220	20	35	≤LOQ	n/a	n/a	≤LOQ	≤LOQ	≤LOQ	≤LOQ	n/a	n/a	≤LOQ	3.4	2	≤LOQ
3,236	2.9	2.9	52	4.3	540	239	1.2	2.9	2	≤LOQ	≤LOQ	≤LOQ	5	≤LOQ	4	≤LOQ	41	1.4	71	90	270	140	140	4.2	n/a	n/a	4	≤LOQ	≤LOQ	≤LOQ	n/a	n/a	≤LOQ	≤LOQ	3	≤LOQ
4,417	6.2	2.9	117	8.1	791	379	1.6	2.9	5	≤LOQ	≤LOQ	≤LOQ	13	1.1	10	≤LOQ	88	4.1	81	83	300	270	280	18	n/a	n/a	10	≤LOQ	≤LOQ	≤LOQ	n/a	n/a	≤LOQ	≤LOQ	3	≤LOQ
6,013	38	20	297	48	1,279	630	11	17	27	2.8	≤LOQ	≤LOQ	53	4.6	36	≤LOQ	170	24	100	96	360	370	470	110	n/a	n/a	40	≤LOQ	≤LOQ	≤LOQ	n/a	n/a	6	3.2	6	2.2
7,242	75	8	451	78	1,345	812	26	5	49	2.3	≤LOQ	≤LOQ	120	2.6	66	1.8	130	66	88	100	230	360	430	270	n/a	n/a	66	1.8	≤LOQ	≤LOQ	n/a	n/a	15	≤LOQ	5	2.1

Figures 47 to 52 show Test 11 PFAS removal data expressed as concentration per volume treated (i.e., gallons per pound of sorbent). The data displayed on the graphs were taken from the data found in Tables 26 and 27 above.

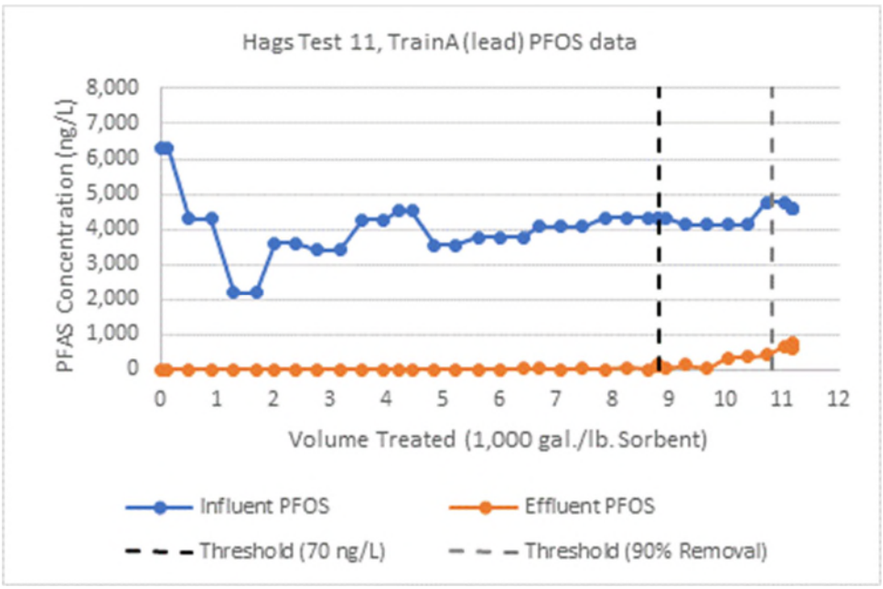

Figure 47: HAGS Test 11, Train A (Lead) PFOS Data

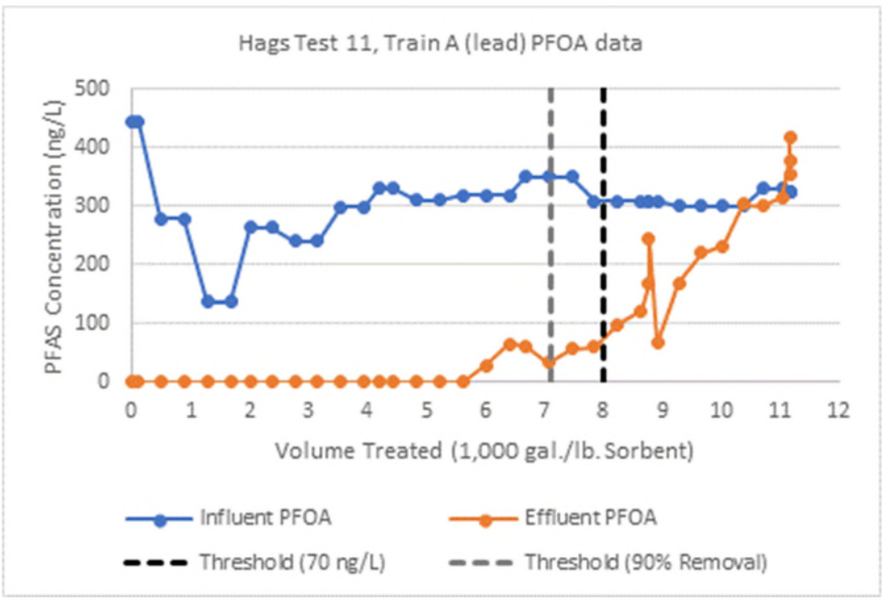

Figure 48: HAGS Test 11, Train A (Lead) PFOA Data

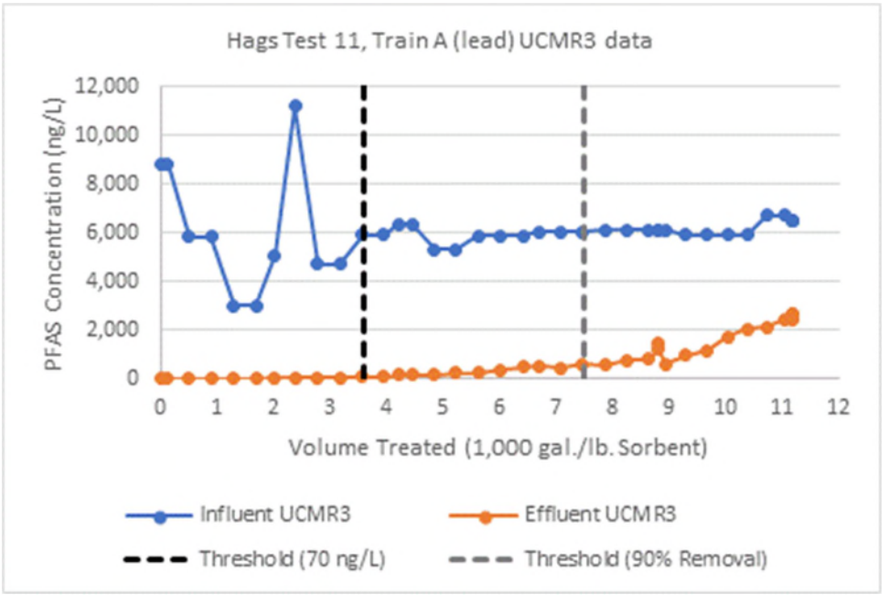

Figure 49: HAGS Test 11, Train A (Lead) UCMR3 Data

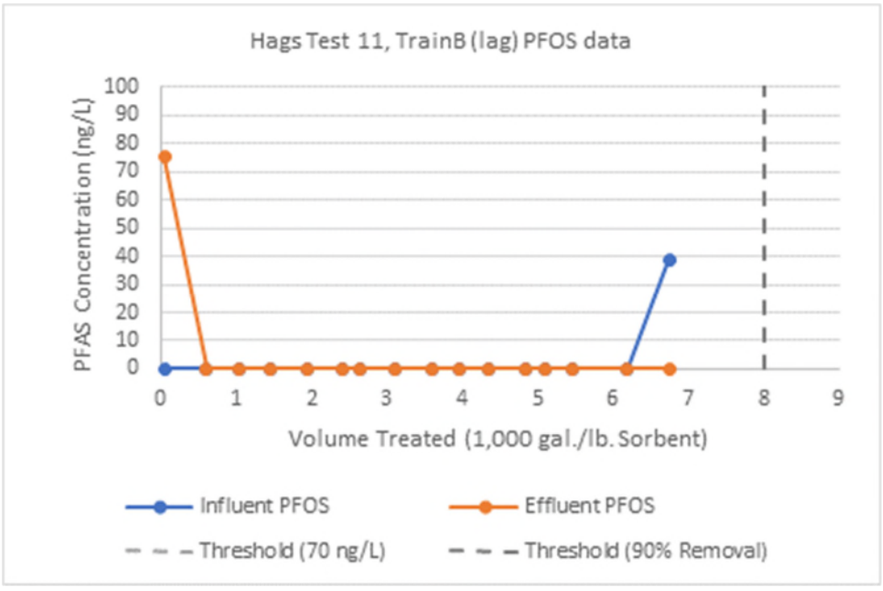

Figure 50: HAGS Test 11, Train B (Lag) PFOS Data

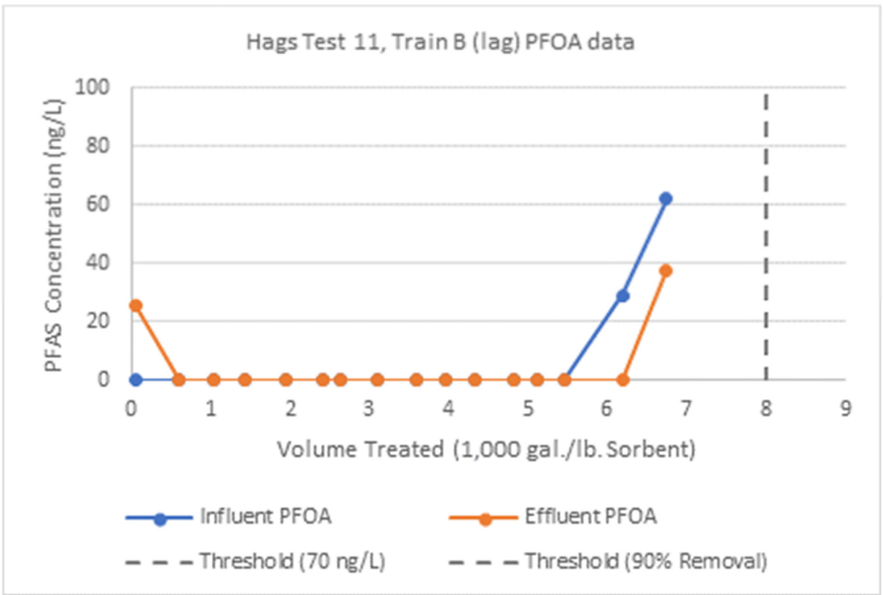

Figure 51: HAGS Test 11, Train B (Lag) PFOA Data

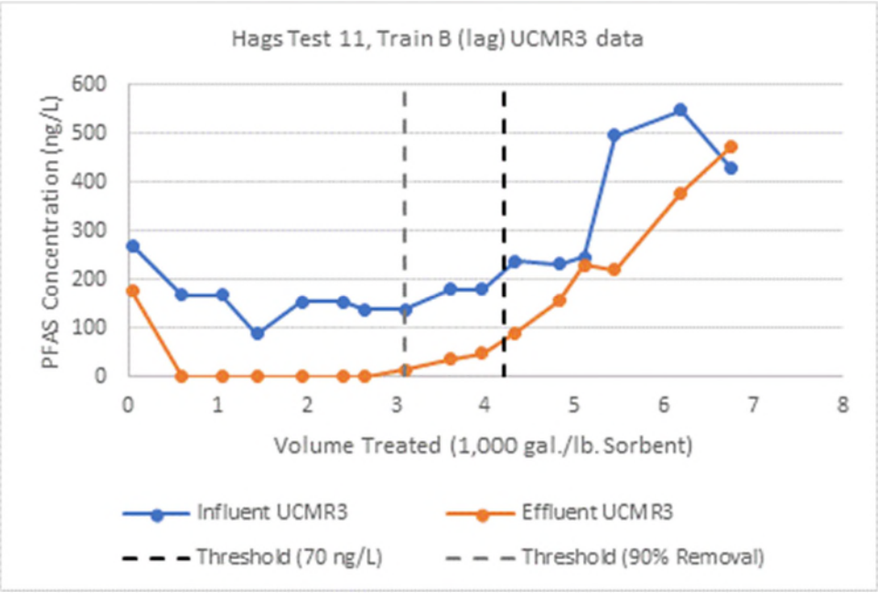

Figure 52: HAGS Test 11, Train B (Lag) UCMR3 Data

12. Test 12

Test 12 was conducted from February 24, 2021, to March 8, 2021, at the HAGS test site with Trains A and B operated in series (i.e., Train A was the lead position, and Train B was the lag position). The objective for Test 12 was to evaluate PFAS removals when operating the AquaPRS in series (i.e., effluent from Train A was fed to Train B). Other parameters were changed from Test 11, such as membrane flux, recycle rate, effluent flow rate, and filtration cycle duration time. The operating parameters are listed in Table 28.

Table 28: HAGS Test 12 Operational Parameters

Operational Parameter	Train A (lead, fresh sorbent)	Train B (lag, fresh sorbent)	Units
Membrane flux rate	150	140	Lmh
Recycle flow rate	10	10	L/minute
Permeate flow rate	1	0.93	L/minute
Filtration cycle duration (backwash frequency)	30	60	Minutes
Sorption reactor detention time	5	5.37	Minutes
Sorption reactor volume	5	5.012	L
Sorbent concentration	40,000	40,000	mg/L as C

Note:
Green highlighted cells on the table indicate the operating parameter that was evaluated.

The following data tables and graphs represent the analytical data generated during Test 12 at the HAGS test site. Tables 29 and 30 list the PFAS analytical data as measured from the CSM laboratory for Trains A and B, respectively. The grey columns represent the UCMR3 compounds. The blue columns represent summed data for PFOS and PFOA, total PFAS, and the UCMR3 compounds.

Table 29: HAGS Test 12, Train A (Lead) PFAS Data

Train A *Blank cells were sample error and/or 1.5xIQR. Cells in italics are either averages or values with sample error removed

	PFOA + PFOS (LOQ=6)		UCMR3 (LOQ=18)		Total PFAS (LOQ=60)		PFOS (LOQ=3)		PFOA (LOQ=3)		PFNA (LOQ=3)		PFHxS (LOQ=3)		PFHpA (LOQ=3)		PFBS (LOQ=3)		PFBA (LOQ=3)		PFPeA (LOQ=3)		PFHxA (LOQ=3)		PFPrS (LOQ=3)		PFPeS (LOQ=3)		PFHpS (LOQ=3)		4:2 FTS (LOQ=3)		6:2 FTS (LOQ=15)		8:2 FTS (LOQ=6.0)	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
0	1,373	≤LOQ	1,784		2,468		1,286	≤LOQ	87	≤LOQ	n/a	n/a	329	≤LOQ	36		47	≤LOQ	43	≤LOQ	108	≤LOQ	236		27	≤LOQ	63	≤LOQ	29	≤LOQ	≤LOQ	≤LOQ	179	≤LOQ	≤LOQ	≤LOQ
240	3,807	≤LOQ	5,088	≤LOQ	7,317	≤LOQ	*3,559*	≤LOQ	*346*	≤LOQ	n/a	n/a	*1,036*	≤LOQ	*90*	≤LOQ	*163*	≤LOQ	*105*	≤LOQ	*330*	≤LOQ	*570*	≤LOQ	*73*	≤LOQ	*183*	≤LOQ	*69*	≤LOQ	*≤LOQ*	≤LOQ	*900*	≤LOQ	≤LOQ	≤LOQ
860	1,317	≤LOQ	1,641	7	2,106	74	1,237	≤LOQ	79	≤LOQ	n/a	n/a	262	≤LOQ	33	7	30	≤LOQ	27	22	94	≤LOQ	215	45	21	≤LOQ	44	≤LOQ	21	≤LOQ	≤LOQ	≤LOQ	46	≤LOQ	≤LOQ	≤LOQ
1,387	3,807	5	5,088	5	7,317	212	*3,559*	≤LOQ	*346*	5	n/a	n/a	*1,036*	≤LOQ	*90*	≤LOQ	*163*	≤LOQ	*105*	80	*330*	31	*570*	28	*73*	8	*183*	≤LOQ	*69*	≤LOQ	*≤LOQ*	≤LOQ	*900*	≤LOQ	≤LOQ	≤LOQ
1,388	3,807	6	5,088	12	7,317	229	*3,559*	≤LOQ	*346*	6	n/a	n/a	*1,036*	≤LOQ	*90*	6	*163*	≤LOQ	*105*	32	*330*	76	*570*	42	*73*	8	*183*	≤LOQ	*69*	≤LOQ	*≤LOQ*	≤LOQ	*900*	≤LOQ	≤LOQ	≤LOQ
1,390	3,807	20	5,088	25	7,317	193	*3,559*	≤LOQ	*346*	20	n/a	n/a	*1,036*	≤LOQ	*90*	5	*163*	≤LOQ	*105*	39	*330*	56	*570*	5	*73*	8	*183*	≤LOQ	*69*	≤LOQ	*≤LOQ*	≤LOQ	*900*	≤LOQ	≤LOQ	≤LOQ
1,607	2,648	≤LOQ	3,297	8	4,306	203	2,485	≤LOQ	153	≤LOQ	n/a	n/a	529	≤LOQ	51	8	69	≤LOQ	78	88	169	59	351	38	33	10	83	≤LOQ	55	≤LOQ	≤LOQ	≤LOQ	241	≤LOQ	≤LOQ	≤LOQ
2,863	3,646	≤LOQ	4,556	≤LOQ	6,034	316	3,410	≤LOQ	236	≤LOQ	n/a	n/a	733	≤LOQ	72	≤LOQ	106	≤LOQ	90	82	274	154	428	53	49	26	121	≤LOQ	69	≤LOQ	≤LOQ	≤LOQ	507	≤LOQ	≤LOQ	≤LOQ
3,461	3,807	≤LOQ	5,088	≤LOQ	7,317	480	*3,559*	≤LOQ	*346*	≤LOQ	n/a	n/a	*1,036*	≤LOQ	*90*	≤LOQ	*163*	≤LOQ	*105*	105	*330*	236	*570*	108	*73*	32	*183*	≤LOQ	*69*	≤LOQ	*≤LOQ*	≤LOQ	*900*	≤LOQ	≤LOQ	≤LOQ
4,033	3,328	≤LOQ	5,014	31	6,901	778	3,663	≤LOQ	259	≤LOQ	n/a	n/a	862	≤LOQ	34	5	131	26	108	114	277	358	513	194	62	75	144	7	89	≤LOQ	12	≤LOQ	675	≤LOQ	≤LOQ	≤LOQ
4,701	3,807	≤LOQ	5,088	32	7,317	624	*3,559*	≤LOQ	*346*	≤LOQ	n/a	n/a	*1,036*	≤LOQ	*90*	7	*163*	24	*105*	106	*330*	275	*570*	147	*73*	57	*183*	6	*69*	≤LOQ	*≤LOQ*	≤LOQ	*900*	≤LOQ	≤LOQ	≤LOQ
5,354	4,242	≤LOQ	5,605	217	8,104	1,081	4,000	≤LOQ	242	≤LOQ	n/a	n/a	1,103	11	97	15	163	192	127	124	358	355	663	230	76	82	187	13	100	≤LOQ	11	≤LOQ	977	≤LOQ	≤LOQ	≤LOQ
5,972	3,807	≤LOQ	5,088	52	7,317	809	*3,559*	≤LOQ	*346*	≤LOQ	n/a	n/a	*1,036*	≤LOQ	*90*	10	*163*	41	*105*	107	*330*	285	*570*	294	*73*	60	*183*	11	*69*	≤LOQ	*≤LOQ*	≤LOQ	*900*	≤LOQ	≤LOQ	≤LOQ
6,620	3,807	≤LOQ	5,089	114	7,555	1,108	3,553	≤LOQ	248	≤LOQ	n/a	n/a	1,028	13	90	17	164	84	126	111	378	353	631	416	77	90	229	18	57	≤LOQ	10	≤LOQ	958	≤LOQ	≤LOQ	≤LOQ
7,274	3,807	10	5,088	138	7,317	1,131	*3,559*	≤LOQ	*346*	10	n/a	n/a	*1,036*	19	*90*	22	*163*	87	*105*	120	*330*	302	*570*	451	*73*	79	*183*	30	*69*	≤LOQ	*≤LOQ*	10	*900*	≤LOQ	≤LOQ	≤LOQ
7,908	4,030	23	5,336	193	7,815	1,248	3,735	≤LOQ	295	23	n/a	n/a	1,052	28	89	22	165	120	105	110	339	329	593	501	76	84	183	30	100	≤LOQ	18	≤LOQ	1,066	≤LOQ	≤LOQ	≤LOQ
8,518	3,807	17	5,088	197	7,317	1,228	*3,559*	≤LOQ	*346*	17	n/a	n/a	*1,036*	32	*90*	28	*163*	120	*105*	105	*330*	307	*570*	508	*73*	77	*183*	33	*69*	≤LOQ	*≤LOQ*	≤LOQ	*900*	≤LOQ	≤LOQ	≤LOQ
9,170	2,392	31	4,321	341	6,816	1,666	2,694	≤LOQ	238	31	n/a	n/a	1,070	67	91	48	168	136	103	122	330	325	570	705	73	95	200	65	97	≤LOQ	≤LOQ	12	1,123	≤LOQ	≤LOQ	≤LOQ
9,858	3,807	18	5,088	272	7,317	1,386	*3,559*	≤LOQ	*346*	18	n/a	n/a	*1,036*	67	*90*	41	*163*	146	*105*	117	*330*	275	*570*	584	*73*	77	*183*	60	*69*	≤LOQ	*≤LOQ*	≤LOQ	*900*	≤LOQ	≤LOQ	≤LOQ
10,555	4,152	59	5,513	436	8,025	1,911	3,841	8	311	51	n/a	n/a	1,093	137	94	65	174	236	123	124	430	326	665	765	81	92	191	109	104	≤LOQ	19	≤LOQ	900	≤LOQ	≤LOQ	≤LOQ
11,204	3,807	90	5,088	491	7,317	1,883	*3,559*	24	*346*	66	n/a	n/a	*1,036*	137	*90*	67	*163*	196	*105*	132	*330*	322	*570*	725	*73*	90	*183*	130	*69*	≤LOQ	*≤LOQ*	≤LOQ	*900*	≤LOQ	≤LOQ	≤LOQ
11,736	4,236	62	5,603	632	8,071	2,251	3,901	≤LOQ	336	62	n/a	n/a	1,088	258	106	34	173	278	133	134	407	368	651	787	82	97	203	160	64	≤LOQ	≤LOQ	13	322	≤LOQ	≤LOQ	≤LOQ
11,736	3,807	87	5,088	748	7,317	2,232	*3,559*	20	*346*	68	n/a	n/a	*1,036*	281	*90*	100	*163*	279	*105*	122	*330*	348	*570*	793	*73*	96	*183*	184	*69*	≤LOQ	*≤LOQ*	≤LOQ	*900*	≤LOQ	≤LOQ	≤LOQ

Table 30: HAGS Test 12, Train B (Lag) PFAS Data

Train B *Blank cells were sample error and/or 1.5xIQR. Cells in italics are either averages or values with sample error removed

	PFOA + PFOS (LOQ=6)		UCMR3 (LOQ=18)		Total PFAS (LOQ=60)		PFOS (LOQ=3)		PFOA (LOQ=3)		PFNA (LOQ=3)		PFHxS (LOQ=3)		PFHpA (LOQ=3)		PFBS (LOQ=3)		PFBA (LOQ=3)		PFPeA (LOQ=3)		PFHxA (LOQ=3)		PFPrS (LOQ=3)		PFPeS (LOQ=3)		PFHpS (LOQ=3)		4:2 FTS (LOQ=3)		6:2 FTS (LOQ=15)		8:2 FTS (LOQ=6.0)	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
49	≤LOQ		≤LOQ		≤LOQ		≤LOQ	≤LOQ	≤LOQ		n/a	n/a	≤LOQ		≤LOQ		≤LOQ		≤LOQ		≤LOQ		≤LOQ		≤LOQ		≤LOQ		≤LOQ		≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ
559	≤LOQ	≤LOQ	7	≤LOQ	74	*≤LOQ*	≤LOQ	≤LOQ	≤LOQ	≤LOQ	n/a	n/a	≤LOQ	≤LOQ	7	≤LOQ	≤LOQ	≤LOQ	22	≤LOQ	≤LOQ		45		≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ
1,036	5	≤LOQ	5	5	212	*88*	≤LOQ	≤LOQ	5	≤LOQ	n/a	n/a	≤LOQ	≤LOQ	≤LOQ	5	≤LOQ	≤LOQ	80	23	91		28		8	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ
1,036	6	≤LOQ	12	7	229	*96*	≤LOQ	≤LOQ	6	≤LOQ	n/a	n/a	≤LOQ	≤LOQ	6	7	≤LOQ	≤LOQ	92	30	76		42		8	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ
1,037	20	≤LOQ	25	6	193	*53*	≤LOQ	≤LOQ	20	≤LOQ	n/a	n/a	≤LOQ	≤LOQ	5	6	≤LOQ	≤LOQ	99	27	56	≤LOQ	5		8	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ
1,187	≤LOQ	≤LOQ	8	7	203	64	≤LOQ	≤LOQ	≤LOQ	≤LOQ	n/a	n/a	≤LOQ	≤LOQ	8	7	≤LOQ	≤LOQ	88	56	59	≤LOQ	38	≤LOQ	10	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ
2,260	≤LOQ	≤LOQ	≤LOQ	11	316	146	≤LOQ	≤LOQ	≤LOQ	≤LOQ	n/a	n/a	≤LOQ	≤LOQ	≤LOQ	11	≤LOQ	≤LOQ	82	89	154	38	53	7	26	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ
3,346	≤LOQ	≤LOQ	31	11	778	350	≤LOQ	≤LOQ	≤LOQ	≤LOQ	n/a	n/a	≤LOQ	≤LOQ	5	11	26	≤LOQ	114	123	358	159	194	36	75	21	7	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ
4,440	≤LOQ	6	217	10	1,081	512	≤LOQ	≤LOQ	≤LOQ	6	n/a	n/a	11	≤LOQ	15	5	132	≤LOQ	124	107	355	302	290	41	82	51	13	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ
5,565	≤LOQ	9	114	9	1,108	627	≤LOQ	≤LOQ	≤LOQ	9	n/a	n/a	13	≤LOQ	17	0	84	≤LOQ	111	93	359	379	416	75	90	71	18	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ
6,673	23	≤LOQ	193	26	1,248	643	≤LOQ	≤LOQ	23	≤LOQ	n/a	n/a	28	≤LOQ	22	12	120	13	110	91	329	307	501	144	84	76	30	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ
7,784	31	≤LOQ	341	50	1,666	347	≤LOQ	≤LOQ	31	≤LOQ	n/a	n/a	67	≤LOQ	48	0	196	50	122	123	325	388	705	276	95	104	65	5	≤LOQ	≤LOQ	12	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ
9,041	59	8	436	128	1,911	1,191	8	≤LOQ	51	8	n/a	n/a	137	≤LOQ	65	9	236	112	124	112	326	347	765	486	92	108	109	11	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ
10,171	62	10	632	256	2,251	1,736	≤LOQ	≤LOQ	62	10	n/a	n/a	258	6	94	19	278	221	134	125	368	376	787	845	97	107	160	28	≤LOQ	≤LOQ	13	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ

Figures 53 to 58 show Test 12 PFAS removal data expressed as concentration per volume treated (i.e., gallons per pound of sorbent). The data displayed on the graphs were taken from the data found in Tables 29 and 30 above.

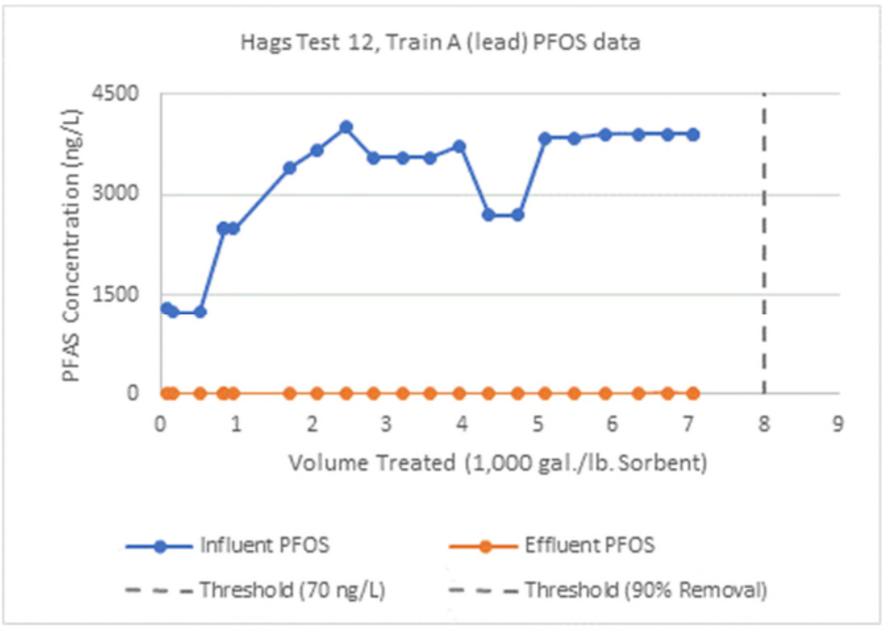

Figure 53: HAGS Test 12, Train A (Lead) PFOS Data

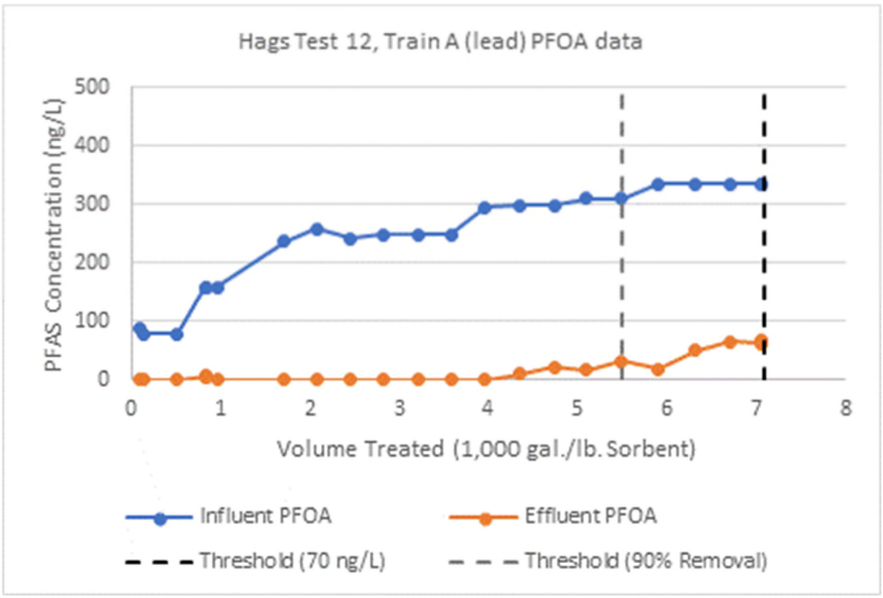

Figure 54: HAGS Test 12, Train A (Lead) PFOA Data

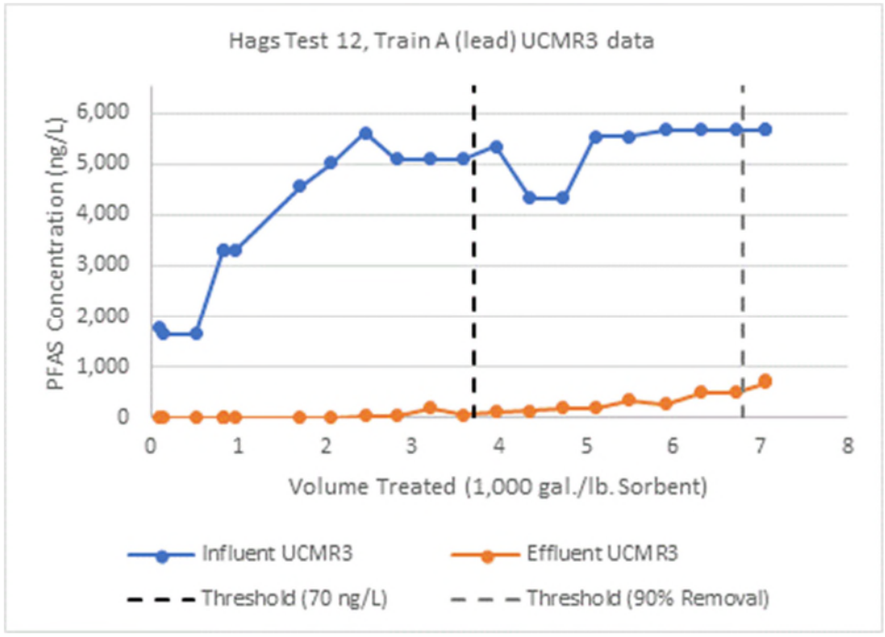

Figure 55: HAGS Test 12, Train A (Lead) UCMR3 Data

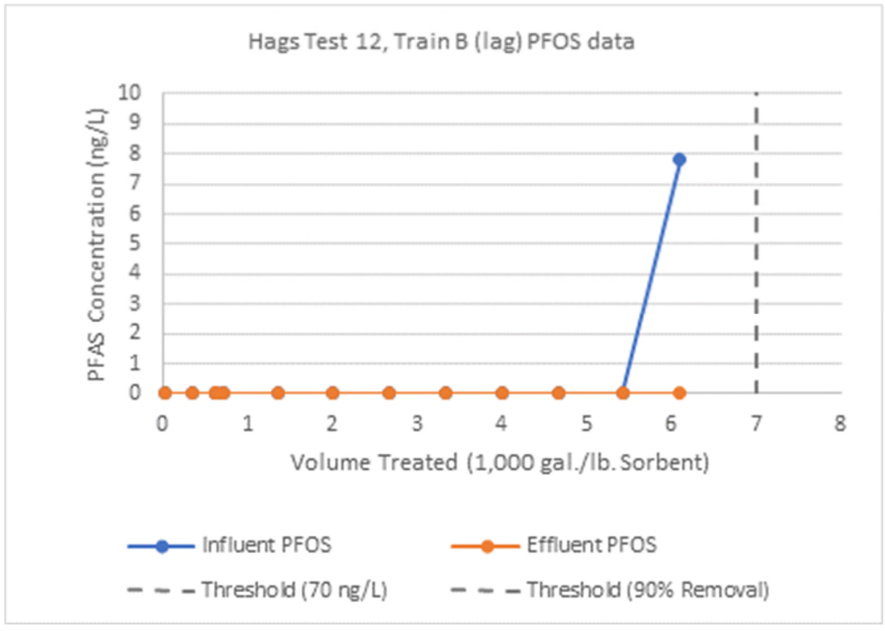

Figure 56: HAGS Test 12, Train B (Lag) PFOS Data

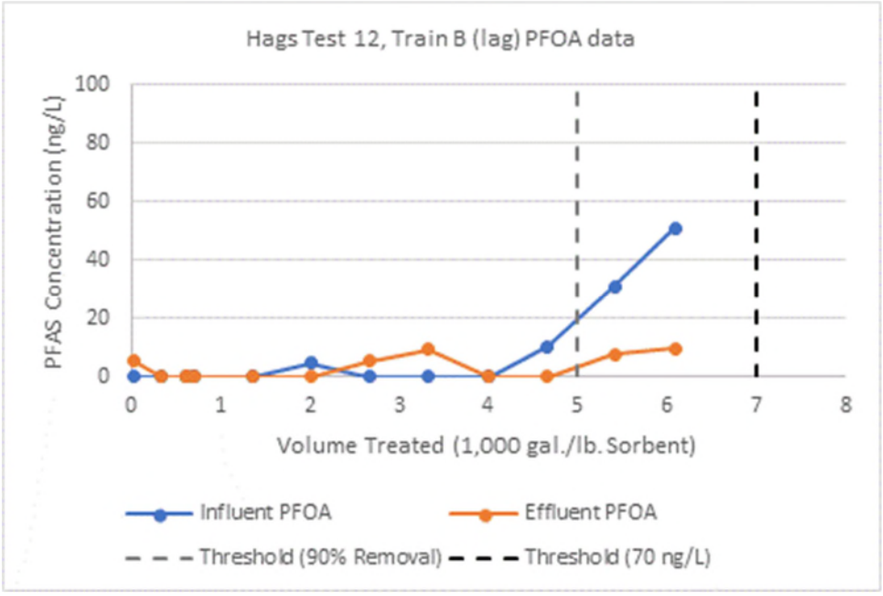

Figure 57: HAGS Test 12, Train B (Lag) PFOA Data

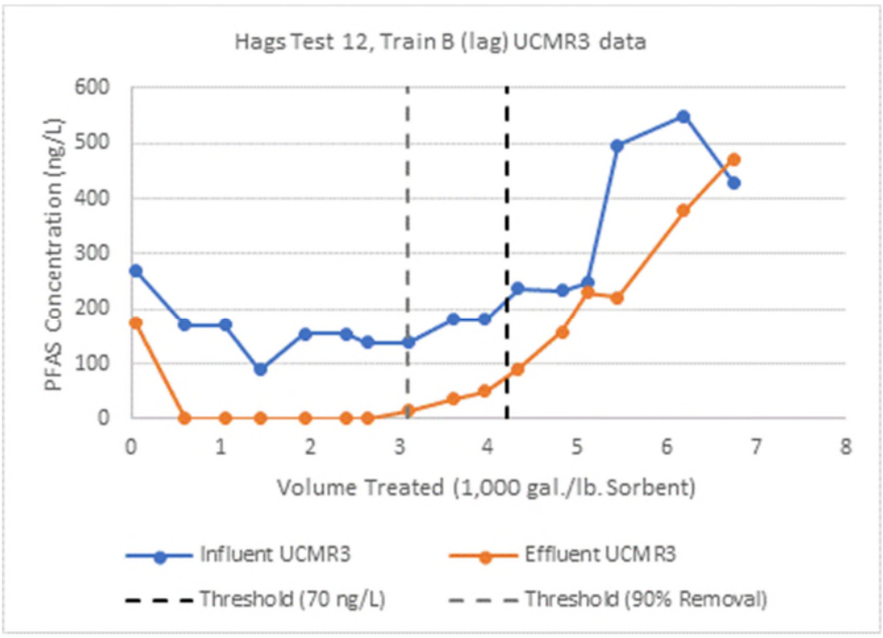

Figure 58: HAGS Test 12, Train B (Lag) UCMR3 Data

13. Test 13

Test 13 was conducted from March 11, 2021, to April 7, 2021, at the HAGS test site with Trains A and B operated in series (i.e., Train A was the lag position, and Train B was the lead position). The objective for Test 13 was to evaluate PFAS removals when operating the AquaPRS in series (i.e., effluent from Train B was fed to Train A). In this test, Train B was operated with sorbent previously used with Train B in Test 12. The operating parameters are listed in Table 31.

Table 31: HAGS Test 13 Operational Parameters

Operational Parameter	Train A (lag, fresh sorbent)	Train B (lead, with Test 12, Train B sorbent)	Units
Membrane flux rate	140	150	Lmh
Recycle flow rate	10	10	L/minute
Permeate flow rate	0.93	1	L/minute
Filtration cycle duration (backwash frequency)	60	30	Minutes
Sorption reactor detention time	5.4	5	Minutes

Operational Parameter	Train A (lag, fresh sorbent)	Train B (lead, with Test 12, Train B sorbent)	Units
Sorption reactor volume	5	5	L
Sorbent concentration	40,000	40,000	mg/L as C

Note:
Green highlighted cells on the table indicate the operating parameter that was evaluated.

The following data tables and graphs represent the analytical data generated during Test 13 at the HAGS test site. Tables 32 and 33 list the PFAS analytical data as measured from the CSM laboratory for Trains A and B, respectively. The grey columns represent the UCMR3 compounds. The blue columns represent summed data for PFOS and PFOA, total PFAS, and the UCMR3 compounds.

Table 32: HAGS Test 13, Train A (Lag) PFAS Data

Train A *Blank cells were sample error and/or 1.5x10R. Cells in italics are either averages or values with sample error removed

	PFOA + PFOS (LOQ=6)		UCMR3		Total PFAS		PFOS (LOQ=3)		PFOA (LOQ=3)		PFNA (LOQ=3)		PFHxS (LOQ=3)		PFHpA (LOQ=3)		PFBS (LOQ=3)		PFBA (LOQ=30)		PFPeA		PFHxA		PFPrS		PFPeS (LOQ=3)		PFHpS (LOQ=3)		4:2 FTS (LOQ=15)		6:2 FTS (LOQ=30)		8:2 FTS	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
66	12		332		1,999		12		≤LOQ	≤LOQ	n/a	n/a	11	≤LOQ	22		288	≤LOQ	145	≤LOQ	498	109	834	146	149	25	28		≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	13	13
1,345	29	≤LOQ	613	19	2,231	330	≤LOQ	≤LOQ	29	≤LOQ	n/a	n/a	33	≤LOQ	84	7	408	12	116	140	425	171	812	22	123	23	119	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	15	15
2,245	149	≤LOQ	357	21	2,545	353	44	≤LOQ	105	≤LOQ	n/a	n/a	334	≤LOQ	134	5	340	16	127	101	414	172	614	22	133	31	215	≤LOQ	8	≤LOQ	≤LOQ	≤LOQ	60	≤LOQ	17	13
2,946	580	≤LOQ	1,860	29	3,732	516	317	≤LOQ	263	≤LOQ	n/a	n/a	855	≤LOQ	142	6	283	23	130	128	389	248	680	48	124	49	242	≤LOQ	37	≤LOQ	≤LOQ	≤LOQ	317	≤LOQ	14	14
3,344	353	≤LOQ	2,035	37	4,212	653	≤LOQ	≤LOQ	353	≤LOQ	n/a	n/a	1,245	≤LOQ	149	12	288	26	99	135	406	331	610	73	122	63	278	≤LOQ	73	≤LOQ	≤LOQ	≤LOQ	577	≤LOQ	13	14
4,657	641	≤LOQ	2,275	47	4,250	871	371	≤LOQ	271	≤LOQ	n/a	n/a	1,174	≤LOQ	156	6	303	41	143	153	403	473	650	101	136	82	230	≤LOQ	25	≤LOQ	26	≤LOQ	281	≤LOQ	15	14
4,463	388	≤LOQ	1,587	40	3,287	854	187	≤LOQ	201	≤LOQ	n/a	n/a	757	≤LOQ	138	≤LOQ	304	40	130	114	436	471	556	132	131	86	254	≤LOQ	22	≤LOQ	≤LOQ	≤LOQ	170	≤LOQ	11	11
5,127	460	≤LOQ	1,832	108	3,834	1,864	186	≤LOQ	274	≤LOQ	n/a	n/a	930	≤LOQ	150	7	292	101	148	125	427	1139	629	316	122	150	287	11	23	≤LOQ	≤LOQ	≤LOQ	291	≤LOQ	15	14
5,134	852	≤LOQ	2,275	114	4,283	1,322	551	≤LOQ	301	≤LOQ	n/a	n/a	1,023	≤LOQ	136	8	264	106	117	142	415	597	609	292	114	156	248	11	48	≤LOQ	≤LOQ	≤LOQ	443	≤LOQ	16	11
5,722	240	≤LOQ	1,549	149	3,413	1,275	87	≤LOQ	153	≤LOQ	n/a	n/a	857	6	145	13	307	130	113	117	375	440	680	403	125	136	306	16	15	≤LOQ	≤LOQ	≤LOQ	231	≤LOQ	18	14
6,140	1,005	≤LOQ	2,314	204	5,232	1,488	614	≤LOQ	391	≤LOQ	n/a	n/a	1,498	14	139	13	272	171	140	143	448	412	606	561	123	128	269	27	61	≤LOQ	≤LOQ	≤LOQ	716	≤LOQ	15	12
6,144	1,005	≤LOQ	2,314	219	5,232	1,505	614	≤LOQ	391	≤LOQ	n/a	n/a	1,498	12	139	30	272	177	140	139	448	414	606	562	123	129	269	27	61	≤LOQ	≤LOQ	≤LOQ	716	≤LOQ	15	13
6,167	1,282	≤LOQ	3,417	532	5,818	3,226	856	≤LOQ	425	≤LOQ	n/a	n/a	1,674	23	174	39	288	464	95	155	391	840	607	1309	109	319	360	60	68	≤LOQ	26	≤LOQ	731	≤LOQ	13	12
6,169	1,234	≤LOQ	3,388	553	5,724	3,419	843	≤LOQ	452	≤LOQ	n/a	n/a	1,647	34	173	42	274	477	94	195	383	902	597	1362	107	331	343	63	73	≤LOQ	≤LOQ	≤LOQ	725	≤LOQ	14	12
6,181	391	9	3,260	622	5,804	3,480	532	≤LOQ	460	9	n/a	n/a	1,718	40	195	51	356	523	94	177	349	911	763	1352	109	331	406	75	73	≤LOQ	≤LOQ	≤LOQ	736	≤LOQ	13	11
6,626	391	36	3,260	645	5,804	2,468	532	5	460	31	n/a	n/a	1,718	126	195	77	356	407	94	135	349	420	763	391	109	131	406	131	73	≤LOQ	≤LOQ	≤LOQ	736	≤LOQ	13	14
6,872	2,741	56	4,536	813	7,054	2,628	2,376	8	365	48	n/a	n/a	1,479	130	130	124	245	448	102	102	371	339	523	963	110	135	250	193	115	≤LOQ	≤LOQ	≤LOQ	369	≤LOQ	19	13
6,979	3,383	56	6,089	657	9,060	2,351	3,552	7	431	49	n/a	n/a	1,713	149	130	103	263	350	94	120	436	481	582	803	115	115	268	162	150	≤LOQ	≤LOQ	≤LOQ	1,306	≤LOQ	21	13
7,040	4,758	54	6,696	652	9,623	2,281	4,372	7	386	47	n/a	n/a	1,554	155	129	111	255	332	142	112	411	394	556	839	114	116	249	155	156	≤LOQ	25	≤LOQ	1,250	≤LOQ	24	12
7,053	4,086	55	5,365	676	7,173	2,318	3,815	6	270	48	n/a	n/a	1,075	157	79	111	126	354	47	96	184	406	265	844	50	121	134	160	131	≤LOQ	≤LOQ	≤LOQ	970	≤LOQ	27	14
7,055	2,036	52	3,404	688	5,308	2,454	1,875	8	221	44	n/a	n/a	1,052	153	86	115	171	361	88	118	265	458	403	881	74	125	166	171	89	≤LOQ	≤LOQ	≤LOQ	739	≤LOQ	20	13

Table 33: HAGS Test 13, Train B (Lead) PFAS Data

Train B *Blank cells were sample error and/or 1.5xIQR. Cells in italics are either averages or values with sample error removed

	PFOA + PFOS		UCMR3		Total PFAS		PFOS (LOQ=3)		PFOA (LOQ=3)		PFNA (LOQ=3)		PFHxS		PFHpA		PFBS		PFBA		PFPeA		PFHxA		PFPrS		PFPeS		PFHpS (LOQ=3)		4:2 FTS (LOQ=15)		6:2 FTS (LOQ=30)		8:2 FTS	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
39	1,383	12	3,207	332	5,235	1,339	1,785	12	204	≤LOQ	n/a	n/a	770	11	125	22	324	288	118	145	464	498	677	834	128	149	239	28	42	≤LOQ	≤LOQ	≤LOQ	343	≤LOQ	17	13
820	6,499	8	8,564	358	11,531	1,785	*6,066*	8	*411*	≤LOQ	n/a	n/a	*1,654*	24	*137*	36	*274*	290	*117*	127	*362*	393	*584*	728	*116*	120	*261*	48	*164*	≤LOQ	≤LOQ	≤LOQ	*1,362*	≤LOQ	*39*	12
1,473	6,595	29	8,668	613	11,922	2,231	6,183	≤LOQ	411	29	n/a	n/a	1,654	93	145	84	274	408	138	118	445	425	613	812	118	129	291	119	134	≤LOQ	≤LOQ	≤LOQ	1,464	≤LOQ	50	15
2,197	6,499	64	8,564	608	11,531	2,004	*6,066*	18	*411*	46	n/a	n/a	*1,654*	150	*137*	96	*274*	299	*117*	131	*362*	392	*584*	601	*116*	119	*261*	138	*164*	≤LOQ	≤LOQ	≤LOQ	*1,362*	≤LOQ	*39*	16
2,906	7,097	149	9,260	957	12,566	2,545	6,648	44	448	105	n/a	n/a	1,735	334	150	134	279	340	121	127	482	414	622	614	124	133	276	215	171	7.9	≤LOQ	≤LOQ	1,465	60	45	17
3,577	6,499	284	8,564	1,202	11,531	2,840	*6,066*	139	*411*	145	n/a	n/a	*1,654*	475	*137*	140	*274*	303	*117*	140	*362*	477	*584*	549	*116*	129	*261*	226	*164*	12.3	≤LOQ	≤LOQ	*1,362*	94	*39*	11
4,252	6,845	580	8,950	1,860	12,238	3,732	6,402	317	443	263	n/a	n/a	1,679	855	143	142	283	283	154	130	449	389	663	680	127	124	302	242	130	36.7	≤LOQ	≤LOQ	1,431	317	33	14
4,913	6,499	644	8,564	2,346	11,531	4,422	*6,066*	278	*411*	366	n/a	n/a	*1,654*	1,246	*137*	152	*274*	303	*117*	127	*362*	393	*584*	574	*116*	128	*261*	286	*164*	50.0	≤LOQ	≤LOQ	*1,362*	505	*39*	13
5,468	6,566	353	8,699	2,035	11,943	4,212	6,133		433	353	n/a	n/a	1,706	1,245	136	149	291	288	144	99	409	406	711	610	129	122	285	278	174	73.1	≤LOQ	≤LOQ	1,362	577	31	13
5,997	6,499	439	8,564	1,995	11,531	4,035	*6,066*	194	*411*	245	n/a	n/a	*1,654*	1,108	*137*	151	*274*	297	*117*	141	*362*	389	*584*	690	*116*	126	*261*	288	*164*	24.0	≤LOQ	24	*1,362*	343	*39*	15
6,241	6,523	641	8,644	2,275	11,928	4,250	6,088	371	435	271	n/a	n/a	1,636	1,174	139	156	287	303	159	143	407	409	661	650	130	136	266	290	182	25.3	≤LOQ	26	1,441	281	39	15
6,242	6,499	118	8,564	484	11,531	1,849	*6,066*	72	*411*	46	n/a	n/a	*1,654*	175	*137*	36	*274*	156	*117*	149	*362*	486	*584*	454	*116*	143	*261*	52	*164*	6.4	≤LOQ	≤LOQ	*1,362*	61	*39*	14
6,280	7,008	388	9,191	1,587	12,490	3,297	6,576	187	432	201	n/a	n/a	1,750	757	143	138	290	304	126	130	450	436	660	556	130	131	282	254	190	21.8	≤LOQ	≤LOQ	1,417	170	42	11
7,331	2,170	460	2,730	1,892	3,880	3,834	2,054	186	116	274	n/a	n/a	439	990	45	150	77	292	*117*	148	*362*	427	162	629	34	122	67	287	46	23.0	≤LOQ	≤LOQ	321	291	20	15
7,706	4,322	852	5,340	2,275	8,379	4,283	4,041	551	281	301	n/a	n/a	1,268	1,023	*137*	136	213	264	37	117	363	415	441	609	35	114	203	248	129	47.6	33	≤LOQ	1,034	443	44	16
8,021	7,780	240	10,072	1,549	13,416	3,413	7,278	87	503	153	n/a	n/a	1,875	857	145	145	272	307	116	113	421	375	622	680	122	125	302	306	179	14.9	≤LOQ	≤LOQ	1,538	231	44	18
8,239	6,499	1,724	8,564	3,524	11,531	5,835	*6,066*	1,342	*411*	382	n/a	n/a	*1,654*	1,373	*137*	147	*274*	279	*117*	101	*362*	386	*584*	644	*116*	121	*261*	271	*164*	88.6	≤LOQ	≤LOQ	*1,362*	685	*39*	14
8,451	7,374	313	9,644	2,786	12,826	5,065	6,918	542	456	371	n/a	n/a	1,852	1,457	144	144	274	272	123	114	381	372	522	611	122	119	289	263	170	61.1	≤LOQ	≤LOQ	1,536	726	39	13
8,451	6,542	1,005	8,844	2,314	12,176	5,232	6,060	614	482	391	n/a	n/a	1,871	1,498	147	139	284	272	141	140	434	448	607	606	119	123	268	269	201	61.4	27	≤LOQ	1,498	716	36	15
8,607	6,683	1,282	8,652	3,417	11,277	5,818	6,288	856	394	425	n/a	n/a	1,623	1,674	119	174	227	288	112	95	369	391	446	607	92	109	211	360	172	67.9	≤LOQ	26	1,181	731	41	13
8,609	5,380	1,294	7,102	3,388	9,499	5,724	5,066	843	314	452	n/a	n/a	1,393	1,647	109	173	221	274	100	94	327	383	515	597	94	107	197	343	141	72.5	≤LOQ	≤LOQ	983	725	40	14
8,635	5,836	991	7,514	3,260	9,752	5,804	5,499	532	337	460	n/a	n/a	1,352	1,718	110	195	216	356	101	94	318	349	400	763	87	109	205	406	118	73.3	≤LOQ	≤LOQ	972	736	37	13
9,251	5,374	2,741	7,363	4,536	10,819	7,054	5,604	2,376	370	365	n/a	n/a	1,603	1,479	137	130	255	245	113	102	367	371	530	523	115	110	239	250	162	114.6	≤LOQ	≤LOQ	1,285	969	38	19
9,745	8,104	3,383	10,425	6,089	13,746	9,060	7,611	3,552	494	431	n/a	n/a	1,901	1,713	141	130	279	263	107	94	382	436	605	582	121	115	264	268	200	150.4	≤LOQ	≤LOQ	1,578	1306	64	21
10,166	7,251	4,758	9,516	6,636	12,855	9,623	6,790	4,372	461	386	n/a	n/a	1,836	1,554	154	129	275	255	132	142	446	411	584	556	114	114	261	249	201	155.8	23	25	1,538	1250	41	24
10,474	3,220	4,086	4,234	5,365	5,587	7,173	3,024	3,815	196	270	n/a	n/a	829	1,075	60	79	125	126	52	47	173	184	227	265	51	50	104	134	84	131.2	≤LOQ	≤LOQ	622	970	41	27
10,716	3,954	1,444	5,408	2,705	7,370	4,494	3,635	1,196	259	248	n/a	n/a	1,189	1,026	90	86	174	148	66	76	277	267	331	323	66	65	155	149	112	71.8	≤LOQ	≤LOQ	323	822	32	16
10,767	5,380	2,096	7,286	3,404	9,371	5,308	5,016	1,875	364	221	n/a	n/a	1,568	1,052	114	86	224	171	93	88	355	265	495	403	94	74	205	166	164	89.5	≤LOQ	≤LOQ	1,241	799	38	20

Figures 59 to 64 show Test 13 PFAS removal data expressed as concentration per volume treated (i.e., gallons per pound of sorbent). The data displayed on the graphs were taken from the data found in Tables 32 and 33 above.

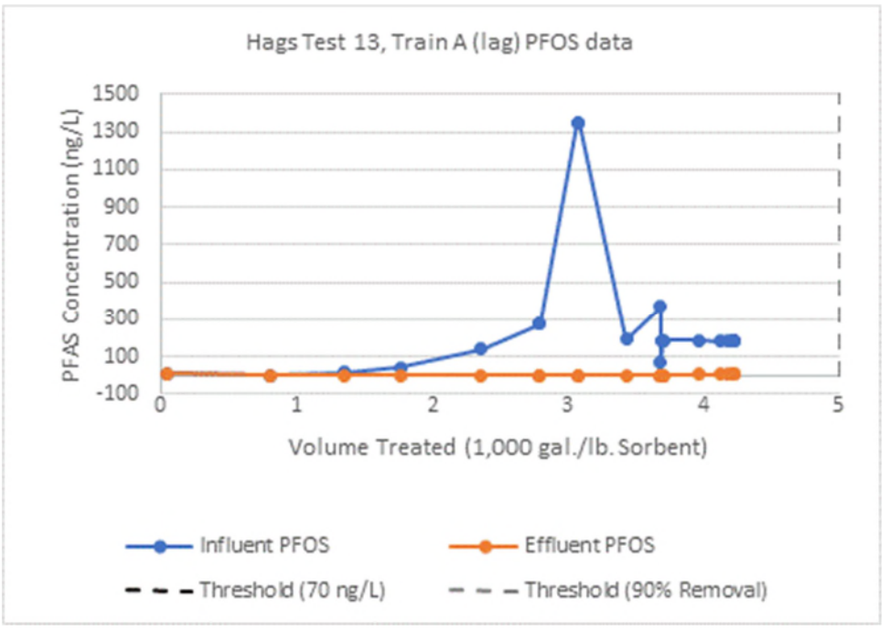

Figure 59: HAGS Test 13, Train A (Lag) PFOS Data

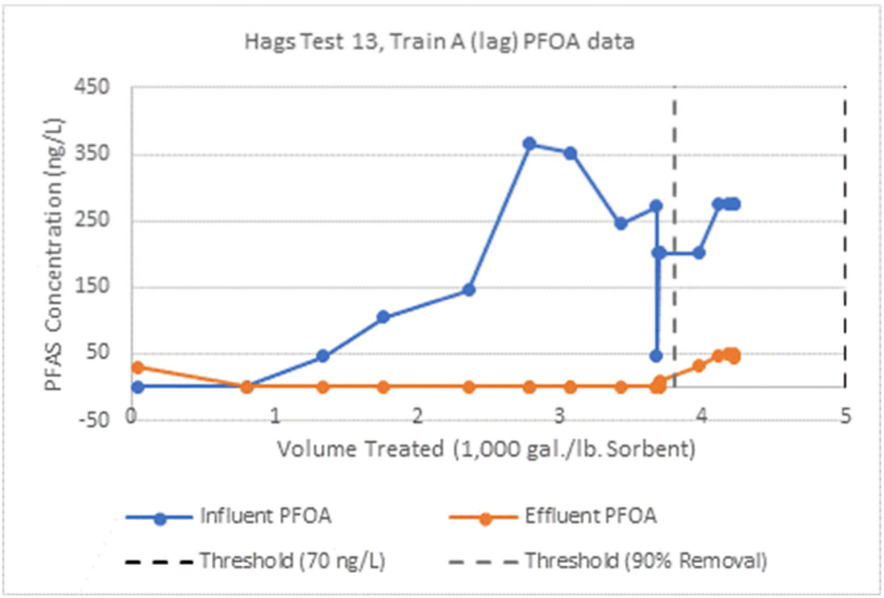

Figure 60: HAGS Test 13, Train A (Lag) PFOA Data

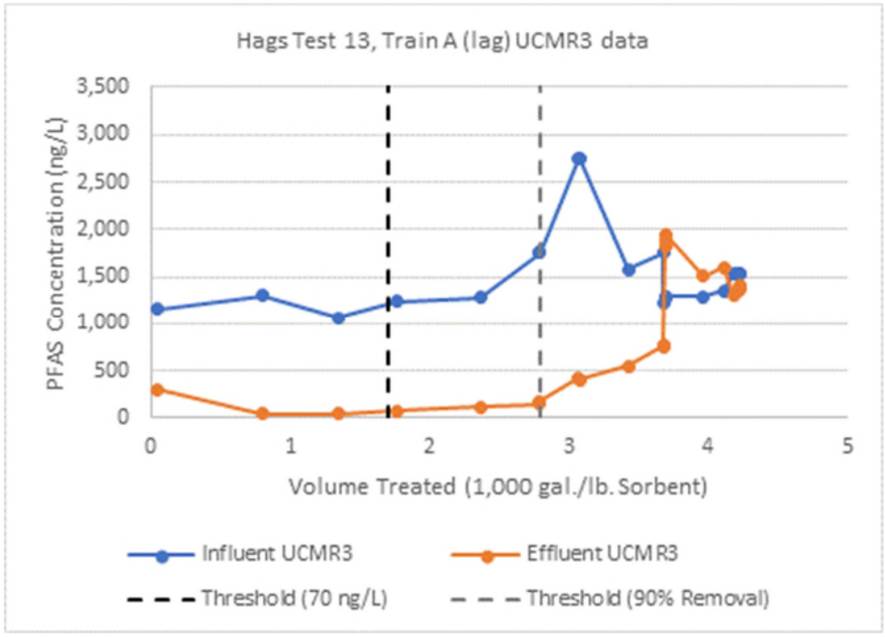

Figure 61: HAGS Test 13, Train A (Lag) UCMR3 Data

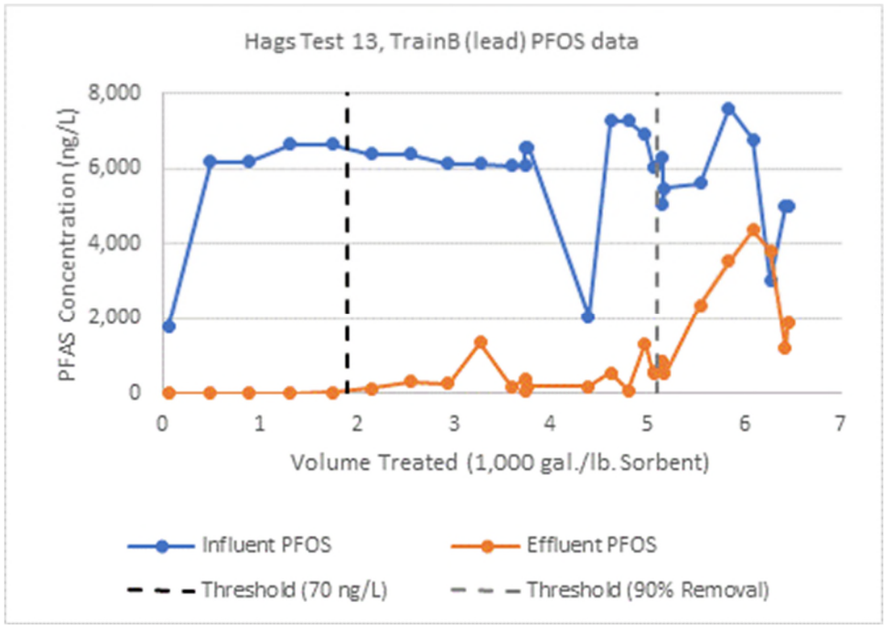

Figure 62: HAGS Test 13, Train B (Lead) PFOS Data

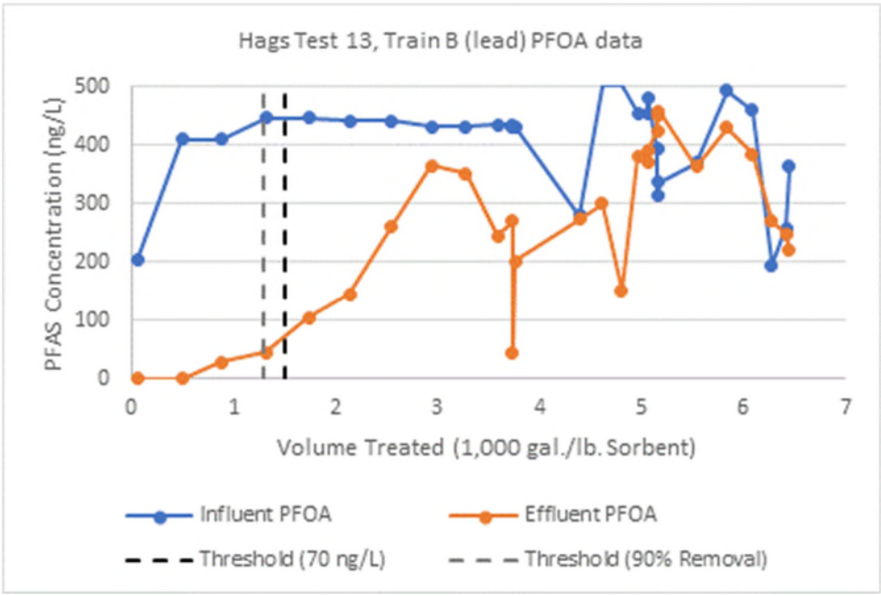

Figure 63: HAGS Test 13, Train B (Lead) PFOA Data

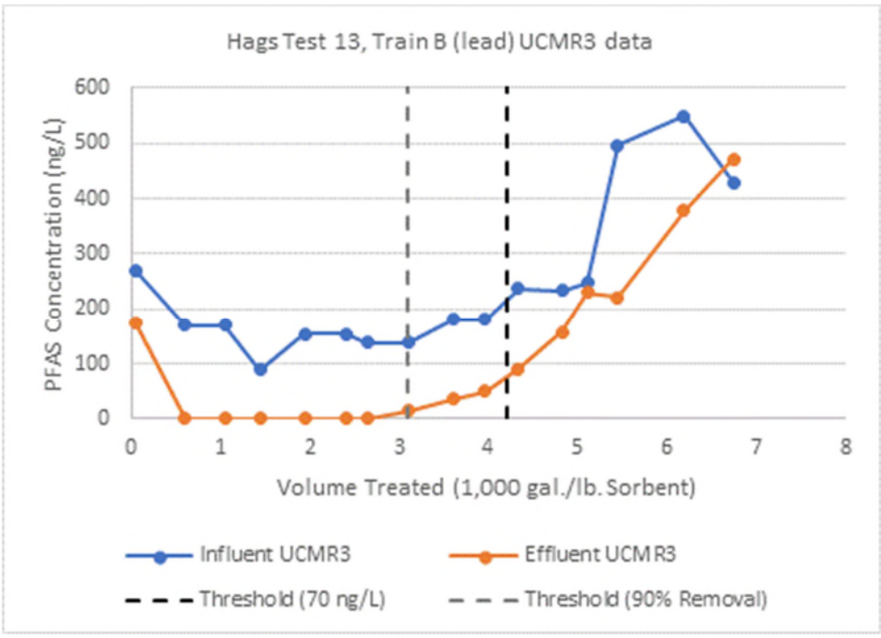

Figure 64: HAGS Test 13, Train B (Lead) UCMR3 Data

Appendix F

Willow Grove NASJRB Test Site Data Summary

Appendix F

Willow Grove, Pennsylvania, NASJRB Test Data Summary

1. Test 1

Test 1 was conducted at the Willow Grove, Pennsylvania, Naval Air Station Joint Reserve Base (NASJRB) test site from May 27, 2021, to June 21, 2021, with the operating conditions listed below in Table 1. For this test, two treatment trains were operated in parallel (i.e., single stage/single pass operation) with a common feed source from a Willow Grove, Pennsylvania, NASJRB contaminated well. This test was conducted to evaluate the impact of detention time on adsorption capacity. All operating conditions were the same for each treatment train except for the detention time (highlighted in gray in Table 1), which was 10 minutes for Train A and 20 minutes for Train B. Table 2 lists a summary of the per-and polyfluoroalkyl substances (PFAS) analytical data per treatment train. The grey columns represent the third Unregulated Contaminant Monitoring Rule (UCMR3) compounds. The blue columns represent summed data for perfluorooctanesulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) and, separately, the summed UCMR3 compounds. The metrics used in Figures 1 through 8 include (a) the threshold at 70 nanograms per liter (ng/L), which indicates the health advisory level established by the United States Environmental Protection Agency (USEPA) in 2016, and (b) the 90% removal threshold, indicating the breakthrough point.

Table 1: WG Test 1 Operating Conditions

Train	Single Pass/Series Configuration (lead/lag)	Detention Time (minutes)	Sorbent Type	Sorbent Concentration (g/L)	Sorption Volume (L)	Membrane Permeate Flow Rate (L/min)	Test Duration (days)
Train A	SP	10	AquaPR-206	20	10	1	24
Train B	SP	20	AquaPR-206	10	20	1	24

Notes:
g/L = gram per liter
L = liter
L/min = liter per minute

Figures 1 to 4 present removal performance for treatment Train A during Test 1. All figures in this section show the removal process rate of key PFAS compounds quantified as gallons of PFAS-contaminated water treated per pound of sorbent material. Table 2 presents all the raw data that were used to establish the Train A performance exhibited in Figures 1 to 4.

- Figure 1 presents PFOS removal performance data with an influent PFOS range of 20,000 to 30,000 ng/L. Effluent PFOS levels reached the 70 ng/L threshold at a removal process rate of 8,660 gallons per pound (gal/lb) of sorbent; the 90% removal threshold was not reached with this test duration (i.e., 24 days).
- Figure 2 presents PFOA removal performance data with an influent PFOA range of 2,500 to 3,500 ng/L. Effluent PFOA levels reached the 70 ng/L effluent threshold at a removal process rate of 5,100 gal/lb sorbent, and the 90% removal threshold was reached at a removal process rate of 8,400 gal/lb sorbent.
- Figure 3 presents the summed PFOA plus PFOS removal performance data with an influent PFOA plus PFOS range of 25,000 to 35,000 ng/L. Effluent PFOA plus PFOS levels reached the 70 ng/L effluent threshold at a removal process rate of 2,900 gal/lb sorbent, and the 90% removal threshold was reached at a removal process rate of 14,500 gal/lb sorbent
- Figure 4 presents the UCMR3 compounds' removal performance data with an influent (summed) UCMR3 level range of 30,000 to 40,000 ng/L. Effluent UCMR3 levels surpassed the 70ng/L threshold at test start, and the 90% removal threshold was reached at a removal process rate of 12,400 gal/lb sorbent.

Figures 5 to 8 present removal performance for treatment Train B during Test 1. All figures in this section demonstrate the removal process rate of key PFAS compounds quantified as gallons of PFAS-

contaminated water treated per pound of sorbent material. Table 3 presents all the raw data that were used to establish the Train B performance exhibited in Figures 5 to 8.

- Figure 5 presents PFOS removal performance data with an influent PFOS range of 20,000 to 30,000 ng/L. Effluent PFOS levels reached the 70 ng/L threshold at a removal process rate of 8,650 gal/lb sorbent; the 90% removal threshold was not reached with this test duration (i.e., 24 days).
- Figure 6 presents PFOA removal performance data with an influent PFOA range of 2,000 to 3,500 ng/L. Effluent PFOA levels reached the 70 ng/L effluent threshold at a removal process rate of 8,100 gal/lb sorbent, and the 90% removal threshold was reached at a removal process rate of 8,900 gal/lb sorbent.
- Figure 7 presents the summed PFOA plus PFOS removal performance data with an influent PFOA plus PFOS range of 23,000 to 35,000 ng/L. Effluent PFOA plus PFOS levels reached the 70 ng/L effluent threshold at a process rate of 3,700 gal/lb sorbent, and the 90% removal threshold was reached at a removal process rate of 16,300 gal/lb sorbent
- Figure 8 presents the UCMR3 compounds' removal performance data with an influent (summed) UCMR3 level range of 28,000 to 41,000 ng/L. Effluent UCMR3 levels surpassed the 70 ng/L threshold at test start, and the 90% removal threshold was reached at a removal process rate of 12,500 gal/lb sorbent.

Table 2: WG NASJRB Test 1 Trains A and B Summary PFAS Analytical Data

Train A

	PFOA + PFOS		UCMR3		Total PFAS		PFOS		PFOA		PFNA		PFHxS		PFHpA		PFBS		PFBA		PFPeA		PFHxA		PFPrS		PFPeS		PFHpS		4:2 FTS		6:2 FTS (LOQ=8.6)		8:2 FTS	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
2,569	25,900	67	32,400	164	39,840	1,602	23,000	62	2,900	5	n/a	n/a	5,100	12	410	4	930	82	410	540	870	700	1,800	130	n/a	n/a	810	7	750	1	n/a	n/a	2,800	≤LOQ	n/a	n/a
7,341	26,700	75	34,630	837	42,200	3,700	26,000	26	2,700	49	n/a	n/a	4,800	86	370	46	820	630	380	400	780	320	1,700	1400	n/a	n/a	750	80	600	1	n/a	n/a	3,300	2	n/a	n/a
13,313	27,300	268	33,950	2,038	41,380	6,173	24,000	38	3,300	230	n/a	n/a	5,300	440	330	130	960	1,200	380	370	770	800	1,700	2500	n/a	n/a	630	330	530	3	n/a	n/a	3,300	12	n/a	n/a
18,036	33,200	1,110	39,480	3,650	46,450	7,575	30,000	170	3,200	940	n/a	n/a	5,100	1,200	390	430	730	910	400	390	840	780	1,600	1900	n/a	n/a	760	770	570	15	n/a	n/a	2,800	70	n/a	n/a
20,713	33,200	1,540	39,480	4,120	46,450	7,673	30,000	440	3,200	1,100	n/a	n/a	5,100	1,400	390	460	730	720	400	370	840	730	1,600	1600	n/a	n/a	760	640	570	23	n/a	n/a	2,800	130	n/a	n/a
24,741	25,500	2,750	30,800	7,350	36,700	11,364	23,000	750	2,500	2,000	n/a	n/a	4,100	3,300	380	480	820	820	380	360	750	770	1,400	1600	n/a	n/a	760	370	510	44	n/a	n/a	2,100	270	n/a	n/a
28,761	25,500	4,400	30,800	9,840	36,700	14,050	23,000	1400	2,500	3,000	n/a	n/a	4,100	4,200	380	460	820	780	380	380	750	810	1,400	1500	n/a	n/a	760	900	510	110	n/a	n/a	2,100	510	n/a	n/a
32,688	28,900	5,100	35,110	10,830	41,740	15,300	26,000	2200	2,900	2,900	n/a	n/a	5,000	4,600	380	430	830	760	400	410	810	820	1,700	1500	n/a	n/a	750	800	670	180	n/a	n/a	2,300	700	n/a	n/a

Train B

	PFOA + PFOS		UCMR3		Total PFAS		PFOS		PFOA		PFNA		PFHxS		PFHpA		PFBS		PFBA		PFPeA		PFHxA		PFPrS		PFPeS		PFHpS		4:2 FTS		6:2 FTS (LOQ=8.6)		8:2 FTS	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
2,558	25,900	21	32,400	33	39,840	1,333	23,000	19	2,900	2	n/a	n/a	5,100	4	410	3	930	71	410	510	870	640	1,800	140	n/a	n/a	810	5	750	≤LOQ	n/a	n/a	2,800	≤LOQ	n/a	n/a
7,389	26,700	96	34,630	601	42,200	4,225	26,000	46	2,700	50	n/a	n/a	4,800	76	370	39	820	390	380	400	780	860	1,700	2100	n/a	n/a	750	240	600	2	n/a	n/a	3,300	22	n/a	n/a
13,416	27,300	105	33,950	868	41,380	3,268	24,000	59	3,300	46	n/a	n/a	5,300	75	330	38	960	650	380	400	770	830	1,700	1100	n/a	n/a	630	69	530	1	n/a	n/a	3,300	≤LOQ	n/a	n/a
18,171	23,200	780	28,260	2,860	33,810	6,330	21,000	110	2,200	670	n/a	n/a	4,100	650	350	350	610	880	350	360	710	750	1,200	1700	n/a	n/a	760	640	530	10	n/a	n/a	2,000	70	n/a	n/a
20,884	33,200	1,450	39,480	4,470	46,450	8,336	30,000	250	3,200	1,200	n/a	n/a	5,100	1,600	390	420	730	1,000	400	380	840	820	1,600	1700	n/a	n/a	760	880	570	16	n/a	n/a	2,800	130	n/a	n/a
24,346	34,300	2,230	40,670	5,310	47,680	9,523	31,000	530	3,300	1,700	n/a	n/a	5,100	2,400	370	510	900	770	390	370	800	430	1,700	1600	n/a	n/a	810	850	610	33	n/a	n/a	2,700	270	n/a	n/a
29,013	25,500	3,210	30,800	7,390	36,700	12,253	23,000	310	2,500	2,300	n/a	n/a	4,100	3,500	380	470	820	810	380	380	750	730	1,400	1600	n/a	n/a	760	330	510	53	n/a	n/a	2,100	510	n/a	n/a
33,004	28,900	3,070	35,110	8,850	41,740	13,530	26,000	670	2,900	2,400	n/a	n/a	5,000	4,400	380	500	830	880	400	430	810	760	1,700	1800	n/a	n/a	750	330	670	60	n/a	n/a	2,300	700	n/a	n/a

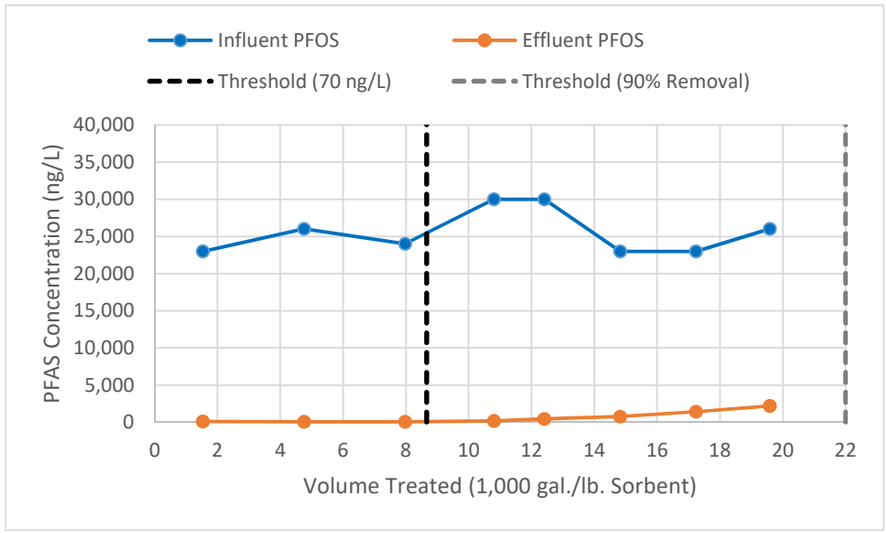

Figure 1: WG Test 1 PFOS Removal Performance—Train A (Single Stage)

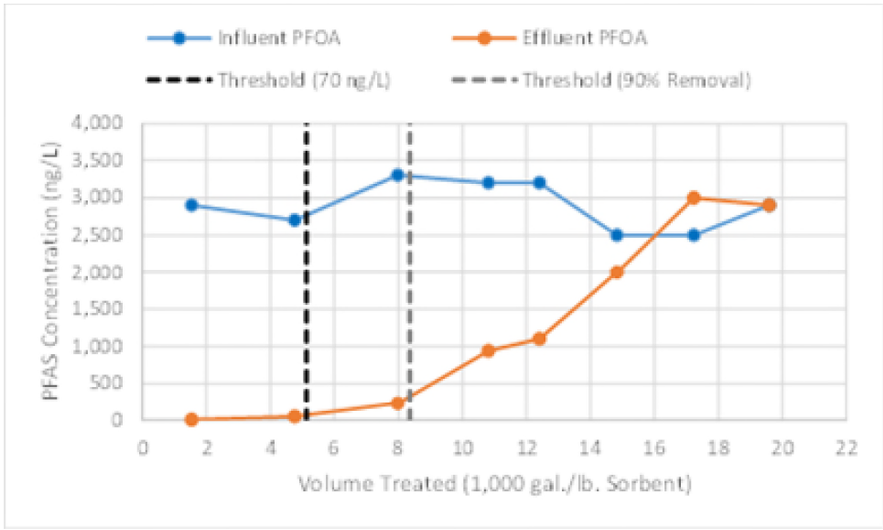

Figure 2: WG Test 1 PFOA Removal Performance—Train A (Single Stage)

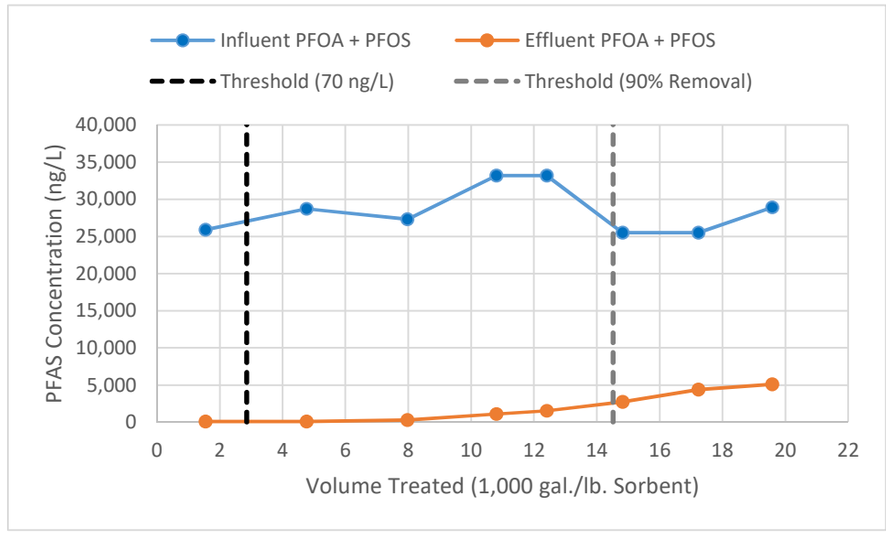

Figure 3: WG Test 1 PFOA+PFOS Removal Performance—Train A (Single Stage)

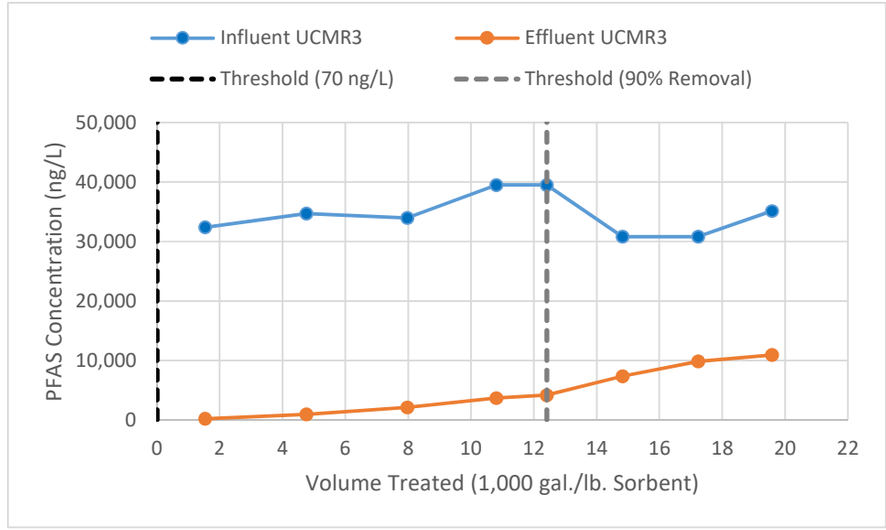

Figure 4: WG Test 1 UCMR3 Removal Performance—Train A (Single Stage)

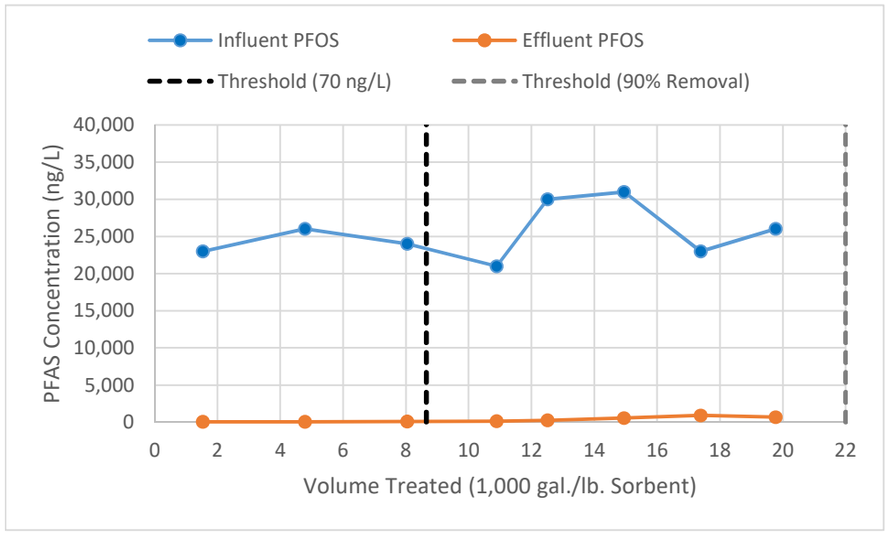

Figure 5: WG Test 1 PFOS Removal Performance—Train B (Single Stage)

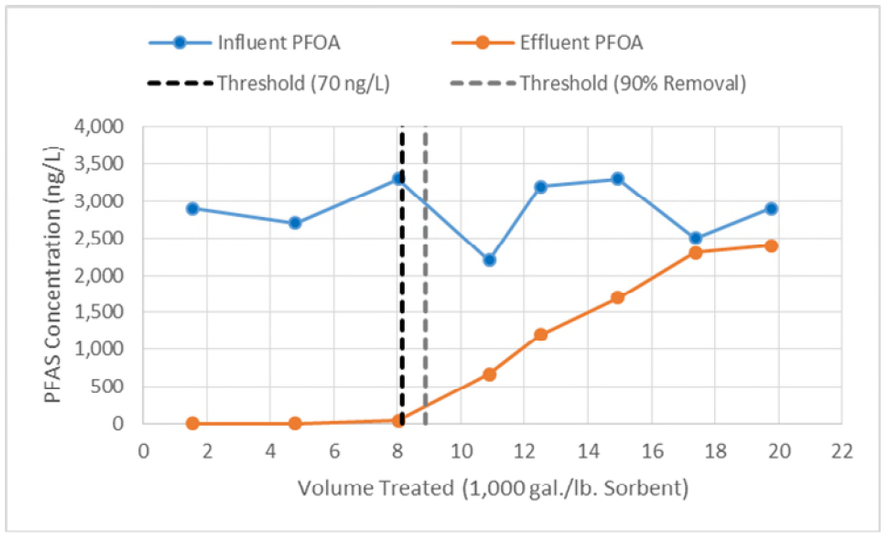

Figure 6: WG Test 1 PFOA Removal Performance—Train B (Single Stage)

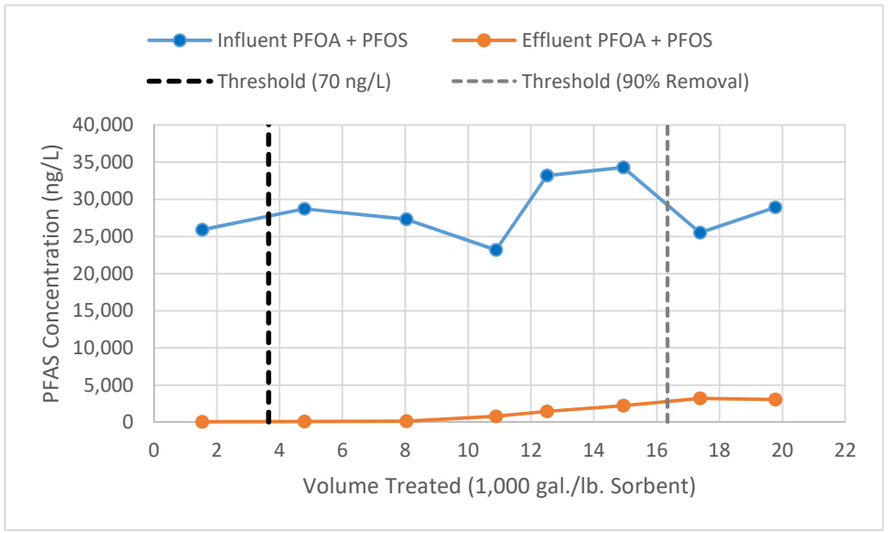

Figure 7: WG Test 1 PFOA+PFOS Removal Performance—Train B (Single Stage)

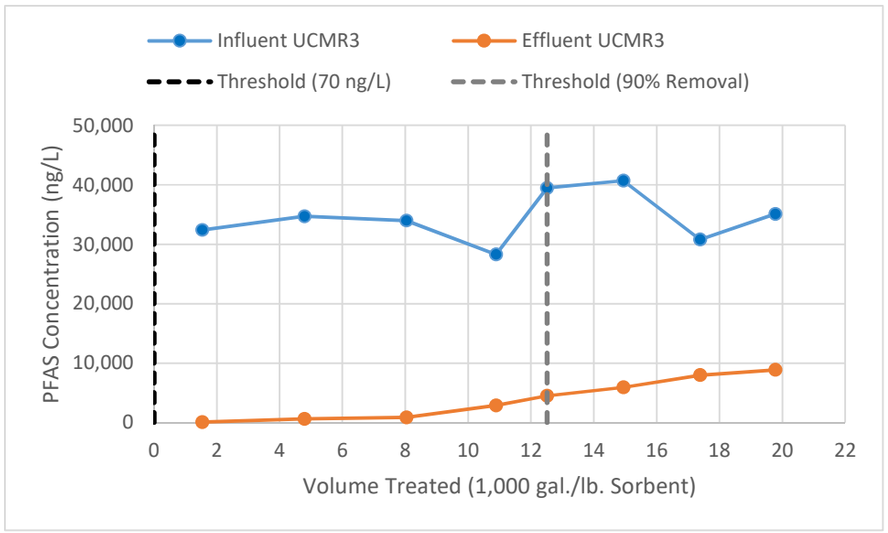

Figure 8: WG Test 1 UCMR3 Removal Performance—Train B (Single Stage)

2. Test 2

Test 2 was conducted at the Willow Grove, Pennsylvania, NASJRB test site from June 24, 2021, to July 13, 2021, with the operating conditions listed below in Table 3. For this test, two treatment trains were operated in parallel (i.e., single stage/single pass operation) with a common feed source from a Willow Grove, Pennsylvania, NASJRB contaminated well. This test was conducted to evaluate the impact of detention time on adsorption capacity. All operating conditions were the same for each treatment train except for detention time (highlighted in gray in Table 3), which was 8 minutes for Train A and 16 minutes for Train B. Table 4 lists a summary of the PFAS data per treatment train. The gray columns represent the UCMR3 compounds. The blue columns represent summed data for PFOS and PFOA and, separately, the summed UCMR3 compounds. The metrics used in Figures 9 to 16 include (a) the threshold at 70 ng/L, which indicates the health advisory level established by the USEPA in 2016, and (b) the 90% removal threshold, indicating the breakthrough point.

Table 3: WG Test 2 Operating Conditions

Train	Single Pass/Series Configuration (lead/lag)	Detention Time (minutes)	Sorbent Type	Sorbent Concentration (g/L)	Sorption Volume (L)	Membrane Permeate Flow Rate (L/min)	Test Duration (days)
Train A	SP	8	AquaPR-206	25	8	1	12
Train B	SP	16	AquaPR-206	12.5	16	1	12

Figures 9 to 12 present removal performance for treatment Train A during Test 2. All figures in this section demonstrate the removal process rate of key PFAS compounds quantified as gallons of PFAS-contaminated water treated per pound of sorbent material. Table 4 presents all the raw data that were used to establish the Train A performance exhibited in Figures 9 to 12.

- Figure 9 presents PFOS removal performance data with an influent PFOS range of 23,000 to 32,000 ng/L. Effluent PFOS levels surpassed the 70 ng/L threshold at test start, and the 90% removal threshold was reached at a removal process rate of 7,000 gal/lb sorbent.
- Figure 10 presents PFOA removal performance data with an influent PFOA range of 1,600 to 2,000 ng/L. Effluent PFOA levels reached the 70 ng/L effluent threshold at a removal process rate of 1,400 gal/lb sorbent, and the 90% removal threshold was reached at a removal process rate of 2,200 gal/lb sorbent.
- Figure 11 presents the summed PFOA plus PFOS removal performance data with an influent PFOA plus PFOS range of 25,000 to 35,000 ng/L. Effluent PFOS levels surpassed the 70 ng/L threshold at test start, and the 90% removal threshold was reached at a removal process rate of 6,400 gal/lb sorbent.
- Figure 12 presents the UCMR3 compounds' removal performance data with an influent (summed) UCMR3 level range of 30,000 to 42,000 ng/L. Effluent PFOS levels surpassed the 70 ng/L threshold at test start, and the 90% removal threshold was reached at a removal process rate of 2,600 gal/lb sorbent.

Figures 13 to 16 present removal performance for treatment Train B during Test 2. All figures in this section demonstrate the removal process rate of key PFAS compounds quantified as gallons of PFAS-contaminated water treated per pound of sorbent material. Table 4 presents all the raw data and relevant calculations that were used to establish the Train B performance exhibited in Figures 13 to 16.

- Figure 13 presents PFOS removal performance data with an influent PFOS range of 23,000 to 34,000 ng/L. Effluent PFOS levels reached the 70 ng/L threshold at a removal process rate of 7,320 gal/lb sorbent; the 90% removal threshold was not reached with this test duration (i.e., 12 days).
- Figure 14 presents PFOA removal performance data with an influent PFOA range of 1,500 to 2,000 ng/L. Effluent PFOA levels reached the 70 ng/L effluent threshold at a removal process rate of 6,100 gal/lb sorbent; the 90% removal threshold was reached at a removal process rate of 7,700 gal/lb sorbent.
- Figure 15 presents the summed PFOA plus PFOS removal performance data with an influent PFOA plus PFOS range of 25,000 to 35,000 ng/L. Effluent PFOA plus PFOS levels reached the 70 ng/L effluent threshold at a removal process rate of 5,300 gal/lb sorbent; the 90% removal threshold was not reached with this test duration (i.e., 12 days).

- Figure 16 presents the UCMR3 compounds' removal performance data with an influent (summed) UCMR3 level range of 30,000 to 42,000 ng/L. Effluent UCMR3 levels surpassed the 70 ng/L threshold at test start; the 90% removal threshold was reached at a removal process rate of 8,100 gal/lb sorbent.

Table 4: WG NASJRB Test 2 Trains A and B Summary PFAS Analytical Data

Train A

	PFOA + PFOS		UCMR3		Total PFAS		PFOS		PFOA		PFNA (LOQ=1.0)		PFHxS		PFHpA		PFBS		PFBA		PFPeA		PFHxA		PFPrS		PFPeS		PFHpS		4:2 FTS (LOQ=41		6:2 FTS (LOQ=41		8:2 FTS (LOQ=21	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
1,566	32,049	338	37,776	830	43,224	4,215	30,236	361	1,813	37	n/a	n/a	4,289	37	765	23	672	372	237	632	451	1172	1,056	756	297	692	681	62	765	10	n/a	n/a	1,360	≤LOQ	n/a	n/a
2,393	28,764	412	34,413	1,386	39,811	7,422	27,123	308	1,641	105	n/a	n/a	4,253	234	697	105	699	1235	236	651	507	1314	1,117	2233	305	900	713	209	697	13	n/a	n/a	1,825	117	n/a	n/a
5,835	24,695	741	30,530	4,568	35,996	11,618	23,061	370	1,633	372	n/a	n/a	4,417	1080	699	422	719	2324	236	611	494	1176	1,152	3461	321	840	747	338	699	24	n/a	n/a	1,757	≤LOQ	n/a	n/a
7,346	26,146	4,231	32,348	10,226	38,124	17,684	24,460	3295	1,687	936	n/a	n/a	4,681	3135	723	631	738	2110	239	638	503	1195	1,181	3045	351	812	809	1591	723	144	n/a	n/a	1,905	32	n/a	n/a
9,348	33,805	4,622	40,335	11,488	46,503	19,063	31,859	2934	1,946	1688	n/a	n/a	4,871	4155	880	739	779	1972	268	649	500	1131	1,186	2875	337	788	814	1846	880	173	n/a	n/a	2,189	113	n/a	n/a
10,730	33,805	3,385	40,335	10,772	46,503	18,144	31,859	2232	1,946	1034	n/a	n/a	4,871	4710	880	762	779	1915	268	579	500	1127	1,186	2736	337	782	814	2003	880	135	n/a	n/a	2,189	10	n/a	n/a
11,420	33,805	5,246	40,335	14,287	46,503	22,210	31,859	2753	1,946	2487	n/a	n/a	4,871	6372	880	787	779	1882	268	632	500	1034	1,186	2848	337	766	814	2158	880	263	n/a	n/a	2,189	221	n/a	n/a
13,434	29,369	8,207	35,701	19,511	40,372	28,017	28,236	4748	1,753	3459	n/a	n/a	4,327	8634	718	773	667	1836	250	607	484	1104	1,029	2623	287	753	693	2214	718	418	n/a	n/a	1,811	587	n/a	n/a
14,879	28,830	10,468	34,368	22,520	39,715	30,384	27,032	6524	1,798	3944	n/a	n/a	4,188	3679	695	710	656	1662	219	544	432	1063	1,054	2566	284	674	691	2138	695	548	n/a	n/a	1,913	331	n/a	n/a
16,260	30,677	10,148	36,264	22,610	41,748	30,463	28,886	6135	1,791	4013	n/a	n/a	4,244	10202	701	709	641	1550	224	596	490	1056	1,105	2555	283	646	697	1960	701	620	n/a	n/a	1,983	420	n/a	n/a

Train B

	PFOA + PFOS		UCMR3		Total PFAS		PFOS		PFOA (LOQ=1.0)		PFNA (LOQ=1.0)		PFHxS		PFHpA (LOQ=1.0)		PFBS		PFBA (LOQ=1.0)		PFPeA (LOQ=1.0)		PFHxA (LOQ=2)		PFPrS (LOQ=1.0)		PFPeS		PFHpS (LOQ=1.0)		4:2 FTS (LOQ=41		6:2 FTS (LOQ=41		8:2 FTS (LOQ=21	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
1,452	32,049	45	37,270	36	42,718	1,167	30,236	43	1,813	2	n/a	n/a	4,289	13	260	≤LOQ	672	32	237	534	451	277	1,056	63	297	124	681	7	765	≤LOQ	n/a	n/a	1,360	≤LOQ	n/a	n/a
2,802	28,764	26	33,393	140	39,391	2,055	27,123	26	1,641	≤LOQ	n/a	n/a	4,253	12	277	≤LOQ	699	103	236	668	507	690	1,117	200	305	344	713	13	697	≤LOQ	n/a	n/a	1,825	≤LOQ	n/a	n/a
5,439	24,695	25	30,107	531	35,573	4,448	23,061	14	1,633	11	n/a	n/a	4,417	49	276	28	719	430	236	643	494	1377	1,152	893	321	866	747	61	699	≤LOQ	n/a	n/a	1,757	17	n/a	n/a
8,207	26,146	47	31,904	1,480	37,680	6,703	24,460	15	1,687	32	n/a	n/a	4,681	160	279	85	738	1,187	239	649	503	1278	1,181	2133	351	979	809	184	723	≤LOQ	n/a	n/a	1,905	≤LOQ	n/a	n/a
9,554	33,805	91	39,769	2,076	45,944	8,229	31,859	28	1,946	63	n/a	n/a	4,871	260	314	138	779	1,587	268	739	500	1283	1,186	2839	337	976	814	289	880	5	n/a	n/a	2,189	22	n/a	n/a
10,231	33,805	34	39,769	2,171	45,944	8,125	31,859	25	1,946	69	n/a	n/a	4,871	291	314	148	779	1,638	268	656	500	1277	1,186	2810	337	890	814	317	880	6	n/a	n/a	2,189	≤LOQ	n/a	n/a
11,580	35,533	250	41,603	2,861	47,734	9,212	33,483	56	2,050	194	n/a	n/a	4,363	447	303	227	778	1,936	279	579	523	1128	1,180	3303	329	869	801	453	883	5	n/a	n/a	2,124	13	n/a	n/a
12,930	29,989	265	35,263	3,230	40,534	9,803	28,236	86	1,753	179	n/a	n/a	4,327	635	280	293	667	2,096	250	562	484	1152	1,029	3353	287	812	693	601	718	16	n/a	n/a	1,811	18	n/a	n/a
14,278	28,830	515	33,943	3,740	39,290	9,880	27,032	120	1,798	395	n/a	n/a	4,188	848	270	340	656	2,037	219	547	432	910	1,054	3230	284	683	691	722	695	20	n/a	n/a	1,913	26	n/a	n/a
16,301	30,677	642	35,837	4,376	41,321	12,101	28,886	204	1,791	438	n/a	n/a	4,244	1,516	274	519	641	2,239	224	575	490	1146	1,105	3415	283	711	697	1156	701	37	n/a	n/a	1,983	84	n/a	n/a

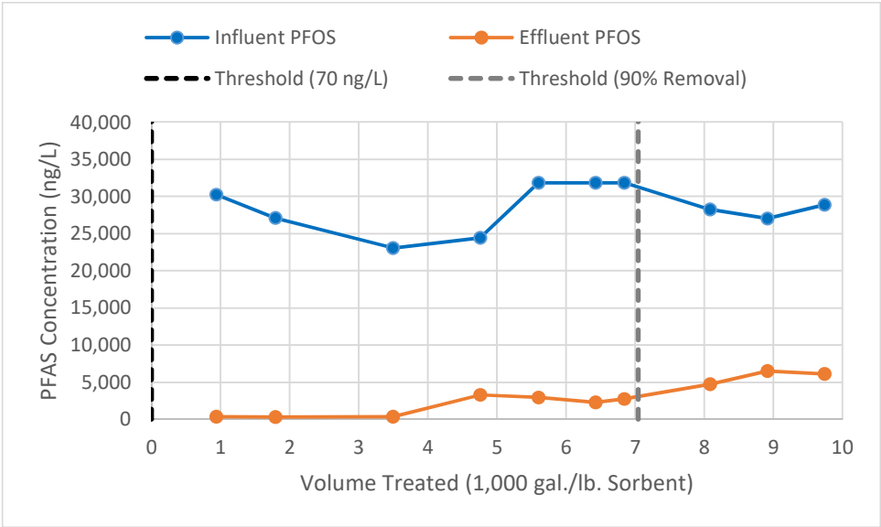

Figure 9: WG Test 2 PFOS Removal Performance—Train A (Single Stage)

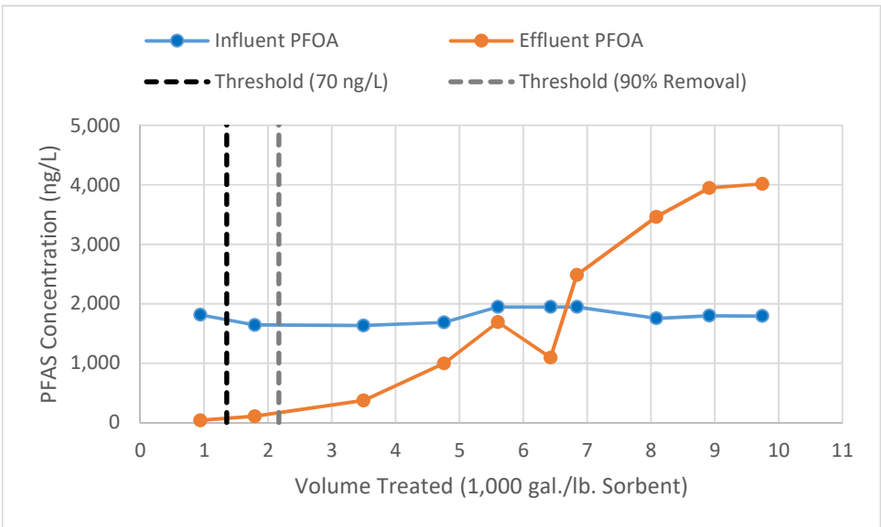

Figure 10: WG Test 2 PFOA Removal Performance—Train A (Single Stage)

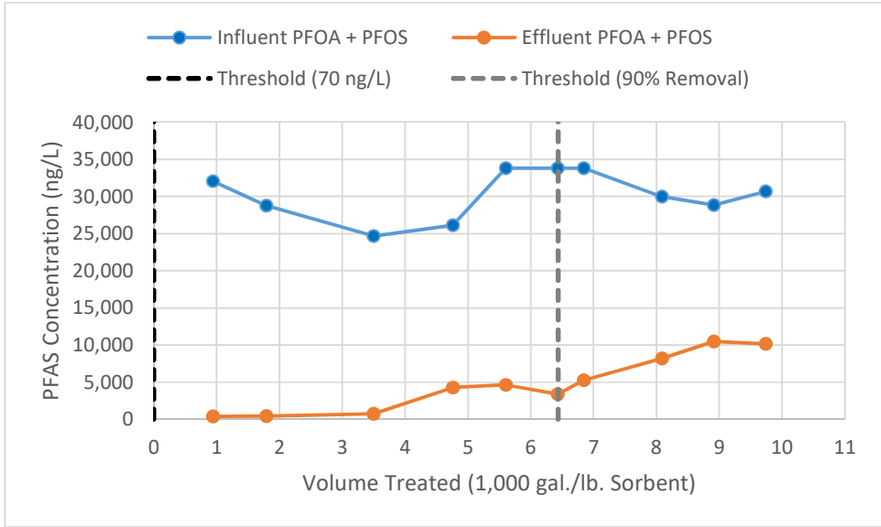

Figure 11: WG Test 2 PFOA+PFOS Removal Performance—Train A (Single Stage)

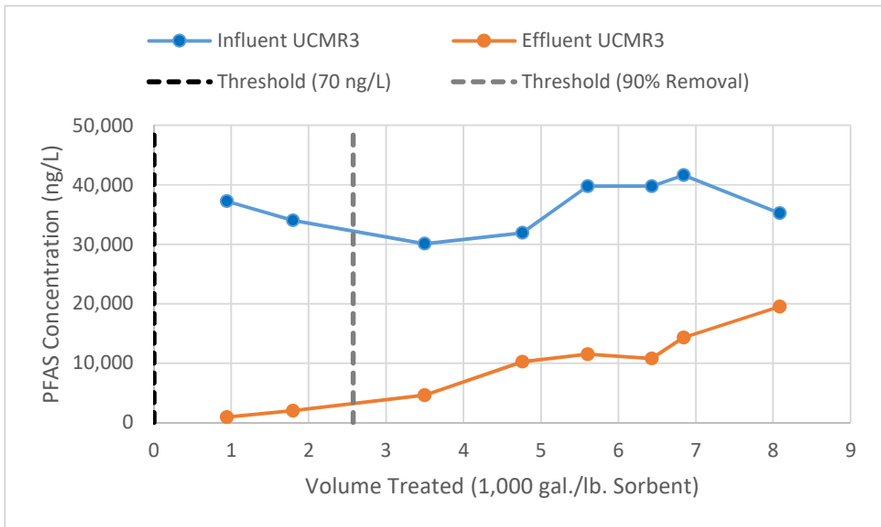

Figure 12: WG Test 2 UCMR3 Removal Performance—Train A (Single Stage)

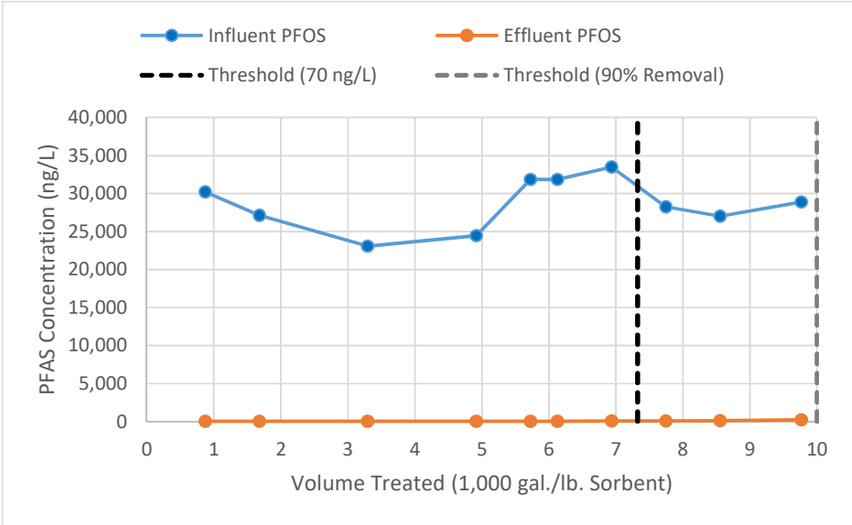

Figure 13: WG Test 2 PFOS Train B (Single Stage)

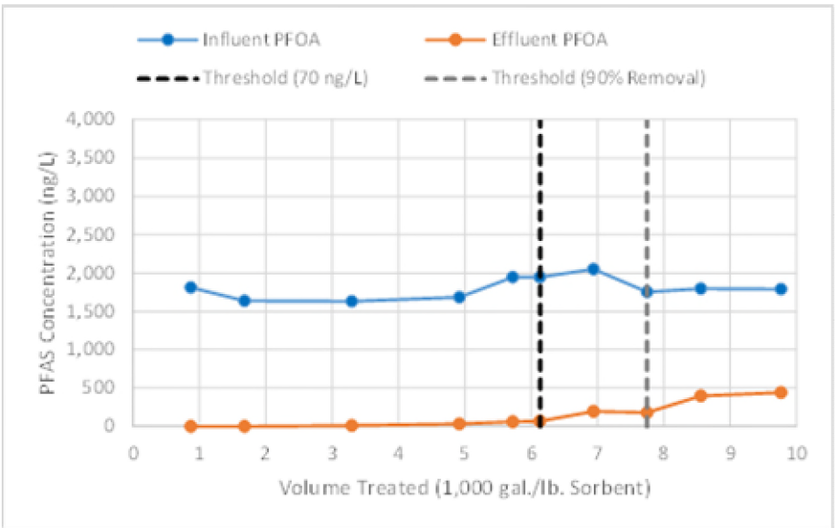

Figure 14: WG Test 2 PFOA Train B (Single Stage)

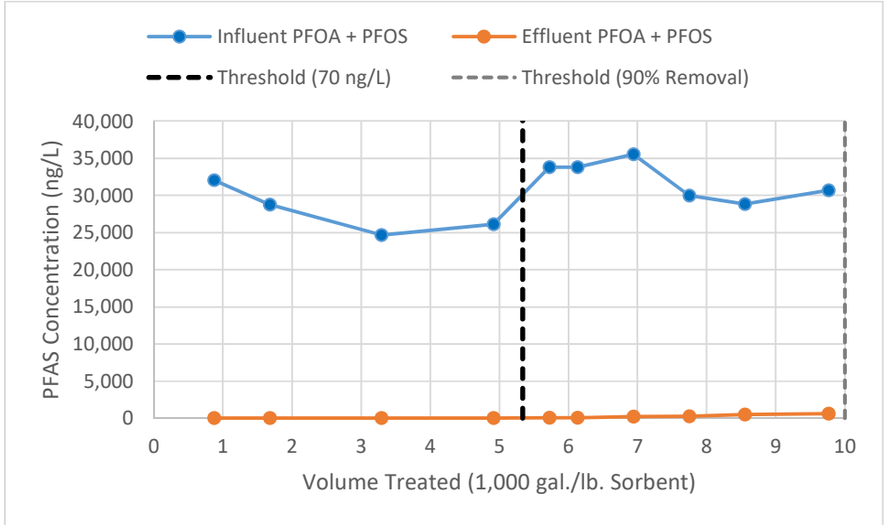

Figure 15: WG Test 2 PFOA+PFOS Train B (Single Stage)

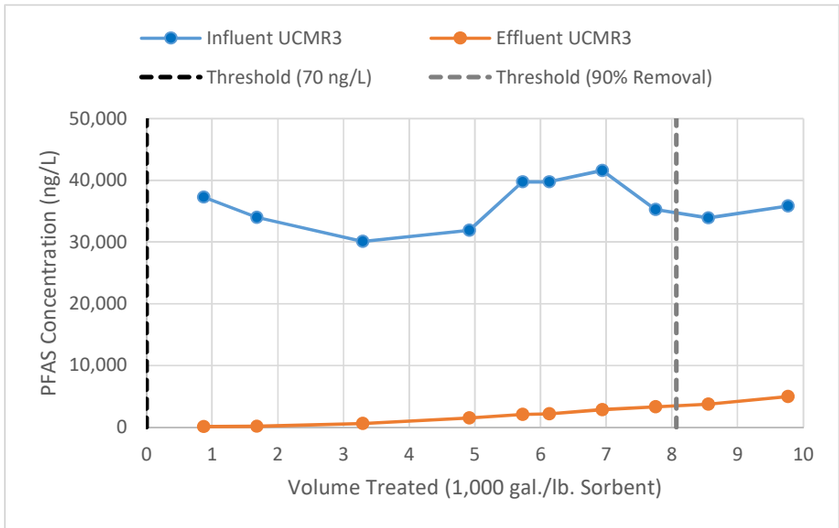

Figure 16: WG Test 2 UCMR3 Train B (Single Stage)

3. Test 3

Test 3 was conducted at the Willow Grove, Pennsylvania, NASJRB test site from August 17, 2021, to August 31, 2021, with the operating conditions listed below in Table 5. For this test, two treatment trains were operated in series with Train A in the lead position with a feed source from a Willow Grove, Pennsylvania, NASJRB contaminated well and Train B in the lag position with feed from Train A effluent. The in-series (lead/lag configuration) treatment trains (A and B) were evaluated based on the combined sorbent concentration of 400 grams (g) (Trains A and B) and compared to a single stage treatment operation using 200 g of sorbent (Train A). This test was conducted to evaluate the PFAS removal process rate of an in-series operation with a lead/lag configuration. Both the lead and lag positions were prepared with fresh sorbent. All operating conditions were the same for each treatment train. Table 6 lists a summary of the PFAS data per treatment train. The gray columns represent the UCMR3 compounds. The blue columns represent summed data for PFOS and PFOA and, separately, the summed UCMR3 compounds. The metrics used in Figures 17 to 24 include (a) the threshold at 70 ng/L, which indicates the health advisory level established by the USEPA in 2016, and (b) the 90% removal threshold, indicating the breakthrough point.

Table 5: WG Test 3 Operating Conditions

Train	Single Pass/Series Configuration (lead/lag)	Detention Time (minutes)	Sorbent Type	Sorbent Concentration (g/L)	Sorption Volume (L)	Membrane Permeate Flow Rate (L/min)	Test Duration (days)
Train A	Lead	10	AquaPR-206	20	10	1	13
Train B	Lag	10	AquaPR-206	20	10	1	13

Figures 17 to 20 present removal performance for series treatment Trains A and B during Test 3. All figures in this section demonstrate the removal process rate of key PFAS compounds quantified as gallons of PFAS-contaminated water treated per pound of sorbent material. Table 6 presents all the raw data that were used to establish the series Trains A and B performance exhibited in Figures 17 to 20.

- Figure 17 presents PFOS removal performance data with an influent PFOS range of 25,000 to 40,000 ng/L. Train A effluent PFOS levels ranged from 12 to 59 ng/L. Train B effluent PFOS levels ranged from 0 to 12 ng/L. The 70 ng/L effluent threshold was not reached for Train B effluent PFOS, and the removal process rate is estimated to be greater than 9,000 gal/lb sorbent before reaching this point.
- Figure 18 presents PFOA removal performance data with an influent PFOA range of 2,100 to 2,800 ng/L. Train A effluent PFOA levels ranged from 0 to 99 ng/L. Train B effluent PFOA levels remained at non-detect levels throughout the test. The 70 ng/L effluent threshold was not reached for Train B effluent PFOA levels, and the removal process rate is estimated to be greater than 9,000 gal/lb sorbent before reaching this point.
- Figure 19 presents the summed PFOA plus PFOS removal performance data with an influent PFOA plus PFOS range of 27,000 to 42,000 ng/L. Train A effluent PFOA plus PFOS levels ranged from 4 to 136 ng/L. Train B effluent levels ranged from 0 to 12 ng/L. The 70 ng/L effluent threshold was not reached for Train B effluent PFOA, and the removal process rate is estimated to be greater than 9,000 gal/lb sorbent before reaching this point.
- Figure 20 presents the UCMR3 compounds' removal performance data with an influent (summed) UCMR3 level range of 33,000 to 50,000 ng/L. Train A effluent PFOS level ranged from 88 to 1,200 ng/L. Train B effluent level ranged from 0 to 217 ng/L. The 70 ng/L effluent threshold was reached for Train B effluent UCMR3 compounds at a removal process rate of 6,800 gal/lb sorbent.

Figures 21 to 24 present removal performance for treatment Train A during Test 3. All figures in this section demonstrate the removal process rate of key PFAS compounds quantified as gallons of PFAS-contaminated water treated per pound of sorbent material. Table 6 presents all the raw data that were used to establish the Train A (lead) performance exhibited in Figures 21 to 24. These results show how well a single stage system works on the raw water.

- Figure 21 presents PFOS removal performance data with an influent range of 25,000 to 40,000 ng/L. Effluent PFOS levels did not reach the 70 ng/L effluent threshold or the 90% removal threshold within the 13-day test duration.

- Figure 22 presents PFOA removal performance data with an influent range of 2,100 to 2,800 ng/L. Effluent PFOA levels reached the 70 ng/L effluent threshold at a removal process rate of 15,600 gal/lb sorbent; the 90% removal threshold was not reached with this test duration (i.e., 13 days).
- Figure 23 presents the summed PFOA plus PFOS removal performance data with an influent level range of 27,000 to 42,000 ng/L. Effluent PFOA plus PFOS levels reached the 70 ng/L threshold at a removal process rate of 12,000 gal/lb sorbent; the 90% removal threshold was not reached with this test duration (i.e., 13 days).
- Figure 24 presents the UCMR3 compounds' removal performance data with an influent (summed) UCMR3 level range of 33,000 to 50,000 ng/L. Effluent UCMR3 levels surpassed the 70 ng/L threshold at test start; the 90% removal threshold was not reached with this test duration (i.e., 13 days).

Table 6: WG NASJRB Test 3 Trains A and B Summary PFAS Analytical Data

Train A - LEAD

	PFOA + PFOS		UCMR3		Total PFAS		PFOS		PFOA (LOQ=1.0)		PFNA (LOQ=1.0)		PFHxS		PFHpA (LOQ=1.0)		PFBS		PFBA		PFPeA		PFHxA		PFPrS		PFPeS		PFHpS (LOQ=1.0)		4:2 FTS (LOQ=4)		6:2 FTS (LOQ=4)		8:2 FTS (LOQ=2)	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
149	39,249	59	45,595	133	53,538	529	36,731	59	2,519	≤LOQ	n/a	n/a	5,193	41	341	5	812	27	343	170	661	77	1,514	74	380	44	364	14	626	2	≤LOQ	≤LOQ	3,326	15	189	1
1,401	41,540	35	49,065	88	58,123	1,035	38,775	35	2,765	≤LOQ	n/a	n/a	6,245	11	382	3	898	40	405	382	710	287	1,695	109	419	138	1,330	6	590	≤LOQ	25	18	3,551	≤LOQ	279	7
2,805	38,087	29	44,593	31	52,574	1,011	35,568	29	2,519	≤LOQ	n/a	n/a	5,309	11	350	3	848	43	372	316	627	303	1,604	142	397	148	967	8	702	1	≤LOQ	≤LOQ	3,027	≤LOQ	285	2
4,230	42,197	21	49,392	123	58,426	1,380	39,429	21	2,768	≤LOQ	n/a	n/a	5,931	13	364	3	901	87	408	329	676	465	1,762	212	416	232	982	13	1,150	≤LOQ	≤LOQ	≤LOQ	3,348	6	292	≤LOQ
5,650	36,146	12	42,428	187	50,334	1,786	33,630	12	2,516	≤LOQ	n/a	n/a	5,201	18	308	5	773	148	366	332	657	580	1,436	344	348	310	860	24	866	2	≤LOQ	≤LOQ	3,062	≤LOQ	251	7
7,074	38,066	16	44,506	286	52,426	2,130	35,515	14	2,551	2	n/a	n/a	5,335	27	328	17	777	227	389	358	643	642	1,455	515	366	354	880	34	855	1	51	≤LOQ	3,022	≤LOQ	260	≤LOQ
8,440	32,843	26	38,696	430	45,892	2,710	30,523	16	2,314	11	n/a	n/a	4,881	39	288	23	683	342	329	321	562	684	1,258	810	317	396	863	68	644	≤LOQ	≤LOQ	≤LOQ	3,022	≤LOQ	201	≤LOQ
8,937	32,008	37	37,548	586	44,424	3,278	29,732	22	2,216	15	n/a	n/a	4,597	52	294	37	648	461	310	302	539	760	1,271	1,092	302	444	885	87	563	1	16	≤LOQ	2,773	3	213	4
10,299	33,267	63	38,701	658	45,555	3,055	31,023	24	2,244	39	n/a	n/a	4,486	78	293	43	654	474	312	298	599	581	1,273	1,054	295	353	912	105	541	1	34	≤LOQ	2,709	5	179	2
11,648	29,578	65	34,376	778	41,843	3,314	27,413	21	2,165	44	n/a	n/a	4,463	102	280	53	654	558	311	306	543	568	1,320	1,177	303	345	922	123	578	3	≤LOQ	12	2,662	≤LOQ	235	2
13,067	27,757	36	33,133	345	39,314	3,685	25,658	28	2,100	68	n/a	n/a	4,419	150	297	74	660	625	324	292	536	541	1,348	1,283	305	330	709	263	773	2	42	≤LOQ	2,484	25	258	5
14,358	37,390	136	43,134	1,158	50,531	4,159	34,893	40	2,491	97	n/a	n/a	4,786	198	284	97	674	726	332	328	539	607	1,390	1,514	303	340	737	204	853	6	54	≤LOQ	2,959	3	230	≤LOQ
15,720	28,005	130	33,469	1,211	40,360	4,282	25,855	30	2,150	99	n/a	n/a	4,489	212	238	115	677	755	312	314	545	556	1,340	1,552	323	323	695	304	712	2	41	≤LOQ	2,532	≤LOQ	190	18
17,090	28,055	235	33,588	1,503	40,077	4,726	25,901	57	2,154	178	n/a	n/a	4,603	337	286	142	645	730	361	300	537	559	1,287	1,612	293	312	672	333	537	6	36	≤LOQ	2,400	14	165	20

Train B - LAG

	PFOA + PFOS (LOQ=3)		UCMR3		Total PFAS		PFOS (LOQ=2)		PFOA (LOQ=1.0)		PFNA (LOQ=1.0)		PFHxS (LOQ=1.0)		PFHpA (LOQ=1.0)		PFBS		PFBA		PFPeA		PFHxA		PFPrS		PFPeS (LOQ=1.0)		PFHpS (LOQ=1.0)		4:2 FTS (LOQ=4)		6:2 FTS (LOQ=4)		8:2 FTS (LOQ=2)	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
35	59	12	133	23	529	131	59	12	≤LOQ	≤LOQ	n/a	n/a	41	4	5	2	27	4	170	34	77	36	74	5	44	20	14	2	2	1	≤LOQ	≤LOQ	15	6	1	4
1,095	35	7	88	13	1,035	293	35	7	≤LOQ	≤LOQ	n/a	n/a	11	2	3	3	40	2	382	208	287	36	109	16	138	17	6	1	≤LOQ	≤LOQ	18	≤LOQ	≤LOQ	≤LOQ	7	3
2,328	29	3	31	6	1,011	405	29	3	≤LOQ	≤LOQ	n/a	n/a	11	≤LOQ	3	≤LOQ	43	2	316	286	303	56	142	15	148	25	8	1	1	≤LOQ	≤LOQ	≤LOQ	≤LOQ	6	2	11
3,625	21	3	123	9	1,380	518	21	3	≤LOQ	≤LOQ	n/a	n/a	13	3	3	≤LOQ	87	2	329	348	465	89	212	32	232	40	13	1	≤LOQ	≤LOQ	≤LOQ	≤LOQ	6	≤LOQ	≤LOQ	≤LOQ
4,316	12	≤LOQ	187	6	1,786	663	12	≤LOQ	≤LOQ	≤LOQ	n/a	n/a	18	2	9	≤LOQ	148	4	332	358	580	178	344	43	310	69	24	1	2	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	7	8
6,200	16	4	286	13	2,190	855	14	4	2	≤LOQ	n/a	n/a	27	1	17	1	227	6	358	377	642	277	515	47	354	114	34	≤LOQ	1	≤LOQ	≤LOQ	≤LOQ	≤LOQ	12	≤LOQ	16
7,438	26	≤LOQ	430	12	2,710	981	16	≤LOQ	11	≤LOQ	n/a	n/a	39	≤LOQ	23	≤LOQ	342	12	321	370	684	386	810	37	396	166	68	1	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	9
7,888	37	6	586	25	3,278	1,235	22	6	15	≤LOQ	n/a	n/a	52	≤LOQ	37	1	461	18	302	373	760	515	1,032	79	444	225	87	1	1	≤LOQ	≤LOQ	≤LOQ	3	8	4	9
9,175	63	4	658	37	3,055	1,405	24	4	39	≤LOQ	n/a	n/a	78	≤LOQ	43	3	474	30	238	326	581	620	1,054	131	353	273	105	2	1	≤LOQ	≤LOQ	≤LOQ	5	7	2	9
10,403	65	≤LOQ	778	47	3,314	1,432	21	≤LOQ	44	≤LOQ	n/a	n/a	102	≤LOQ	53	1	558	46	306	304	568	665	1,177	155	345	315	123	2	3	≤LOQ	12	≤LOQ	≤LOQ	≤LOQ	2	3
11,654	96	≤LOQ	345	78	3,685	1,819	28	≤LOQ	68	≤LOQ	n/a	n/a	150	1	74	5	625	73	232	354	541	764	1,283	249	330	369	263	3	2	≤LOQ	≤LOQ	≤LOQ	25	≤LOQ	5	2
12,393	136	≤LOQ	1,158	114	4,159	1,946	40	≤LOQ	97	≤LOQ	n/a	n/a	198	2	97	3	726	110	328	320	607	754	1,514	342	340	409	204	4	6	≤LOQ	≤LOQ	≤LOQ	3	2	≤LOQ	≤LOQ
14,213	130	≤LOQ	1,211	158	4,282	2,120	30	≤LOQ	99	≤LOQ	n/a	n/a	212	2	115	3	755	152	314	319	556	750	1,552	471	323	412	304	6	2	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	18	3
15,439	235	4	1,503	217	4,726	2,234	57	4	178	≤LOQ	n/a	n/a	337	3	142	5	730	204	300	313	559	706	1,612	626	312	413	333	11	6	≤LOQ	≤LOQ	≤LOQ	14	7	20	≤LOQ

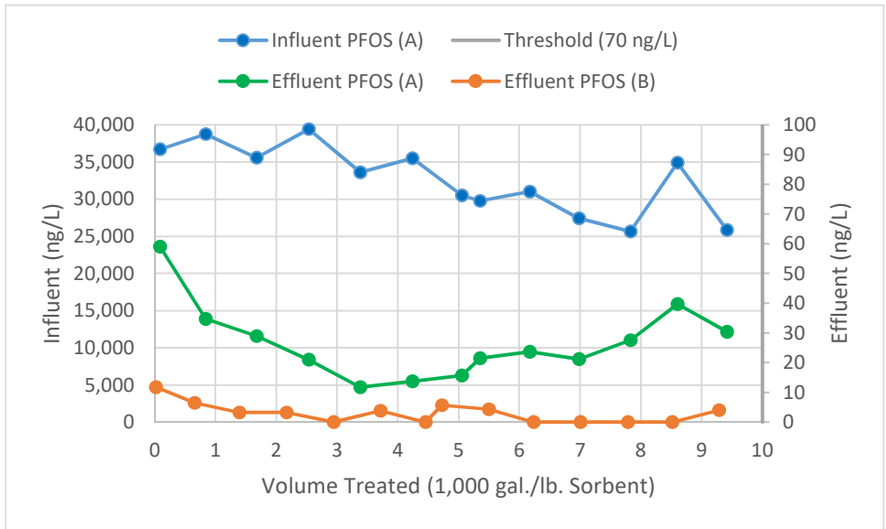

Figure 17: WG Test 3 PFOS Train A–B Series

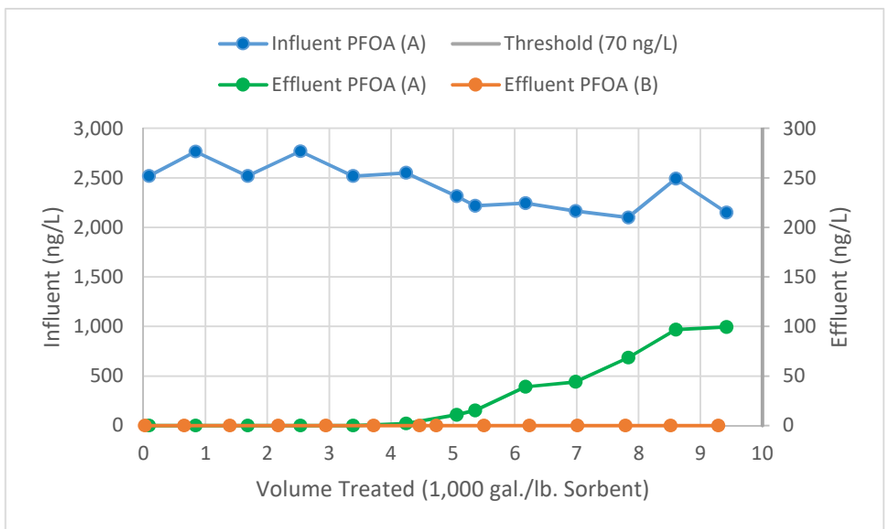

Figure 18: WG Test 3 PFOA Train A–B Series

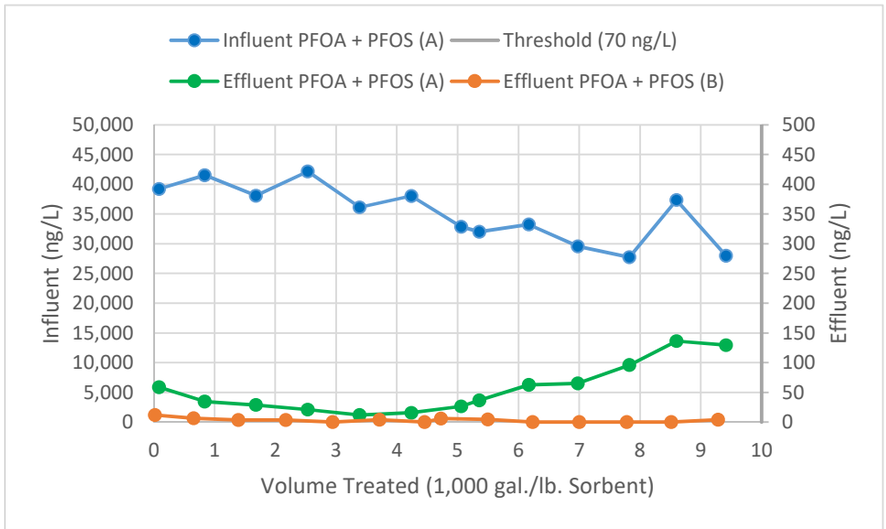

Figure 19: WG Test 3 PFOA+PFOS Train A–B Series

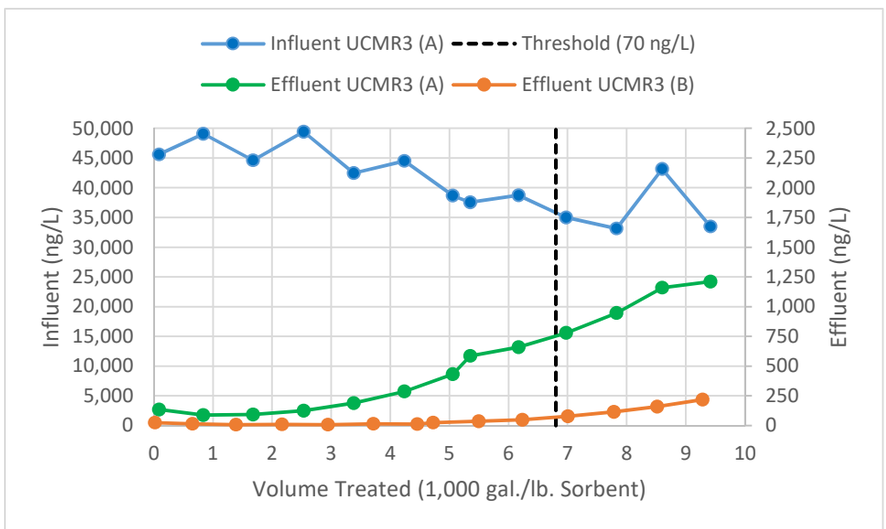

Figure 20: WG Test 3 UCMR3 Train A–B Series

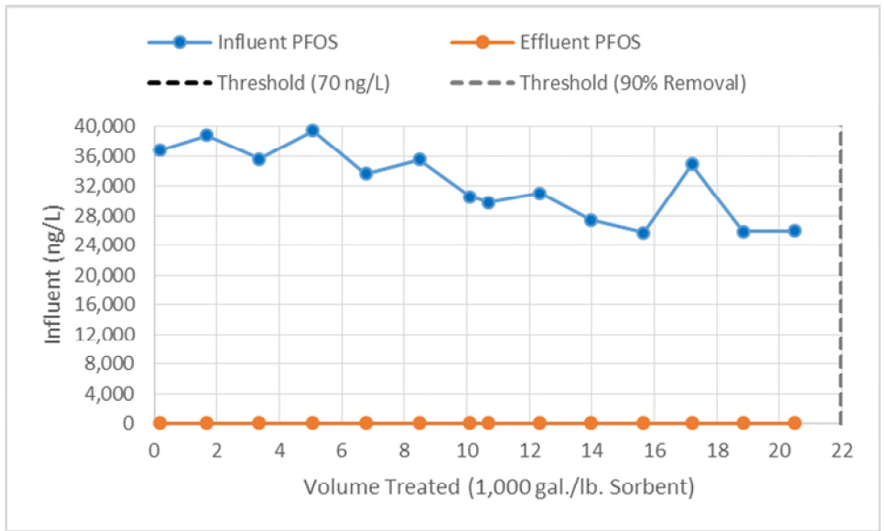

Figure 21: WG Test 3 PFOS Train A (Single Stage)

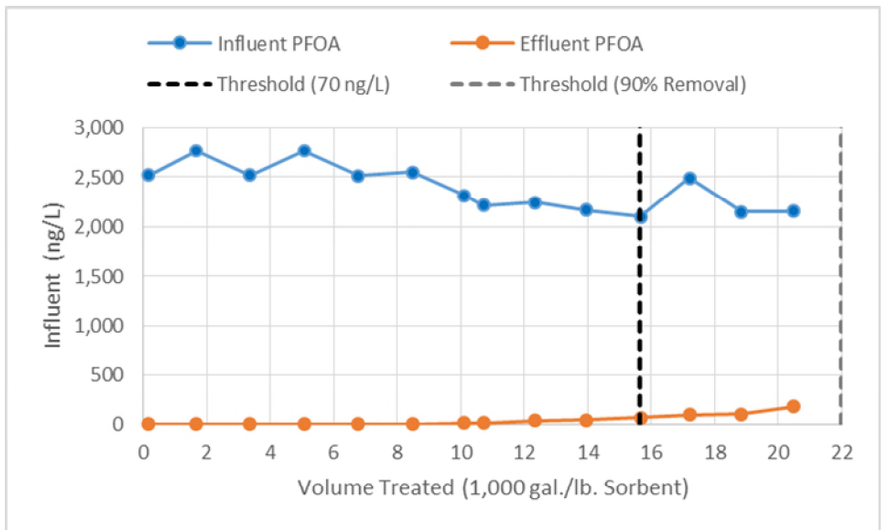

Figure 22: WG Test 3 PFOA Train A (Single Stage)

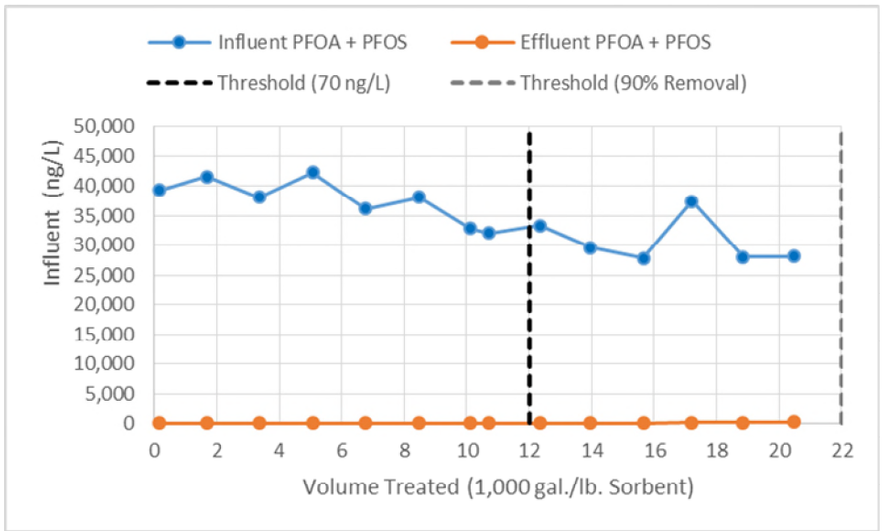

Figure 23: WG Test 3 PFOA+PFOS Train A (Single Stage)

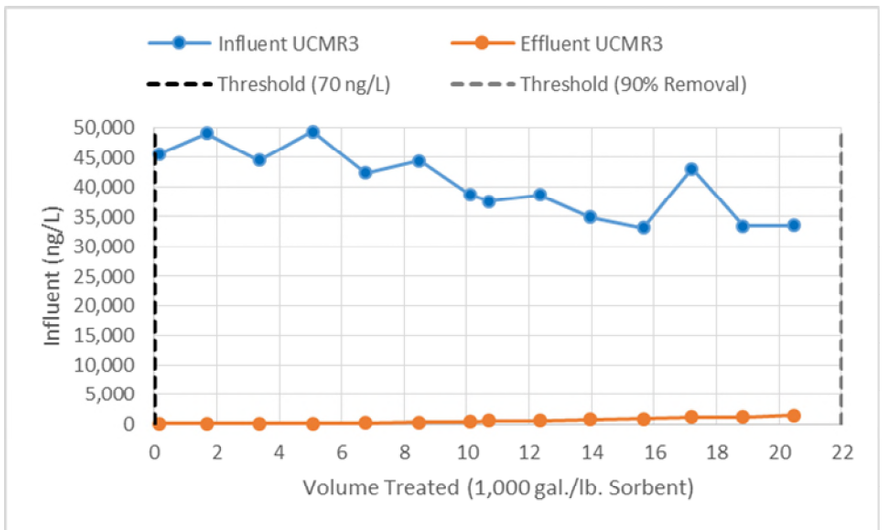

Figure 24: WG Test 3 UCMR3 Train A (Single Stage)

4. Test 4

Test 4 was conducted at the Willow Grove, Pennsylvania, NASJRB test site from August 31, 2021, to September 20, 2021, with the operating conditions listed below in Table 7. For this test, two treatment trains were operated in series with Train B in the lead position with a feed source from a Willow Grove, Pennsylvania, NASJRB contaminated well and Train A in the lag position with feed from Train B effluent. Train B used sorbent from the lag position Train B from Test 3. Train A used fresh sorbent.

This test was conducted to evaluate the process rate of a lead/lag series configuration with the lead position using the lag sorbent from the previous test. All operating conditions were the same for each treatment train. Table 8 lists a summary of the PFAS data per treatment train. The gray columns represent the UCMR3 compounds. The blue columns represent summed data for PFOS and PFOA and, separately, the summed UCMR3 compounds. The metrics used in Figures 25 to 32 include (a) the threshold at 70 ng/L, which indicates the health advisory level established by the USEPA in 2016, and (b) the 90% removal threshold, indicating the breakthrough point.

Table 7: WG Test 4 Operating Conditions

Train	Single Pass/Series Configuration (lead/lag)	Detention Time (minutes)	Sorbent Type	Sorbent Concentration (g/L)	Sorption Volume (L)	Membrane Permeate Flow Rate (L/min)	Test Duration (days)
Train A	lag	10	AquaPR-206	20	10	1	18
Train B	lead	10	AquaPR-206	20	10	1	18

Figures 25 to 28 present removal performance for treatment Trains B–A during Test 4. All figures in this section demonstrate the removal process rate of key PFAS compounds quantified as gallons of PFAS-contaminated water treated per pound of sorbent material. Table 8 presents all the raw data that were used to the establish the series treatment Trains B and A performance exhibited in Figures 25 to 28.

- Figure 25 presents PFOS removal performance data with an influent PFOS range of 19,000 to 27,000 ng/L. Train A (lag) effluent PFOS levels did not reach either the 70 ng/L threshold or the 90% removal threshold.
- Figure 26 presents PFOA removal performance data with an influent PFOA range of 1,750 to 2,000 ng/L. Train A (lag) effluent PFOA levels did not reach either the 70 ng/L threshold or the 90% removal threshold.
- Figure 27 presents the summed PFOA plus PFOS removal performance data with an influent range of 21,000 to 26,000 ng/L.
- Figure 28 presents the UCMR3 compounds' removal performance data with an influent (summed) UCMR3 level range of 25,000 to 31,000 ng/L. The 70 ng/L threshold was reached at 2,500 gal/lb sorbent. The 90% removal threshold was not reached.

Figures 29 to 32 present removal performance for treatment Train B (lead) during Test 4. All figures in this section demonstrate the removal process rate of key PFAS compounds quantified as gallons of PFAS-contaminated water treated per pound of sorbent material. Table 8 presents all the raw data that were used to establish the Train B performance exhibited in Figures 29 to 32.

- Figure 29 presents PFOS removal performance data with an influent PFOS range of 19,000 to 27,000 ng/L. Effluent PFOS levels reached the 70 ng/L threshold at process rate of 17,300 gal/lb sorbent; the 90% removal threshold was reached at process rate of greater than 25,000 gal/lb sorbent.
- Figure 30 presents PFOA removal performance data with an influent PFOA range of 1,750 to 2,100 ng/L. Effluent PFOA levels reached the 70 ng/L effluent threshold at a process rate of 10,100 gal/lb sorbent; the 90% removal threshold was reached at a process rate of 16,500 gal/lb sorbent.
- Figure 31 presents the summed PFOA plus PFOS removal performance data with an influent range of 21,000 to 25,000 ng/L. Effluent PFOA plus PFOS levels reached the 70 ng/L effluent threshold at a process rate of 9,400 gal/lb sorbent; the 90% removal threshold was reached at a process rate of greater than 25,000 gal/lb sorbent.
- Figure 32 presents the UCMR3 compounds' removal performance data with an influent (summed) UCMR3 level range of 25,000 to 35,000 ng/L. Effluent UCMR3 levels surpassed the 70

ng/L threshold at less than 360 gal/lb sorbent; the 90% removal threshold was reached at a process rate of 23,200 gal/lb sorbent.

Table 8: WG Test 4 Train A (Lag) and Train B (Lead) Summary PFAS Analytical Data

Train A - LAG *Blank cells were sample error and/or 1.5x10R. Cells in italics are either averages or values with sample error removed

	PFOA + PFOS		UCMR3		Total PFAS		PFOS		PFOA (LOQ=1.0)		PFNA (LOQ=1.0)		PFHxS		PFHpA (LOQ=1.0)		PFBS		PFBA		PFPeA		PFHxA		PFPrS		PFPeS		PFHpS (LOQ=1.0)		4:2 FTS (LOQ=41)		6:2 FTS (LOQ=41)		8:2 FTS (LOQ=21)	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
133	4	8	87	31	888	278	4	4	≤LOQ	3	n/a	n/a	6	3	3	1	75	20	150	84	247	63	229	38	152	41	3	3	1	1	8	≤LOQ	≤LOQ	7	5	12
613	6	44	34		380	888	6	23	≤LOQ		n/a	n/a	6	56	4	17	79	116	233	188	232	138	206	221	146	80	7	47	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	2	1
1,680	6	12	138	61	1,383	621	6	12	≤LOQ	≤LOQ	n/a	n/a	10	13	8	1	114	35	265	265	393	133	341	76	203	75	17	6	≤LOQ	≤LOQ	≤LOQ	≤LOQ	18	≤LOQ	3	1
2,315	53	20	242	73	1,853	795	18	20	36	≤LOQ	n/a	n/a	13	14	13	1	157	38	305	281	473	206	457	113	254	105	40	7	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	8	81	2
4,172	4	15	278	71	2,114	548	4	15	≤LOQ	≤LOQ	n/a	n/a	20	11	15	1	238	45	296	282	576	313	613	129	321	146	29	6	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ
4,857	31	20	393	101	2,618	1,228	5	20	26	≤LOQ	n/a	n/a	43	17	27	3	232	61	313	311	580	426	779	171	340	197	103	10	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	≤LOQ	110	12
5,801	56	*34*	640	141	3,534	1,610	20	34	36		n/a	n/a	58	22	41	6	485	80	311	303	629	537	1260	224	394	273	122	18	≤LOQ	≤LOQ	8	≤LOQ	20	69	209	45
7,091	59	15	664	146	3,277	1,762	24	15	35	≤LOQ	n/a	n/a	74	14	46	5	485	112	325	316	541	628	1150	339	335	317	170	9	1	1	≤LOQ	≤LOQ	52	5	40	1
8,377	36	*23*	808	179	3,563	1,984	12	23	84		n/a	n/a	111	18	62	8	540	131	239	263	526	621	1248	432	324	318	255	24	≤LOQ	≤LOQ	12	≤LOQ	55	59	40	88
9,666	235	19	1,080	219	3,872	2,091	84	19	152	≤LOQ	n/a	n/a	160	17	78	5	606	178	308	304	518	622	1193	547	310	349	318	27	1	≤LOQ	≤LOQ	≤LOQ	67	≤LOQ	70	24
14,619	124	19	1,037	462	3,785	2,770	25	19	98	≤LOQ	n/a	n/a	170	16	82	16	661	410	232	303	523	574	1433	1038	302	361	187	32	3	≤LOQ	≤LOQ	≤LOQ	9	≤LOQ	≤LOQ	≤LOQ
16,104	155	19	1,234	543	4,152	3,030	32	16	123	3	n/a	n/a	230	21	110	17	739	432	285	318	551	539	1525	1162	309	361	236	40	5	1	≤LOQ	≤LOQ	6	≤LOQ	≤LOQ	2
17,333	263	30	1,554	660	4,676	3,432	62	30	202	≤LOQ	n/a	n/a	346	28	148	26	796	575	315	314	578	597	1511	1406	316	371	377	84	6	≤LOQ	≤LOQ	8	11	≤LOQ	7	50
18,685	331	11	1,796	677	5,074	3,464	89	9	242	1	n/a	n/a	451	24	184	24	830	619	307	313	539	589	1583	1456	319	368	461	62	9	≤LOQ	≤LOQ	≤LOQ	42	≤LOQ	12	≤LOQ
19,373	406	43	2,116	823	5,442	3,806	82	34	324	10	n/a	n/a	583	40	220	34	900	712	297	331	541	601	1614	1568	340	398	465	80	15	1	8	≤LOQ	46	≤LOQ	≤LOQ	≤LOQ

Train B - LEAD

	PFOA + PFOS		UCMR3		Total PFAS		PFOS		PFOA (LOQ=1.0)		PFNA (LOQ=1.0)		PFHxS		PFHpA		PFBS		PFBA		PFPeA		PFHxA		PFPrS		PFPeS		PFHpS (LOQ=1.0)		4:2 FTS (LOQ=41)		6:2 FTS (LOQ=41)		8:2 FTS (LOQ=21)	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
297	21,017	4	25,616	87	31,683	888	19,175	4	1,842	≤LOQ	n/a	n/a	3770	6	233	3	596	75	289	150	537	247	1200	229	273	152	635	9	620	1	≤LOQ	8	2354	≤LOQ	165	5
775	24,253	6	28,307	34	34,869	380	22,450	6	1,803	≤LOQ	n/a	n/a	3832	6	254	4	562	79	237	233	532	292	1133	206	260	146	631	7	640	≤LOQ	≤LOQ	≤LOQ	2281	≤LOQ	188	2
1,863	23,420	6	28,061	138	34,013	1,383	21,637	6	1,783	≤LOQ	n/a	n/a	3800	10	257	8	584	114	236	265	479	393	1189	341	262	203	647	17	612	≤LOQ	37	≤LOQ	2225	18	207	3
3,112	24,866	53	29,249	242	34,828	1,853	23,020	18	1,846	36	n/a	n/a	3646	13	248	13	489	157	227	305	392	473	940	457	214	254	549	40	654	≤LOQ	≤LOQ	≤LOQ	2396	≤LOQ	207	81
4,362	25,247	4	29,608	278	35,342	2,114	23,484	4	1,763	≤LOQ	n/a	n/a	3560	20	251	15	550	238	286	296	450	576	1040	613	246	321	611	29	616	≤LOQ	≤LOQ	≤LOQ	2244	≤LOQ	241	≤LOQ
5,236	24,489	31	29,235	393	35,489	2,618	22,481	5	2,008	26	n/a	n/a	3882	43	279	27	585	292	268	313	508	580	1186	779	271	340	641	103	695	≤LOQ	≤LOQ	≤LOQ	2424	≤LOQ	261	110
6,184	23,777	56	28,289	640	34,129	3,594	21,911	20	1,867	36	n/a	n/a	3703	58	276	41	532	485	279	311	447	629	1061	1260	244	394	609	122	663	≤LOQ	≤LOQ	8	2359	20	179	209
7,432	23,102	59	27,496	664	33,125	3,277	21,295	24	1,807	35	n/a	n/a	3601	74	237	46	556	485	274	325	501	541	1063	1150	254	335	630	170	600	1	≤LOQ	≤LOQ	2106	52	200	40
8,806	23,681	96	28,551	808	34,503	3,569	21,964	12	1,917	84	n/a	n/a	3849	111	242	62	579	540	305	299	476	526	1120	1248	267	324	640	255	626	≤LOQ	≤LOQ	12	2282	55	235	40
10,120	22,258	235	26,776	1,080	32,500	3,872	20,467	84	1,791	152	n/a	n/a	3711	160	239	78	568	606	285	308	474	518	1088	1193	256	310	640	318	615	1	31	≤LOQ	2143	67	186	70
11,431	22,762	124	27,525	1,037	33,438	3,785	20,877	25	1,885	98	n/a	n/a	3888	170	267	82	607	661	313	232	486	523	1164	1433	280	302	679	187	623	3	≤LOQ	≤LOQ	2174	9	195	≤LOQ
12,745	24,309	155	29,114	1,234	35,162	4,152	22,298	32	2,011	123	n/a	n/a	3973	230	251	110	581	739	266	285	442	551	1140	1525	265	309	640	236	719	5	≤LOQ	≤LOQ	2396	6	180	≤LOQ
14,061	24,412	263	29,022	1,554	34,850	4,676	22,602	62	1,810	202	n/a	n/a	3782	346	239	148	590	796	300	315	464	578	1120	1511	263	316	655	377	666	6	≤LOQ	≤LOQ	2161	11	193	7
15,373	25,093	331	30,436	1,796	37,122	5,074	23,028	89	2,065	242	n/a	n/a	4397	451	293	184	653	830	287	307	579	539	1280	1583	300	319	727	461	762	9	33	≤LOQ	2525	42	194	12
16,689	26,272	406	31,295	2,116	37,555	5,442	24,480	82	1,793	324	n/a	n/a	4114	589	263	220	646	900	305	297	528	541	1282	1614	298	340	709	465	708	15	≤LOQ	8	2230	46	201	≤LOQ
18,007	24,537	633	29,384	2,571	36,278	6,557	22,526	137	2,071	436	n/a	n/a	4394	782	300	238	693	858	277	333	499	561	1348	1575	318	333	746	862	613	10	≤LOQ	11	2324	81	163	220
19,330	24,867	740	30,365	2,901	36,759	6,801	22,846	214	2,022	526	n/a	n/a	4488	989	291	302	719	870	309	298	538	562	1326	1559	327	365	770	966	783	19	≤LOQ	18	2157	113	184	≤LOQ
20,642	23,282	592	34,788	2,844	41,395	6,583	27,345	133	1,937	459	n/a	n/a	4490	1016	263	302	747	934	322	317	548	560	1315	1622	346	378	805	761	803	20	≤LOQ	≤LOQ	2256	79	211	2

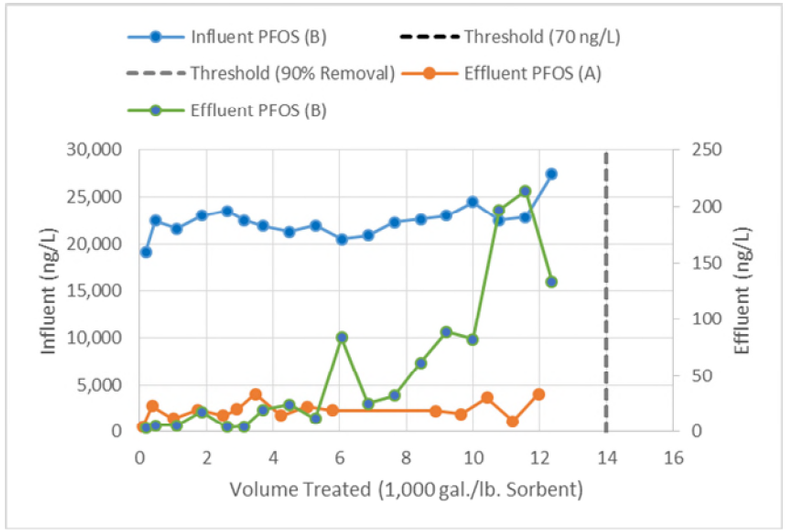

Figure 255: WG Test 4 PFOS Train B–A Series

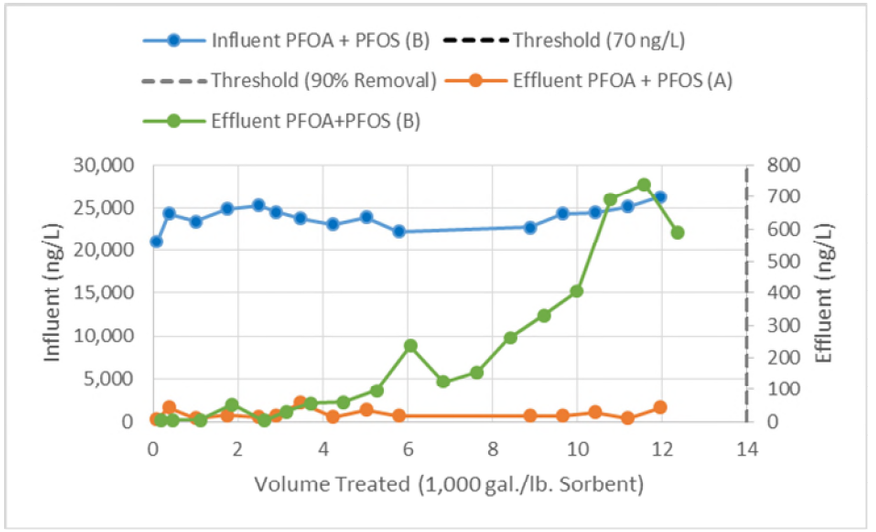

Figure 277: WG Test 4 PFOA+PFOS Train B–A Series

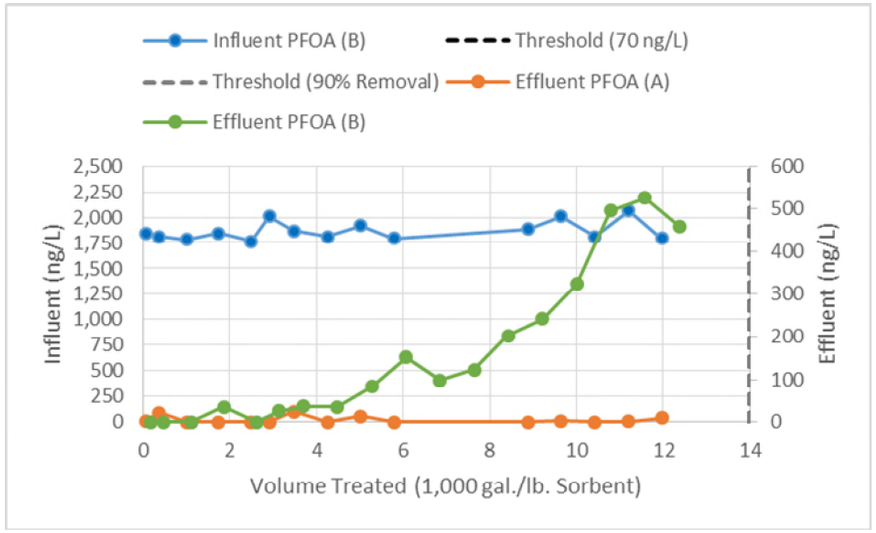

Figure 266: WG Test 4 PFOA Train B–A Series

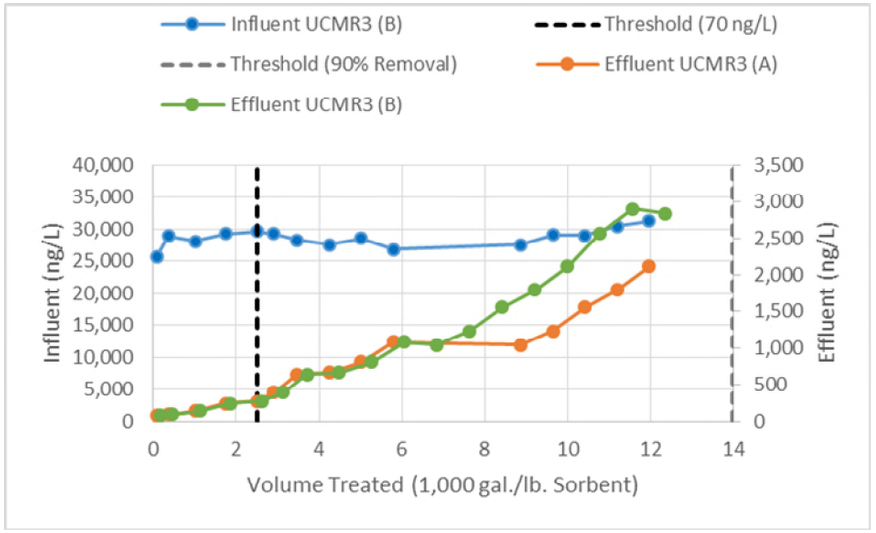

Figure 28: WG Test 4 UCMR3 Train B–A Series

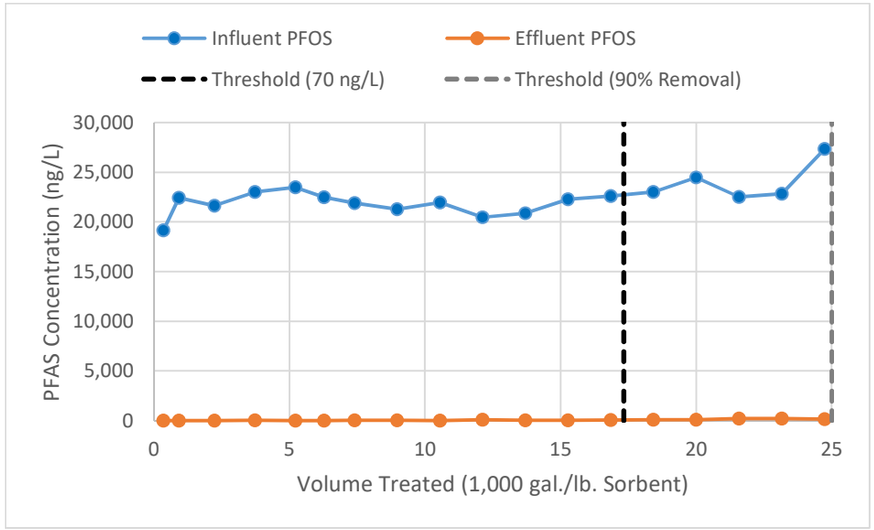

Figure 29: WG Test 4 PFOS Train B (Single Stage)

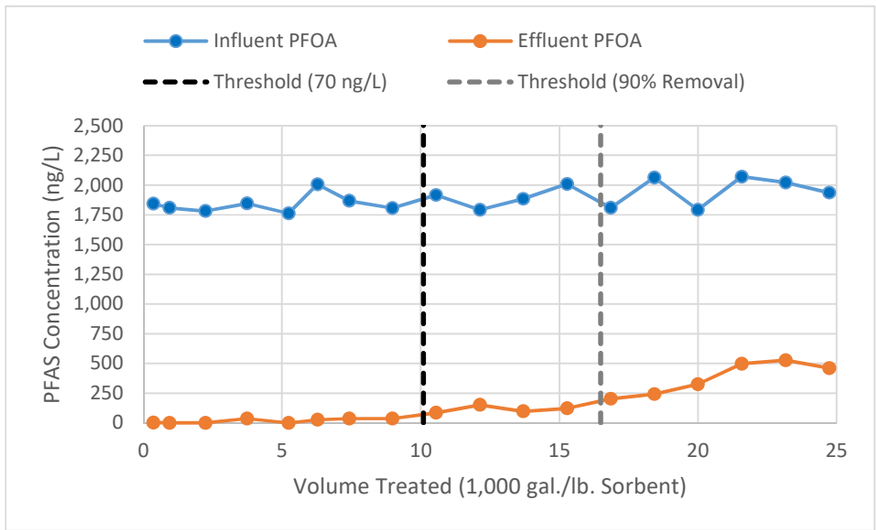

Figure 30: WG Test 4 PFOA Train B (Single Stage)

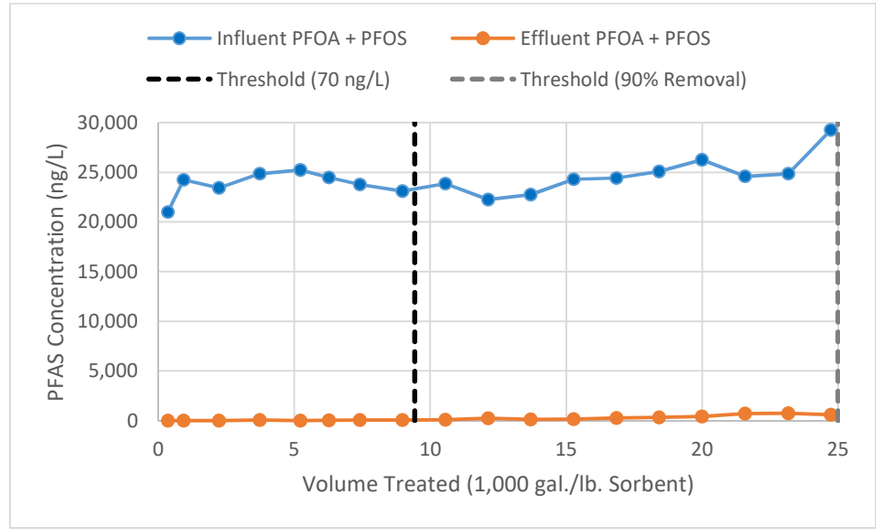

Figure 31: WG Test 4 PFOA+PFOS Train B (Single Stage)

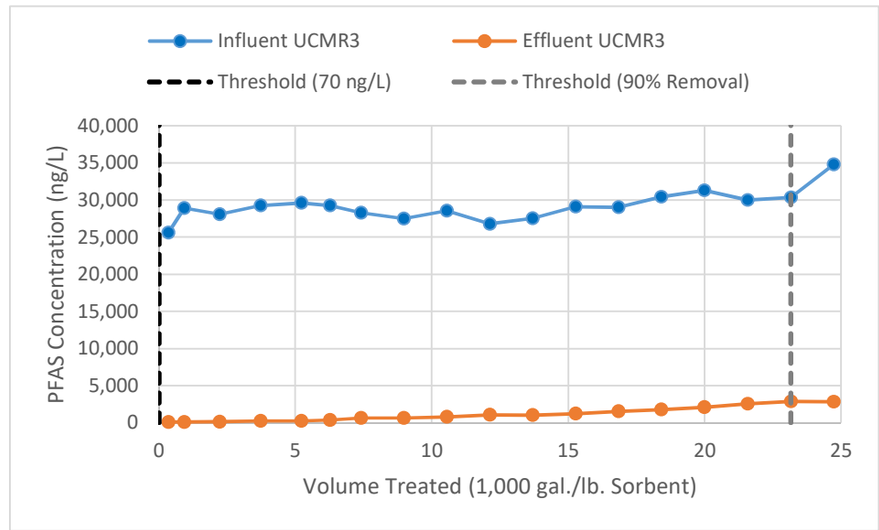

Figure 32: WG Test 4 UCMR3 Train B (Single Stage)

5. Test 5

Test 5 was conducted at the Willow Grove, Pennsylvania, NASJRB test site from September 29, 2021, to October 11, 2021, with the operating conditions listed below in Table 10. Two treatment trains were used in parallel operation (single stage) with a feed source from a Willow Grove, Pennsylvania, NASJRB contaminated well feeding both Trains A and B. This test was conducted to evaluate the adsorptive capacities of two different sorbent types: AquaPR-206 (Train A) and AquaPR-312 (Train B).

All operating conditions were the same for each treatment train except for the sorbent type (highlighted in gray in Table 10). Table 11 lists a summary of the PFAS data per treatment train. The gray columns represent the UCMR3 compounds. The blue columns represent summed data for PFOS and PFOA and, separately, the summed UCMR3 compounds. The metrics used in Figures 33 to 40 include (a) the threshold at 70 ng/L, which indicates the health advisory level established by the USEPA in 2016, and (b) the 90% removal threshold, indicating the breakthrough point.

Table 9: WG Test 5 Operating Conditions

Train	Single Pass/Series Operation (SO)	Detention Time (minutes)	Sorbent Type	Sorbent Concentration (g/L)	Sorption Volume (L)	Membrane Permeate Flow Rate (L/min)	Test Duration (days)
Train A	SP	10	AquaPR-206	20	10	1	12
Train B	SP	10	AquaPR-312	20	10	1	12

Figures 33 to 36 present removal performance for treatment Train A during Test 5. All figures in this section demonstrate the removal process rate of key PFAS compounds quantified as gallons of PFAS-contaminated water treated per pound of sorbent material. Table 11 presents all the raw data that were used to establish the Train A performance exhibited in Figures 33 to 36.

- Figure 33 presents PFOS removal performance data with an influent PFOS range of 24,600 to 36,000 ng/L. Effluent PFOS levels did not reach the 70 ng/L threshold within the test duration limit of 12 days; the 90% removal threshold was also not reached.
- Figure 34 presents PFOA removal performance data with an influent PFOA range of 1,665 to 2,080 ng/L. Effluent PFOA levels reached the 70 ng/L effluent threshold at a process rate of 5,500 gal/lb sorbent; the 90% removal threshold was not reached.
- Figure 35 presents the summed PFOA plus PFOS removal performance data with an influent PFOA plus PFOS range of 26,000 to 38,000 ng/L. Effluent PFOS levels reached the 70 ng/L threshold at a process rate of 4,500 gal/lb sorbent; the 90% removal threshold was not reached.
- Figure 36 presents the UCMR3 compounds' removal performance data with an influent (summed) UCMR3 level range of 29,000 to 42,000 ng/L. Effluent PFOS levels reached the 70 ng/L threshold at test start; the 90% removal threshold was not reached.

Figures 37 to 40 present removal performance for treatment Train B during Test 5. All figures in this section demonstrate the removal process rate of key PFAS compounds quantified as gallons of PFAS-contaminated water treated per pound of sorbent material. Table 11 presents all the raw data that were used to establish the Train B performance exhibited in Figures 37 to 40.

- Figure 37 presents PFOS removal performance data with an influent PFOS range of 24,000 to 36,000 ng/L. Effluent PFOS levels did not reach the 70 ng/L threshold within the limits of the test duration; the 90% removal threshold was not reached with the test duration (i.e., 12 days).
- Figure 38 presents PFOA removal performance data with an influent PFOA range of 1,600 to 2,080 ng/L. Effluent PFOS levels did not reach the 70 ng/L threshold within the limits of test duration; the 90% removal threshold was not reached with the test duration (i.e., 12 days).
- Figure 39 presents the summed PFOA plus PFOS removal performance data with an influent PFOA plus PFOS range of 26,000 to 38,000 ng/L. Effluent PFOA plus PFOS levels reached the 70 ng/L effluent threshold at a process rate of 6,300 gal/lb sorbent; the 90% removal threshold was not reached with this test duration (i.e., 12 days).
- Figure 40 presents the summed UCMR3 compounds' removal performance data with an influent (summed) UCMR3 level range of 29,000 to 42,000 ng/L. Effluent UCMR3 levels reached the 70 ng/L threshold at a process rate of 1,400 gal/lb sorbent; the 90% removal threshold was not reached with this test duration (i.e., 12 days).

Table 10: WG Test 5 Train A Summary PFAS Data

Train A

	PFOA + PFOS		UCMR3		Total PFAS		PFOS		PFOA		PFNA (LOQ=1.0)		PFHxS		PFHpA (LOQ=1.0)		PFBS		PFBA		PFPeA		PFHxA		PFPrS		PFPeS		PFHpS (LOQ=1.0)		4:2 FTS (LOQ=4)		6:2 FTS (LOQ=4)		8:2 FTS (LOQ=2)	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
74	30,719	19	33,386	145	40,781	876	28,386	10	1,733	9	n/a	n/a	2,207	8	248	5	812	113	290	201	617	186	1351	235	378	97	550	9	486	3	35	≤LOQ	2,381	≤LOQ	107	≤LOQ
387	30,119	16	33,332	105	39,773	883	28,424	9	1,695	7	n/a	n/a	2,166	5	232	4	815	80	266	226	582	251	1336	165	384	125	575	5	494	3	42	3	2,614	≤LOQ	148	≤LOQ
1,628	26,342	10	29,510	87	35,672	941	24,677	5	1,665	6	n/a	n/a	2,128	3	238	3	802	71	254	242	606	300	1316	160	364	141	555	6	469	≤LOQ	30	5	2,456	≤LOQ	112	≤LOQ
2,541	26,376	12	30,253	139	36,793	1,372	25,278	5	1,699	7	n/a	n/a	2,197	4	242	6	838	117	308	235	568	463	1346	231	401	233	616	10	462	≤LOQ	19	≤LOQ	2,682	≤LOQ	139	≤LOQ
3,451	37,967	22	41,624	214	49,114	1,755	35,887	8	2,080	14	n/a	n/a	2,537	6	274	8	846	177	298	269	625	584	1362	343	398	329	716	17	586	≤LOQ	14	≤LOQ	3,283	≤LOQ	207	≤LOQ
4,364	28,374	23	32,331	349	38,300	2,479	27,276	7	1,638	16	n/a	n/a	2,266	10	254	13	836	303	274	300	588	731	1351	610	394	460	539	24	497	3	29	≤LOQ	2,712	≤LOQ	124	≤LOQ
5,276	27,716	26	30,964	416	37,658	2,617	25,977	7	1,739	19	n/a	n/a	2,162	13	251	19	835	358	271	287	569	689	1352	731	401	457	617	33	503	3	40	≤LOQ	2,808	≤LOQ	133	≤LOQ
6,191	34,395	27	38,081	562	45,560	3,056	32,315	6	2,080	21	n/a	n/a	2,510	18	268	26	907	491	236	289	647	737	1482	897	449	527	704	41	569	4	85	≤LOQ	3,076	≤LOQ	232	≤LOQ
7,105	34,133	60	37,536	880	44,456	3,937	32,277	14	1,856	46	n/a	n/a	2,267	38	268	46	868	746	297	315	617	710	1382	1377	400	539	636	34	523	4	30	7	2,821	≤LOQ	214	≤LOQ
8,020	29,417	81	32,709	1,074	39,327	4,281	27,656	21	1,760	60	n/a	n/a	2,184	50	244	60	864	883	263	299	626	708	1372	1492	397	567	594	136	532	4	53	≤LOQ	2,648	≤LOQ	134	≤LOQ
8,931	34,844	80	38,332	1,142	45,147	4,336	33,060	14	1,784	66	n/a	n/a	2,329	56	260	68	899	938	277	316	615	679	1441	1553	418	523	814	113	548	4	65	≤LOQ	2,631	≤LOQ	206	≤LOQ
9,843	28,335	106	32,214	1,300	38,658	4,652	27,170	19	1,765	86	n/a	n/a	2,161	77	250	83	869	1035	289	299	579	677	1366	1670	416	518	595	176	451	5	≤LOQ	6	2,592	≤LOQ	155	≤LOQ
10,753	30,151	146	33,622	1,414	40,688	4,804	28,302	31	1,848	116	n/a	n/a	2,323	94	245	99	902	1074	308	294	631	674	1478	1663	435	511	727	232	441	4	53	7	2,822	≤LOQ	172	≤LOQ

Train B *Blank cells were sample error and/or 1.5xIQR. Cells in italics are either averages or values with sample error removed

	PFOA + PFOS		UCMR3		Total PFAS		PFOS		PFOA		PFNA		PFHxS		PFHpA		PFBS		PFBA		PFPeA		PFHxA		PFPrS		PFPeS		PFHpS (LOQ=1.0)		4:2 FTS (LOQ=4)		6:2 FTS (LOQ=4)		8:2 FTS (LOQ=2)	
Volume (L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)	Influent (ng/L)	Effluent (ng/L)
58	30,719		33,386		40,781		28,386		1,733		n/a	n/a	2,207		248		812		290		617		1351		378		550		486		35		2,381		107	
870	30,119	46	33,332	88	39,773	477	28,424	21	1,695	24	n/a	n/a	2,166	15	232	6	815	22	266	182	582	102	1336	34	384	43	575	10	494	4	42	8	2,614	≤LOQ	148	≤LOQ
1,490	26,342	38	29,510	64	35,672	554	24,677	23	1,665	15	n/a	n/a	2,128	5	238	2	802	19	254	231	606	148	1316	27	364	73	555	4	469	3	30	4	2,456	≤LOQ	112	≤LOQ
2,353	26,376	18	30,253	61	36,793	790	25,278	7	1,699	11	n/a	n/a	2,197	4	242	3	838	36	308	262	568	251	1346	68	401	138	616	5	462	3	19	≤LOQ	2,682	≤LOQ	139	≤LOQ
3,217	37,967	22	41,624	102	49,114	1,154	35,887	9	2,080	13	n/a	n/a	2,537	6	274	5	846	69	298	288	625	402	1362	119	398	235	716	9	586	≤LOQ	14	≤LOQ	3,283	≤LOQ	207	≤LOQ
4,085	28,374	27	32,331	157	38,300	1,580	27,276	12	1,638	15	n/a	n/a	2,266	8	254	5	836	116	274	232	588	565	1351	200	394	344	539	14	497	3	29	4	2,712	≤LOQ	124	≤LOQ
4,951	27,716	20	30,964	192	37,658	1,713	25,977	7	1,739	12	n/a	n/a	2,162	9	251	9	835	155	271	268	569	586	1352	278	401	363	617	16	503	3	40	7	2,808	≤LOQ	133	≤LOQ
5,821	34,395	25	38,081	279	45,560	2,124	32,315	10	2,080	15	n/a	n/a	2,510	12	268	11	907	232	236	267	647	638	1482	406	449	434	704	24	569	3	85	12	3,076	≤LOQ	232	≤LOQ
6,690	34,133	33	37,536	421	44,456	2,655	32,277	11	1,856	22	n/a	n/a	2,267	19	268	18	868	351	297	320	617	782	1382	564	400	521	636	42	523	4	30	≤LOQ	2,821	≤LOQ	214	≤LOQ
7,557	29,417	31	32,709	510	39,327	2,783	27,656	9	1,760	22	n/a	n/a	2,184	21	244	23	864	435	263	301	626	747	1372	654	397	518	594	50	532	3	53	5	2,648	≤LOQ	134	≤LOQ
8,426	34,844	41	38,332	589	45,147	2,866	33,060	10	1,784	30	n/a	n/a	2,329	28	260	28	899	432	277	286	615	696	1441	756	418	482	814	52	548	4	65	≤LOQ	2,631	≤LOQ	206	≤LOQ
9,298	28,335	51	32,214	684	38,658	3,127	27,170	14	1,765	37	n/a	n/a	2,161	34	250	32	869	567	289	295	579	664	1366	932	416	479	595	63	451	4	≤LOQ	4	2,592	≤LOQ	155	≤LOQ
10,168	30,151	66	33,622	822	40,688	3,523	28,302	17	1,848	43	n/a	n/a	2,323	45	245	42	902	669	308	292	631	693	1478	1136	435	501	727	73	441	5	53	≤LOQ	2,822	≤LOQ	172	≤LOQ
10,743	24,409	72	27,617	838	34,467	3,460	22,747	18	1,662	54	n/a	n/a	2,092	43	260	45	857	671	301	254	565	643	1432	1170	426	457	604	81	415	5	66	4	2,830	≤LOQ	152	≤LOQ

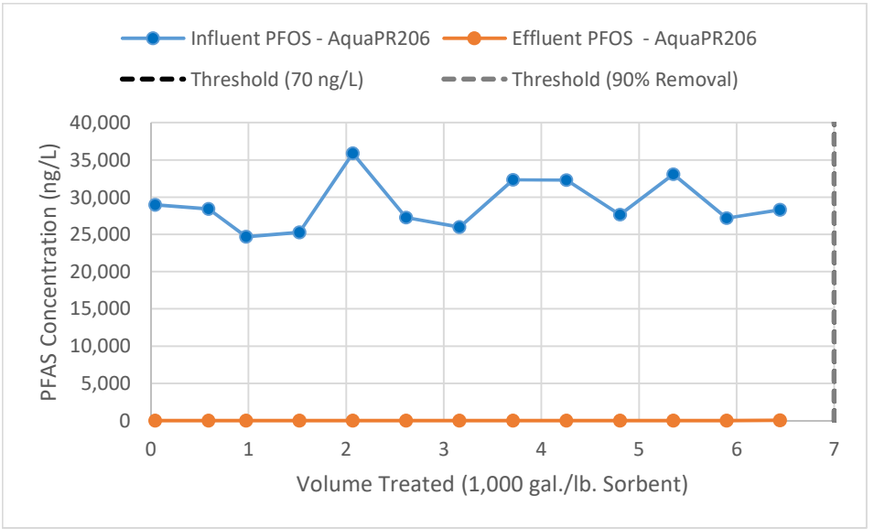

Figure 33: WG Test 5 PFOS Train A (Single Stage)

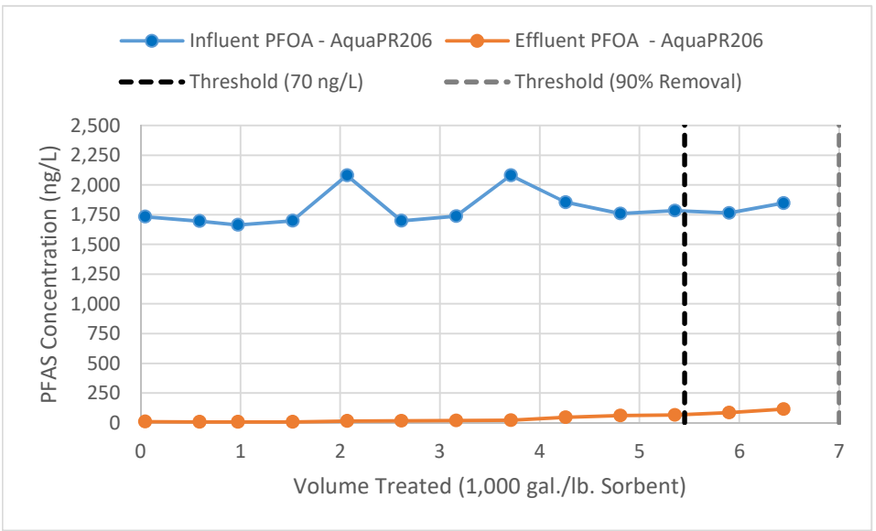

Figure 34: WG Test 5 PFOA Train A (Single Stage)

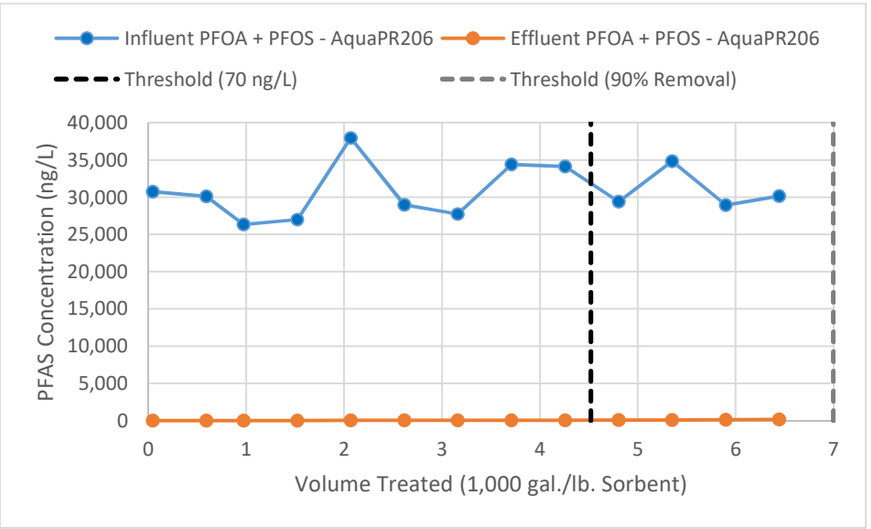

Figure 35: WG Test 5 PFOA+PFOS Train A (Single Stage)

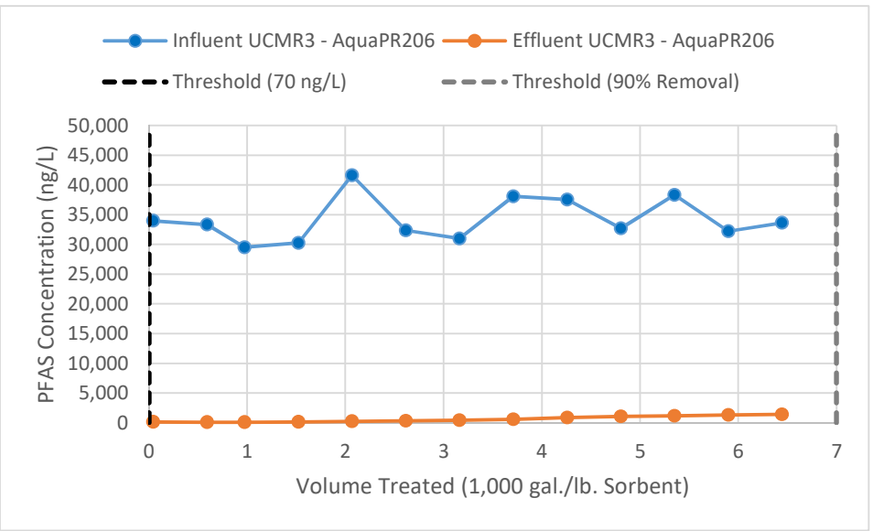

Figure 36: WG Test 5 UCMR3 Train A (Single Stage)

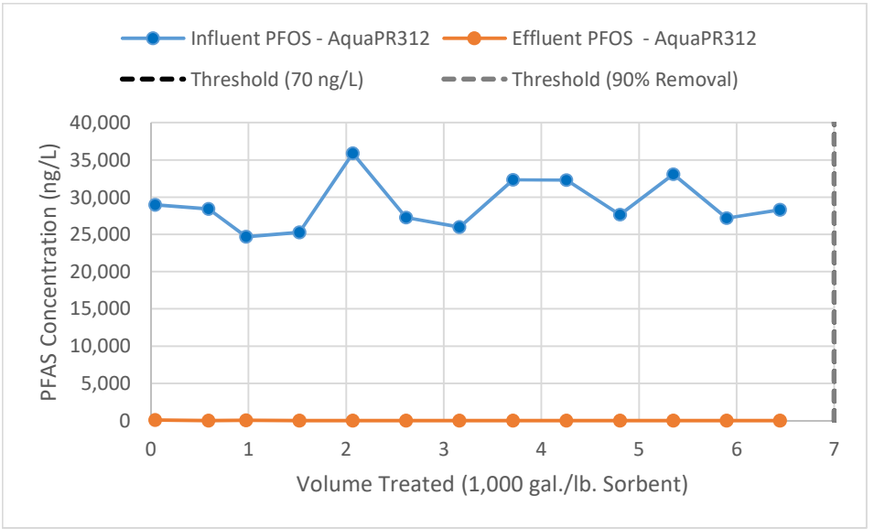

Figure 37: WG Test 5 PFOS Train B (Single Stage)

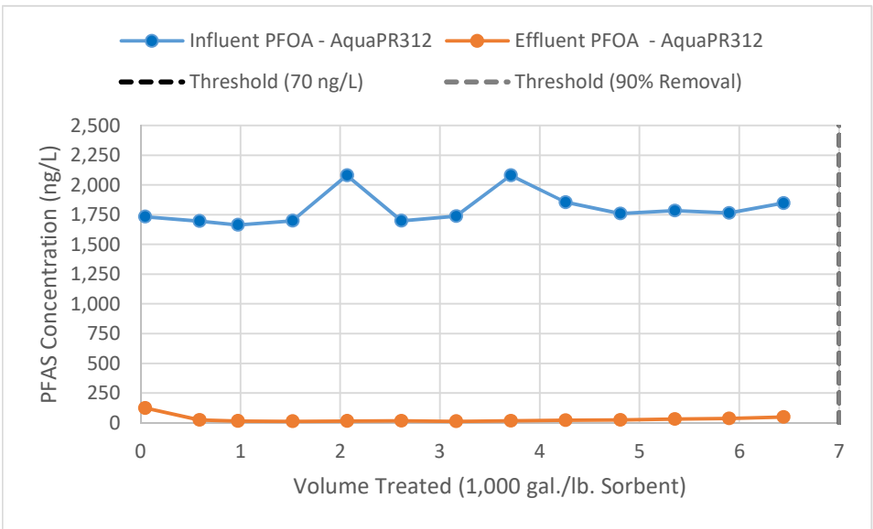

Figure 38: WG Test 5 PFOA (Single Stage)

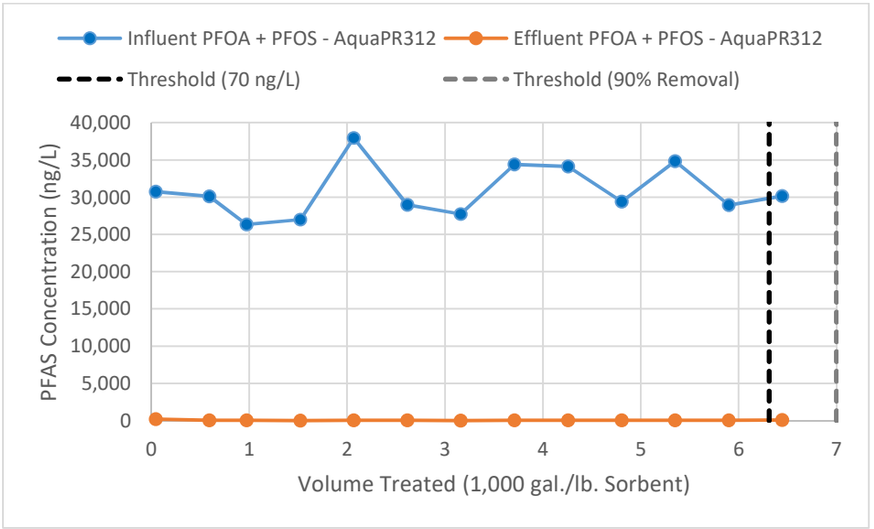

Figure 39: WG Test 5 PFOA+PFOS Train B (Single Stage)

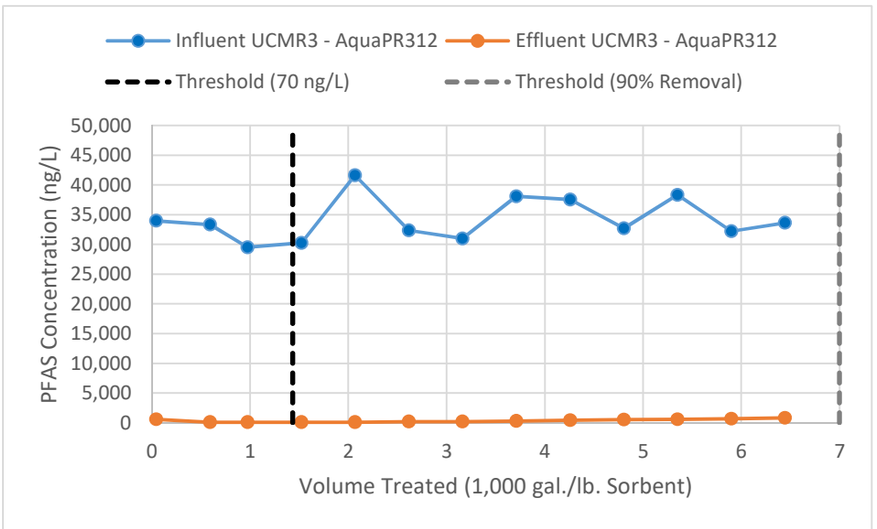

Figure 40: WG Test 5 UCMR3 (Single Stage)

Appendix G

RSSCT Data

Horsham AGS Waste Composition used in RSSCT

Compound	ng/L
PFOS	**2,311**
PFOA	**301**
PFNA	
PFHxS	**1,316**
PFHpA	**119**
PFBS	256
PFBA	149
PFPeA	405
PFHxA	540
PFPeS	246
PFHpS	90
PFPrS	117
6:2 FTS	843
Total	6,693
Vermont Regulated Compounds	**4,047**

Media Performance at Break-Through for Vermont Compounds (UCMR3 less PFBS)

Product	(kg/m3)	(lb/kgal)	(m3/kg)	(kgal/lb)	(ng/L)	**(µg/g)**	***Notes***
GAC	3.06	25.53712	0.3	0.04	4,047	**1.2**	*70 ng/L not met*
SPAC-CMF Test 10A	0.0226	0.18861	44.2	5.3	7,922	**338**	*Yes, at 70 ng/L target*

Media Performance at Break-Through for USEPA HAL (< 70 ng/L PFOA, PFOS)

Product	(kg/m3)	(lb/kgal)	(m3/kg)	(kgal/lb)	(ng/L)	**(µg/g)**	***Notes***
GAC	3.06	25.53712	0.3	0.0	2,612	**0.9**	*70 ng/L not met*
SPAC-CMF Test 3	0.0136	0.11350	73.5	8.8	5,662	**410**	*Yes, at 70 ng/L target*

Media Performance at Break-Through for PFOA

Product	(kg/m3)	(lb/kgal)	(m3/kg)	(kgal/lb)	(ng/L)	**(µg/g)**	***Notes***
GAC	0.62	5.17419	1.6	0.2	301	**0.49**	*70 ng/L not met*
SPAC-CMF Test 10A	0.013	0.11016	75.8	9.1	466	**34.0**	*Yes, at 70 ng/L target*

Media Performance at Break-Through for PFOS

Product	(kg/m3)	(lb/kgal)	(m3/kg)	(kgal/lb)	(ng/L)	**(µg/g)**	***Notes***
GAC	3.06	25.53712	0.3	0.0	2,311	**0.76**	*70 ng/L not met*
SPAC-CMF Test 10A	0.021	0.17108	48.8	5.8	5,125	**>400**	*BT not reached*

Note: GAC's SAR values were based on 90% PFAS removal due to its inability to meet the 70 ng/L targeted effluent.

Willow Grove NAS Waste Composition used in IX Trials

Compound	ng/L
PFOS	**22,376**
PFOA	**2,525**
PFNA	
PFHxS	**5,391**
PFHpA	**361**
PFBS	894
PFBA	685
PFPeA	819
PFHxA	1,723
PFPeS	842
PFHpS	715
PFPrS	409
Total	36,740
Vermont Regulated Compounds	**30,653**

Media Performance at Break-Through for Vermont Compounds (UCMR3 less PFBS)

Product	(kg/m3)	(lb/kgal)	(m3/kg)	(kgal/lb)	(ng/L)	**(µg/g)**	***BT Reached***
Ion Exchange (2301)	0.0085	0.07094	117.6	14.1	30,653	**3,606**	Yes
Ion Exchange (Regenerable)	0.0221	0.18443	45.2	5.4	30,653	**1,387**	Yes
SPAC-CMF Test 3	0.0117	0.09764	85.5	10.2	39,984	**3,417**	*No*

Media Performance at Break-Through for USEPA HAL (< 70 ng/L PFOA, PFOS)

Product	(kg/m3)	(lb/kgal)	(m3/kg)	(kgal/lb)	(ng/L)	**(µg/g)**	***BT Reached***
Ion Exchange (2301)	0.0085	0.07094	117.6	14.1	24,901	**2,930**	*No*
Ion Exchange (Regenerable)	0.0221	0.18443	45.2	5.4	24,901	**1,127**	Yes
SPAC-CMF Test 3	0.0084	0.07028	118.8	14.2	36,118	**4,289**	*Yes, 1-stage only*

Media Performance at Break-Through for PFOA

Product	(kg/m3)	(lb/kgal)	(m3/kg)	(kgal/lb)	(ng/L)	**(µg/g)**	***BT Reached***
Ion Exchange (2301)	0.004	0.03338	250.0	30.0	2,525	**631**	Yes
Ion Exchange (Regenerable)	0.034	0.28375	29.4	3.5	2,525	**74**	Yes
SPAC-CMF Test 3	0.008	0.06401	130.4	15.6	2,432	**317**	*Yes, 1-stage only*

Media Performance at Break-Through for PFOS

Product	(kg/m3)	(lb/kgal)	(m3/kg)	(kgal/lb)	(ng/L)	**(µg/g)**	***BT Reached***
Ion Exchange (2301)	0.004	0.03338	250.0	30.0	22,376	**5,594**	No
Ion Exchange (Regenerable)	0.034	0.28375	29.4	3.5	22,376	**658**	Yes
SPAC-CMF Test 3	0.006	0.04883	170.9	20.5	31,943	**5,459**	*No, 1-stage only*

Appendix H

Pace Analytical Lab Data

Report of Analysis

Aqua-Aerobic Systems, Inc.
6306 N. Alpine Rd.
Loves Park, IL 61111
Attention: Joseph Campanaro

Project Name: Horsham

Lot Number:**WB25052**

Date Completed:03/05/2021

03/07/2021 9:16 PM
Approved and released by:
Project Manager II: **Karen L. Coonan**

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Case Narrative
Aqua-Aerobic Systems, Inc.
Lot Number: WB25052

This Report of Analysis contains the analytical result(s) for the sample(s) listed on the Sample Summary following this Case Narrative. The sample receiving date is documented in the header information associated with each sample.

All results listed in this report relate only to the samples that are contained within this report.

Sample receipt, sample analysis, and data review have been performed in accordance with the most current approved The NELAC Institute (TNI) standards, the Pace Analytical Services, LLC ("Pace") Laboratory Quality Manual, standard operating procedures (SOPs), and Pace policies. Additionally, the DoD QSM version 5.3 has been followed for these samples, and specifically Table B-15 was followed for all PFAS samples. Any exceptions to the TNI standards, the Laboratory Quality Manual, SOPs, the DoD QSM, or policies are qualified on the results page or discussed below.

If you have any questions regarding this report please contact the Pace Project Manager listed on the cover page.

Sample Summary
Aqua-Aerobic Systems, Inc.
Lot Number: WB25052

Sample Number	Sample ID	Matrix	Date Sampled	Date Received
001	TAT11	Aqueous	02/04/2021 1800	02/25/2021
002	TAT11	Aqueous	02/06/2021 1800	02/25/2021
003	TAT11	Aqueous	02/08/2021 1800	02/25/2021
004	TAT11	Aqueous	02/10/2021 1800	02/25/2021
005	TAT11	Aqueous	02/12/2021 1800	02/25/2021
006	TAT11	Aqueous	02/14/2021 1800	02/25/2021
007	TBT11	Aqueous	02/04/2021 1800	02/25/2021
008	TBT11	Aqueous	02/06/2021 1800	02/25/2021
009	TBT11	Aqueous	02/08/2021 1800	02/25/2021
010	TBT11	Aqueous	02/10/2021 1800	02/25/2021
011	TBT11	Aqueous	02/12/2021 1800	02/25/2021
012	TBT11	Aqueous	02/14/2021 1800	02/25/2021
013	FT11	Aqueous	02/04/2021 1620	02/25/2021
014	FT11	Aqueous	02/06/2021 1620	02/25/2021
015	FT11	Aqueous	02/08/2021 1620	02/25/2021
016	FT11	Aqueous	02/10/2021 1620	02/25/2021
017	FT11	Aqueous	02/12/2021 1620	02/25/2021
018	FT11	Aqueous	02/14/2021 1620	02/25/2021

(18 samples)

Detection Summary

Aqua-Aerobic Systems, Inc.

Lot Number: WB25052

Sample	Sample ID	Matrix	Parameter	Method	Result	Q	Units	Page
001	TAT11	Aqueous	PFBS	PFAS by ID	11		ng/L	9
001	TAT11	Aqueous	PFPeS	PFAS by ID	3.7		ng/L	9
001	TAT11	Aqueous	PFHxS	PFAS by ID	6.7		ng/L	9
001	TAT11	Aqueous	PFBA	PFAS by ID	18		ng/L	9
001	TAT11	Aqueous	PFHpA	PFAS by ID	3.9		ng/L	9
001	TAT11	Aqueous	PFHxA	PFAS by ID	25		ng/L	9
001	TAT11	Aqueous	PFOA	PFAS by ID	4.3		ng/L	9
001	TAT11	Aqueous	PFPeA	PFAS by ID	23		ng/L	9
001	TAT11	Aqueous	PFOS	PFAS by ID	5.4		ng/L	9
002	TAT11	Aqueous	GenX	PFAS by ID	1.7	J	ng/L	11
002	TAT11	Aqueous	PFBS	PFAS by ID	10		ng/L	11
002	TAT11	Aqueous	PFHxS	PFAS by ID	0.92	J	ng/L	11
002	TAT11	Aqueous	PFBA	PFAS by ID	66		ng/L	11
002	TAT11	Aqueous	PFHxA	PFAS by ID	35		ng/L	11
002	TAT11	Aqueous	PFPeA	PFAS by ID	220		ng/L	11
002	TAT11	Aqueous	PFOS	PFAS by ID	1.5	J	ng/L	11
003	TAT11	Aqueous	GenX	PFAS by ID	2.7	J	ng/L	13
003	TAT11	Aqueous	PFBS	PFAS by ID	41		ng/L	13
003	TAT11	Aqueous	PFPeS	PFAS by ID	3.9		ng/L	13
003	TAT11	Aqueous	PFHxS	PFAS by ID	4.5		ng/L	13
003	TAT11	Aqueous	PFBA	PFAS by ID	71		ng/L	13
003	TAT11	Aqueous	PFHpA	PFAS by ID	3.7		ng/L	13
003	TAT11	Aqueous	PFHxA	PFAS by ID	140		ng/L	13
003	TAT11	Aqueous	PFOA	PFAS by ID	1.7	J	ng/L	13
003	TAT11	Aqueous	PFPeA	PFAS by ID	270		ng/L	13
003	TAT11	Aqueous	PFOS	PFAS by ID	1.2	J	ng/L	13
004	TAT11	Aqueous	GenX	PFAS by ID	2.9	J	ng/L	15
004	TAT11	Aqueous	PFBS	PFAS by ID	88		ng/L	15
004	TAT11	Aqueous	PFPeS	PFAS by ID	10		ng/L	15
004	TAT11	Aqueous	PFHxS	PFAS by ID	13		ng/L	15
004	TAT11	Aqueous	PFBA	PFAS by ID	81		ng/L	15
004	TAT11	Aqueous	PFHpA	PFAS by ID	10		ng/L	15
004	TAT11	Aqueous	PFHxA	PFAS by ID	280		ng/L	15
004	TAT11	Aqueous	PFOA	PFAS by ID	4.6		ng/L	15
004	TAT11	Aqueous	PFPeA	PFAS by ID	300		ng/L	15
004	TAT11	Aqueous	PFOS	PFAS by ID	1.6	J	ng/L	15
005	TAT11	Aqueous	6:2 FTS	PFAS by ID	6.3	J	ng/L	17
005	TAT11	Aqueous	4:2 FTS	PFAS by ID	3.7	J	ng/L	17
005	TAT11	Aqueous	GenX	PFAS by ID	2.1	J	ng/L	17
005	TAT11	Aqueous	PFBS	PFAS by ID	170		ng/L	17
005	TAT11	Aqueous	PFPeS	PFAS by ID	40		ng/L	17
005	TAT11	Aqueous	PFHxS	PFAS by ID	53		ng/L	17
005	TAT11	Aqueous	PFBA	PFAS by ID	100		ng/L	17
005	TAT11	Aqueous	PFHpA	PFAS by ID	36		ng/L	17
005	TAT11	Aqueous	PFHxA	PFAS by ID	470		ng/L	17

Detection Summary (Continued)

Lot Number: WB25052

Sample	Sample ID	Matrix	Parameter	Method	Result	Q	Units	Page
005	TAT11	Aqueous	PFOA	PFAS by ID	27		ng/L	17
005	TAT11	Aqueous	PFPeA	PFAS by ID	360		ng/L	17
005	TAT11	Aqueous	PFOS	PFAS by ID	11		ng/L	17
006	TAT11	Aqueous	6:2 FTS	PFAS by ID	15		ng/L	19
006	TAT11	Aqueous	4:2 FTS	PFAS by ID	4.8	J	ng/L	19
006	TAT11	Aqueous	PFBS	PFAS by ID	190		ng/L	19
006	TAT11	Aqueous	PFHpS	PFAS by ID	1.2	J	ng/L	19
006	TAT11	Aqueous	PFPeS	PFAS by ID	66		ng/L	19
006	TAT11	Aqueous	PFHxS	PFAS by ID	120		ng/L	19
006	TAT11	Aqueous	PFBA	PFAS by ID	88		ng/L	19
006	TAT11	Aqueous	PFHpA	PFAS by ID	66		ng/L	19
006	TAT11	Aqueous	PFHxA	PFAS by ID	430		ng/L	19
006	TAT11	Aqueous	PFOA	PFAS by ID	49		ng/L	19
006	TAT11	Aqueous	PFPeA	PFAS by ID	290		ng/L	19
006	TAT11	Aqueous	PFOS	PFAS by ID	26		ng/L	19
007	TBT11	Aqueous	6:2 FTS	PFAS by ID	24		ng/L	21
007	TBT11	Aqueous	PFBS	PFAS by ID	9.8		ng/L	21
007	TBT11	Aqueous	PFHpS	PFAS by ID	2.5	J	ng/L	21
007	TBT11	Aqueous	PFPeS	PFAS by ID	7.5		ng/L	21
007	TBT11	Aqueous	PFHxS	PFAS by ID	38		ng/L	21
007	TBT11	Aqueous	PFBA	PFAS by ID	9.9		ng/L	21
007	TBT11	Aqueous	PFHpA	PFAS by ID	5.1		ng/L	21
007	TBT11	Aqueous	PFHxA	PFAS by ID	28		ng/L	21
007	TBT11	Aqueous	PFNA	PFAS by ID	1.2	J	ng/L	21
007	TBT11	Aqueous	PFOA	PFAS by ID	17		ng/L	21
007	TBT11	Aqueous	PFPeA	PFAS by ID	26		ng/L	21
007	TBT11	Aqueous	PFOS	PFAS by ID	69		ng/L	21
008	TBT11	Aqueous	6:2 FTS	PFAS by ID	3.4	J	ng/L	23
008	TBT11	Aqueous	PFHxS	PFAS by ID	1.6	J	ng/L	23
008	TBT11	Aqueous	PFBA	PFAS by ID	81		ng/L	23
008	TBT11	Aqueous	PFPeA	PFAS by ID	20		ng/L	23
008	TBT11	Aqueous	PFOS	PFAS by ID	4.2	J	ng/L	23
009	TBT11	Aqueous	PFBS	PFAS by ID	1.4	J	ng/L	25
009	TBT11	Aqueous	PFBA	PFAS by ID	90		ng/L	25
009	TBT11	Aqueous	PFHxA	PFAS by ID	4.2		ng/L	25
009	TBT11	Aqueous	PFPeA	PFAS by ID	140		ng/L	25
009	TBT11	Aqueous	PFOS	PFAS by ID	2.9	J	ng/L	25
010	TBT11	Aqueous	PFBS	PFAS by ID	4.1	J	ng/L	27
010	TBT11	Aqueous	PFHxS	PFAS by ID	1.1	J	ng/L	27
010	TBT11	Aqueous	PFBA	PFAS by ID	83		ng/L	27
010	TBT11	Aqueous	PFHxA	PFAS by ID	18		ng/L	27
010	TBT11	Aqueous	PFPeA	PFAS by ID	270		ng/L	27
010	TBT11	Aqueous	PFOS	PFAS by ID	2.9	J	ng/L	27
011	TBT11	Aqueous	6:2 FTS	PFAS by ID	3.2	J	ng/L	29
011	TBT11	Aqueous	GenX	PFAS by ID	2.2	J	ng/L	29
011	TBT11	Aqueous	PFBS	PFAS by ID	24		ng/L	29
011	TBT11	Aqueous	PFHxS	PFAS by ID	4.6		ng/L	29
011	TBT11	Aqueous	PFBA	PFAS by ID	96		ng/L	29

Detection Summary (Continued)

Lot Number: WB25052

Sample	Sample ID	Matrix	Parameter	Method	Result	Q	Units	Page
011	TBT11	Aqueous	PFHxA	PFAS by ID	110		ng/L	29
011	TBT11	Aqueous	PFOA	PFAS by ID	2.8	J	ng/L	29
011	TBT11	Aqueous	PFPeA	PFAS by ID	370	S	ng/L	29
011	TBT11	Aqueous	PFOS	PFAS by ID	17	B	ng/L	29
012	TBT11	Aqueous	GenX	PFAS by ID	2.1	J	ng/L	31
012	TBT11	Aqueous	PFBS	PFAS by ID	66		ng/L	31
012	TBT11	Aqueous	PFPeS	PFAS by ID	1.8	J	ng/L	31
012	TBT11	Aqueous	PFHxS	PFAS by ID	2.6	J	ng/L	31
012	TBT11	Aqueous	PFBA	PFAS by ID	100		ng/L	31
012	TBT11	Aqueous	PFHpA	PFAS by ID	1.8	J	ng/L	31
012	TBT11	Aqueous	PFHxA	PFAS by ID	270		ng/L	31
012	TBT11	Aqueous	PFOA	PFAS by ID	2.3	J	ng/L	31
012	TBT11	Aqueous	PFPeA	PFAS by ID	360		ng/L	31
012	TBT11	Aqueous	PFOS	PFAS by ID	5.4	B	ng/L	31
013	FT11	Aqueous	8:2 FTS	PFAS by ID	19		ng/L	33
013	FT11	Aqueous	6:2 FTS	PFAS by ID	920		ng/L	33
013	FT11	Aqueous	4:2 FTS	PFAS by ID	7.2	J	ng/L	33
013	FT11	Aqueous	GenX	PFAS by ID	2.2	J	ng/L	33
013	FT11	Aqueous	PFBS	PFAS by ID	200		ng/L	33
013	FT11	Aqueous	PFHpS	PFAS by ID	81		ng/L	33
013	FT11	Aqueous	PFNS	PFAS by ID	4.1		ng/L	33
013	FT11	Aqueous	PFOSA	PFAS by ID	4.8		ng/L	33
013	FT11	Aqueous	PFPeS	PFAS by ID	180		ng/L	33
013	FT11	Aqueous	PFHxS	PFAS by ID	1000		ng/L	33
013	FT11	Aqueous	PFBA	PFAS by ID	120		ng/L	33
013	FT11	Aqueous	PFDA	PFAS by ID	2.3	J	ng/L	33
013	FT11	Aqueous	PFHpA	PFAS by ID	110		ng/L	33
013	FT11	Aqueous	PFHxA	PFAS by ID	490		ng/L	33
013	FT11	Aqueous	PFNA	PFAS by ID	13		ng/L	33
013	FT11	Aqueous	PFOA	PFAS by ID	390		ng/L	33
013	FT11	Aqueous	PFPeA	PFAS by ID	350		ng/L	33
013	FT11	Aqueous	PFOS	PFAS by ID	3100	B	ng/L	33
014	FT11	Aqueous	8:2 FTS	PFAS by ID	12		ng/L	35
014	FT11	Aqueous	6:2 FTS	PFAS by ID	400		ng/L	35
014	FT11	Aqueous	4:2 FTS	PFAS by ID	3.9	J	ng/L	35
014	FT11	Aqueous	GenX	PFAS by ID	4.0	J	ng/L	35
014	FT11	Aqueous	PFBS	PFAS by ID	96		ng/L	35
014	FT11	Aqueous	PFHpS	PFAS by ID	41		ng/L	35
014	FT11	Aqueous	PFPeS	PFAS by ID	85		ng/L	35
014	FT11	Aqueous	PFHxS	PFAS by ID	590		ng/L	35
014	FT11	Aqueous	PFBA	PFAS by ID	61		ng/L	35
014	FT11	Aqueous	PFDA	PFAS by ID	1.7	J	ng/L	35
014	FT11	Aqueous	PFHpA	PFAS by ID	58		ng/L	35
014	FT11	Aqueous	PFHxA	PFAS by ID	230		ng/L	35
014	FT11	Aqueous	PFNA	PFAS by ID	7.0		ng/L	35
014	FT11	Aqueous	PFOA	PFAS by ID	170		ng/L	35
014	FT11	Aqueous	PFPeA	PFAS by ID	180		ng/L	35
014	FT11	Aqueous	PFOS	PFAS by ID	1700	B	ng/L	35

Detection Summary (Continued)

Lot Number: WB25052

Sample	Sample ID	Matrix	Parameter	Method	Result	Q	Units	Page
015	FT11	Aqueous	8:2 FTS	PFAS by ID	9.1	J	ng/L	37
015	FT11	Aqueous	6:2 FTS	PFAS by ID	520		ng/L	37
015	FT11	Aqueous	4:2 FTS	PFAS by ID	3.4	J	ng/L	37
015	FT11	Aqueous	GenX	PFAS by ID	2.6	J	ng/L	37
015	FT11	Aqueous	PFBS	PFAS by ID	120		ng/L	37
015	FT11	Aqueous	PFHpS	PFAS by ID	46		ng/L	37
015	FT11	Aqueous	PFOSA	PFAS by ID	2.0	J	ng/L	37
015	FT11	Aqueous	PFPeS	PFAS by ID	110		ng/L	37
015	FT11	Aqueous	PFHxS	PFAS by ID	700		ng/L	37
015	FT11	Aqueous	PFBA	PFAS by ID	73		ng/L	37
015	FT11	Aqueous	PFDA	PFAS by ID	1.5	J	ng/L	37
015	FT11	Aqueous	PFHpA	PFAS by ID	72		ng/L	37
015	FT11	Aqueous	PFHxA	PFAS by ID	270		ng/L	37
015	FT11	Aqueous	PFNA	PFAS by ID	8.2		ng/L	37
015	FT11	Aqueous	PFOA	PFAS by ID	230		ng/L	37
015	FT11	Aqueous	PFPeA	PFAS by ID	210		ng/L	37
015	FT11	Aqueous	PFOS	PFAS by ID	1900	B	ng/L	37
016	FT11	Aqueous	8:2 FTS	PFAS by ID	20		ng/L	39
016	FT11	Aqueous	6:2 FTS	PFAS by ID	720		ng/L	39
016	FT11	Aqueous	4:2 FTS	PFAS by ID	6.2	J	ng/L	39
016	FT11	Aqueous	PFBS	PFAS by ID	160		ng/L	39
016	FT11	Aqueous	PFHpS	PFAS by ID	69		ng/L	39
016	FT11	Aqueous	PFOSA	PFAS by ID	2.6	J	ng/L	39
016	FT11	Aqueous	PFPeS	PFAS by ID	150		ng/L	39
016	FT11	Aqueous	PFHxS	PFAS by ID	960		ng/L	39
016	FT11	Aqueous	PFBA	PFAS by ID	99		ng/L	39
016	FT11	Aqueous	PFDA	PFAS by ID	2.0	J	ng/L	39
016	FT11	Aqueous	PFHpA	PFAS by ID	95		ng/L	39
016	FT11	Aqueous	PFHxA	PFAS by ID	400		ng/L	39
016	FT11	Aqueous	PFNA	PFAS by ID	11		ng/L	39
016	FT11	Aqueous	PFOA	PFAS by ID	330		ng/L	39
016	FT11	Aqueous	PFPeA	PFAS by ID	280		ng/L	39
016	FT11	Aqueous	PFOS	PFAS by ID	2700	B	ng/L	39
017	FT11	Aqueous	8:2 FTS	PFAS by ID	19		ng/L	41
017	FT11	Aqueous	6:2 FTS	PFAS by ID	710		ng/L	41
017	FT11	Aqueous	4:2 FTS	PFAS by ID	6.4	J	ng/L	41
017	FT11	Aqueous	PFBS	PFAS by ID	170		ng/L	41
017	FT11	Aqueous	PFHpS	PFAS by ID	63		ng/L	41
017	FT11	Aqueous	PFOSA	PFAS by ID	2.9	J	ng/L	41
017	FT11	Aqueous	PFPeS	PFAS by ID	150		ng/L	41
017	FT11	Aqueous	PFHxS	PFAS by ID	1000	E	ng/L	41
017	FT11	Aqueous	PFBA	PFAS by ID	99		ng/L	41
017	FT11	Aqueous	PFDA	PFAS by ID	2.4	J	ng/L	41
017	FT11	Aqueous	PFHpA	PFAS by ID	93		ng/L	41
017	FT11	Aqueous	PFHxA	PFAS by ID	420		ng/L	41
017	FT11	Aqueous	PFNA	PFAS by ID	11		ng/L	41
017	FT11	Aqueous	PFOA	PFAS by ID	330		ng/L	41
017	FT11	Aqueous	PFPeA	PFAS by ID	300		ng/L	41

Detection Summary (Continued)

Lot Number: WB25052

Sample	Sample ID	Matrix	Parameter	Method	Result	Q	Units	Page
017	FT11	Aqueous	PFOS	PFAS by ID	2700	B	ng/L	41
018	FT11	Aqueous	8:2 FTS	PFAS by ID	16		ng/L	43
018	FT11	Aqueous	6:2 FTS	PFAS by ID	700		ng/L	43
018	FT11	Aqueous	4:2 FTS	PFAS by ID	4.9	J	ng/L	43
018	FT11	Aqueous	PFBS	PFAS by ID	160		ng/L	43
018	FT11	Aqueous	PFHpS	PFAS by ID	60		ng/L	43
018	FT11	Aqueous	PFOSA	PFAS by ID	3.1	J	ng/L	43
018	FT11	Aqueous	PFPeS	PFAS by ID	140		ng/L	43
018	FT11	Aqueous	PFHxS	PFAS by ID	900		ng/L	43
018	FT11	Aqueous	PFBA	PFAS by ID	94		ng/L	43
018	FT11	Aqueous	PFDA	PFAS by ID	2.2	J	ng/L	43
018	FT11	Aqueous	PFHpA	PFAS by ID	89		ng/L	43
018	FT11	Aqueous	PFHxA	PFAS by ID	360		ng/L	43
018	FT11	Aqueous	PFNA	PFAS by ID	11		ng/L	43
018	FT11	Aqueous	PFOA	PFAS by ID	300		ng/L	43
018	FT11	Aqueous	PFPeA	PFAS by ID	270		ng/L	43
018	FT11	Aqueous	PFOS	PFAS by ID	2800	B	ng/L	43

(206 detections)

PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.** Laboratory ID: **WB25052-001**

Description: **TAT11** Matrix: **Aqueous**

Date Sampled: **02/04/2021 1800**

Date Received: **02/25/2021**

Run	Prep Method	Analytical Method	Dilution	Analysis Date	Analyst	Prep Date	Batch
1	SOP SPE	PFAS by ID SOP	1	02/28/2021 1253	MMM	02/26/2021 1024	84062

Parameter	CAS Number	Analytical Method	Result	Q	LOQ	DL	Units	Run
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9Cl-PF3ONS)	756426-58-1	PFAS by ID SOP	ND		7.0	1.7	ng/L	1
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3...)	763051-92-9	PFAS by ID SOP	ND		7.0	1.7	ng/L	1
1H, 1H, 2H, 2H-perfluorodecane sulfonic acid (8:2 FTS)	39108-34-4	PFAS by ID SOP	ND		7.0	1.7	ng/L	1
1H, 1H, 2H, 2H-perfluorooctane sulfonic acid (6:2 FTS)	27619-97-2	PFAS by ID SOP	ND		7.0	1.7	ng/L	1
1H,1H,2H,2H-perfluorododecane sulfonic acid (10:2 FTS)	120226-60-0	PFAS by ID SOP	ND		7.0	1.7	ng/L	1
1H,1H,2H,2H-perfluorohexane sulfonic acid (4:2 FTS)	757124-72-4	PFAS by ID SOP	ND		7.0	1.7	ng/L	1
Hexafluoropropylene oxide dimer acid (GenX)	13252-13-6	PFAS by ID SOP	ND		7.0	1.7	ng/L	1
4,8-dioxa-3H-perfluorononanoic acid (ADONA)	919005-14-4	PFAS by ID SOP	ND		7.0	1.7	ng/L	1
N-ethylperfluoro-1-octanesulfonamide (EtFOSA)	4151-50-2	PFAS by ID SOP	ND		7.0	1.7	ng/L	1
N-ethylperfluoro-1-octanesulfonamidoacetic acid (EtFOSAA)	2991-50-6	PFAS by ID SOP	ND		7.0	1.7	ng/L	1
2-N-ethylperfluoro-1-octanesulfonamido-ethanol (EtFOSE)	1691-99-2	PFAS by ID SOP	ND		7.0	1.7	ng/L	1
N-methylperfluoro-1-octanesulfonamide (MeFOSA)	31506-32-8	PFAS by ID SOP	ND		14	3.5	ng/L	1
N-methylperfluoro-1-octanesulfonamidoacetic acid (MeFOSAA)	2355-31-9	PFAS by ID SOP	ND		7.0	1.7	ng/L	1
2-N-methylperfluoro-1-octanesulfonamido-ethanol (MeFOSE)	24448-09-7	PFAS by ID SOP	ND		7.0	1.7	ng/L	1
Perfluoro-1-butanesulfonic acid (PFBS)	**375-73-5**	**PFAS by ID SOP**	**11**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-1-decanesulfonic acid (PFDS)	335-77-3	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-1-heptanesulfonic acid (PFHpS)	375-92-8	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-1-nonanesulfonic acid (PFNS)	68259-12-1	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-1-octanesulfonamide (PFOSA)	754-91-6	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-1-pentanesulfonic acid (PFPeS)	**2706-91-4**	**PFAS by ID SOP**	**3.7**		**3.5**	**0.87**	**ng/L**	**1**
Perfluorohexanesulfonic acid (PFHxS)	**355-46-4**	**PFAS by ID SOP**	**6.7**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-n-butanoic acid (PFBA)	**375-22-4**	**PFAS by ID SOP**	**18**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-n-decanoic acid (PFDA)	335-76-2	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-n-dodecanoic acid (PFDoA)	307-55-1	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-n-heptanoic acid (PFHpA)	**375-85-9**	**PFAS by ID SOP**	**3.9**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-n-hexanoic acid (PFHxA)	**307-24-4**	**PFAS by ID SOP**	**25**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-n-nonanoic acid (PFNA)	375-95-1	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-n-octanoic acid (PFOA)	**335-67-1**	**PFAS by ID SOP**	**4.3**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-n-pentanoic acid (PFPeA)	**2706-90-3**	**PFAS by ID SOP**	**23**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-n-tetradecanoic acid (PFTeDA)	376-06-7	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-n-tridecanoic acid (PFTrDA)	72629-94-8	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-n-undecanoic acid (PFUdA)	2058-94-8	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluorooctanesulfonic acid (PFOS)	**1763-23-1**	**PFAS by ID SOP**	**5.4**		**3.5**	**0.87**	**ng/L**	**1**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits
13C2_4:2FTS		115	25-150
13C2_6:2FTS		101	25-150
13C2_8:2FTS		91	25-150
13C2_PFDoA		62	25-150
13C2_PFTeDA		69	25-150
13C3_PFBS		98	25-150
13C3_PFHxS		89	25-150
13C3-HFPO-DA		99	25-150
13C4_PFBA		90	25-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
J = Estimated result < LOQ and ≥ DL
L = LCS/LCSD failure
H = Out of holding time
W = Reported on wet weight basis
S = MS/MSD failure

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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.**
Laboratory ID: **WB25052-001**
Description: **TAT11**
Matrix: **Aqueous**
Date Sampled: **02/04/2021 1800**
Date Received: **02/25/2021**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits
13C4_PFHpA		86	25-150
13C5_PFHxA		101	25-150
13C5_PFPeA		90	25-150
13C6_PFDA		89	25-150
13C7_PFUdA		75	25-150
13C8_PFOA		84	25-150
13C8_PFOS		79	25-150
13C8_PFOSA		122	10-150
13C9_PFNA		91	25-150
d-EtFOSA		68	10-150
d5-EtFOSAA		86	25-150
d9-EtFOSE		71	10-150
d-MeFOSA		74	10-150
d3-MeFOSAA		86	25-150
d7-MeFOSE		78	10-150

LOQ = Limit of Quantitation
ND = Not detected at or above the DL
H = Out of holding time
B = Detected in the method blank
N = Recovery is out of criteria
W = Reported on wet weight basis
E = Quantitation of compound exceeded the calibration range
P = The RPD between two GC columns exceeds 40%
DL = Detection Limit
J = Estimated result < LOQ and ≥ DL
Q = Surrogate failure
L = LCS/LCSD failure
S = MS/MSD failure

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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.** Laboratory ID: **WB25052-002**

Description: **TAT11** Matrix: **Aqueous**

Date Sampled: **02/06/2021 1800**

Date Received: **02/25/2021**

Run	Prep Method	Analytical Method	Dilution	Analysis Date	Analyst	Prep Date	Batch
1	SOP SPE	PFAS by ID SOP	1	02/28/2021 1314	MMM	02/26/2021 1024	84062

Parameter	CAS Number	Analytical Method	Result	Q	LOQ	DL	Units	Run
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9Cl-PF3ONS)	756426-58-1	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3...)	763051-92-9	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
1H, 1H, 2H, 2H-perfluorodecane sulfonic acid (8:2 FTS)	39108-34-4	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
1H, 1H, 2H, 2H-perfluorooctane sulfonic acid (6:2 FTS)	27619-97-2	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
1H,1H,2H,2H-perfluorododecane sulfonic acid (10:2 FTS)	120226-60-0	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
1H,1H,2H,2H-perfluorohexane sulfonic acid (4:2 FTS)	757124-72-4	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
Hexafluoropropylene oxide dimer acid (GenX)	**13252-13-6**	**PFAS by ID SOP**	**1.7**	**J**	**6.9**	**1.7**	**ng/L**	**1**
4,8-dioxa-3H-perfluorononanoic acid (ADONA)	919005-14-4	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
N-ethylperfluoro-1-octanesulfonamide (EtFOSA)	4151-50-2	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
N-ethylperfluoro-1-octanesulfonamidoacetic acid (EtFOSAA)	2991-50-6	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
2-N-ethylperfluoro-1-octanesulfonamido-ethanol (EtFOSE)	1691-99-2	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
N-methylperfluoro-1-octanesulfonamide (MeFOSA)	31506-32-8	PFAS by ID SOP	ND		14	3.5	ng/L	1
N-methylperfluoro-1-octanesulfonamidoacetic acid (MeFOSAA)	2355-31-9	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
2-N-methylperfluoro-1-octanesulfonamido-ethanol (MeFOSE)	24448-09-7	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
Perfluoro-1-butanesulfonic acid (PFBS)	**375-73-5**	**PFAS by ID SOP**	**10**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-1-decanesulfonic acid (PFDS)	335-77-3	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-1-heptanesulfonic acid (PFHpS)	375-92-8	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-1-nonanesulfonic acid (PFNS)	68259-12-1	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-1-octanesulfonamide (PFOSA)	754-91-6	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-1-pentanesulfonic acid (PFPeS)	2706-91-4	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluorohexanesulfonic acid (PFHxS)	**355-46-4**	**PFAS by ID SOP**	**0.92**	**J**	**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-n-butanoic acid (PFBA)	**375-22-4**	**PFAS by ID SOP**	**66**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-n-decanoic acid (PFDA)	335-76-2	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-n-dodecanoic acid (PFDoA)	307-55-1	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-n-heptanoic acid (PFHpA)	375-85-9	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-n-hexanoic acid (PFHxA)	**307-24-4**	**PFAS by ID SOP**	**35**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-n-nonanoic acid (PFNA)	375-95-1	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-n-octanoic acid (PFOA)	335-67-1	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-n-pentanoic acid (PFPeA)	**2706-90-3**	**PFAS by ID SOP**	**220**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-n-tetradecanoic acid (PFTeDA)	376-06-7	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-n-tridecanoic acid (PFTrDA)	72629-94-8	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-n-undecanoic acid (PFUdA)	2058-94-8	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluorooctanesulfonic acid (PFOS)	**1763-23-1**	**PFAS by ID SOP**	**1.5**	**J**	**3.5**	**0.87**	**ng/L**	**1**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits
13C2_4:2FTS		115	25-150
13C2_6:2FTS		109	25-150
13C2_8:2FTS		97	25-150
13C2_PFDoA		79	25-150
13C2_PFTeDA		79	25-150
13C3_PFBS		113	25-150
13C3_PFHxS		101	25-150
13C3-HFPO-DA		116	25-150
13C4_PFBA		95	25-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
J = Estimated result < LOQ and ≥ DL
L = LCS/LCSD failure
H = Out of holding time
W = Reported on wet weight basis
S = MS/MSD failure

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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.**
Laboratory ID: **WB25052-002**
Description: **TAT11**
Matrix: **Aqueous**
Date Sampled: **02/06/2021 1800**
Date Received: **02/25/2021**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits
13C4_PFHpA		91	25-150
13C5_PFHxA		100	25-150
13C5_PFPeA		99	25-150
13C6_PFDA		83	25-150
13C7_PFUdA		84	25-150
13C8_PFOA		95	25-150
13C8_PFOS		92	25-150
13C8_PFOSA		100	10-150
13C9_PFNA		95	25-150
d-EtFOSA		72	10-150
d5-EtFOSAA		90	25-150
d9-EtFOSE		69	10-150
d-MeFOSA		79	10-150
d3-MeFOSAA		81	25-150
d7-MeFOSE		82	10-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
J = Estimated result < LOQ and ≥ DL
L = LCS/LCSD failure
H = Out of holding time
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S = MS/MSD failure

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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.** Laboratory ID: **WB25052-003**

Description: **TAT11** Matrix: **Aqueous**

Date Sampled: **02/08/2021 1800**

Date Received: **02/25/2021**

Run	Prep Method	Analytical Method	Dilution	Analysis Date	Analyst	Prep Date	Batch
1	SOP SPE	PFAS by ID SOP	1	02/28/2021 1336	MMM	02/26/2021 1024	84062

Parameter	CAS Number	Analytical Method	Result	Q	LOQ	DL	Units	Run
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9Cl-PF3ONS)	756426-58-1	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3...)	763051-92-9	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
1H, 1H, 2H, 2H-perfluorodecane sulfonic acid (8:2 FTS)	39108-34-4	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
1H, 1H, 2H, 2H-perfluorooctane sulfonic acid (6:2 FTS)	27619-97-2	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
1H,1H,2H,2H-perfluorododecane sulfonic acid (10:2 FTS)	120226-60-0	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
1H,1H,2H,2H-perfluorohexane sulfonic acid (4:2 FTS)	757124-72-4	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
Hexafluoropropylene oxide dimer acid (GenX)	**13252-13-6**	**PFAS by ID SOP**	**2.7**	**J**	**6.9**	**1.7**	**ng/L**	**1**
4,8-dioxa-3H-perfluorononanoic acid (ADONA)	919005-14-4	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
N-ethylperfluoro-1-octanesulfonamide (EtFOSA)	4151-50-2	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
N-ethylperfluoro-1-octanesulfonamidoacetic acid (EtFOSAA)	2991-50-6	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
2-N-ethylperfluoro-1-octanesulfonamido-ethanol (EtFOSE)	1691-99-2	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
N-methylperfluoro-1-octanesulfonamide (MeFOSA)	31506-32-8	PFAS by ID SOP	ND		14	3.4	ng/L	1
N-methylperfluoro-1-octanesulfonamidoacetic acid (MeFOSAA)	2355-31-9	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
2-N-methylperfluoro-1-octanesulfonamido-ethanol (MeFOSE)	24448-09-7	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
Perfluoro-1-butanesulfonic acid (PFBS)	**375-73-5**	**PFAS by ID SOP**	**41**		**3.4**	**0.86**	**ng/L**	**1**
Perfluoro-1-decanesulfonic acid (PFDS)	335-77-3	PFAS by ID SOP	ND		3.4	0.86	ng/L	1
Perfluoro-1-heptanesulfonic acid (PFHpS)	375-92-8	PFAS by ID SOP	ND		3.4	0.86	ng/L	1
Perfluoro-1-nonanesulfonic acid (PFNS)	68259-12-1	PFAS by ID SOP	ND		3.4	0.86	ng/L	1
Perfluoro-1-octanesulfonamide (PFOSA)	754-91-6	PFAS by ID SOP	ND		3.4	0.86	ng/L	1
Perfluoro-1-pentanesulfonic acid (PFPeS)	**2706-91-4**	**PFAS by ID SOP**	**3.9**		**3.4**	**0.86**	**ng/L**	**1**
Perfluorohexanesulfonic acid (PFHxS)	**355-46-4**	**PFAS by ID SOP**	**4.5**		**3.4**	**0.86**	**ng/L**	**1**
Perfluoro-n-butanoic acid (PFBA)	**375-22-4**	**PFAS by ID SOP**	**71**		**3.4**	**0.86**	**ng/L**	**1**
Perfluoro-n-decanoic acid (PFDA)	335-76-2	PFAS by ID SOP	ND		3.4	0.86	ng/L	1
Perfluoro-n-dodecanoic acid (PFDoA)	307-55-1	PFAS by ID SOP	ND		3.4	0.86	ng/L	1
Perfluoro-n-heptanoic acid (PFHpA)	**375-85-9**	**PFAS by ID SOP**	**3.7**		**3.4**	**0.86**	**ng/L**	**1**
Perfluoro-n-hexanoic acid (PFHxA)	**307-24-4**	**PFAS by ID SOP**	**140**		**3.4**	**0.86**	**ng/L**	**1**
Perfluoro-n-nonanoic acid (PFNA)	375-95-1	PFAS by ID SOP	ND		3.4	0.86	ng/L	1
Perfluoro-n-octanoic acid (PFOA)	**335-67-1**	**PFAS by ID SOP**	**1.7**	**J**	**3.4**	**0.86**	**ng/L**	**1**
Perfluoro-n-pentanoic acid (PFPeA)	**2706-90-3**	**PFAS by ID SOP**	**270**		**3.4**	**0.86**	**ng/L**	**1**
Perfluoro-n-tetradecanoic acid (PFTeDA)	376-06-7	PFAS by ID SOP	ND		3.4	0.86	ng/L	1
Perfluoro-n-tridecanoic acid (PFTrDA)	72629-94-8	PFAS by ID SOP	ND		3.4	0.86	ng/L	1
Perfluoro-n-undecanoic acid (PFUdA)	2058-94-8	PFAS by ID SOP	ND		3.4	0.86	ng/L	1
Perfluorooctanesulfonic acid (PFOS)	**1763-23-1**	**PFAS by ID SOP**	**1.2**	**J**	**3.4**	**0.86**	**ng/L**	**1**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits
13C2_4:2FTS		117	25-150
13C2_6:2FTS		118	25-150
13C2_8:2FTS		91	25-150
13C2_PFDoA		74	25-150
13C2_PFTeDA		87	25-150
13C3_PFBS		104	25-150
13C3_PFHxS		104	25-150
13C3-HFPO-DA		104	25-150
13C4_PFBA		96	25-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
J = Estimated result < LOQ and ≥ DL
L = LCS/LCSD failure
H = Out of holding time
W = Reported on wet weight basis
S = MS/MSD failure

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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.**
Laboratory ID: **WB25052-003**
Description: **TAT11**
Matrix: **Aqueous**
Date Sampled: **02/08/2021 1800**
Date Received: **02/25/2021**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits
13C4_PFHpA		100	25-150
13C5_PFHxA		102	25-150
13C5_PFPeA		102	25-150
13C6_PFDA		84	25-150
13C7_PFUdA		86	25-150
13C8_PFOA		97	25-150
13C8_PFOS		104	25-150
13C8_PFOSA		111	10-150
13C9_PFNA		107	25-150
d-EtFOSA		76	10-150
d5-EtFOSAA		92	25-150
d9-EtFOSE		87	10-150
d-MeFOSA		74	10-150
d3-MeFOSAA		101	25-150
d7-MeFOSE		88	10-150

LOQ = Limit of Quantitation
ND = Not detected at or above the DL
H = Out of holding time
B = Detected in the method blank
N = Recovery is out of criteria
W = Reported on wet weight basis
E = Quantitation of compound exceeded the calibration range
P = The RPD between two GC columns exceeds 40%
DL = Detection Limit
J = Estimated result < LOQ and ≥ DL
Q = Surrogate failure
L = LCS/LCSD failure
S = MS/MSD failure

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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.** Laboratory ID: **WB25052-004**

Description: **TAT11** Matrix: **Aqueous**

Date Sampled: **02/10/2021 1800**

Date Received: **02/25/2021**

Run	Prep Method	Analytical Method	Dilution	Analysis Date	Analyst	Prep Date	Batch
1	SOP SPE	PFAS by ID SOP	1	02/28/2021 1346	MMM	02/26/2021 1024	84062

Parameter	CAS Number	Analytical Method	Result	Q	LOQ	DL	Units	Run
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9Cl-PF3ONS)	756426-58-1	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3...)	763051-92-9	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
1H, 1H, 2H, 2H-perfluorodecane sulfonic acid (8:2 FTS)	39108-34-4	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
1H, 1H, 2H, 2H-perfluorooctane sulfonic acid (6:2 FTS)	27619-97-2	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
1H,1H,2H,2H-perfluorododecane sulfonic acid (10:2 FTS)	120226-60-0	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
1H,1H,2H,2H-perfluorohexane sulfonic acid (4:2 FTS)	757124-72-4	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
Hexafluoropropylene oxide dimer acid (GenX)	**13252-13-6**	**PFAS by ID SOP**	**2.9**	**J**	**6.9**	**1.7**	**ng/L**	**1**
4,8-dioxa-3H-perfluorononanoic acid (ADONA)	919005-14-4	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
N-ethylperfluoro-1-octanesulfonamide (EtFOSA)	4151-50-2	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
N-ethylperfluoro-1-octanesulfonamidoacetic acid (EtFOSAA)	2991-50-6	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
2-N-ethylperfluoro-1-octanesulfonamido-ethanol (EtFOSE)	1691-99-2	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
N-methylperfluoro-1-octanesulfonamide (MeFOSA)	31506-32-8	PFAS by ID SOP	ND		14	3.5	ng/L	1
N-methylperfluoro-1-octanesulfonamidoacetic acid (MeFOSAA)	2355-31-9	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
2-N-methylperfluoro-1-octanesulfonamido-ethanol (MeFOSE)	24448-09-7	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
Perfluoro-1-butanesulfonic acid (PFBS)	**375-73-5**	**PFAS by ID SOP**	**88**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-1-decanesulfonic acid (PFDS)	335-77-3	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-1-heptanesulfonic acid (PFHpS)	375-92-8	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-1-nonanesulfonic acid (PFNS)	68259-12-1	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-1-octanesulfonamide (PFOSA)	754-91-6	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-1-pentanesulfonic acid (PFPeS)	**2706-91-4**	**PFAS by ID SOP**	**10**		**3.5**	**0.87**	**ng/L**	**1**
Perfluorohexanesulfonic acid (PFHxS)	**355-46-4**	**PFAS by ID SOP**	**13**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-n-butanoic acid (PFBA)	**375-22-4**	**PFAS by ID SOP**	**81**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-n-decanoic acid (PFDA)	335-76-2	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-n-dodecanoic acid (PFDoA)	307-55-1	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-n-heptanoic acid (PFHpA)	**375-85-9**	**PFAS by ID SOP**	**10**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-n-hexanoic acid (PFHxA)	**307-24-4**	**PFAS by ID SOP**	**280**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-n-nonanoic acid (PFNA)	375-95-1	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-n-octanoic acid (PFOA)	**335-67-1**	**PFAS by ID SOP**	**4.6**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-n-pentanoic acid (PFPeA)	**2706-90-3**	**PFAS by ID SOP**	**300**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-n-tetradecanoic acid (PFTeDA)	376-06-7	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-n-tridecanoic acid (PFTrDA)	72629-94-8	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-n-undecanoic acid (PFUdA)	2058-94-8	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluorooctanesulfonic acid (PFOS)	**1763-23-1**	**PFAS by ID SOP**	**1.6**	**J**	**3.5**	**0.87**	**ng/L**	**1**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits
13C2_4:2FTS		132	25-150
13C2_6:2FTS		121	25-150
13C2_8:2FTS		96	25-150
13C2_PFDoA		80	25-150
13C2_PFTeDA		87	25-150
13C3_PFBS		109	25-150
13C3_PFHxS		106	25-150
13C3-HFPO-DA		120	25-150
13C4_PFBA		105	25-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
J = Estimated result < LOQ and ≥ DL
L = LCS/LCSD failure
H = Out of holding time
W = Reported on wet weight basis
S = MS/MSD failure

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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.** Laboratory ID: **WB25052-004**

Description: **TAT11** Matrix: **Aqueous**

Date Sampled: **02/10/2021 1800**

Date Received: **02/25/2021**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits
13C4_PFHpA		109	25-150
13C5_PFHxA		109	25-150
13C5_PFPeA		104	25-150
13C6_PFDA		87	25-150
13C7_PFUdA		76	25-150
13C8_PFOA		92	25-150
13C8_PFOS		101	25-150
13C8_PFOSA		119	10-150
13C9_PFNA		97	25-150
d-EtFOSA		83	10-150
d5-EtFOSAA		91	25-150
d9-EtFOSE		85	10-150
d-MeFOSA		67	10-150
d3-MeFOSAA		84	25-150
d7-MeFOSE		87	10-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
J = Estimated result < LOQ and ≥ DL
L = LCS/LCSD failure
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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.** Laboratory ID: **WB25052-005**

Description: **TAT11** Matrix: **Aqueous**

Date Sampled: **02/12/2021 1800**

Date Received: **02/25/2021**

Run	Prep Method	Analytical Method	Dilution	Analysis Date	Analyst	Prep Date	Batch
1	SOP SPE	PFAS by ID SOP	1	02/28/2021 1357	MMM	02/26/2021 1024	84062

Parameter	CAS Number	Analytical Method	Result	Q	LOQ	DL	Units	Run
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9Cl-PF3ONS)	756426-58-1	PFAS by ID SOP	ND		6.6	1.7	ng/L	1
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3...)	763051-92-9	PFAS by ID SOP	ND		6.6	1.7	ng/L	1
1H, 1H, 2H, 2H-perfluorodecane sulfonic acid (8:2 FTS)	39108-34-4	PFAS by ID SOP	ND		6.6	1.7	ng/L	1
1H, 1H, 2H, 2H-perfluorooctane sulfonic acid (6:2 FTS)	**27619-97-2**	**PFAS by ID SOP**	**6.3**	**J**	**6.6**	**1.7**	**ng/L**	**1**
1H,1H,2H,2H-perfluorododecane sulfonic acid (10:2 FTS)	120226-60-0	PFAS by ID SOP	ND		6.6	1.7	ng/L	1
1H,1H,2H,2H-perfluorohexane sulfonic acid (4:2 FTS)	**757124-72-4**	**PFAS by ID SOP**	**3.7**	**J**	**6.6**	**1.7**	**ng/L**	**1**
Hexafluoropropylene oxide dimer acid (GenX)	**13252-13-6**	**PFAS by ID SOP**	**2.1**	**J**	**6.6**	**1.7**	**ng/L**	**1**
4,8-dioxa-3H-perfluorononanoic acid (ADONA)	919005-14-4	PFAS by ID SOP	ND		6.6	1.7	ng/L	1
N-ethylperfluoro-1-octanesulfonamide (EtFOSA)	4151-50-2	PFAS by ID SOP	ND		6.6	1.7	ng/L	1
N-ethylperfluoro-1-octanesulfonamidoacetic acid (EtFOSAA)	2991-50-6	PFAS by ID SOP	ND		6.6	1.7	ng/L	1
2-N-ethylperfluoro-1-octanesulfonamido-ethanol (EtFOSE)	1691-99-2	PFAS by ID SOP	ND		6.6	1.7	ng/L	1
N-methylperfluoro-1-octanesulfonamide (MeFOSA)	31506-32-8	PFAS by ID SOP	ND		13	3.3	ng/L	1
N-methylperfluoro-1-octanesulfonamidoacetic acid (MeFOSAA)	2355-31-9	PFAS by ID SOP	ND		6.6	1.7	ng/L	1
2-N-methylperfluoro-1-octanesulfonamido-ethanol (MeFOSE)	24448-09-7	PFAS by ID SOP	ND		6.6	1.7	ng/L	1
Perfluoro-1-butanesulfonic acid (PFBS)	**375-73-5**	**PFAS by ID SOP**	**170**		**3.3**	**0.83**	**ng/L**	**1**
Perfluoro-1-decanesulfonic acid (PFDS)	335-77-3	PFAS by ID SOP	ND		3.3	0.83	ng/L	1
Perfluoro-1-heptanesulfonic acid (PFHpS)	375-92-8	PFAS by ID SOP	ND		3.3	0.83	ng/L	1
Perfluoro-1-nonanesulfonic acid (PFNS)	68259-12-1	PFAS by ID SOP	ND		3.3	0.83	ng/L	1
Perfluoro-1-octanesulfonamide (PFOSA)	754-91-6	PFAS by ID SOP	ND		3.3	0.83	ng/L	1
Perfluoro-1-pentanesulfonic acid (PFPeS)	**2706-91-4**	**PFAS by ID SOP**	**40**		**3.3**	**0.83**	**ng/L**	**1**
Perfluorohexanesulfonic acid (PFHxS)	**355-46-4**	**PFAS by ID SOP**	**53**		**3.3**	**0.83**	**ng/L**	**1**
Perfluoro-n-butanoic acid (PFBA)	**375-22-4**	**PFAS by ID SOP**	**100**		**3.3**	**0.83**	**ng/L**	**1**
Perfluoro-n-decanoic acid (PFDA)	335-76-2	PFAS by ID SOP	ND		3.3	0.83	ng/L	1
Perfluoro-n-dodecanoic acid (PFDoA)	307-55-1	PFAS by ID SOP	ND		3.3	0.83	ng/L	1
Perfluoro-n-heptanoic acid (PFHpA)	**375-85-9**	**PFAS by ID SOP**	**36**		**3.3**	**0.83**	**ng/L**	**1**
Perfluoro-n-hexanoic acid (PFHxA)	**307-24-4**	**PFAS by ID SOP**	**470**		**3.3**	**0.83**	**ng/L**	**1**
Perfluoro-n-nonanoic acid (PFNA)	375-95-1	PFAS by ID SOP	ND		3.3	0.83	ng/L	1
Perfluoro-n-octanoic acid (PFOA)	**335-67-1**	**PFAS by ID SOP**	**27**		**3.3**	**0.83**	**ng/L**	**1**
Perfluoro-n-pentanoic acid (PFPeA)	**2706-90-3**	**PFAS by ID SOP**	**360**		**3.3**	**0.83**	**ng/L**	**1**
Perfluoro-n-tetradecanoic acid (PFTeDA)	376-06-7	PFAS by ID SOP	ND		3.3	0.83	ng/L	1
Perfluoro-n-tridecanoic acid (PFTrDA)	72629-94-8	PFAS by ID SOP	ND		3.3	0.83	ng/L	1
Perfluoro-n-undecanoic acid (PFUdA)	2058-94-8	PFAS by ID SOP	ND		3.3	0.83	ng/L	1
Perfluorooctanesulfonic acid (PFOS)	**1763-23-1**	**PFAS by ID SOP**	**11**		**3.3**	**0.83**	**ng/L**	**1**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits
13C2_4:2FTS		104	25-150
13C2_6:2FTS		99	25-150
13C2_8:2FTS		81	25-150
13C2_PFDoA		64	25-150
13C2_PFTeDA		71	25-150
13C3_PFBS		91	25-150
13C3_PFHxS		82	25-150
13C3-HFPO-DA		96	25-150
13C4_PFBA		87	25-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
J = Estimated result < LOQ and ≥ DL
L = LCS/LCSD failure
H = Out of holding time
W = Reported on wet weight basis
S = MS/MSD failure

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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.** Laboratory ID: **WB25052-005**

Description: **TAT11** Matrix: **Aqueous**

Date Sampled: **02/12/2021 1800**

Date Received: **02/25/2021**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits
13C4_PFHpA		85	25-150
13C5_PFHxA		86	25-150
13C5_PFPeA		85	25-150
13C6_PFDA		73	25-150
13C7_PFUdA		78	25-150
13C8_PFOA		68	25-150
13C8_PFOS		85	25-150
13C8_PFOSA		91	10-150
13C9_PFNA		88	25-150
d-EtFOSA		65	10-150
d5-EtFOSAA		84	25-150
d9-EtFOSE		68	10-150
d-MeFOSA		71	10-150
d3-MeFOSAA		80	25-150
d7-MeFOSE		71	10-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
J = Estimated result < LOQ and ≥ DL
L = LCS/LCSD failure
H = Out of holding time
W = Reported on wet weight basis
S = MS/MSD failure

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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.** Laboratory ID: **WB25052-006**

Description: **TAT11** Matrix: **Aqueous**

Date Sampled: **02/14/2021 1800**

Date Received: **02/25/2021**

Run	Prep Method	Analytical Method	Dilution	Analysis Date	Analyst	Prep Date	Batch
1	SOP SPE	PFAS by ID SOP	1	02/28/2021 1407	MMM	02/26/2021 1024	84062

Parameter	CAS Number	Analytical Method	Result	Q	LOQ	DL	Units	Run
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9Cl-PF3ONS)	756426-58-1	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3...)	763051-92-9	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
1H, 1H, 2H, 2H-perfluorodecane sulfonic acid (8:2 FTS)	39108-34-4	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
1H, 1H, 2H, 2H-perfluorooctane sulfonic acid (6:2 FTS)	**27619-97-2**	**PFAS by ID SOP**	**15**		**6.9**	**1.7**	**ng/L**	**1**
1H,1H,2H,2H-perfluorododecane sulfonic acid (10:2 FTS)	120226-60-0	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
1H,1H,2H,2H-perfluorohexane sulfonic acid (4:2 FTS)	**757124-72-4**	**PFAS by ID SOP**	**4.8**	**J**	**6.9**	**1.7**	**ng/L**	**1**
Hexafluoropropylene oxide dimer acid (GenX)	13252-13-6	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
4,8-dioxa-3H-perfluorononanoic acid (ADONA)	919005-14-4	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
N-ethylperfluoro-1-octanesulfonamide (EtFOSA)	4151-50-2	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
N-ethylperfluoro-1-octanesulfonamidoacetic acid (EtFOSAA)	2991-50-6	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
2-N-ethylperfluoro-1-octanesulfonamido-ethanol (EtFOSE)	1691-99-2	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
N-methylperfluoro-1-octanesulfonamide (MeFOSA)	31506-32-8	PFAS by ID SOP	ND		14	3.5	ng/L	1
N-methylperfluoro-1-octanesulfonamidoacetic acid (MeFOSAA)	2355-31-9	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
2-N-methylperfluoro-1-octanesulfonamido-ethanol (MeFOSE)	24448-09-7	PFAS by ID SOP	ND		6.9	1.7	ng/L	1
Perfluoro-1-butanesulfonic acid (PFBS)	**375-73-5**	**PFAS by ID SOP**	**190**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-1-decanesulfonic acid (PFDS)	335-77-3	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-1-heptanesulfonic acid (PFHpS)	**375-92-8**	**PFAS by ID SOP**	**1.2**	**J**	**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-1-nonanesulfonic acid (PFNS)	68259-12-1	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-1-octanesulfonamide (PFOSA)	754-91-6	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-1-pentanesulfonic acid (PFPeS)	**2706-91-4**	**PFAS by ID SOP**	**66**		**3.5**	**0.87**	**ng/L**	**1**
Perfluorohexanesulfonic acid (PFHxS)	**355-46-4**	**PFAS by ID SOP**	**120**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-n-butanoic acid (PFBA)	**375-22-4**	**PFAS by ID SOP**	**88**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-n-decanoic acid (PFDA)	335-76-2	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-n-dodecanoic acid (PFDoA)	307-55-1	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-n-heptanoic acid (PFHpA)	**375-85-9**	**PFAS by ID SOP**	**66**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-n-hexanoic acid (PFHxA)	**307-24-4**	**PFAS by ID SOP**	**430**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-n-nonanoic acid (PFNA)	375-95-1	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-n-octanoic acid (PFOA)	**335-67-1**	**PFAS by ID SOP**	**49**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-n-pentanoic acid (PFPeA)	**2706-90-3**	**PFAS by ID SOP**	**290**		**3.5**	**0.87**	**ng/L**	**1**
Perfluoro-n-tetradecanoic acid (PFTeDA)	376-06-7	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-n-tridecanoic acid (PFTrDA)	72629-94-8	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluoro-n-undecanoic acid (PFUdA)	2058-94-8	PFAS by ID SOP	ND		3.5	0.87	ng/L	1
Perfluorooctanesulfonic acid (PFOS)	**1763-23-1**	**PFAS by ID SOP**	**26**		**3.5**	**0.87**	**ng/L**	**1**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits
13C2_4:2FTS		121	25-150
13C2_6:2FTS		121	25-150
13C2_8:2FTS		97	25-150
13C2_PFDoA		83	25-150
13C2_PFTeDA		86	25-150
13C3_PFBS		98	25-150
13C3_PFHxS		97	25-150
13C3-HFPO-DA		110	25-150
13C4_PFBA		98	25-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
J = Estimated result < LOQ and ≥ DL
L = LCS/LCSD failure
H = Out of holding time
W = Reported on wet weight basis
S = MS/MSD failure

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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.**
Laboratory ID: **WB25052-006**
Description: **TAT11**
Matrix: **Aqueous**
Date Sampled: **02/14/2021 1800**
Date Received: **02/25/2021**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits
13C4_PFHpA		91	25-150
13C5_PFHxA		94	25-150
13C5_PFPeA		99	25-150
13C6_PFDA		86	25-150
13C7_PFUdA		90	25-150
13C8_PFOA		88	25-150
13C8_PFOS		111	25-150
13C8_PFOSA		115	10-150
13C9_PFNA		81	25-150
d-EtFOSA		79	10-150
d5-EtFOSAA		93	25-150
d9-EtFOSE		87	10-150
d-MeFOSA		77	10-150
d3-MeFOSAA		98	25-150
d7-MeFOSE		94	10-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
J = Estimated result < LOQ and ≥ DL
L = LCS/LCSD failure
H = Out of holding time
W = Reported on wet weight basis
S = MS/MSD failure

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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.** Laboratory ID: **WB25052-007**

Description: **TBT11** Matrix: **Aqueous**

Date Sampled: **02/04/2021 1800**

Date Received: **02/25/2021**

Run	Prep Method	Analytical Method	Dilution	Analysis Date	Analyst	Prep Date	Batch
1	SOP SPE	PFAS by ID SOP	1	02/28/2021 1418	MMM	02/26/2021 1024	84062

Parameter	CAS Number	Analytical Method	Result	Q	LOQ	DL	Units	Run
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9Cl-PF3ONS)	756426-58-1	PFAS by ID SOP	ND		7.0	1.8	ng/L	1
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3...)	763051-92-9	PFAS by ID SOP	ND		7.0	1.8	ng/L	1
1H, 1H, 2H, 2H-perfluorodecane sulfonic acid (8:2 FTS)	39108-34-4	PFAS by ID SOP	ND		7.0	1.8	ng/L	1
1H, 1H, 2H, 2H-perfluorooctane sulfonic acid (6:2 FTS)	**27619-97-2**	**PFAS by ID SOP**	**24**		**7.0**	**1.8**	**ng/L**	**1**
1H,1H,2H,2H-perfluorododecane sulfonic acid (10:2 FTS)	120226-60-0	PFAS by ID SOP	ND		7.0	1.8	ng/L	1
1H,1H,2H,2H-perfluorohexane sulfonic acid (4:2 FTS)	757124-72-4	PFAS by ID SOP	ND		7.0	1.8	ng/L	1
Hexafluoropropylene oxide dimer acid (GenX)	13252-13-6	PFAS by ID SOP	ND		7.0	1.8	ng/L	1
4,8-dioxa-3H-perfluorononanoic acid (ADONA)	919005-14-4	PFAS by ID SOP	ND		7.0	1.8	ng/L	1
N-ethylperfluoro-1-octanesulfonamide (EtFOSA)	4151-50-2	PFAS by ID SOP	ND		7.0	1.8	ng/L	1
N-ethylperfluoro-1-octanesulfonamidoacetic acid (EtFOSAA)	2991-50-6	PFAS by ID SOP	ND		7.0	1.8	ng/L	1
2-N-ethylperfluoro-1-octanesulfonamido-ethanol (EtFOSE)	1691-99-2	PFAS by ID SOP	ND		7.0	1.8	ng/L	1
N-methylperfluoro-1-octanesulfonamide (MeFOSA)	31506-32-8	PFAS by ID SOP	ND		14	3.5	ng/L	1
N-methylperfluoro-1-octanesulfonamidoacetic acid (MeFOSAA)	2355-31-9	PFAS by ID SOP	ND		7.0	1.8	ng/L	1
2-N-methylperfluoro-1-octanesulfonamido-ethanol (MeFOSE)	24448-09-7	PFAS by ID SOP	ND		7.0	1.8	ng/L	1
Perfluoro-1-butanesulfonic acid (PFBS)	**375-73-5**	**PFAS by ID SOP**	**9.8**		**3.5**	**0.88**	**ng/L**	**1**
Perfluoro-1-decanesulfonic acid (PFDS)	335-77-3	PFAS by ID SOP	ND		3.5	0.88	ng/L	1
Perfluoro-1-heptanesulfonic acid (PFHpS)	**375-92-8**	**PFAS by ID SOP**	**2.5**	**J**	**3.5**	**0.88**	**ng/L**	**1**
Perfluoro-1-nonanesulfonic acid (PFNS)	68259-12-1	PFAS by ID SOP	ND		3.5	0.88	ng/L	1
Perfluoro-1-octanesulfonamide (PFOSA)	754-91-6	PFAS by ID SOP	ND		3.5	0.88	ng/L	1
Perfluoro-1-pentanesulfonic acid (PFPeS)	**2706-91-4**	**PFAS by ID SOP**	**7.5**		**3.5**	**0.88**	**ng/L**	**1**
Perfluorohexanesulfonic acid (PFHxS)	**355-46-4**	**PFAS by ID SOP**	**38**		**3.5**	**0.88**	**ng/L**	**1**
Perfluoro-n-butanoic acid (PFBA)	**375-22-4**	**PFAS by ID SOP**	**9.9**		**3.5**	**0.88**	**ng/L**	**1**
Perfluoro-n-decanoic acid (PFDA)	335-76-2	PFAS by ID SOP	ND		3.5	0.88	ng/L	1
Perfluoro-n-dodecanoic acid (PFDoA)	307-55-1	PFAS by ID SOP	ND		3.5	0.88	ng/L	1
Perfluoro-n-heptanoic acid (PFHpA)	**375-85-9**	**PFAS by ID SOP**	**5.1**		**3.5**	**0.88**	**ng/L**	**1**
Perfluoro-n-hexanoic acid (PFHxA)	**307-24-4**	**PFAS by ID SOP**	**28**		**3.5**	**0.88**	**ng/L**	**1**
Perfluoro-n-nonanoic acid (PFNA)	**375-95-1**	**PFAS by ID SOP**	**1.2**	**J**	**3.5**	**0.88**	**ng/L**	**1**
Perfluoro-n-octanoic acid (PFOA)	**335-67-1**	**PFAS by ID SOP**	**17**		**3.5**	**0.88**	**ng/L**	**1**
Perfluoro-n-pentanoic acid (PFPeA)	**2706-90-3**	**PFAS by ID SOP**	**26**		**3.5**	**0.88**	**ng/L**	**1**
Perfluoro-n-tetradecanoic acid (PFTeDA)	376-06-7	PFAS by ID SOP	ND		3.5	0.88	ng/L	1
Perfluoro-n-tridecanoic acid (PFTrDA)	72629-94-8	PFAS by ID SOP	ND		3.5	0.88	ng/L	1
Perfluoro-n-undecanoic acid (PFUdA)	2058-94-8	PFAS by ID SOP	ND		3.5	0.88	ng/L	1
Perfluorooctanesulfonic acid (PFOS)	**1763-23-1**	**PFAS by ID SOP**	**69**		**3.5**	**0.88**	**ng/L**	**1**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits
13C2_4:2FTS		117	25-150
13C2_6:2FTS		99	25-150
13C2_8:2FTS		90	25-150
13C2_PFDoA		72	25-150
13C2_PFTeDA		72	25-150
13C3_PFBS		100	25-150
13C3_PFHxS		95	25-150
13C3-HFPO-DA		101	25-150
13C4_PFBA		97	25-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
J = Estimated result < LOQ and ≥ DL
L = LCS/LCSD failure
H = Out of holding time
W = Reported on wet weight basis
S = MS/MSD failure

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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.**
Laboratory ID: **WB25052-007**
Description: **TBT11**
Matrix: **Aqueous**
Date Sampled: **02/04/2021 1800**
Date Received: **02/25/2021**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits
13C4_PFHpA		92	25-150
13C5_PFHxA		100	25-150
13C5_PFPeA		105	25-150
13C6_PFDA		79	25-150
13C7_PFUdA		82	25-150
13C8_PFOA		89	25-150
13C8_PFOS		75	25-150
13C8_PFOSA		102	10-150
13C9_PFNA		81	25-150
d-EtFOSA		71	10-150
d5-EtFOSAA		103	25-150
d9-EtFOSE		77	10-150
d-MeFOSA		76	10-150
d3-MeFOSAA		84	25-150
d7-MeFOSE		80	10-150

LOQ = Limit of Quantitation
ND = Not detected at or above the DL
H = Out of holding time
B = Detected in the method blank
N = Recovery is out of criteria
W = Reported on wet weight basis
E = Quantitation of compound exceeded the calibration range
P = The RPD between two GC columns exceeds 40%
DL = Detection Limit
J = Estimated result < LOQ and ≥ DL
Q = Surrogate failure
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S = MS/MSD failure

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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.** Laboratory ID: **WB25052-008**

Description: **TBT11** Matrix: **Aqueous**

Date Sampled: **02/06/2021 1800**

Date Received: **02/25/2021**

Run	Prep Method	Analytical Method	Dilution	Analysis Date	Analyst	Prep Date	Batch
1	SOP SPE	PFAS by ID SOP	1	02/28/2021 1428	MMM	02/26/2021 1024	84062

Parameter	CAS Number	Analytical Method	Result	Q	LOQ	DL	Units	Run
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9Cl-PF3ONS)	756426-58-1	PFAS by ID SOP	ND		8.8	2.2	ng/L	1
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3...)	763051-92-9	PFAS by ID SOP	ND		8.8	2.2	ng/L	1
1H, 1H, 2H, 2H-perfluorodecane sulfonic acid (8:2 FTS)	39108-34-4	PFAS by ID SOP	ND		8.8	2.2	ng/L	1
1H, 1H, 2H, 2H-perfluorooctane sulfonic acid (6:2 FTS)	**27619-97-2**	**PFAS by ID SOP**	**3.4**	**J**	**8.8**	**2.2**	**ng/L**	**1**
1H,1H,2H,2H-perfluorododecane sulfonic acid (10:2 FTS)	120226-60-0	PFAS by ID SOP	ND		8.8	2.2	ng/L	1
1H,1H,2H,2H-perfluorohexane sulfonic acid (4:2 FTS)	757124-72-4	PFAS by ID SOP	ND		8.8	2.2	ng/L	1
Hexafluoropropylene oxide dimer acid (GenX)	13252-13-6	PFAS by ID SOP	ND		8.8	2.2	ng/L	1
4,8-dioxa-3H-perfluorononanoic acid (ADONA)	919005-14-4	PFAS by ID SOP	ND		8.8	2.2	ng/L	1
N-ethylperfluoro-1-octanesulfonamide (EtFOSA)	4151-50-2	PFAS by ID SOP	ND		8.8	2.2	ng/L	1
N-ethylperfluoro-1-octanesulfonamidoacetic acid (EtFOSAA)	2991-50-6	PFAS by ID SOP	ND		8.8	2.2	ng/L	1
2-N-ethylperfluoro-1-octanesulfonamido-ethanol (EtFOSE)	1691-99-2	PFAS by ID SOP	ND		8.8	2.2	ng/L	1
N-methylperfluoro-1-octanesulfonamide (MeFOSA)	31506-32-8	PFAS by ID SOP	ND		18	4.4	ng/L	1
N-methylperfluoro-1-octanesulfonamidoacetic acid (MeFOSAA)	2355-31-9	PFAS by ID SOP	ND		8.8	2.2	ng/L	1
2-N-methylperfluoro-1-octanesulfonamido-ethanol (MeFOSE)	24448-09-7	PFAS by ID SOP	ND		8.8	2.2	ng/L	1
Perfluoro-1-butanesulfonic acid (PFBS)	375-73-5	PFAS by ID SOP	ND		4.4	1.1	ng/L	1
Perfluoro-1-decanesulfonic acid (PFDS)	335-77-3	PFAS by ID SOP	ND		4.4	1.1	ng/L	1
Perfluoro-1-heptanesulfonic acid (PFHpS)	375-92-8	PFAS by ID SOP	ND		4.4	1.1	ng/L	1
Perfluoro-1-nonanesulfonic acid (PFNS)	68259-12-1	PFAS by ID SOP	ND		4.4	1.1	ng/L	1
Perfluoro-1-octanesulfonamide (PFOSA)	754-91-6	PFAS by ID SOP	ND		4.4	1.1	ng/L	1
Perfluoro-1-pentanesulfonic acid (PFPeS)	2706-91-4	PFAS by ID SOP	ND		4.4	1.1	ng/L	1
Perfluorohexanesulfonic acid (PFHxS)	**355-46-4**	**PFAS by ID SOP**	**1.6**	**J**	**4.4**	**1.1**	**ng/L**	**1**
Perfluoro-n-butanoic acid (PFBA)	**375-22-4**	**PFAS by ID SOP**	**81**		**4.4**	**1.1**	**ng/L**	**1**
Perfluoro-n-decanoic acid (PFDA)	335-76-2	PFAS by ID SOP	ND		4.4	1.1	ng/L	1
Perfluoro-n-dodecanoic acid (PFDoA)	307-55-1	PFAS by ID SOP	ND		4.4	1.1	ng/L	1
Perfluoro-n-heptanoic acid (PFHpA)	375-85-9	PFAS by ID SOP	ND		4.4	1.1	ng/L	1
Perfluoro-n-hexanoic acid (PFHxA)	307-24-4	PFAS by ID SOP	ND		4.4	1.1	ng/L	1
Perfluoro-n-nonanoic acid (PFNA)	375-95-1	PFAS by ID SOP	ND		4.4	1.1	ng/L	1
Perfluoro-n-octanoic acid (PFOA)	335-67-1	PFAS by ID SOP	ND		4.4	1.1	ng/L	1
Perfluoro-n-pentanoic acid (PFPeA)	**2706-90-3**	**PFAS by ID SOP**	**20**		**4.4**	**1.1**	**ng/L**	**1**
Perfluoro-n-tetradecanoic acid (PFTeDA)	376-06-7	PFAS by ID SOP	ND		4.4	1.1	ng/L	1
Perfluoro-n-tridecanoic acid (PFTrDA)	72629-94-8	PFAS by ID SOP	ND		4.4	1.1	ng/L	1
Perfluoro-n-undecanoic acid (PFUdA)	2058-94-8	PFAS by ID SOP	ND		4.4	1.1	ng/L	1
Perfluorooctanesulfonic acid (PFOS)	**1763-23-1**	**PFAS by ID SOP**	**4.2**	**J**	**4.4**	**1.1**	**ng/L**	**1**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits
13C2_4:2FTS		113	25-150
13C2_6:2FTS		113	25-150
13C2_8:2FTS		94	25-150
13C2_PFDoA		76	25-150
13C2_PFTeDA		79	25-150
13C3_PFBS		94	25-150
13C3_PFHxS		94	25-150
13C3-HFPO-DA		110	25-150
13C4_PFBA		94	25-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
J = Estimated result < LOQ and ≥ DL
L = LCS/LCSD failure
H = Out of holding time
W = Reported on wet weight basis
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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.** Laboratory ID: **WB25052-008**

Description: **TBT11** Matrix: **Aqueous**

Date Sampled: **02/06/2021 1800**

Date Received: **02/25/2021**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits
13C4_PFHpA		101	25-150
13C5_PFHxA		104	25-150
13C5_PFPeA		101	25-150
13C6_PFDA		83	25-150
13C7_PFUdA		83	25-150
13C8_PFOA		90	25-150
13C8_PFOS		92	25-150
13C8_PFOSA		105	10-150
13C9_PFNA		91	25-150
d-EtFOSA		75	10-150
d5-EtFOSAA		95	25-150
d9-EtFOSE		90	10-150
d-MeFOSA		71	10-150
d3-MeFOSAA		102	25-150
d7-MeFOSE		81	10-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
J = Estimated result < LOQ and ≥ DL
L = LCS/LCSD failure
H = Out of holding time
W = Reported on wet weight basis
S = MS/MSD failure

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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.** Laboratory ID: **WB25052-009**

Description: **TBT11** Matrix: **Aqueous**

Date Sampled: **02/08/2021 1800**

Date Received: **02/25/2021**

Run	Prep Method	Analytical Method	Dilution	Analysis Date	Analyst	Prep Date	Batch
1	SOP SPE	PFAS by ID SOP	1	02/28/2021 1439	MMM	02/26/2021 1024	84062

Parameter	CAS Number	Analytical Method	Result	Q	LOQ	DL	Units	Run
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9Cl-PF3ONS)	756426-58-1	PFAS by ID SOP	ND		7.5	1.9	ng/L	1
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3...)	763051-92-9	PFAS by ID SOP	ND		7.5	1.9	ng/L	1
1H, 1H, 2H, 2H-perfluorodecane sulfonic acid (8:2 FTS)	39108-34-4	PFAS by ID SOP	ND		7.5	1.9	ng/L	1
1H, 1H, 2H, 2H-perfluorooctane sulfonic acid (6:2 FTS)	27619-97-2	PFAS by ID SOP	ND		7.5	1.9	ng/L	1
1H,1H,2H,2H-perfluorododecane sulfonic acid (10:2 FTS)	120226-60-0	PFAS by ID SOP	ND		7.5	1.9	ng/L	1
1H,1H,2H,2H-perfluorohexane sulfonic acid (4:2 FTS)	757124-72-4	PFAS by ID SOP	ND		7.5	1.9	ng/L	1
Hexafluoropropylene oxide dimer acid (GenX)	13252-13-6	PFAS by ID SOP	ND		7.5	1.9	ng/L	1
4,8-dioxa-3H-perfluorononanoic acid (ADONA)	919005-14-4	PFAS by ID SOP	ND		7.5	1.9	ng/L	1
N-ethylperfluoro-1-octanesulfonamide (EtFOSA)	4151-50-2	PFAS by ID SOP	ND		7.5	1.9	ng/L	1
N-ethylperfluoro-1-octanesulfonamidoacetic acid (EtFOSAA)	2991-50-6	PFAS by ID SOP	ND		7.5	1.9	ng/L	1
2-N-ethylperfluoro-1-octanesulfonamido-ethanol (EtFOSE)	1691-99-2	PFAS by ID SOP	ND		7.5	1.9	ng/L	1
N-methylperfluoro-1-octanesulfonamide (MeFOSA)	31506-32-8	PFAS by ID SOP	ND		15	3.8	ng/L	1
N-methylperfluoro-1-octanesulfonamidoacetic acid (MeFOSAA)	2355-31-9	PFAS by ID SOP	ND		7.5	1.9	ng/L	1
2-N-methylperfluoro-1-octanesulfonamido-ethanol (MeFOSE)	24448-09-7	PFAS by ID SOP	ND		7.5	1.9	ng/L	1
Perfluoro-1-butanesulfonic acid (PFBS)	**375-73-5**	**PFAS by ID SOP**	**1.4**	**J**	**3.8**	**0.94**	**ng/L**	**1**
Perfluoro-1-decanesulfonic acid (PFDS)	335-77-3	PFAS by ID SOP	ND		3.8	0.94	ng/L	1
Perfluoro-1-heptanesulfonic acid (PFHpS)	375-92-8	PFAS by ID SOP	ND		3.8	0.94	ng/L	1
Perfluoro-1-nonanesulfonic acid (PFNS)	68259-12-1	PFAS by ID SOP	ND		3.8	0.94	ng/L	1
Perfluoro-1-octanesulfonamide (PFOSA)	754-91-6	PFAS by ID SOP	ND		3.8	0.94	ng/L	1
Perfluoro-1-pentanesulfonic acid (PFPeS)	2706-91-4	PFAS by ID SOP	ND		3.8	0.94	ng/L	1
Perfluorohexanesulfonic acid (PFHxS)	355-46-4	PFAS by ID SOP	ND		3.8	0.94	ng/L	1
Perfluoro-n-butanoic acid (PFBA)	**375-22-4**	**PFAS by ID SOP**	**90**		**3.8**	**0.94**	**ng/L**	**1**
Perfluoro-n-decanoic acid (PFDA)	335-76-2	PFAS by ID SOP	ND		3.8	0.94	ng/L	1
Perfluoro-n-dodecanoic acid (PFDoA)	307-55-1	PFAS by ID SOP	ND		3.8	0.94	ng/L	1
Perfluoro-n-heptanoic acid (PFHpA)	375-85-9	PFAS by ID SOP	ND		3.8	0.94	ng/L	1
Perfluoro-n-hexanoic acid (PFHxA)	**307-24-4**	**PFAS by ID SOP**	**4.2**		**3.8**	**0.94**	**ng/L**	**1**
Perfluoro-n-nonanoic acid (PFNA)	375-95-1	PFAS by ID SOP	ND		3.8	0.94	ng/L	1
Perfluoro-n-octanoic acid (PFOA)	335-67-1	PFAS by ID SOP	ND		3.8	0.94	ng/L	1
Perfluoro-n-pentanoic acid (PFPeA)	**2706-90-3**	**PFAS by ID SOP**	**140**		**3.8**	**0.94**	**ng/L**	**1**
Perfluoro-n-tetradecanoic acid (PFTeDA)	376-06-7	PFAS by ID SOP	ND		3.8	0.94	ng/L	1
Perfluoro-n-tridecanoic acid (PFTrDA)	72629-94-8	PFAS by ID SOP	ND		3.8	0.94	ng/L	1
Perfluoro-n-undecanoic acid (PFUdA)	2058-94-8	PFAS by ID SOP	ND		3.8	0.94	ng/L	1
Perfluorooctanesulfonic acid (PFOS)	**1763-23-1**	**PFAS by ID SOP**	**2.9**	**J**	**3.8**	**0.94**	**ng/L**	**1**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits
13C2_4:2FTS		137	25-150
13C2_6:2FTS		104	25-150
13C2_8:2FTS		106	25-150
13C2_PFDoA		94	25-150
13C2_PFTeDA		86	25-150
13C3_PFBS		102	25-150
13C3_PFHxS		99	25-150
13C3-HFPO-DA		104	25-150
13C4_PFBA		95	25-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
J = Estimated result < LOQ and ≥ DL
L = LCS/LCSD failure
H = Out of holding time
W = Reported on wet weight basis
S = MS/MSD failure

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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.** Laboratory ID: **WB25052-009**

Description: **TBT11** Matrix: **Aqueous**

Date Sampled: **02/08/2021 1800**

Date Received: **02/25/2021**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits
13C4_PFHpA		102	25-150
13C5_PFHxA		101	25-150
13C5_PFPeA		104	25-150
13C6_PFDA		80	25-150
13C7_PFUdA		105	25-150
13C8_PFOA		89	25-150
13C8_PFOS		99	25-150
13C8_PFOSA		104	10-150
13C9_PFNA		90	25-150
d-EtFOSA		89	10-150
d5-EtFOSAA		100	25-150
d9-EtFOSE		100	10-150
d-MeFOSA		93	10-150
d3-MeFOSAA		96	25-150
d7-MeFOSE		96	10-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
J = Estimated result < LOQ and ≥ DL
L = LCS/LCSD failure
H = Out of holding time
W = Reported on wet weight basis
S = MS/MSD failure

Pace Analytical Services, LLC *(formerly Shealy Environmental Services, Inc.)*
106 Vantage Point Drive West Columbia, SC 29172 (803) 791-9700 Fax (803) 791-9111 www.pacelabs.com

PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.** Laboratory ID: **WB25052-010**

Description: **TBT11** Matrix: **Aqueous**

Date Sampled: **02/10/2021 1800**

Date Received: **02/25/2021**

Run	Prep Method	Analytical Method	Dilution	Analysis Date	Analyst	Prep Date	Batch
1	SOP SPE	PFAS by ID SOP	1	02/28/2021 1450	MMM	02/26/2021 1024	84062

Parameter	CAS Number	Analytical Method	Result	Q	LOQ	DL	Units	Run
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9Cl-PF3ONS)	756426-58-1	PFAS by ID SOP	ND		8.4	2.1	ng/L	1
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3...)	763051-92-9	PFAS by ID SOP	ND		8.4	2.1	ng/L	1
1H, 1H, 2H, 2H-perfluorodecane sulfonic acid (8:2 FTS)	39108-34-4	PFAS by ID SOP	ND		8.4	2.1	ng/L	1
1H, 1H, 2H, 2H-perfluorooctane sulfonic acid (6:2 FTS)	27619-97-2	PFAS by ID SOP	ND		8.4	2.1	ng/L	1
1H,1H,2H,2H-perfluorododecane sulfonic acid (10:2 FTS)	120226-60-0	PFAS by ID SOP	ND		8.4	2.1	ng/L	1
1H,1H,2H,2H-perfluorohexane sulfonic acid (4:2 FTS)	757124-72-4	PFAS by ID SOP	ND		8.4	2.1	ng/L	1
Hexafluoropropylene oxide dimer acid (GenX)	13252-13-6	PFAS by ID SOP	ND		8.4	2.1	ng/L	1
4,8-dioxa-3H-perfluorononanoic acid (ADONA)	919005-14-4	PFAS by ID SOP	ND		8.4	2.1	ng/L	1
N-ethylperfluoro-1-octanesulfonamide (EtFOSA)	4151-50-2	PFAS by ID SOP	ND		8.4	2.1	ng/L	1
N-ethylperfluoro-1-octanesulfonamidoacetic acid (EtFOSAA)	2991-50-6	PFAS by ID SOP	ND		8.4	2.1	ng/L	1
2-N-ethylperfluoro-1-octanesulfonamido-ethanol (EtFOSE)	1691-99-2	PFAS by ID SOP	ND		8.4	2.1	ng/L	1
N-methylperfluoro-1-octanesulfonamide (MeFOSA)	31506-32-8	PFAS by ID SOP	ND		17	4.2	ng/L	1
N-methylperfluoro-1-octanesulfonamidoacetic acid (MeFOSAA)	2355-31-9	PFAS by ID SOP	ND		8.4	2.1	ng/L	1
2-N-methylperfluoro-1-octanesulfonamido-ethanol (MeFOSE)	24448-09-7	PFAS by ID SOP	ND		8.4	2.1	ng/L	1
Perfluoro-1-butanesulfonic acid (PFBS)	**375-73-5**	**PFAS by ID SOP**	**4.1**	**J**	**4.2**	**1.1**	**ng/L**	**1**
Perfluoro-1-decanesulfonic acid (PFDS)	335-77-3	PFAS by ID SOP	ND		4.2	1.1	ng/L	1
Perfluoro-1-heptanesulfonic acid (PFHpS)	375-92-8	PFAS by ID SOP	ND		4.2	1.1	ng/L	1
Perfluoro-1-nonanesulfonic acid (PFNS)	68259-12-1	PFAS by ID SOP	ND		4.2	1.1	ng/L	1
Perfluoro-1-octanesulfonamide (PFOSA)	754-91-6	PFAS by ID SOP	ND		4.2	1.1	ng/L	1
Perfluoro-1-pentanesulfonic acid (PFPeS)	2706-91-4	PFAS by ID SOP	ND		4.2	1.1	ng/L	1
Perfluorohexanesulfonic acid (PFHxS)	**355-46-4**	**PFAS by ID SOP**	**1.1**	**J**	**4.2**	**1.1**	**ng/L**	**1**
Perfluoro-n-butanoic acid (PFBA)	**375-22-4**	**PFAS by ID SOP**	**83**		**4.2**	**1.1**	**ng/L**	**1**
Perfluoro-n-decanoic acid (PFDA)	335-76-2	PFAS by ID SOP	ND		4.2	1.1	ng/L	1
Perfluoro-n-dodecanoic acid (PFDoA)	307-55-1	PFAS by ID SOP	ND		4.2	1.1	ng/L	1
Perfluoro-n-heptanoic acid (PFHpA)	375-85-9	PFAS by ID SOP	ND		4.2	1.1	ng/L	1
Perfluoro-n-hexanoic acid (PFHxA)	**307-24-4**	**PFAS by ID SOP**	**18**		**4.2**	**1.1**	**ng/L**	**1**
Perfluoro-n-nonanoic acid (PFNA)	375-95-1	PFAS by ID SOP	ND		4.2	1.1	ng/L	1
Perfluoro-n-octanoic acid (PFOA)	335-67-1	PFAS by ID SOP	ND		4.2	1.1	ng/L	1
Perfluoro-n-pentanoic acid (PFPeA)	**2706-90-3**	**PFAS by ID SOP**	**270**		**4.2**	**1.1**	**ng/L**	**1**
Perfluoro-n-tetradecanoic acid (PFTeDA)	376-06-7	PFAS by ID SOP	ND		4.2	1.1	ng/L	1
Perfluoro-n-tridecanoic acid (PFTrDA)	72629-94-8	PFAS by ID SOP	ND		4.2	1.1	ng/L	1
Perfluoro-n-undecanoic acid (PFUdA)	2058-94-8	PFAS by ID SOP	ND		4.2	1.1	ng/L	1
Perfluorooctanesulfonic acid (PFOS)	**1763-23-1**	**PFAS by ID SOP**	**2.9**	**J**	**4.2**	**1.1**	**ng/L**	**1**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits
13C2_4:2FTS		119	25-150
13C2_6:2FTS		100	25-150
13C2_8:2FTS		99	25-150
13C2_PFDoA		83	25-150
13C2_PFTeDA		88	25-150
13C3_PFBS		104	25-150
13C3_PFHxS		94	25-150
13C3-HFPO-DA		109	25-150
13C4_PFBA		96	25-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
J = Estimated result < LOQ and ≥ DL
L = LCS/LCSD failure
H = Out of holding time
W = Reported on wet weight basis
S = MS/MSD failure

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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.** Laboratory ID: **WB25052-010**

Description: **TBT11** Matrix: **Aqueous**

Date Sampled: **02/10/2021 1800**

Date Received: **02/25/2021**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits
13C4_PFHpA		99	25-150
13C5_PFHxA		98	25-150
13C5_PFPeA		106	25-150
13C6_PFDA		80	25-150
13C7_PFUdA		96	25-150
13C8_PFOA		96	25-150
13C8_PFOS		97	25-150
13C8_PFOSA		108	10-150
13C9_PFNA		104	25-150
d-EtFOSA		90	10-150
d5-EtFOSAA		96	25-150
d9-EtFOSE		89	10-150
d-MeFOSA		78	10-150
d3-MeFOSAA		95	25-150
d7-MeFOSE		98	10-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.** Laboratory ID: **WB25052-011**

Description: **TBT11** Matrix: **Aqueous**

Date Sampled: **02/12/2021 1800**

Date Received: **02/25/2021**

Run	Prep Method	Analytical Method	Dilution	Analysis Date	Analyst	Prep Date	Batch
1	SOP SPE	PFAS by ID SOP	1	03/01/2021 1350	JJG	02/26/2021 1041	84057

Parameter	CAS Number	Analytical Method	Result	Q	LOQ	DL	Units	Run
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9Cl-PF3ONS)	756426-58-1	PFAS by ID SOP	ND		8.7	2.2	ng/L	1
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3...)	763051-92-9	PFAS by ID SOP	ND		8.7	2.2	ng/L	1
1H, 1H, 2H, 2H-perfluorodecane sulfonic acid (8:2 FTS)	39108-34-4	PFAS by ID SOP	ND		8.7	2.2	ng/L	1
1H, 1H, 2H, 2H-perfluorooctane sulfonic acid (6:2 FTS)	**27619-97-2**	**PFAS by ID SOP**	**3.2**	**J**	**8.7**	**2.2**	**ng/L**	**1**
1H,1H,2H,2H-perfluorododecane sulfonic acid (10:2 FTS)	120226-60-0	PFAS by ID SOP	ND		8.7	2.2	ng/L	1
1H,1H,2H,2H-perfluorohexane sulfonic acid (4:2 FTS)	757124-72-4	PFAS by ID SOP	ND		8.7	2.2	ng/L	1
Hexafluoropropylene oxide dimer acid (GenX)	**13252-13-6**	**PFAS by ID SOP**	**2.2**	**J**	**8.7**	**2.2**	**ng/L**	**1**
4,8-dioxa-3H-perfluorononanoic acid (ADONA)	919005-14-4	PFAS by ID SOP	ND		8.7	2.2	ng/L	1
N-ethylperfluoro-1-octanesulfonamide (EtFOSA)	4151-50-2	PFAS by ID SOP	ND		8.7	2.2	ng/L	1
N-ethylperfluoro-1-octanesulfonamidoacetic acid (EtFOSAA)	2991-50-6	PFAS by ID SOP	ND		8.7	2.2	ng/L	1
2-N-ethylperfluoro-1-octanesulfonamido-ethanol (EtFOSE)	1691-99-2	PFAS by ID SOP	ND		8.7	2.2	ng/L	1
N-methylperfluoro-1-octanesulfonamide (MeFOSA)	31506-32-8	PFAS by ID SOP	ND		17	4.3	ng/L	1
N-methylperfluoro-1-octanesulfonamidoacetic acid (MeFOSAA)	2355-31-9	PFAS by ID SOP	ND		8.7	2.2	ng/L	1
2-N-methylperfluoro-1-octanesulfonamido-ethanol (MeFOSE)	24448-09-7	PFAS by ID SOP	ND		8.7	2.2	ng/L	1
Perfluoro-1-butanesulfonic acid (PFBS)	**375-73-5**	**PFAS by ID SOP**	**24**		**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-1-decanesulfonic acid (PFDS)	335-77-3	PFAS by ID SOP	ND		4.3	1.1	ng/L	1
Perfluoro-1-heptanesulfonic acid (PFHpS)	375-92-8	PFAS by ID SOP	ND		4.3	1.1	ng/L	1
Perfluoro-1-nonanesulfonic acid (PFNS)	68259-12-1	PFAS by ID SOP	ND		4.3	1.1	ng/L	1
Perfluoro-1-octanesulfonamide (PFOSA)	754-91-6	PFAS by ID SOP	ND		4.3	1.1	ng/L	1
Perfluoro-1-pentanesulfonic acid (PFPeS)	2706-91-4	PFAS by ID SOP	ND		4.3	1.1	ng/L	1
Perfluorohexanesulfonic acid (PFHxS)	**355-46-4**	**PFAS by ID SOP**	**4.6**		**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-n-butanoic acid (PFBA)	**375-22-4**	**PFAS by ID SOP**	**96**		**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-n-decanoic acid (PFDA)	335-76-2	PFAS by ID SOP	ND		4.3	1.1	ng/L	1
Perfluoro-n-dodecanoic acid (PFDoA)	307-55-1	PFAS by ID SOP	ND		4.3	1.1	ng/L	1
Perfluoro-n-heptanoic acid (PFHpA)	375-85-9	PFAS by ID SOP	ND		4.3	1.1	ng/L	1
Perfluoro-n-hexanoic acid (PFHxA)	**307-24-4**	**PFAS by ID SOP**	**110**		**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-n-nonanoic acid (PFNA)	375-95-1	PFAS by ID SOP	ND		4.3	1.1	ng/L	1
Perfluoro-n-octanoic acid (PFOA)	**335-67-1**	**PFAS by ID SOP**	**2.8**	**J**	**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-n-pentanoic acid (PFPeA)	**2706-90-3**	**PFAS by ID SOP**	**370**	**S**	**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-n-tetradecanoic acid (PFTeDA)	376-06-7	PFAS by ID SOP	ND		4.3	1.1	ng/L	1
Perfluoro-n-tridecanoic acid (PFTrDA)	72629-94-8	PFAS by ID SOP	ND		4.3	1.1	ng/L	1
Perfluoro-n-undecanoic acid (PFUdA)	2058-94-8	PFAS by ID SOP	ND		4.3	1.1	ng/L	1
Perfluorooctanesulfonic acid (PFOS)	**1763-23-1**	**PFAS by ID SOP**	**17**	**B**	**4.3**	**1.1**	**ng/L**	**1**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits
13C2_4:2FTS		118	25-150
13C2_6:2FTS		109	25-150
13C2_8:2FTS		101	25-150
13C2_PFDoA		92	25-150
13C2_PFTeDA		89	25-150
13C3_PFBS		102	25-150
13C3_PFHxS		99	25-150
13C3-HFPO-DA		113	25-150
13C4_PFBA		101	25-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
J = Estimated result < LOQ and ≥ DL
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H = Out of holding time
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S = MS/MSD failure

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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.**
Laboratory ID: **WB25052-011**
Description: **TBT11**
Matrix: **Aqueous**
Date Sampled: **02/12/2021 1800**
Date Received: **02/25/2021**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits
13C4_PFHpA		105	25-150
13C5_PFHxA		98	25-150
13C5_PFPeA		95	25-150
13C6_PFDA		98	25-150
13C7_PFUdA		92	25-150
13C8_PFOA		99	25-150
13C8_PFOS		96	25-150
13C8_PFOSA		108	10-150
13C9_PFNA		100	25-150
d-EtFOSA		98	10-150
d5-EtFOSAA		108	25-150
d9-EtFOSE		96	10-150
d-MeFOSA		100	10-150
d3-MeFOSAA		105	25-150
d7-MeFOSE		97	10-150

LOQ = Limit of Quantitation
ND = Not detected at or above the DL
H = Out of holding time
B = Detected in the method blank
N = Recovery is out of criteria
W = Reported on wet weight basis
E = Quantitation of compound exceeded the calibration range
P = The RPD between two GC columns exceeds 40%
DL = Detection Limit
J = Estimated result < LOQ and ≥ DL
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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.** Laboratory ID: **WB25052-012**

Description: **TBT11** Matrix: **Aqueous**

Date Sampled: **02/14/2021 1800**

Date Received: **02/25/2021**

Run	Prep Method	Analytical Method	Dilution	Analysis Date	Analyst	Prep Date	Batch
1	SOP SPE	PFAS by ID SOP	1	03/01/2021 1411	JJG	02/26/2021 1041	84057

Parameter	CAS Number	Analytical Method	Result	Q	LOQ	DL	Units	Run
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9Cl-PF3ONS)	756426-58-1	PFAS by ID SOP	ND		7.0	1.8	ng/L	1
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3...)	763051-92-9	PFAS by ID SOP	ND		7.0	1.8	ng/L	1
1H, 1H, 2H, 2H-perfluorodecane sulfonic acid (8:2 FTS)	39108-34-4	PFAS by ID SOP	ND		7.0	1.8	ng/L	1
1H, 1H, 2H, 2H-perfluorooctane sulfonic acid (6:2 FTS)	27619-97-2	PFAS by ID SOP	ND		7.0	1.8	ng/L	1
1H,1H,2H,2H-perfluorododecane sulfonic acid (10:2 FTS)	120226-60-0	PFAS by ID SOP	ND		7.0	1.8	ng/L	1
1H,1H,2H,2H-perfluorohexane sulfonic acid (4:2 FTS)	757124-72-4	PFAS by ID SOP	ND		7.0	1.8	ng/L	1
Hexafluoropropylene oxide dimer acid (GenX)	**13252-13-6**	**PFAS by ID SOP**	**2.1**	**J**	**7.0**	**1.8**	**ng/L**	**1**
4,8-dioxa-3H-perfluorononanoic acid (ADONA)	919005-14-4	PFAS by ID SOP	ND		7.0	1.8	ng/L	1
N-ethylperfluoro-1-octanesulfonamide (EtFOSA)	4151-50-2	PFAS by ID SOP	ND		7.0	1.8	ng/L	1
N-ethylperfluoro-1-octanesulfonamidoacetic acid (EtFOSAA)	2991-50-6	PFAS by ID SOP	ND		7.0	1.8	ng/L	1
2-N-ethylperfluoro-1-octanesulfonamido-ethanol (EtFOSE)	1691-99-2	PFAS by ID SOP	ND		7.0	1.8	ng/L	1
N-methylperfluoro-1-octanesulfonamide (MeFOSA)	31506-32-8	PFAS by ID SOP	ND		14	3.5	ng/L	1
N-methylperfluoro-1-octanesulfonamidoacetic acid (MeFOSAA)	2355-31-9	PFAS by ID SOP	ND		7.0	1.8	ng/L	1
2-N-methylperfluoro-1-octanesulfonamido-ethanol (MeFOSE)	24448-09-7	PFAS by ID SOP	ND		7.0	1.8	ng/L	1
Perfluoro-1-butanesulfonic acid (PFBS)	**375-73-5**	**PFAS by ID SOP**	**66**		**3.5**	**0.88**	**ng/L**	**1**
Perfluoro-1-decanesulfonic acid (PFDS)	335-77-3	PFAS by ID SOP	ND		3.5	0.88	ng/L	1
Perfluoro-1-heptanesulfonic acid (PFHpS)	375-92-8	PFAS by ID SOP	ND		3.5	0.88	ng/L	1
Perfluoro-1-nonanesulfonic acid (PFNS)	68259-12-1	PFAS by ID SOP	ND		3.5	0.88	ng/L	1
Perfluoro-1-octanesulfonamide (PFOSA)	754-91-6	PFAS by ID SOP	ND		3.5	0.88	ng/L	1
Perfluoro-1-pentanesulfonic acid (PFPeS)	**2706-91-4**	**PFAS by ID SOP**	**1.8**	**J**	**3.5**	**0.88**	**ng/L**	**1**
Perfluorohexanesulfonic acid (PFHxS)	**355-46-4**	**PFAS by ID SOP**	**2.6**	**J**	**3.5**	**0.88**	**ng/L**	**1**
Perfluoro-n-butanoic acid (PFBA)	**375-22-4**	**PFAS by ID SOP**	**100**		**3.5**	**0.88**	**ng/L**	**1**
Perfluoro-n-decanoic acid (PFDA)	335-76-2	PFAS by ID SOP	ND		3.5	0.88	ng/L	1
Perfluoro-n-dodecanoic acid (PFDoA)	307-55-1	PFAS by ID SOP	ND		3.5	0.88	ng/L	1
Perfluoro-n-heptanoic acid (PFHpA)	**375-85-9**	**PFAS by ID SOP**	**1.8**	**J**	**3.5**	**0.88**	**ng/L**	**1**
Perfluoro-n-hexanoic acid (PFHxA)	**307-24-4**	**PFAS by ID SOP**	**270**		**3.5**	**0.88**	**ng/L**	**1**
Perfluoro-n-nonanoic acid (PFNA)	375-95-1	PFAS by ID SOP	ND		3.5	0.88	ng/L	1
Perfluoro-n-octanoic acid (PFOA)	**335-67-1**	**PFAS by ID SOP**	**2.3**	**J**	**3.5**	**0.88**	**ng/L**	**1**
Perfluoro-n-pentanoic acid (PFPeA)	**2706-90-3**	**PFAS by ID SOP**	**360**		**3.5**	**0.88**	**ng/L**	**1**
Perfluoro-n-tetradecanoic acid (PFTeDA)	376-06-7	PFAS by ID SOP	ND		3.5	0.88	ng/L	1
Perfluoro-n-tridecanoic acid (PFTrDA)	72629-94-8	PFAS by ID SOP	ND		3.5	0.88	ng/L	1
Perfluoro-n-undecanoic acid (PFUdA)	2058-94-8	PFAS by ID SOP	ND		3.5	0.88	ng/L	1
Perfluorooctanesulfonic acid (PFOS)	**1763-23-1**	**PFAS by ID SOP**	**5.4**	**B**	**3.5**	**0.88**	**ng/L**	**1**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits
13C2_4:2FTS		112	25-150
13C2_6:2FTS		97	25-150
13C2_8:2FTS		86	25-150
13C2_PFDoA		90	25-150
13C2_PFTeDA		84	25-150
13C3_PFBS		91	25-150
13C3_PFHxS		90	25-150
13C3-HFPO-DA		103	25-150
13C4_PFBA		93	25-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
J = Estimated result < LOQ and ≥ DL
L = LCS/LCSD failure
H = Out of holding time
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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.**
Laboratory ID: **WB25052-012**
Description: **TBT11**
Matrix: **Aqueous**
Date Sampled: **02/14/2021 1800**
Date Received: **02/25/2021**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits
13C4_PFHpA		100	25-150
13C5_PFHxA		90	25-150
13C5_PFPeA		86	25-150
13C6_PFDA		91	25-150
13C7_PFUdA		91	25-150
13C8_PFOA		96	25-150
13C8_PFOS		87	25-150
13C8_PFOSA		104	10-150
13C9_PFNA		92	25-150
d-EtFOSA		84	10-150
d5-EtFOSAA		101	25-150
d9-EtFOSE		96	10-150
d-MeFOSA		82	10-150
d3-MeFOSAA		99	25-150
d7-MeFOSE		91	10-150

LOQ = Limit of Quantitation
ND = Not detected at or above the DL
H = Out of holding time
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W = Reported on wet weight basis
E = Quantitation of compound exceeded the calibration range
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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.** Laboratory ID: **WB25052-013**

Description: **FT11** Matrix: **Aqueous**

Date Sampled: **02/04/2021 1620**

Date Received: **02/25/2021**

Run	Prep Method	Analytical Method	Dilution	Analysis Date	Analyst	Prep Date	Batch
1	SOP SPE	PFAS by ID SOP	1	03/01/2021 1433	JJG	02/26/2021 1041	84057
2	SOP SPE	PFAS by ID SOP	10	03/02/2021 1345	JJG	02/26/2021 1041	84057

Parameter	CAS Number	Analytical Method	Result	Q	LOQ	DL	Units	Run
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9Cl-PF3ONS)	756426-58-1	PFAS by ID SOP	ND		8.0	2.0	ng/L	1
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3...)	763051-92-9	PFAS by ID SOP	ND		8.0	2.0	ng/L	1
1H, 1H, 2H, 2H-perfluorodecane sulfonic acid (8:2 FTS)	**39108-34-4**	**PFAS by ID SOP**	**19**		**8.0**	**2.0**	**ng/L**	**1**
1H, 1H, 2H, 2H-perfluorooctane sulfonic acid (6:2 FTS)	**27619-97-2**	**PFAS by ID SOP**	**920**		**80**	**20**	**ng/L**	**2**
1H,1H,2H,2H-perfluorododecane sulfonic acid (10:2 FTS)	120226-60-0	PFAS by ID SOP	ND		8.0	2.0	ng/L	1
1H,1H,2H,2H-perfluorohexane sulfonic acid (4:2 FTS)	**757124-72-4**	**PFAS by ID SOP**	**7.2**	**J**	**8.0**	**2.0**	**ng/L**	**1**
Hexafluoropropylene oxide dimer acid (GenX)	**13252-13-6**	**PFAS by ID SOP**	**2.2**	**J**	**8.0**	**2.0**	**ng/L**	**1**
4,8-dioxa-3H-perfluorononanoic acid (ADONA)	919005-14-4	PFAS by ID SOP	ND		8.0	2.0	ng/L	1
N-ethylperfluoro-1-octanesulfonamide (EtFOSA)	4151-50-2	PFAS by ID SOP	ND		8.0	2.0	ng/L	1
N-ethylperfluoro-1-octanesulfonamidoacetic acid (EtFOSAA)	2991-50-6	PFAS by ID SOP	ND		8.0	2.0	ng/L	1
2-N-ethylperfluoro-1-octanesulfonamido-ethanol (EtFOSE)	1691-99-2	PFAS by ID SOP	ND		8.0	2.0	ng/L	1
N-methylperfluoro-1-octanesulfonamide (MeFOSA)	31506-32-8	PFAS by ID SOP	ND		16	4.0	ng/L	1
N-methylperfluoro-1-octanesulfonamidoacetic acid (MeFOSAA)	2355-31-9	PFAS by ID SOP	ND		8.0	2.0	ng/L	1
2-N-methylperfluoro-1-octanesulfonamido-ethanol (MeFOSE)	24448-09-7	PFAS by ID SOP	ND		8.0	2.0	ng/L	1
Perfluoro-1-butanesulfonic acid (PFBS)	**375-73-5**	**PFAS by ID SOP**	**200**		**4.0**	**1.0**	**ng/L**	**1**
Perfluoro-1-decanesulfonic acid (PFDS)	335-77-3	PFAS by ID SOP	ND		4.0	1.0	ng/L	1
Perfluoro-1-heptanesulfonic acid (PFHpS)	**375-92-8**	**PFAS by ID SOP**	**81**		**4.0**	**1.0**	**ng/L**	**1**
Perfluoro-1-nonanesulfonic acid (PFNS)	**68259-12-1**	**PFAS by ID SOP**	**4.1**		**4.0**	**1.0**	**ng/L**	**1**
Perfluoro-1-octanesulfonamide (PFOSA)	**754-91-6**	**PFAS by ID SOP**	**4.8**		**4.0**	**1.0**	**ng/L**	**1**
Perfluoro-1-pentanesulfonic acid (PFPeS)	**2706-91-4**	**PFAS by ID SOP**	**180**		**4.0**	**1.0**	**ng/L**	**1**
Perfluorohexanesulfonic acid (PFHxS)	**355-46-4**	**PFAS by ID SOP**	**1000**		**40**	**10**	**ng/L**	**2**
Perfluoro-n-butanoic acid (PFBA)	**375-22-4**	**PFAS by ID SOP**	**120**		**4.0**	**1.0**	**ng/L**	**1**
Perfluoro-n-decanoic acid (PFDA)	**335-76-2**	**PFAS by ID SOP**	**2.3**	**J**	**4.0**	**1.0**	**ng/L**	**1**
Perfluoro-n-dodecanoic acid (PFDoA)	307-55-1	PFAS by ID SOP	ND		4.0	1.0	ng/L	1
Perfluoro-n-heptanoic acid (PFHpA)	**375-85-9**	**PFAS by ID SOP**	**110**		**4.0**	**1.0**	**ng/L**	**1**
Perfluoro-n-hexanoic acid (PFHxA)	**307-24-4**	**PFAS by ID SOP**	**490**		**4.0**	**1.0**	**ng/L**	**1**
Perfluoro-n-nonanoic acid (PFNA)	**375-95-1**	**PFAS by ID SOP**	**13**		**4.0**	**1.0**	**ng/L**	**1**
Perfluoro-n-octanoic acid (PFOA)	**335-67-1**	**PFAS by ID SOP**	**390**		**4.0**	**1.0**	**ng/L**	**1**
Perfluoro-n-pentanoic acid (PFPeA)	**2706-90-3**	**PFAS by ID SOP**	**350**		**4.0**	**1.0**	**ng/L**	**1**
Perfluoro-n-tetradecanoic acid (PFTeDA)	376-06-7	PFAS by ID SOP	ND		4.0	1.0	ng/L	1
Perfluoro-n-tridecanoic acid (PFTrDA)	72629-94-8	PFAS by ID SOP	ND		4.0	1.0	ng/L	1
Perfluoro-n-undecanoic acid (PFUdA)	2058-94-8	PFAS by ID SOP	ND		4.0	1.0	ng/L	1
Perfluorooctanesulfonic acid (PFOS)	**1763-23-1**	**PFAS by ID SOP**	**3100**	**B**	**40**	**10**	**ng/L**	**2**

Surrogate	Run 1 Q	Run 1 % Recovery	Run 1 Acceptance Limits	Run 2 Q	Run 2 % Recovery	Run 2 Acceptance Limits
13C2_4:2FTS		118	25-150		112	25-150
13C2_6:2FTS		93	25-150		109	25-150
13C2_8:2FTS		97	25-150		112	25-150
13C2_PFDoA		81	25-150		106	25-150
13C2_PFTeDA		69	25-150		106	25-150
13C3_PFBS		91	25-150		108	25-150
13C3_PFHxS		83	25-150		111	25-150
13C3-HFPO-DA		104	25-150		109	25-150

LOQ = Limit of Quantitation
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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.**
Laboratory ID: **WB25052-013**
Description: **FT11**
Matrix: **Aqueous**
Date Sampled: **02/04/2021 1620**
Date Received: **02/25/2021**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits	Q	Run 2 % Recovery	Acceptance Limits
13C4_PFBA		99	25-150		114	25-150
13C4_PFHpA		96	25-150		106	25-150
13C5_PFHxA		90	25-150		105	25-150
13C5_PFPeA		92	25-150		107	25-150
13C6_PFDA		88	25-150		107	25-150
13C7_PFUdA		87	25-150		107	25-150
13C8_PFOA		84	25-150		111	25-150
13C8_PFOS		70	25-150		102	25-150
13C8_PFOSA		96	10-150		114	10-150
13C9_PFNA		86	25-150		109	25-150
d-EtFOSA		88	10-150		107	10-150
d5-EtFOSAA		95	25-150		105	25-150
d9-EtFOSE		84	10-150		107	10-150
d-MeFOSA		108	10-150		115	10-150
d3-MeFOSAA		93	25-150		114	25-150
d7-MeFOSE		84	10-150		97	10-150

LOQ = Limit of Quantitation
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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.** Laboratory ID: **WB25052-014**

Description: **FT11** Matrix: **Aqueous**

Date Sampled: **02/06/2021 1620**

Date Received: **02/25/2021**

Run	Prep Method	Analytical Method	Dilution	Analysis Date	Analyst	Prep Date	Batch
1	SOP SPE	PFAS by ID SOP	1	03/01/2021 1443	JJG	02/26/2021 1041	84057
2	SOP SPE	PFAS by ID SOP	5	03/02/2021 1355	JJG	02/26/2021 1041	84057

Parameter	CAS Number	Analytical Method	Result	Q	LOQ	DL	Units	Run
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9Cl-PF3ONS)	756426-58-1	PFAS by ID SOP	ND		11	2.7	ng/L	1
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3...)	763051-92-9	PFAS by ID SOP	ND		11	2.7	ng/L	1
1H, 1H, 2H, 2H-perfluorodecane sulfonic acid (8:2 FTS)	**39108-34-4**	**PFAS by ID SOP**	**12**		**11**	**2.7**	**ng/L**	**1**
1H, 1H, 2H, 2H-perfluorooctane sulfonic acid (6:2 FTS)	**27619-97-2**	**PFAS by ID SOP**	**400**		**11**	**2.7**	**ng/L**	**1**
1H,1H,2H,2H-perfluorododecane sulfonic acid (10:2 FTS)	120226-60-0	PFAS by ID SOP	ND		11	2.7	ng/L	1
1H,1H,2H,2H-perfluorohexane sulfonic acid (4:2 FTS)	**757124-72-4**	**PFAS by ID SOP**	**3.9**	**J**	**11**	**2.7**	**ng/L**	**1**
Hexafluoropropylene oxide dimer acid (GenX)	**13252-13-6**	**PFAS by ID SOP**	**4.0**	**J**	**11**	**2.7**	**ng/L**	**1**
4,8-dioxa-3H-perfluorononanoic acid (ADONA)	919005-14-4	PFAS by ID SOP	ND		11	2.7	ng/L	1
N-ethylperfluoro-1-octanesulfonamide (EtFOSA)	4151-50-2	PFAS by ID SOP	ND		11	2.7	ng/L	1
N-ethylperfluoro-1-octanesulfonamidoacetic acid (EtFOSAA)	2991-50-6	PFAS by ID SOP	ND		11	2.7	ng/L	1
2-N-ethylperfluoro-1-octanesulfonamido-ethanol (EtFOSE)	1691-99-2	PFAS by ID SOP	ND		11	2.7	ng/L	1
N-methylperfluoro-1-octanesulfonamide (MeFOSA)	31506-32-8	PFAS by ID SOP	ND		21	5.3	ng/L	1
N-methylperfluoro-1-octanesulfonamidoacetic acid (MeFOSAA)	2355-31-9	PFAS by ID SOP	ND		11	2.7	ng/L	1
2-N-methylperfluoro-1-octanesulfonamido-ethanol (MeFOSE)	24448-09-7	PFAS by ID SOP	ND		11	2.7	ng/L	1
Perfluoro-1-butanesulfonic acid (PFBS)	**375-73-5**	**PFAS by ID SOP**	**96**		**5.3**	**1.3**	**ng/L**	**1**
Perfluoro-1-decanesulfonic acid (PFDS)	335-77-3	PFAS by ID SOP	ND		5.3	1.3	ng/L	1
Perfluoro-1-heptanesulfonic acid (PFHpS)	**375-92-8**	**PFAS by ID SOP**	**41**		**5.3**	**1.3**	**ng/L**	**1**
Perfluoro-1-nonanesulfonic acid (PFNS)	68259-12-1	PFAS by ID SOP	ND		5.3	1.3	ng/L	1
Perfluoro-1-octanesulfonamide (PFOSA)	754-91-6	PFAS by ID SOP	ND		5.3	1.3	ng/L	1
Perfluoro-1-pentanesulfonic acid (PFPeS)	**2706-91-4**	**PFAS by ID SOP**	**85**		**5.3**	**1.3**	**ng/L**	**1**
Perfluorohexanesulfonic acid (PFHxS)	**355-46-4**	**PFAS by ID SOP**	**590**		**5.3**	**1.3**	**ng/L**	**1**
Perfluoro-n-butanoic acid (PFBA)	**375-22-4**	**PFAS by ID SOP**	**61**		**5.3**	**1.3**	**ng/L**	**1**
Perfluoro-n-decanoic acid (PFDA)	**335-76-2**	**PFAS by ID SOP**	**1.7**	**J**	**5.3**	**1.3**	**ng/L**	**1**
Perfluoro-n-dodecanoic acid (PFDoA)	307-55-1	PFAS by ID SOP	ND		5.3	1.3	ng/L	1
Perfluoro-n-heptanoic acid (PFHpA)	**375-85-9**	**PFAS by ID SOP**	**58**		**5.3**	**1.3**	**ng/L**	**1**
Perfluoro-n-hexanoic acid (PFHxA)	**307-24-4**	**PFAS by ID SOP**	**230**		**5.3**	**1.3**	**ng/L**	**1**
Perfluoro-n-nonanoic acid (PFNA)	**375-95-1**	**PFAS by ID SOP**	**7.0**		**5.3**	**1.3**	**ng/L**	**1**
Perfluoro-n-octanoic acid (PFOA)	**335-67-1**	**PFAS by ID SOP**	**170**		**5.3**	**1.3**	**ng/L**	**1**
Perfluoro-n-pentanoic acid (PFPeA)	**2706-90-3**	**PFAS by ID SOP**	**180**		**5.3**	**1.3**	**ng/L**	**1**
Perfluoro-n-tetradecanoic acid (PFTeDA)	376-06-7	PFAS by ID SOP	ND		5.3	1.3	ng/L	1
Perfluoro-n-tridecanoic acid (PFTrDA)	72629-94-8	PFAS by ID SOP	ND		5.3	1.3	ng/L	1
Perfluoro-n-undecanoic acid (PFUdA)	2058-94-8	PFAS by ID SOP	ND		5.3	1.3	ng/L	1
Perfluorooctanesulfonic acid (PFOS)	**1763-23-1**	**PFAS by ID SOP**	**1700**	**B**	**27**	**6.6**	**ng/L**	**2**

Surrogate	Run 1 Q	Run 1 % Recovery	Run 1 Acceptance Limits	Run 2 Q	Run 2 % Recovery	Run 2 Acceptance Limits
13C2_4:2FTS		106	25-150		102	25-150
13C2_6:2FTS		89	25-150		104	25-150
13C2_8:2FTS		79	25-150		114	25-150
13C2_PFDoA		72	25-150		104	25-150
13C2_PFTeDA		64	25-150		96	25-150
13C3_PFBS		83	25-150		100	25-150
13C3_PFHxS		76	25-150		103	25-150
13C3-HFPO-DA		98	25-150		100	25-150

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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.**
Laboratory ID: **WB25052-014**
Description: **FT11**
Matrix: **Aqueous**
Date Sampled: **02/06/2021 1620**
Date Received: **02/25/2021**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits	Q	Run 2 % Recovery	Acceptance Limits
13C4_PFBA		90	25-150		107	25-150
13C4_PFHpA		84	25-150		97	25-150
13C5_PFHxA		84	25-150		101	25-150
13C5_PFPeA		83	25-150		103	25-150
13C6_PFDA		83	25-150		101	25-150
13C7_PFUdA		71	25-150		101	25-150
13C8_PFOA		82	25-150		104	25-150
13C8_PFOS		72	25-150		89	25-150
13C8_PFOSA		91	10-150		111	10-150
13C9_PFNA		81	25-150		99	25-150
d-EtFOSA		78	10-150		103	10-150
d5-EtFOSAA		83	25-150		100	25-150
d9-EtFOSE		75	10-150		107	10-150
d-MeFOSA		89	10-150		104	10-150
d3-MeFOSAA		87	25-150		108	25-150
d7-MeFOSE		78	10-150		104	10-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
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L = LCS/LCSD failure
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S = MS/MSD failure

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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.** Laboratory ID: **WB25052-015**

Description: **FT11** Matrix: **Aqueous**

Date Sampled: **02/08/2021 1620**

Date Received: **02/25/2021**

Run	Prep Method	Analytical Method	Dilution	Analysis Date	Analyst	Prep Date	Batch
1	SOP SPE	PFAS by ID SOP	1	03/01/2021 1454	JJG	02/26/2021 1041	84057
2	SOP SPE	PFAS by ID SOP	5	03/02/2021 1406	JJG	02/26/2021 1041	84057

Parameter	CAS Number	Analytical Method	Result	Q	LOQ	DL	Units	Run
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9Cl-PF3ONS)	756426-58-1	PFAS by ID SOP	ND		9.6	2.4	ng/L	1
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3...)	763051-92-9	PFAS by ID SOP	ND		9.6	2.4	ng/L	1
1H, 1H, 2H, 2H-perfluorodecane sulfonic acid (8:2 FTS)	**39108-34-4**	**PFAS by ID SOP**	**9.1**	**J**	**9.6**	**2.4**	**ng/L**	**1**
1H, 1H, 2H, 2H-perfluorooctane sulfonic acid (6:2 FTS)	**27619-97-2**	**PFAS by ID SOP**	**520**		**9.6**	**2.4**	**ng/L**	**1**
1H,1H,2H,2H-perfluorododecane sulfonic acid (10:2 FTS)	120226-60-0	PFAS by ID SOP	ND		9.6	2.4	ng/L	1
1H,1H,2H,2H-perfluorohexane sulfonic acid (4:2 FTS)	**757124-72-4**	**PFAS by ID SOP**	**3.4**	**J**	**9.6**	**2.4**	**ng/L**	**1**
Hexafluoropropylene oxide dimer acid (GenX)	**13252-13-6**	**PFAS by ID SOP**	**2.6**	**J**	**9.6**	**2.4**	**ng/L**	**1**
4,8-dioxa-3H-perfluorononanoic acid (ADONA)	919005-14-4	PFAS by ID SOP	ND		9.6	2.4	ng/L	1
N-ethylperfluoro-1-octanesulfonamide (EtFOSA)	4151-50-2	PFAS by ID SOP	ND		9.6	2.4	ng/L	1
N-ethylperfluoro-1-octanesulfonamidoacetic acid (EtFOSAA)	2991-50-6	PFAS by ID SOP	ND		9.6	2.4	ng/L	1
2-N-ethylperfluoro-1-octanesulfonamido-ethanol (EtFOSE)	1691-99-2	PFAS by ID SOP	ND		9.6	2.4	ng/L	1
N-methylperfluoro-1-octanesulfonamide (MeFOSA)	31506-32-8	PFAS by ID SOP	ND		19	4.8	ng/L	1
N-methylperfluoro-1-octanesulfonamidoacetic acid (MeFOSAA)	2355-31-9	PFAS by ID SOP	ND		9.6	2.4	ng/L	1
2-N-methylperfluoro-1-octanesulfonamido-ethanol (MeFOSE)	24448-09-7	PFAS by ID SOP	ND		9.6	2.4	ng/L	1
Perfluoro-1-butanesulfonic acid (PFBS)	**375-73-5**	**PFAS by ID SOP**	**120**		**4.8**	**1.2**	**ng/L**	**1**
Perfluoro-1-decanesulfonic acid (PFDS)	335-77-3	PFAS by ID SOP	ND		4.8	1.2	ng/L	1
Perfluoro-1-heptanesulfonic acid (PFHpS)	**375-92-8**	**PFAS by ID SOP**	**46**		**4.8**	**1.2**	**ng/L**	**1**
Perfluoro-1-nonanesulfonic acid (PFNS)	68259-12-1	PFAS by ID SOP	ND		4.8	1.2	ng/L	1
Perfluoro-1-octanesulfonamide (PFOSA)	**754-91-6**	**PFAS by ID SOP**	**2.0**	**J**	**4.8**	**1.2**	**ng/L**	**1**
Perfluoro-1-pentanesulfonic acid (PFPeS)	**2706-91-4**	**PFAS by ID SOP**	**110**		**4.8**	**1.2**	**ng/L**	**1**
Perfluorohexanesulfonic acid (PFHxS)	**355-46-4**	**PFAS by ID SOP**	**700**		**4.8**	**1.2**	**ng/L**	**1**
Perfluoro-n-butanoic acid (PFBA)	**375-22-4**	**PFAS by ID SOP**	**73**		**4.8**	**1.2**	**ng/L**	**1**
Perfluoro-n-decanoic acid (PFDA)	**335-76-2**	**PFAS by ID SOP**	**1.5**	**J**	**4.8**	**1.2**	**ng/L**	**1**
Perfluoro-n-dodecanoic acid (PFDoA)	307-55-1	PFAS by ID SOP	ND		4.8	1.2	ng/L	1
Perfluoro-n-heptanoic acid (PFHpA)	**375-85-9**	**PFAS by ID SOP**	**72**		**4.8**	**1.2**	**ng/L**	**1**
Perfluoro-n-hexanoic acid (PFHxA)	**307-24-4**	**PFAS by ID SOP**	**270**		**4.8**	**1.2**	**ng/L**	**1**
Perfluoro-n-nonanoic acid (PFNA)	**375-95-1**	**PFAS by ID SOP**	**8.2**		**4.8**	**1.2**	**ng/L**	**1**
Perfluoro-n-octanoic acid (PFOA)	**335-67-1**	**PFAS by ID SOP**	**230**		**4.8**	**1.2**	**ng/L**	**1**
Perfluoro-n-pentanoic acid (PFPeA)	**2706-90-3**	**PFAS by ID SOP**	**210**		**4.8**	**1.2**	**ng/L**	**1**
Perfluoro-n-tetradecanoic acid (PFTeDA)	376-06-7	PFAS by ID SOP	ND		4.8	1.2	ng/L	1
Perfluoro-n-tridecanoic acid (PFTrDA)	72629-94-8	PFAS by ID SOP	ND		4.8	1.2	ng/L	1
Perfluoro-n-undecanoic acid (PFUdA)	2058-94-8	PFAS by ID SOP	ND		4.8	1.2	ng/L	1
Perfluorooctanesulfonic acid (PFOS)	**1763-23-1**	**PFAS by ID SOP**	**1900**	**B**	**24**	**6.0**	**ng/L**	**2**

Surrogate	Run 1 Q	Run 1 % Recovery	Run 1 Acceptance Limits	Run 2 Q	Run 2 % Recovery	Run 2 Acceptance Limits
13C2_4:2FTS		123	25-150		103	25-150
13C2_6:2FTS		95	25-150		100	25-150
13C2_8:2FTS		97	25-150		117	25-150
13C2_PFDoA		89	25-150		104	25-150
13C2_PFTeDA		75	25-150		103	25-150
13C3_PFBS		92	25-150		106	25-150
13C3_PFHxS		89	25-150		105	25-150
13C3-HFPO-DA		107	25-150		105	25-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
J = Estimated result < LOQ and ≥ DL
L = LCS/LCSD failure
H = Out of holding time
W = Reported on wet weight basis
S = MS/MSD failure

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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.**
Laboratory ID: **WB25052-015**
Description: **FT11**
Matrix: **Aqueous**
Date Sampled: **02/08/2021 1620**
Date Received: **02/25/2021**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits	Q	Run 2 % Recovery	Acceptance Limits
13C4_PFBA		100	25-150		109	25-150
13C4_PFHpA		92	25-150		102	25-150
13C5_PFHxA		99	25-150		106	25-150
13C5_PFPeA		95	25-150		104	25-150
13C6_PFDA		91	25-150		99	25-150
13C7_PFUdA		89	25-150		103	25-150
13C8_PFOA		90	25-150		110	25-150
13C8_PFOS		79	25-150		99	25-150
13C8_PFOSA		100	10-150		112	10-150
13C9_PFNA		89	25-150		109	25-150
d-EtFOSA		100	10-150		109	10-150
d5-EtFOSAA		97	25-150		105	25-150
d9-EtFOSE		100	10-150		108	10-150
d-MeFOSA		97	10-150		106	10-150
d3-MeFOSAA		94	25-150		111	25-150
d7-MeFOSE		93	10-150		105	10-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.** Laboratory ID: **WB25052-016**

Description: **FT11** Matrix: **Aqueous**

Date Sampled: **02/10/2021 1620**

Date Received: **02/25/2021**

Run	Prep Method	Analytical Method	Dilution	Analysis Date	Analyst	Prep Date	Batch
1	SOP SPE	PFAS by ID SOP	1	03/01/2021 1504	JJG	02/26/2021 1041	84057
2	SOP SPE	PFAS by ID SOP	5	03/02/2021 1416	JJG	02/26/2021 1041	84057

Parameter	CAS Number	Analytical Method	Result	Q	LOQ	DL	Units	Run
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9Cl-PF3ONS)	756426-58-1	PFAS by ID SOP	ND		11	2.8	ng/L	1
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3...)	763051-92-9	PFAS by ID SOP	ND		11	2.8	ng/L	1
1H, 1H, 2H, 2H-perfluorodecane sulfonic acid (8:2 FTS)	**39108-34-4**	**PFAS by ID SOP**	**20**		**11**	**2.8**	**ng/L**	**1**
1H, 1H, 2H, 2H-perfluorooctane sulfonic acid (6:2 FTS)	**27619-97-2**	**PFAS by ID SOP**	**720**		**11**	**2.8**	**ng/L**	**1**
1H,1H,2H,2H-perfluorododecane sulfonic acid (10:2 FTS)	120226-60-0	PFAS by ID SOP	ND		11	2.8	ng/L	1
1H,1H,2H,2H-perfluorohexane sulfonic acid (4:2 FTS)	**757124-72-4**	**PFAS by ID SOP**	**6.2**	**J**	**11**	**2.8**	**ng/L**	**1**
Hexafluoropropylene oxide dimer acid (GenX)	13252-13-6	PFAS by ID SOP	ND		11	2.8	ng/L	1
4,8-dioxa-3H-perfluorononanoic acid (ADONA)	919005-14-4	PFAS by ID SOP	ND		11	2.8	ng/L	1
N-ethylperfluoro-1-octanesulfonamide (EtFOSA)	4151-50-2	PFAS by ID SOP	ND		11	2.8	ng/L	1
N-ethylperfluoro-1-octanesulfonamidoacetic acid (EtFOSAA)	2991-50-6	PFAS by ID SOP	ND		11	2.8	ng/L	1
2-N-ethylperfluoro-1-octanesulfonamido-ethanol (EtFOSE)	1691-99-2	PFAS by ID SOP	ND		11	2.8	ng/L	1
N-methylperfluoro-1-octanesulfonamide (MeFOSA)	31506-32-8	PFAS by ID SOP	ND		22	5.6	ng/L	1
N-methylperfluoro-1-octanesulfonamidoacetic acid (MeFOSAA)	2355-31-9	PFAS by ID SOP	ND		11	2.8	ng/L	1
2-N-methylperfluoro-1-octanesulfonamido-ethanol (MeFOSE)	24448-09-7	PFAS by ID SOP	ND		11	2.8	ng/L	1
Perfluoro-1-butanesulfonic acid (PFBS)	**375-73-5**	**PFAS by ID SOP**	**160**		**5.6**	**1.4**	**ng/L**	**1**
Perfluoro-1-decanesulfonic acid (PFDS)	335-77-3	PFAS by ID SOP	ND		5.6	1.4	ng/L	1
Perfluoro-1-heptanesulfonic acid (PFHpS)	**375-92-8**	**PFAS by ID SOP**	**69**		**5.6**	**1.4**	**ng/L**	**1**
Perfluoro-1-nonanesulfonic acid (PFNS)	68259-12-1	PFAS by ID SOP	ND		5.6	1.4	ng/L	1
Perfluoro-1-octanesulfonamide (PFOSA)	**754-91-6**	**PFAS by ID SOP**	**2.6**	**J**	**5.6**	**1.4**	**ng/L**	**1**
Perfluoro-1-pentanesulfonic acid (PFPeS)	**2706-91-4**	**PFAS by ID SOP**	**150**		**5.6**	**1.4**	**ng/L**	**1**
Perfluorohexanesulfonic acid (PFHxS)	**355-46-4**	**PFAS by ID SOP**	**960**		**5.6**	**1.4**	**ng/L**	**1**
Perfluoro-n-butanoic acid (PFBA)	**375-22-4**	**PFAS by ID SOP**	**99**		**5.6**	**1.4**	**ng/L**	**1**
Perfluoro-n-decanoic acid (PFDA)	**335-76-2**	**PFAS by ID SOP**	**2.0**	**J**	**5.6**	**1.4**	**ng/L**	**1**
Perfluoro-n-dodecanoic acid (PFDoA)	307-55-1	PFAS by ID SOP	ND		5.6	1.4	ng/L	1
Perfluoro-n-heptanoic acid (PFHpA)	**375-85-9**	**PFAS by ID SOP**	**95**		**5.6**	**1.4**	**ng/L**	**1**
Perfluoro-n-hexanoic acid (PFHxA)	**307-24-4**	**PFAS by ID SOP**	**400**		**5.6**	**1.4**	**ng/L**	**1**
Perfluoro-n-nonanoic acid (PFNA)	**375-95-1**	**PFAS by ID SOP**	**11**		**5.6**	**1.4**	**ng/L**	**1**
Perfluoro-n-octanoic acid (PFOA)	**335-67-1**	**PFAS by ID SOP**	**330**		**5.6**	**1.4**	**ng/L**	**1**
Perfluoro-n-pentanoic acid (PFPeA)	**2706-90-3**	**PFAS by ID SOP**	**280**		**5.6**	**1.4**	**ng/L**	**1**
Perfluoro-n-tetradecanoic acid (PFTeDA)	376-06-7	PFAS by ID SOP	ND		5.6	1.4	ng/L	1
Perfluoro-n-tridecanoic acid (PFTrDA)	72629-94-8	PFAS by ID SOP	ND		5.6	1.4	ng/L	1
Perfluoro-n-undecanoic acid (PFUdA)	2058-94-8	PFAS by ID SOP	ND		5.6	1.4	ng/L	1
Perfluorooctanesulfonic acid (PFOS)	**1763-23-1**	**PFAS by ID SOP**	**2700**	**B**	**28**	**7.0**	**ng/L**	**2**

Surrogate	Run 1 Q	Run 1 % Recovery	Run 1 Acceptance Limits	Run 2 Q	Run 2 % Recovery	Run 2 Acceptance Limits
13C2_4:2FTS		110	25-150		107	25-150
13C2_6:2FTS		89	25-150		108	25-150
13C2_8:2FTS		84	25-150		111	25-150
13C2_PFDoA		79	25-150		102	25-150
13C2_PFTeDA		73	25-150		101	25-150
13C3_PFBS		88	25-150		107	25-150
13C3_PFHxS		86	25-150		107	25-150
13C3-HFPO-DA		97	25-150		106	25-150

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E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.** Laboratory ID: **WB25052-016**

Description: **FT11** Matrix: **Aqueous**

Date Sampled: **02/10/2021 1620**

Date Received: **02/25/2021**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits	Q	Run 2 % Recovery	Acceptance Limits
13C4_PFBA		93	25-150		108	25-150
13C4_PFHpA		86	25-150		101	25-150
13C5_PFHxA		87	25-150		103	25-150
13C5_PFPeA		90	25-150		106	25-150
13C6_PFDA		86	25-150		98	25-150
13C7_PFUdA		79	25-150		107	25-150
13C8_PFOA		79	25-150		105	25-150
13C8_PFOS		76	25-150		96	25-150
13C8_PFOSA		92	10-150		116	10-150
13C9_PFNA		83	25-150		103	25-150
d-EtFOSA		85	10-150		106	10-150
d5-EtFOSAA		87	25-150		106	25-150
d9-EtFOSE		89	10-150		105	10-150
d-MeFOSA		82	10-150		105	10-150
d3-MeFOSAA		89	25-150		110	25-150
d7-MeFOSE		83	10-150		107	10-150

LOQ = Limit of Quantitation
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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.** Laboratory ID: **WB25052-017**

Description: **FT11** Matrix: **Aqueous**

Date Sampled: **02/12/2021 1620**

Date Received: **02/25/2021**

Run	Prep Method	Analytical Method	Dilution	Analysis Date	Analyst	Prep Date	Batch
1	SOP SPE	PFAS by ID SOP	1	03/01/2021 1515	JJG	02/26/2021 1041	84057
2	SOP SPE	PFAS by ID SOP	10	03/02/2021 1427	JJG	02/26/2021 1041	84057

Parameter	CAS Number	Analytical Method	Result	Q	LOQ	DL	Units	Run
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9Cl-PF3ONS)	756426-58-1	PFAS by ID SOP	ND		8.7	2.2	ng/L	1
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3...)	763051-92-9	PFAS by ID SOP	ND		8.7	2.2	ng/L	1
1H, 1H, 2H, 2H-perfluorodecane sulfonic acid (8:2 FTS)	**39108-34-4**	**PFAS by ID SOP**	**19**		**8.7**	**2.2**	**ng/L**	**1**
1H, 1H, 2H, 2H-perfluorooctane sulfonic acid (6:2 FTS)	**27619-97-2**	**PFAS by ID SOP**	**710**		**8.7**	**2.2**	**ng/L**	**1**
1H,1H,2H,2H-perfluorododecane sulfonic acid (10:2 FTS)	120226-60-0	PFAS by ID SOP	ND		8.7	2.2	ng/L	1
1H,1H,2H,2H-perfluorohexane sulfonic acid (4:2 FTS)	**757124-72-4**	**PFAS by ID SOP**	**6.4**	**J**	**8.7**	**2.2**	**ng/L**	**1**
Hexafluoropropylene oxide dimer acid (GenX)	13252-13-6	PFAS by ID SOP	ND		8.7	2.2	ng/L	1
4,8-dioxa-3H-perfluorononanoic acid (ADONA)	919005-14-4	PFAS by ID SOP	ND		8.7	2.2	ng/L	1
N-ethylperfluoro-1-octanesulfonamide (EtFOSA)	4151-50-2	PFAS by ID SOP	ND		8.7	2.2	ng/L	1
N-ethylperfluoro-1-octanesulfonamidoacetic acid (EtFOSAA)	2991-50-6	PFAS by ID SOP	ND		8.7	2.2	ng/L	1
2-N-ethylperfluoro-1-octanesulfonamido-ethanol (EtFOSE)	1691-99-2	PFAS by ID SOP	ND		8.7	2.2	ng/L	1
N-methylperfluoro-1-octanesulfonamide (MeFOSA)	31506-32-8	PFAS by ID SOP	ND		17	4.3	ng/L	1
N-methylperfluoro-1-octanesulfonamidoacetic acid (MeFOSAA)	2355-31-9	PFAS by ID SOP	ND		8.7	2.2	ng/L	1
2-N-methylperfluoro-1-octanesulfonamido-ethanol (MeFOSE)	24448-09-7	PFAS by ID SOP	ND		8.7	2.2	ng/L	1
Perfluoro-1-butanesulfonic acid (PFBS)	**375-73-5**	**PFAS by ID SOP**	**170**		**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-1-decanesulfonic acid (PFDS)	335-77-3	PFAS by ID SOP	ND		4.3	1.1	ng/L	1
Perfluoro-1-heptanesulfonic acid (PFHpS)	**375-92-8**	**PFAS by ID SOP**	**63**		**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-1-nonanesulfonic acid (PFNS)	68259-12-1	PFAS by ID SOP	ND		4.3	1.1	ng/L	1
Perfluoro-1-octanesulfonamide (PFOSA)	**754-91-6**	**PFAS by ID SOP**	**2.9**	**J**	**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-1-pentanesulfonic acid (PFPeS)	**2706-91-4**	**PFAS by ID SOP**	**150**		**4.3**	**1.1**	**ng/L**	**1**
Perfluorohexanesulfonic acid (PFHxS)	**355-46-4**	**PFAS by ID SOP**	**1000**	**E**	**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-n-butanoic acid (PFBA)	**375-22-4**	**PFAS by ID SOP**	**99**		**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-n-decanoic acid (PFDA)	**335-76-2**	**PFAS by ID SOP**	**2.4**	**J**	**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-n-dodecanoic acid (PFDoA)	307-55-1	PFAS by ID SOP	ND		4.3	1.1	ng/L	1
Perfluoro-n-heptanoic acid (PFHpA)	**375-85-9**	**PFAS by ID SOP**	**93**		**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-n-hexanoic acid (PFHxA)	**307-24-4**	**PFAS by ID SOP**	**420**		**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-n-nonanoic acid (PFNA)	**375-95-1**	**PFAS by ID SOP**	**11**		**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-n-octanoic acid (PFOA)	**335-67-1**	**PFAS by ID SOP**	**330**		**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-n-pentanoic acid (PFPeA)	**2706-90-3**	**PFAS by ID SOP**	**300**		**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-n-tetradecanoic acid (PFTeDA)	376-06-7	PFAS by ID SOP	ND		4.3	1.1	ng/L	1
Perfluoro-n-tridecanoic acid (PFTrDA)	72629-94-8	PFAS by ID SOP	ND		4.3	1.1	ng/L	1
Perfluoro-n-undecanoic acid (PFUdA)	2058-94-8	PFAS by ID SOP	ND		4.3	1.1	ng/L	1
Perfluorooctanesulfonic acid (PFOS)	**1763-23-1**	**PFAS by ID SOP**	**2700**	**B**	**43**	**11**	**ng/L**	**2**

Surrogate	Run 1 Q	Run 1 % Recovery	Run 1 Acceptance Limits	Run 2 Q	Run 2 % Recovery	Run 2 Acceptance Limits
13C2_4:2FTS		110	25-150		103	25-150
13C2_6:2FTS		92	25-150		108	25-150
13C2_8:2FTS		88	25-150		107	25-150
13C2_PFDoA		78	25-150		109	25-150
13C2_PFTeDA		72	25-150		99	25-150
13C3_PFBS		84	25-150		107	25-150
13C3_PFHxS		83	25-150		99	25-150
13C3-HFPO-DA		101	25-150		103	25-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.**
Laboratory ID: **WB25052-017**
Description: **FT11**
Matrix: **Aqueous**
Date Sampled: **02/12/2021 1620**
Date Received: **02/25/2021**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits	Q	Run 2 % Recovery	Acceptance Limits
13C4_PFBA		93	25-150		107	25-150
13C4_PFHpA		91	25-150		101	25-150
13C5_PFHxA		88	25-150		101	25-150
13C5_PFPeA		87	25-150		104	25-150
13C6_PFDA		84	25-150		97	25-150
13C7_PFUdA		79	25-150		101	25-150
13C8_PFOA		81	25-150		102	25-150
13C8_PFOS		71	25-150		90	25-150
13C8_PFOSA		99	10-150		113	10-150
13C9_PFNA		81	25-150		104	25-150
d-EtFOSA		89	10-150		90	10-150
d5-EtFOSAA		85	25-150		103	25-150
d9-EtFOSE		85	10-150		106	10-150
d-MeFOSA		88	10-150		109	10-150
d3-MeFOSAA		88	25-150		108	25-150
d7-MeFOSE		84	10-150		102	10-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
J = Estimated result < LOQ and ≥ DL
L = LCS/LCSD failure
H = Out of holding time
W = Reported on wet weight basis
S = MS/MSD failure

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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.** Laboratory ID: **WB25052-018**

Description: **FT11** Matrix: **Aqueous**

Date Sampled: **02/14/2021 1620**

Date Received: **02/25/2021**

Run	Prep Method	Analytical Method	Dilution	Analysis Date	Analyst	Prep Date	Batch
1	SOP SPE	PFAS by ID SOP	1	03/01/2021 1526	JJG	02/26/2021 1041	84057
2	SOP SPE	PFAS by ID SOP	10	03/02/2021 1438	JJG	02/26/2021 1041	84057

Parameter	CAS Number	Analytical Method	Result	Q	LOQ	DL	Units	Run
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9Cl-PF3ONS)	756426-58-1	PFAS by ID SOP	ND		8.5	2.1	ng/L	1
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3...)	763051-92-9	PFAS by ID SOP	ND		8.5	2.1	ng/L	1
1H, 1H, 2H, 2H-perfluorodecane sulfonic acid (8:2 FTS)	**39108-34-4**	**PFAS by ID SOP**	**16**		**8.5**	**2.1**	**ng/L**	**1**
1H, 1H, 2H, 2H-perfluorooctane sulfonic acid (6:2 FTS)	**27619-97-2**	**PFAS by ID SOP**	**700**		**8.5**	**2.1**	**ng/L**	**1**
1H,1H,2H,2H-perfluorododecane sulfonic acid (10:2 FTS)	120226-60-0	PFAS by ID SOP	ND		8.5	2.1	ng/L	1
1H,1H,2H,2H-perfluorohexane sulfonic acid (4:2 FTS)	**757124-72-4**	**PFAS by ID SOP**	**4.9**	**J**	**8.5**	**2.1**	**ng/L**	**1**
Hexafluoropropylene oxide dimer acid (GenX)	13252-13-6	PFAS by ID SOP	ND		8.5	2.1	ng/L	1
4,8-dioxa-3H-perfluorononanoic acid (ADONA)	919005-14-4	PFAS by ID SOP	ND		8.5	2.1	ng/L	1
N-ethylperfluoro-1-octanesulfonamide (EtFOSA)	4151-50-2	PFAS by ID SOP	ND		8.5	2.1	ng/L	1
N-ethylperfluoro-1-octanesulfonamidoacetic acid (EtFOSAA)	2991-50-6	PFAS by ID SOP	ND		8.5	2.1	ng/L	1
2-N-ethylperfluoro-1-octanesulfonamido-ethanol (EtFOSE)	1691-99-2	PFAS by ID SOP	ND		8.5	2.1	ng/L	1
N-methylperfluoro-1-octanesulfonamide (MeFOSA)	31506-32-8	PFAS by ID SOP	ND		17	4.3	ng/L	1
N-methylperfluoro-1-octanesulfonamidoacetic acid (MeFOSAA)	2355-31-9	PFAS by ID SOP	ND		8.5	2.1	ng/L	1
2-N-methylperfluoro-1-octanesulfonamido-ethanol (MeFOSE)	24448-09-7	PFAS by ID SOP	ND		8.5	2.1	ng/L	1
Perfluoro-1-butanesulfonic acid (PFBS)	**375-73-5**	**PFAS by ID SOP**	**160**		**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-1-decanesulfonic acid (PFDS)	335-77-3	PFAS by ID SOP	ND		4.3	1.1	ng/L	1
Perfluoro-1-heptanesulfonic acid (PFHpS)	**375-92-8**	**PFAS by ID SOP**	**60**		**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-1-nonanesulfonic acid (PFNS)	68259-12-1	PFAS by ID SOP	ND		4.3	1.1	ng/L	1
Perfluoro-1-octanesulfonamide (PFOSA)	**754-91-6**	**PFAS by ID SOP**	**3.1**	**J**	**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-1-pentanesulfonic acid (PFPeS)	**2706-91-4**	**PFAS by ID SOP**	**140**		**4.3**	**1.1**	**ng/L**	**1**
Perfluorohexanesulfonic acid (PFHxS)	**355-46-4**	**PFAS by ID SOP**	**900**		**43**	**11**	**ng/L**	**2**
Perfluoro-n-butanoic acid (PFBA)	**375-22-4**	**PFAS by ID SOP**	**94**		**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-n-decanoic acid (PFDA)	**335-76-2**	**PFAS by ID SOP**	**2.2**	**J**	**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-n-dodecanoic acid (PFDoA)	307-55-1	PFAS by ID SOP	ND		4.3	1.1	ng/L	1
Perfluoro-n-heptanoic acid (PFHpA)	**375-85-9**	**PFAS by ID SOP**	**89**		**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-n-hexanoic acid (PFHxA)	**307-24-4**	**PFAS by ID SOP**	**360**		**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-n-nonanoic acid (PFNA)	**375-95-1**	**PFAS by ID SOP**	**11**		**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-n-octanoic acid (PFOA)	**335-67-1**	**PFAS by ID SOP**	**300**		**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-n-pentanoic acid (PFPeA)	**2706-90-3**	**PFAS by ID SOP**	**270**		**4.3**	**1.1**	**ng/L**	**1**
Perfluoro-n-tetradecanoic acid (PFTeDA)	376-06-7	PFAS by ID SOP	ND		4.3	1.1	ng/L	1
Perfluoro-n-tridecanoic acid (PFTrDA)	72629-94-8	PFAS by ID SOP	ND		4.3	1.1	ng/L	1
Perfluoro-n-undecanoic acid (PFUdA)	2058-94-8	PFAS by ID SOP	ND		4.3	1.1	ng/L	1
Perfluorooctanesulfonic acid (PFOS)	**1763-23-1**	**PFAS by ID SOP**	**2800**	**B**	**43**	**11**	**ng/L**	**2**

Surrogate	Run 1 Q	Run 1 % Recovery	Run 1 Acceptance Limits	Run 2 Q	Run 2 % Recovery	Run 2 Acceptance Limits
13C2_4:2FTS		133	25-150		97	25-150
13C2_6:2FTS		98	25-150		113	25-150
13C2_8:2FTS		100	25-150		123	25-150
13C2_PFDoA		88	25-150		107	25-150
13C2_PFTeDA		82	25-150		103	25-150
13C3_PFBS		95	25-150		108	25-150
13C3_PFHxS		94	25-150		104	25-150
13C3-HFPO-DA		110	25-150		106	25-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
J = Estimated result < LOQ and ≥ DL
L = LCS/LCSD failure
H = Out of holding time
W = Reported on wet weight basis
S = MS/MSD failure

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PFAS by LC/MS/MS

Client: **Aqua-Aerobic Systems, Inc.**
Laboratory ID: **WB25052-018**
Description: **FT11**
Matrix: **Aqueous**
Date Sampled: **02/14/2021 1620**
Date Received: **02/25/2021**

Surrogate	Q	Run 1 % Recovery	Acceptance Limits	Q	Run 2 % Recovery	Acceptance Limits
13C4_PFBA		101	25-150		110	25-150
13C4_PFHpA		96	25-150		101	25-150
13C5_PFHxA		97	25-150		104	25-150
13C5_PFPeA		99	25-150		105	25-150
13C6_PFDA		96	25-150		102	25-150
13C7_PFUdA		95	25-150		103	25-150
13C8_PFOA		95	25-150		109	25-150
13C8_PFOS		84	25-150		95	25-150
13C8_PFOSA		101	10-150		109	10-150
13C9_PFNA		88	25-150		101	25-150
d-EtFOSA		95	10-150		106	10-150
d5-EtFOSAA		101	25-150		105	25-150
d9-EtFOSE		100	10-150		102	10-150
d-MeFOSA		100	10-150		102	10-150
d3-MeFOSAA		98	25-150		113	25-150
d7-MeFOSE		95	10-150		108	10-150

LOQ = Limit of Quantitation
B = Detected in the method blank
E = Quantitation of compound exceeded the calibration range
DL = Detection Limit
Q = Surrogate failure
ND = Not detected at or above the DL
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
J = Estimated result < LOQ and ≥ DL
L = LCS/LCSD failure
H = Out of holding time
W = Reported on wet weight basis
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QC Summary

PFAS by LC/MS/MS - MB

Sample ID: WQ84057-001
Batch: 84057
Analytical Method: PFAS by ID SOP
Matrix: Aqueous
Prep Method: SOP SPE
Prep Date: 02/26/2021 1041

Parameter	Result	Q	Dil	LOQ	DL	Units	Analysis Date
9Cl-PF3ONS	ND		1	8.0	2.0	ng/L	03/01/2021 1308
11Cl-PF3OUdS	ND		1	8.0	2.0	ng/L	03/01/2021 1308
8:2 FTS	ND		1	8.0	2.0	ng/L	03/01/2021 1308
6:2 FTS	ND		1	8.0	2.0	ng/L	03/01/2021 1308
10:2 FTS	ND		1	8.0	2.0	ng/L	03/01/2021 1308
4:2 FTS	ND		1	8.0	2.0	ng/L	03/01/2021 1308
GenX	ND		1	8.0	2.0	ng/L	03/01/2021 1308
ADONA	ND		1	8.0	2.0	ng/L	03/01/2021 1308
EtFOSA	ND		1	8.0	2.0	ng/L	03/01/2021 1308
EtFOSAA	ND		1	8.0	2.0	ng/L	03/01/2021 1308
EtFOSE	ND		1	8.0	2.0	ng/L	03/01/2021 1308
MeFOSA	ND		1	16	4.0	ng/L	03/01/2021 1308
MeFOSAA	ND		1	8.0	2.0	ng/L	03/01/2021 1308
MeFOSE	ND		1	8.0	2.0	ng/L	03/01/2021 1308
PFBS	ND		1	4.0	1.0	ng/L	03/01/2021 1308
PFDS	ND		1	4.0	1.0	ng/L	03/01/2021 1308
PFHpS	ND		1	4.0	1.0	ng/L	03/01/2021 1308
PFNS	ND		1	4.0	1.0	ng/L	03/01/2021 1308
PFOSA	ND		1	4.0	1.0	ng/L	03/01/2021 1308
PFPeS	ND		1	4.0	1.0	ng/L	03/01/2021 1308
PFHxS	ND		1	4.0	1.0	ng/L	03/01/2021 1308
PFBA	ND		1	4.0	1.0	ng/L	03/01/2021 1308
PFDA	ND		1	4.0	1.0	ng/L	03/01/2021 1308
PFDoA	ND		1	4.0	1.0	ng/L	03/01/2021 1308
PFHpA	ND		1	4.0	1.0	ng/L	03/01/2021 1308
PFHxA	ND		1	4.0	1.0	ng/L	03/01/2021 1308
PFNA	ND		1	4.0	1.0	ng/L	03/01/2021 1308
PFOA	ND		1	4.0	1.0	ng/L	03/01/2021 1308
PFPeA	ND		1	4.0	1.0	ng/L	03/01/2021 1308
PFTeDA	ND		1	4.0	1.0	ng/L	03/01/2021 1308
PFTrDA	ND		1	4.0	1.0	ng/L	03/01/2021 1308
PFUdA	ND		1	4.0	1.0	ng/L	03/01/2021 1308
PFOS	**1.4**	**J**	**1**	**4.0**	**1.0**	**ng/L**	**03/01/2021 1308**

Surrogate	Q	% Rec	Acceptance Limit
13C2_4:2FTS		113	25-150
13C2_6:2FTS		114	25-150
13C2_8:2FTS		100	25-150
13C2_PFDoA		98	25-150
13C2_PFTeDA		99	25-150
13C3_PFBS		97	25-150
13C3_PFHxS		97	25-150
13C3-HFPO-DA		113	25-150

LOQ = Limit of Quantitation
DL = Detection Limit
ND = Not detected at or above the DL
J = Estimated result < LOQ and ≥ DL
* = RSD is out of criteria
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
+ = RPD is out of criteria

Note: Calculations are performed before rounding to avoid round-off errors in calculated results

PFAS by LC/MS/MS - MB

Sample ID: WQ84057-001
Batch: 84057
Analytical Method: PFAS by ID SOP

Matrix: Aqueous
Prep Method: SOP SPE
Prep Date: 02/26/2021 1041

Surrogate	Q	% Rec	Acceptance Limit
13C4_PFBA		101	25-150
13C4_PFHpA		101	25-150
13C5_PFHxA		97	25-150
13C5_PFPeA		99	25-150
13C6_PFDA		98	25-150
13C7_PFUdA		97	25-150
13C8_PFOA		103	25-150
13C8_PFOS		98	25-150
13C8_PFOSA		114	10-150
13C9_PFNA		99	25-150
d-EtFOSA		97	10-150
d5-EtFOSAA		110	25-150
d9-EtFOSE		102	10-150
d-MeFOSA		96	10-150
d3-MeFOSAA		105	25-150
d7-MeFOSE		100	10-150

LOQ = Limit of Quantitation
DL = Detection Limit
ND = Not detected at or above the DL
J = Estimated result < LOQ and ≥ DL
* = RSD is out of criteria
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
+ = RPD is out of criteria

Note: Calculations are performed before rounding to avoid round-off errors in calculated results

PFAS by LC/MS/MS - LCS

Sample ID: WQ84057-002
Batch: 84057
Analytical Method: PFAS by ID SOP
Matrix: Aqueous
Prep Method: SOP SPE
Prep Date: 02/26/2021 1041

Parameter	Spike Amount (ng/L)	Result (ng/L)	Q	Dil	% Rec	% Rec Limit	Analysis Date
9Cl-PF3ONS	15	15		1	102	50-150	03/01/2021 1318
11Cl-PF3OUdS	15	14		1	96	50-150	03/01/2021 1318
8:2 FTS	15	14		1	93	50-150	03/01/2021 1318
6:2 FTS	15	17		1	112	50-150	03/01/2021 1318
10:2 FTS	15	9.5		1	62	50-150	03/01/2021 1318
4:2 FTS	15	13		1	87	50-150	03/01/2021 1318
GenX	32	30		1	95	50-150	03/01/2021 1318
ADONA	15	18		1	117	50-150	03/01/2021 1318
EtFOSA	16	16		1	102	50-150	03/01/2021 1318
EtFOSAA	16	15		1	95	50-150	03/01/2021 1318
EtFOSE	16	14		1	87	50-150	03/01/2021 1318
MeFOSA	16	17		1	106	50-150	03/01/2021 1318
MeFOSAA	16	14		1	87	50-150	03/01/2021 1318
MeFOSE	16	16		1	101	50-150	03/01/2021 1318
PFBS	14	14		1	99	50-150	03/01/2021 1318
PFDS	15	16		1	101	50-150	03/01/2021 1318
PFHpS	15	17		1	110	50-150	03/01/2021 1318
PFNS	15	16		1	103	50-150	03/01/2021 1318
PFOSA	16	15		1	92	50-150	03/01/2021 1318
PFPeS	15	14		1	90	50-150	03/01/2021 1318
PFHxS	15	18		1	126	50-150	03/01/2021 1318
PFBA	16	16		1	101	50-150	03/01/2021 1318
PFDA	16	16		1	102	50-150	03/01/2021 1318
PFDoA	16	17		1	109	50-150	03/01/2021 1318
PFHpA	16	17		1	109	50-150	03/01/2021 1318
PFHxA	16	16		1	103	50-150	03/01/2021 1318
PFNA	16	17		1	105	50-150	03/01/2021 1318
PFOA	16	18		1	110	50-150	03/01/2021 1318
PFPeA	16	17		1	105	50-150	03/01/2021 1318
PFTeDA	16	17		1	107	50-150	03/01/2021 1318
PFTrDA	16	15		1	95	50-150	03/01/2021 1318
PFUdA	16	16		1	100	50-150	03/01/2021 1318
PFOS	15	18		1	118	50-150	03/01/2021 1318

Surrogate	Q	% Rec	Acceptance Limit
13C2_4:2FTS		120	25-150
13C2_6:2FTS		110	25-150
13C2_8:2FTS		112	25-150
13C2_PFDoA		98	25-150
13C2_PFTeDA		94	25-150
13C3_PFBS		106	25-150
13C3_PFHxS		94	25-150
13C3-HFPO-DA		114	25-150

LOQ = Limit of Quantitation
DL = Detection Limit
ND = Not detected at or above the DL
J = Estimated result < LOQ and ≥ DL
* = RSD is out of criteria
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
+ = RPD is out of criteria

Note: Calculations are performed before rounding to avoid round-off errors in calculated results

PFAS by LC/MS/MS - LCS

Sample ID: WQ84057-002
Batch: 84057
Analytical Method: PFAS by ID SOP
Matrix: Aqueous
Prep Method: SOP SPE
Prep Date: 02/26/2021 1041

Surrogate	Q	% Rec	Acceptance Limit
13C4_PFBA		103	25-150
13C4_PFHpA		104	25-150
13C5_PFHxA		101	25-150
13C5_PFPeA		98	25-150
13C6_PFDA		105	25-150
13C7_PFUdA		102	25-150
13C8_PFOA		100	25-150
13C8_PFOS		97	25-150
13C8_PFOSA		107	10-150
13C9_PFNA		102	25-150
d-EtFOSA		84	10-150
d5-EtFOSAA		109	25-150
d9-EtFOSE		109	10-150
d-MeFOSA		82	10-150
d3-MeFOSAA		113	25-150
d7-MeFOSE		97	10-150

LOQ = Limit of Quantitation
DL = Detection Limit
ND = Not detected at or above the DL
J = Estimated result < LOQ and ≥ DL
* = RSD is out of criteria
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
+ = RPD is out of criteria

Note: Calculations are performed before rounding to avoid round-off errors in calculated results

PFAS by LC/MS/MS - MS

Sample ID: WB25052-011MS
Batch: 84057
Analytical Method: PFAS by ID SOP
Matrix: Aqueous
Prep Method: SOP SPE
Prep Date: 02/26/2021 1041

Parameter	Sample Amount (ng/L)	Spike Amount (ng/L)	Result (ng/L)	Q	Dil	% Rec	% Rec Limit	Analysis Date
9Cl-PF3ONS	ND	16	15		1	94	50-150	03/01/2021 1401
11Cl-PF3OUdS	ND	16	13		1	83	50-150	03/01/2021 1401
8:2 FTS	ND	16	18		1	111	50-150	03/01/2021 1401
6:2 FTS	3.2	16	18		1	90	50-150	03/01/2021 1401
10:2 FTS	ND	16	15		1	95	50-150	03/01/2021 1401
4:2 FTS	ND	16	17		1	109	50-150	03/01/2021 1401
GenX	2.2	34	35		1	98	50-150	03/01/2021 1401
ADONA	ND	16	18		1	115	50-150	03/01/2021 1401
EtFOSA	ND	17	20		1	120	50-150	03/01/2021 1401
EtFOSAA	ND	17	16		1	97	50-150	03/01/2021 1401
EtFOSE	ND	17	15		1	92	50-150	03/01/2021 1401
MeFOSA	ND	17	16		1	96	50-150	03/01/2021 1401
MeFOSAA	ND	17	19		1	110	50-150	03/01/2021 1401
MeFOSE	ND	17	15		1	87	50-150	03/01/2021 1401
PFBS	24	15	42		1	120	50-150	03/01/2021 1401
PFDS	ND	16	13		1	82	50-150	03/01/2021 1401
PFHpS	ND	16	16		1	102	50-150	03/01/2021 1401
PFNS	ND	16	17		1	104	50-150	03/01/2021 1401
PFOSA	ND	17	17		1	102	50-150	03/01/2021 1401
PFPeS	ND	16	18		1	116	50-150	03/01/2021 1401
PFHxS	4.6	15	20		1	99	50-150	03/01/2021 1401
PFBA	96	17	120		1	112	50-150	03/01/2021 1401
PFDA	ND	17	18		1	107	50-150	03/01/2021 1401
PFDoA	ND	17	18		1	108	50-150	03/01/2021 1401
PFHpA	ND	17	17		1	97	50-150	03/01/2021 1401
PFHxA	110	17	130		1	72	50-150	03/01/2021 1401
PFNA	ND	17	19		1	113	50-150	03/01/2021 1401
PFOA	2.8	17	20		1	104	50-150	03/01/2021 1401
PFPeA	370	17	370	N	1	26	50-150	03/01/2021 1401
PFTeDA	ND	17	18		1	108	50-150	03/01/2021 1401
PFTrDA	ND	17	16		1	95	50-150	03/01/2021 1401
PFUdA	ND	17	18		1	108	50-150	03/01/2021 1401
PFOS	17	16	32		1	94	50-150	03/01/2021 1401

Surrogate	Q	% Rec	Acceptance Limit
13C2_4:2FTS		113	25-150
13C2_6:2FTS		118	25-150
13C2_8:2FTS		97	25-150
13C2_PFDoA		91	25-150
13C2_PFTeDA		88	25-150
13C3_PFBS		99	25-150
13C3_PFHxS		101	25-150
13C3-HFPO-DA		113	25-150

LOQ = Limit of Quantitation
DL = Detection Limit
ND = Not detected at or above the DL
J = Estimated result < LOQ and ≥ DL
* = RSD is out of criteria
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
+ = RPD is out of criteria

Note: Calculations are performed before rounding to avoid round-off errors in calculated results

PFAS by LC/MS/MS - MS

Sample ID: WB25052-011MS
Batch: 84057
Analytical Method: PFAS by ID SOP

Matrix: Aqueous
Prep Method: SOP SPE
Prep Date: 02/26/2021 1041

Surrogate	Q	% Rec	Acceptance Limit
13C4_PFBA		103	25-150
13C4_PFHpA		104	25-150
13C5_PFHxA		102	25-150
13C5_PFPeA		100	25-150
13C6_PFDA		99	25-150
13C7_PFUdA		89	25-150
13C8_PFOA		99	25-150
13C8_PFOS		89	25-150
13C8_PFOSA		109	10-150
13C9_PFNA		100	25-150
d-EtFOSA		83	10-150
d5-EtFOSAA		113	25-150
d9-EtFOSE		98	10-150
d-MeFOSA		99	10-150
d3-MeFOSAA		102	25-150
d7-MeFOSE		97	10-150

LOQ = Limit of Quantitation
DL = Detection Limit
ND = Not detected at or above the DL
J = Estimated result < LOQ and ≥ DL
* = RSD is out of criteria
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
+ = RPD is out of criteria

Note: Calculations are performed before rounding to avoid round-off errors in calculated results

PFAS by LC/MS/MS - Duplicate

Sample ID: WB25052-012DU
Batch: 84057
Analytical Method: PFAS by ID SOP
Matrix: Aqueous
Prep Method: SOP SPE
Prep Date: 02/26/2021 1041

Parameter	Sample Amount (ng/L)	Result (ng/L)	Q	Dil	% RPD	% RPD Limit	Analysis Date
9Cl-PF3ONS	ND	ND		1	0.00	20	03/01/2021 1422
11Cl-PF3OUdS	ND	ND		1	0.00	20	03/01/2021 1422
8:2 FTS	ND	ND		1	0.00	20	03/01/2021 1422
6:2 FTS	ND	ND		1	0.00	20	03/01/2021 1422
10:2 FTS	ND	ND		1	0.00	20	03/01/2021 1422
4:2 FTS	ND	ND		1	0.00	20	03/01/2021 1422
GenX	2.1	ND		1	0.00	20	03/01/2021 1422
ADONA	ND	ND		1	0.00	20	03/01/2021 1422
EtFOSA	ND	ND		1	0.00	20	03/01/2021 1422
EtFOSAA	ND	ND		1	0.00	20	03/01/2021 1422
EtFOSE	ND	ND		1	0.00	20	03/01/2021 1422
MeFOSA	ND	ND		1	0.00	20	03/01/2021 1422
MeFOSAA	ND	ND		1	0.00	20	03/01/2021 1422
MeFOSE	ND	ND		1	0.00	20	03/01/2021 1422
PFBS	66	66		1	0.80	20	03/01/2021 1422
PFDS	ND	ND		1	0.00	20	03/01/2021 1422
PFHpS	ND	ND		1	0.00	20	03/01/2021 1422
PFNS	ND	ND		1	0.00	20	03/01/2021 1422
PFOSA	ND	ND		1	0.00	20	03/01/2021 1422
PFPeS	1.8	2.1	J	1	14	20	03/01/2021 1422
PFHxS	2.6	3.0	J	1	14	20	03/01/2021 1422
PFBA	100	100		1	1.5	20	03/01/2021 1422
PFDA	ND	ND		1	0.00	20	03/01/2021 1422
PFDoA	ND	ND		1	0.00	20	03/01/2021 1422
PFHpA	1.8	2.1	J	1	11	20	03/01/2021 1422
PFHxA	270	250		1	8.4	20	03/01/2021 1422
PFNA	ND	ND		1	0.00	20	03/01/2021 1422
PFOA	2.3	2.9	+	1	24	20	03/01/2021 1422
PFPeA	360	350		1	3.3	20	03/01/2021 1422
PFTeDA	ND	ND		1	0.00	20	03/01/2021 1422
PFTrDA	ND	ND		1	0.00	20	03/01/2021 1422
PFUdA	ND	ND		1	0.00	20	03/01/2021 1422
PFOS	5.4	8.3	+	1	43	20	03/01/2021 1422

Surrogate	Q	% Rec	Acceptance Limit
13C2_4:2FTS		112	25-150
13C2_6:2FTS		94	25-150
13C2_8:2FTS		99	25-150
13C2_PFDoA		82	25-150
13C2_PFTeDA		85	25-150
13C3_PFBS		90	25-150
13C3_PFHxS		91	25-150
13C3-HFPO-DA		108	25-150

LOQ = Limit of Quantitation
DL = Detection Limit
ND = Not detected at or above the DL
J = Estimated result < LOQ and ≥ DL
* = RSD is out of criteria
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
+ = RPD is out of criteria

Note: Calculations are performed before rounding to avoid round-off errors in calculated results

PFAS by LC/MS/MS - Duplicate

Sample ID: WB25052-012DU
Batch: 84057
Analytical Method: PFAS by ID SOP

Matrix: Aqueous
Prep Method: SOP SPE
Prep Date: 02/26/2021 1041

Surrogate	Q	% Rec	Acceptance Limit
13C4_PFBA		96	25-150
13C4_PFHpA		97	25-150
13C5_PFHxA		95	25-150
13C5_PFPeA		92	25-150
13C6_PFDA		94	25-150
13C7_PFUdA		86	25-150
13C8_PFOA		94	25-150
13C8_PFOS		83	25-150
13C8_PFOSA		100	10-150
13C9_PFNA		94	25-150
d-EtFOSA		79	10-150
d5-EtFOSAA		102	25-150
d9-EtFOSE		97	10-150
d-MeFOSA		89	10-150
d3-MeFOSAA		97	25-150
d7-MeFOSE		87	10-150

LOQ = Limit of Quantitation
DL = Detection Limit
ND = Not detected at or above the DL
J = Estimated result < LOQ and ≥ DL
* = RSD is out of criteria
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
+ = RPD is out of criteria

Note: Calculations are performed before rounding to avoid round-off errors in calculated results

PFAS by LC/MS/MS - MB

Sample ID: WQ84062-001
Batch: 84062
Analytical Method: PFAS by ID SOP
Matrix: Aqueous
Prep Method: SOP SPE
Prep Date: 02/26/2021 1024

Parameter	Result	Q	Dil	LOQ	DL	Units	Analysis Date
9Cl-PF3ONS	ND		1	8.0	2.0	ng/L	02/28/2021 1232
11Cl-PF3OUdS	ND		1	8.0	2.0	ng/L	02/28/2021 1232
8:2 FTS	ND		1	8.0	2.0	ng/L	02/28/2021 1232
6:2 FTS	ND		1	8.0	2.0	ng/L	02/28/2021 1232
10:2 FTS	ND		1	8.0	2.0	ng/L	02/28/2021 1232
4:2 FTS	ND		1	8.0	2.0	ng/L	02/28/2021 1232
GenX	ND		1	8.0	2.0	ng/L	02/28/2021 1232
ADONA	ND		1	8.0	2.0	ng/L	02/28/2021 1232
EtFOSA	ND		1	8.0	2.0	ng/L	02/28/2021 1232
EtFOSAA	ND		1	8.0	2.0	ng/L	02/28/2021 1232
EtFOSE	ND		1	8.0	2.0	ng/L	02/28/2021 1232
MeFOSA	ND		1	16	4.0	ng/L	02/28/2021 1232
MeFOSAA	ND		1	8.0	2.0	ng/L	02/28/2021 1232
MeFOSE	ND		1	8.0	2.0	ng/L	02/28/2021 1232
PFBS	ND		1	4.0	1.0	ng/L	02/28/2021 1232
PFDS	ND		1	4.0	1.0	ng/L	02/28/2021 1232
PFHpS	ND		1	4.0	1.0	ng/L	02/28/2021 1232
PFNS	ND		1	4.0	1.0	ng/L	02/28/2021 1232
PFOSA	ND		1	4.0	1.0	ng/L	02/28/2021 1232
PFPeS	ND		1	4.0	1.0	ng/L	02/28/2021 1232
PFHxS	ND		1	4.0	1.0	ng/L	02/28/2021 1232
PFBA	ND		1	4.0	1.0	ng/L	02/28/2021 1232
PFDA	ND		1	4.0	1.0	ng/L	02/28/2021 1232
PFDoA	ND		1	4.0	1.0	ng/L	02/28/2021 1232
PFHpA	ND		1	4.0	1.0	ng/L	02/28/2021 1232
PFHxA	ND		1	4.0	1.0	ng/L	02/28/2021 1232
PFNA	ND		1	4.0	1.0	ng/L	02/28/2021 1232
PFOA	ND		1	4.0	1.0	ng/L	02/28/2021 1232
PFPeA	ND		1	4.0	1.0	ng/L	02/28/2021 1232
PFTeDA	ND		1	4.0	1.0	ng/L	02/28/2021 1232
PFTrDA	ND		1	4.0	1.0	ng/L	02/28/2021 1232
PFUdA	ND		1	4.0	1.0	ng/L	02/28/2021 1232
PFOS	ND		1	4.0	1.0	ng/L	02/28/2021 1232

Surrogate	Q	% Rec	Acceptance Limit
13C2_4:2FTS		140	25-150
13C2_6:2FTS		113	25-150
13C2_8:2FTS		105	25-150
13C2_PFDoA		108	25-150
13C2_PFTeDA		101	25-150
13C3_PFBS		111	25-150
13C3_PFHxS		105	25-150
13C3-HFPO-DA		113	25-150

LOQ = Limit of Quantitation
DL = Detection Limit
ND = Not detected at or above the DL
J = Estimated result < LOQ and ≥ DL
* = RSD is out of criteria
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
+ = RPD is out of criteria

Note: Calculations are performed before rounding to avoid round-off errors in calculated results

PFAS by LC/MS/MS - MB

Sample ID: WQ84062-001
Batch: 84062
Analytical Method: PFAS by ID SOP

Matrix: Aqueous
Prep Method: SOP SPE
Prep Date: 02/26/2021 1024

Surrogate	Q	% Rec	Acceptance Limit
13C4_PFBA		106	25-150
13C4_PFHpA		105	25-150
13C5_PFHxA		116	25-150
13C5_PFPeA		105	25-150
13C6_PFDA		89	25-150
13C7_PFUdA		103	25-150
13C8_PFOA		99	25-150
13C8_PFOS		106	25-150
13C8_PFOSA		116	10-150
13C9_PFNA		109	25-150
d-EtFOSA		99	10-150
d5-EtFOSAA		117	25-150
d9-EtFOSE		108	10-150
d-MeFOSA		86	10-150
d3-MeFOSAA		109	25-150
d7-MeFOSE		111	10-150

LOQ = Limit of Quantitation
DL = Detection Limit
ND = Not detected at or above the DL
J = Estimated result < LOQ and ≥ DL
* = RSD is out of criteria
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
+ = RPD is out of criteria

Note: Calculations are performed before rounding to avoid round-off errors in calculated results

PFAS by LC/MS/MS - LCS

Sample ID: WQ84062-002
Batch: 84062
Analytical Method: PFAS by ID SOP
Matrix: Aqueous
Prep Method: SOP SPE
Prep Date: 02/26/2021 1024

Parameter	Spike Amount (ng/L)	Result (ng/L)	Q	Dil	% Rec	% Rec Limit	Analysis Date
9Cl-PF3ONS	15	14		1	91	50-150	02/28/2021 1243
11Cl-PF3OUdS	15	13		1	85	50-150	02/28/2021 1243
8:2 FTS	15	13		1	86	50-150	02/28/2021 1243
6:2 FTS	15	11		1	75	50-150	02/28/2021 1243
10:2 FTS	15	11		1	72	50-150	02/28/2021 1243
4:2 FTS	15	12		1	78	50-150	02/28/2021 1243
GenX	32	26		1	81	50-150	02/28/2021 1243
ADONA	15	15		1	100	50-150	02/28/2021 1243
EtFOSA	16	13		1	80	50-150	02/28/2021 1243
EtFOSAA	16	14		1	88	50-150	02/28/2021 1243
EtFOSE	16	12		1	77	50-150	02/28/2021 1243
MeFOSA	16	16		1	98	50-150	02/28/2021 1243
MeFOSAA	16	15		1	92	50-150	02/28/2021 1243
MeFOSE	16	13		1	80	50-150	02/28/2021 1243
PFBS	14	14		1	99	50-150	02/28/2021 1243
PFDS	15	14		1	88	50-150	02/28/2021 1243
PFHpS	15	15		1	99	50-150	02/28/2021 1243
PFNS	15	14		1	89	50-150	02/28/2021 1243
PFOSA	16	14		1	87	50-150	02/28/2021 1243
PFPeS	15	15		1	99	50-150	02/28/2021 1243
PFHxS	15	13		1	87	50-150	02/28/2021 1243
PFBA	16	15		1	95	50-150	02/28/2021 1243
PFDA	16	16		1	98	50-150	02/28/2021 1243
PFDoA	16	16		1	99	50-150	02/28/2021 1243
PFHpA	16	16		1	102	50-150	02/28/2021 1243
PFHxA	16	16		1	99	50-150	02/28/2021 1243
PFNA	16	16		1	101	50-150	02/28/2021 1243
PFOA	16	16		1	103	50-150	02/28/2021 1243
PFPeA	16	16		1	102	50-150	02/28/2021 1243
PFTeDA	16	16		1	102	50-150	02/28/2021 1243
PFTrDA	16	14		1	88	50-150	02/28/2021 1243
PFUdA	16	13		1	82	50-150	02/28/2021 1243
PFOS	15	13		1	85	50-150	02/28/2021 1243

Surrogate	Q	% Rec	Acceptance Limit
13C2_4:2FTS		126	25-150
13C2_6:2FTS		113	25-150
13C2_8:2FTS		116	25-150
13C2_PFDoA		93	25-150
13C2_PFTeDA		92	25-150
13C3_PFBS		105	25-150
13C3_PFHxS		103	25-150
13C3-HFPO-DA		114	25-150

LOQ = Limit of Quantitation
DL = Detection Limit
ND = Not detected at or above the DL
J = Estimated result < LOQ and ≥ DL
* = RSD is out of criteria
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
+ = RPD is out of criteria

Note: Calculations are performed before rounding to avoid round-off errors in calculated results

PFAS by LC/MS/MS - LCS

Sample ID: WQ84062-002
Batch: 84062
Analytical Method: PFAS by ID SOP
Matrix: Aqueous
Prep Method: SOP SPE
Prep Date: 02/26/2021 1024

Surrogate	Q	% Rec	Acceptance Limit
13C4_PFBA		104	25-150
13C4_PFHpA		100	25-150
13C5_PFHxA		105	25-150
13C5_PFPeA		105	25-150
13C6_PFDA		89	25-150
13C7_PFUdA		111	25-150
13C8_PFOA		90	25-150
13C8_PFOS		110	25-150
13C8_PFOSA		117	10-150
13C9_PFNA		103	25-150
d-EtFOSA		89	10-150
d5-EtFOSAA		109	25-150
d9-EtFOSE		105	10-150
d-MeFOSA		76	10-150
d3-MeFOSAA		98	25-150
d7-MeFOSE		109	10-150

LOQ = Limit of Quantitation
DL = Detection Limit
ND = Not detected at or above the DL
J = Estimated result < LOQ and ≥ DL
* = RSD is out of criteria
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
+ = RPD is out of criteria

Note: Calculations are performed before rounding to avoid round-off errors in calculated results

PFAS by LC/MS/MS - Duplicate

Sample ID: WB25052-001DU
Batch: 84062
Analytical Method: PFAS by ID SOP
Matrix: Aqueous
Prep Method: SOP SPE
Prep Date: 02/26/2021 1024

Parameter	Sample Amount (ng/L)	Result (ng/L)	Q	Dil	% RPD	% RPD Limit	Analysis Date
9Cl-PF3ONS	ND	ND		1	0.00	20	02/28/2021 1304
11Cl-PF3OUdS	ND	ND		1	0.00	20	02/28/2021 1304
8:2 FTS	ND	ND		1	0.00	20	02/28/2021 1304
6:2 FTS	ND	ND		1	0.00	20	02/28/2021 1304
10:2 FTS	ND	ND		1	0.00	20	02/28/2021 1304
4:2 FTS	ND	ND		1	0.00	20	02/28/2021 1304
GenX	ND	ND		1	0.00	20	02/28/2021 1304
ADONA	ND	ND		1	0.00	20	02/28/2021 1304
EtFOSA	ND	ND		1	0.00	20	02/28/2021 1304
EtFOSAA	ND	ND		1	0.00	20	02/28/2021 1304
EtFOSE	ND	ND		1	0.00	20	02/28/2021 1304
MeFOSA	ND	ND		1	0.00	20	02/28/2021 1304
MeFOSAA	ND	ND		1	0.00	20	02/28/2021 1304
MeFOSE	ND	ND		1	0.00	20	02/28/2021 1304
PFBS	11	11		1	3.5	20	02/28/2021 1304
PFDS	ND	ND		1	0.00	20	02/28/2021 1304
PFHpS	ND	ND		1	0.00	20	02/28/2021 1304
PFNS	ND	ND		1	0.00	20	02/28/2021 1304
PFOSA	ND	ND		1	0.00	20	02/28/2021 1304
PFPeS	3.7	4.1		1	10	20	02/28/2021 1304
PFHxS	6.7	6.5		1	3.3	20	02/28/2021 1304
PFBA	18	17		1	5.0	20	02/28/2021 1304
PFDA	ND	ND		1	0.00	20	02/28/2021 1304
PFDoA	ND	ND		1	0.00	20	02/28/2021 1304
PFHpA	3.9	3.6		1	8.6	20	02/28/2021 1304
PFHxA	25	27		1	8.2	20	02/28/2021 1304
PFNA	ND	ND		1	0.00	20	02/28/2021 1304
PFOA	4.3	5.0		1	16	20	02/28/2021 1304
PFPeA	23	21		1	9.3	20	02/28/2021 1304
PFTeDA	ND	ND		1	0.00	20	02/28/2021 1304
PFTrDA	ND	ND		1	0.00	20	02/28/2021 1304
PFUdA	ND	ND		1	0.00	20	02/28/2021 1304
PFOS	5.4	4.9		1	11	20	02/28/2021 1304

Surrogate	Q	% Rec	Acceptance Limit
13C2_4:2FTS		124	25-150
13C2_6:2FTS		106	25-150
13C2_8:2FTS		96	25-150
13C2_PFDoA		75	25-150
13C2_PFTeDA		75	25-150
13C3_PFBS		96	25-150
13C3_PFHxS		95	25-150
13C3-HFPO-DA		112	25-150

LOQ = Limit of Quantitation
DL = Detection Limit
ND = Not detected at or above the DL
J = Estimated result < LOQ and ≥ DL
* = RSD is out of criteria
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
+ = RPD is out of criteria

Note: Calculations are performed before rounding to avoid round-off errors in calculated results

PFAS by LC/MS/MS - Duplicate

Sample ID: WB25052-001DU
Batch: 84062
Analytical Method: PFAS by ID SOP

Matrix: Aqueous
Prep Method: SOP SPE
Prep Date: 02/26/2021 1024

Surrogate	Q	% Rec	Acceptance Limit
13C4_PFBA		96	25-150
13C4_PFHpA		85	25-150
13C5_PFHxA		95	25-150
13C5_PFPeA		98	25-150
13C6_PFDA		77	25-150
13C7_PFUdA		87	25-150
13C8_PFOA		89	25-150
13C8_PFOS		93	25-150
13C8_PFOSA		105	10-150
13C9_PFNA		92	25-150
d-EtFOSA		60	10-150
d5-EtFOSAA		83	25-150
d9-EtFOSE		81	10-150
d-MeFOSA		69	10-150
d3-MeFOSAA		100	25-150
d7-MeFOSE		84	10-150

LOQ = Limit of Quantitation
DL = Detection Limit
ND = Not detected at or above the DL
J = Estimated result < LOQ and ≥ DL
* = RSD is out of criteria
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
+ = RPD is out of criteria

Note: Calculations are performed before rounding to avoid round-off errors in calculated results

PFAS by LC/MS/MS - MS

Sample ID: WB25052-002MS
Batch: 84062
Analytical Method: PFAS by ID SOP
Matrix: Aqueous
Prep Method: SOP SPE
Prep Date: 02/26/2021 1024

Parameter	Sample Amount (ng/L)	Spike Amount (ng/L)	Result (ng/L)	Q	Dil	% Rec	% Rec Limit	Analysis Date
9Cl-PF3ONS	ND	13	11		1	86	50-150	02/28/2021 1325
11Cl-PF3OUdS	ND	13	9.7		1	74	50-150	02/28/2021 1325
8:2 FTS	ND	13	11		1	83	50-150	02/28/2021 1325
6:2 FTS	ND	13	13		1	100	50-150	02/28/2021 1325
10:2 FTS	ND	14	8.2		1	61	50-150	02/28/2021 1325
4:2 FTS	ND	13	12		1	94	50-150	02/28/2021 1325
GenX	1.7	28	28		1	99	50-150	02/28/2021 1325
ADONA	ND	13	17		1	126	50-150	02/28/2021 1325
EtFOSA	ND	14	13		1	92	50-150	02/28/2021 1325
EtFOSAA	ND	14	12		1	82	50-150	02/28/2021 1325
EtFOSE	ND	14	13		1	92	50-150	02/28/2021 1325
MeFOSA	ND	14	15		1	109	50-150	02/28/2021 1325
MeFOSAA	ND	14	13		1	91	50-150	02/28/2021 1325
MeFOSE	ND	14	13		1	90	50-150	02/28/2021 1325
PFBS	10	12	25		1	118	50-150	02/28/2021 1325
PFDS	ND	14	13		1	98	50-150	02/28/2021 1325
PFHpS	ND	13	15		1	112	50-150	02/28/2021 1325
PFNS	ND	14	13		1	94	50-150	02/28/2021 1325
PFOSA	ND	14	15		1	103	50-150	02/28/2021 1325
PFPeS	ND	13	15		1	114	50-150	02/28/2021 1325
PFHxS	0.92	13	15		1	115	50-150	02/28/2021 1325
PFBA	66	14	79		1	99	50-150	02/28/2021 1325
PFDA	ND	14	16		1	111	50-150	02/28/2021 1325
PFDoA	ND	14	14		1	97	50-150	02/28/2021 1325
PFHpA	ND	14	17		1	119	50-150	02/28/2021 1325
PFHxA	35	14	56		1	146	50-150	02/28/2021 1325
PFNA	ND	14	12		1	87	50-150	02/28/2021 1325
PFOA	ND	14	14		1	99	50-150	02/28/2021 1325
PFPeA	220	14	230		1	50	50-150	02/28/2021 1325
PFTeDA	ND	14	15		1	104	50-150	02/28/2021 1325
PFTrDA	ND	14	15		1	110	50-150	02/28/2021 1325
PFUdA	ND	14	15		1	106	50-150	02/28/2021 1325
PFOS	1.5	13	13		1	87	50-150	02/28/2021 1325

Surrogate	Q	% Rec	Acceptance Limit
13C2_4:2FTS		121	25-150
13C2_6:2FTS		104	25-150
13C2_8:2FTS		112	25-150
13C2_PFDoA		69	25-150
13C2_PFTeDA		78	25-150
13C3_PFBS		105	25-150
13C3_PFHxS		91	25-150
13C3-HFPO-DA		111	25-150

LOQ = Limit of Quantitation
DL = Detection Limit
ND = Not detected at or above the DL
J = Estimated result < LOQ and ≥ DL
* = RSD is out of criteria
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
+ = RPD is out of criteria

Note: Calculations are performed before rounding to avoid round-off errors in calculated results

PFAS by LC/MS/MS - MS

Sample ID: WB25052-002MS
Batch: 84062
Analytical Method: PFAS by ID SOP

Matrix: Aqueous
Prep Method: SOP SPE
Prep Date: 02/26/2021 1024

Surrogate	Q	% Rec	Acceptance Limit
13C4_PFBA		97	25-150
13C4_PFHpA		101	25-150
13C5_PFHxA		94	25-150
13C5_PFPeA		106	25-150
13C6_PFDA		79	25-150
13C7_PFUdA		80	25-150
13C8_PFOA		87	25-150
13C8_PFOS		95	25-150
13C8_PFOSA		103	10-150
13C9_PFNA		109	25-150
d-EtFOSA		73	10-150
d5-EtFOSAA		95	25-150
d9-EtFOSE		82	10-150
d-MeFOSA		67	10-150
d3-MeFOSAA		86	25-150
d7-MeFOSE		85	10-150

LOQ = Limit of Quantitation
DL = Detection Limit
ND = Not detected at or above the DL
J = Estimated result < LOQ and ≥ DL
* = RSD is out of criteria
N = Recovery is out of criteria
P = The RPD between two GC columns exceeds 40%
+ = RPD is out of criteria

Note: Calculations are performed before rounding to avoid round-off errors in calculated results

Chain of Custody
and
Miscellaneous Documents

PACE ANALYTICAL SERVICES, LLC
106 Vantage Point Drive • West Columbia, SC 29172
Telephone No. 803-791-9700 Fax No. 803-791-9111
www.pacelabs.com

Number 117371

Client: AQUA-Aerobic Sys. Inc	Report to Contact: Joseph Campanaro	Telephone No. / E-mail: 551-795-4260 JCampanaro@aqua-aerobic.com	Quote No.
Address: 6306 N. Alpine Rd.	Sampler's Signature:	Analysis (Attach list if more space is needed)	Page 1 of 1
City: Loves Park State: IL Zip Code: 61111	Printed Name:	PFAS	WB25052
Project Name: Hoosier			

Project No.	P.O. No.		Number of Containers	Matrix			No. of Containers by Preservative Type							
Sample ID / Description (Containers for each sample may be combined on one line.)	Collection Date(s)	Collection Time (Military)		Aqueous	Solid	Other (Specify)	Unpres	H2SO4	HNO3	HCl	NaOH	Na2S2O3	Methanol	Remarks / Cooler I.D.
TAT II	2/4,6,8,10 12,14	18:00	6	X			X						Y	
TB T II	2/4,6,8,10 12,14	18:00	6	X			X						Y	
FT II	2/4,6,8,10 12,14	16:20	6	X			X						Y	

Turn Around Time Required (Prior lab approval required for expedited TAT.)	Sample Disposal	Possible Hazard Identification	QC Requirements (Specify)
X Standard ☐ Rush (Specify)	☐ Return to Client ☐ Disposal by Lab	X Non-Hazard ☐ Flammable ☐ Skin Irritant ☐ Poison ☐ Unknown	

	Date	Time		Date	Time
1. Relinquished by	2/23	15:00	1. Received by		
2. Relinquished by			2. Received by		
3. Relinquished by			3. Received by		
4. Relinquished by: FED EX	2-25-21	1046	4. Laboratory received by: MHaney	2/25/21	1010

Note: All samples are retained for four weeks from receipt unless other arrangements are made.

LAB USE ONLY
Received on ice (Circle) Yes (No) Ice Pack Receipt Temp. 13.4 °C
Temp Blank ☐ Y X N

DISTRIBUTION: WHITE & YELLOW-Return to laboratory with Sample(s); PINK-Field/Client Copy

Document Number: ME005N2-01

PACE ANALYTICAL SERVICES, LLC

Pace Analytical

Samples Receipt Checklist (SRC) (ME0018C-15)
Issuing Authority: Pace ENV - WCOL

Revised:9/29/2020
Page 1 of 1

Sample Receipt Checklist (SRC)

Client: AQUA-AEROBIC SYS. INC Cooler Inspected by/date: MRH / 2/25/2021 Lot #: WB25052

Means of receipt: ☐ Pace ☐ Client ☐ UPS ☑ FedEx ☐ Other: _

☐ Yes	☑ No		1. Were custody seals present on the cooler?
☐ Yes	☐ No	☑ NA	2. If custody seals were present, were they intact and unbroken?

pH Strip ID: NA Chlorine Strip ID: NA Tested by: NA

Original temperature upon receipt / Derived (Corrected) temperature upon receipt %Solid Snap-Cup ID: NA

13.4 / 12.4 °C NA / NA °C NA / NA °C NA / NA °C

Method: ☑ Temperature Blank ☐ Against Bottles IR Gun ID: 5 IR Gun Correction Factor: 0 °C

Method of coolant: ☑ Wet Ice ☐ Ice Packs ☐ Dry Ice ☐ None

☐ Yes	☐ No	☑ NA	3. If temperature of any cooler exceeded 6.0°C, was Project Manager Notified? PM was Notified by: phone / email / face-to-face (circle one).
☐ Yes	☐ No	☑ NA	4. Is the commercial courier's packing slip attached to this form?
☑ Yes	☐ No		5. Were proper custody procedures (relinquished/received) followed?
☑ Yes	☐ No		6. Were sample IDs listed on the COC?
☑ Yes	☐ No		7. Were sample IDs listed on all sample containers?
☑ Yes	☐ No		8. Was collection date & time listed on the COC?
☑ Yes	☐ No		9. Was collection date & time listed on all sample containers?
☑ Yes	☐ No		10. Did all container label information (ID, date, time) agree with the COC?
☑ Yes	☐ No		11. Were tests to be performed listed on the COC?
☑ Yes	☐ No		12. Did all samples arrive in the proper containers for each test and/or in good condition (unbroken, lids on, etc.)?
☑ Yes	☐ No		13. Was adequate sample volume available?
☑ Yes	☐ No		14. Were all samples received within ½ the holding time or 48 hours, whichever comes first?
☐ Yes	☑ No		15. Were any samples containers missing/excess (circle one) samples Not listed on COC?
☐ Yes	☐ No	☑ NA	16. For VOA and RSK-175 samples, were bubbles present >"pea-size" (¼" or 6mm in diameter) in any of the VOA vials?
☐ Yes	☐ No	☑ NA	17. Were all DRO/metals/nutrient samples received at a pH of < 2?
☐ Yes	☐ No	☑ NA	18. Were all cyanide samples received at a pH > 12 and sulfide samples received at a pH > 9?
☐ Yes	☐ No	☑ NA	19. Were all applicable NH_3/TKN/cyanide/phenol/625.1/608.3 (< 0.5mg/L) samples free of residual chlorine?
☐ Yes	☐ No	☑ NA	20. Were client remarks/requests (i.e. requested dilutions, MS/MSD designations, etc…) correctly transcribed from the COC into the comment section in LIMS?
☐ Yes	☑ No		21. Was the quote number listed on the container label? If yes, Quote # _

Sample Preservation (Must be completed for any sample(s) incorrectly preserved or with headspace.)

Sample(s) NA _ were received incorrectly preserved and were adjusted accordingly in sample receiving with NA mL of circle one: H_2SO_4, HNO_3, HCl, NaOH using SR # NA .

Time of preservation NA . If more than one preservative is needed, please note in the comments below.

Sample(s) NA _ were received with bubbles >6 mm in diameter.

Samples(s) NA _ were received with TRC > 0.5 mg/L (If #19 is ***no***) and were adjusted accordingly in sample receiving with sodium thiosulfate ($Na_2S_2O_3$) with Shealy ID: NA .

SR barcode labels applied by: JRG2 Date: 2/25/2021

Comments:

Appendix I

AquaPRS Factory Pilot Request

AquaPRS™ Factory Pilot Request

AquaPRS Pilot Test Description

AASI provides factory pilot testing with a fully-automated AquaPRS treatment system which utilizes production quality sorbent media, separation system and operational controls. Testing can typically be completed within two to three weeks and offers full-scale projections without scale-up correction factors or complex algorithms that may be necessary with other technologies. Depending on the test objectives and water quality, testing can often be completed with a single 330 gallon (1.25 m3) tote which allows one or two-stage treatment. Two totes are suggested if multiple tests are to be performed.

Customer Details

Organization: _____
Address: _____
_____
Telephone Number: _____
Contact: _____

Requestor Details

Name: _____
Address: _____
_____
Telephone Number: _____
Email Address: _____

Project Details:

Project I.D. _____
Source Water: _____
Location: _____
Collection: *Please see next page*

Customer to provide the following:

- Treatment goals, expected effluent
- Brief description of the application. Include epxected flows/volumes, water source, pre-treatment requirements, site constraints and existing treatment (if applicable)
- Minimum of one tote (330 gallons) of representative sample
- Recent water quality analysis prior to shipment, including*:
  - Anticipated PFAS levels and composition
  - Organic content (TOC or COD)
  - Suspended Solids content (TSS)
  - Dissolved solids concent (TDS)
  - Alkalinity (as CaCO3)
  - Anions (Br, Cl, NO3, NO2, PO4, SO4)

**AASI can perform the non-PFAS analyses at additional cost.*

Provided by AASI:

Aqua reviews the lab analysis provided by the Customer, identifies the appropriate operating parameters, sample pre-treatment needs and projects the breakthrough time. The test is then run for a duration twice the projected time before breakthrough.

AASI will collect and store all samples, but will select certain samples for PFAS evaluation to minimize cost. Untested samples may be sent to the lab by AASI for PFAS analyses in the event it is determined that additional design information is required.

Lab results are typically available 2 weeks following the last day of testing. A Project Report will be provided within 7 days of receipt of effluent PFAS data. The total process is estimated to take approximately 4-8 weeks.

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Aqua-Aerobic Systems, Inc.
6306 N. Alpine Rd.
Loves Park, IL 61111
815-654-2501

Chain of Custody Record

AQUA-AEROBIC SYSTEMS, INC.
A Metawater Company

Client Information	Lab PM: Blake Hoffmann		Carrier Tracking No(s):	COC No:
Client Contact:	Phone: 815-639-4491	E-Mail: bhoffmann@aqua-aerobic.com		Page:
Company:		**Analysis Requested**		Job #:
City:	**Due Date Requested:** / **TAT Requested (days):**			**Preservation Codes:**
State, Zip:				A - HCL, B - NaOH, C - Zn Acetate, D - Nitric Acid, E - NaHSO4, F - MeOH, G - Amchlor, H - Ascorbic Acid, I - Ice, J - DI Water, K - EDTA, L - EDA, M - Hexane, N - None, O - AsNaO2, P - Na2O4S, Q - Na2SO3, R - Na2S2O3, S - H2SO4, T - TSP Dodecahydrate, U - Acetone, V - MCAA, W - pH 4-5, Z - other (specify)
Phone:	PO #:			
Email:	WO #:			**Other:**
Project Name:	Project #:			
Site:	SSOW#:			

Sample Identification	Sample Date	Sample Time	Sample Type (C=Comp, G=grab)	Matrix (W=water, S=solid, O=waste/oil, BT=Tissue, A=Air)	Field Filtered Sample (Yes or No)	Perform MS/MSD (Yes or No)	AquaPRS Treatment	Total Number of containers	Special Instructions/Note:
			Preservation Code:				N		
				Water					
				Water					
				Water					
				Water					
				Water					
				Water					
				Water					
				Water					
				Water					
				Water					
				Water					

Possible Hazard Identification
☐ *Non-Hazard* ☐ *Flammable* ☐ *Skin Irritant* ☐ *Poison B* ☐ *Unknown* ☐ *Radiological*

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ *Return To Client* ☐ *Disposal By Lab* ☐ *Archive For _____ Months*

Deliverable Requested: I, II, III, IV, Other (specify)

Special Instructions/QC Requirements:

Empty Kit Relinquished by:	Date:	Time:	Method of Shipment:

Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company
Relinquished by:	Date/Time:	Company	Received by:	Date/Time:	Company

Custody Seals Intact: Δ Yes Δ No	Custody Seal / Tamper-Proof Tag No.:	Cooler Temperature(s) °C and Other Remarks:

Ver: 01/16/2019

NOTICE

ELEVATED PFAS LEVELS

This product can expose you to chemicals including Perflourooctanic Acid (PFOA), which is known to the State of California to cause birth defects or other reproductive harm.
WWW.P65WARNINGS.CA.GOV

DO NOT DUMP OR DISCHARGE ANY LIQUID FROM THIS CONTAINER

PROPER DISPOSAL OF THE CONTENTS AND/OR CONTAINER ARE REQUIRED

Return Container To:
AQUA-AEROBIC SYSTEMS, INC.
ATTN: Blake Hoffmann
6306 N. Alpine Rd.
Loves Park, IL 61111
815-639-4491

Please Complete Before Return Shipping:

AASI Office Use:

Project Number: _____ Y N

Collection Site: _____ Y N
(Name and address) _____
_____
_____

Collection Date: _____ Y N

Collected By: _____ Y N
(Name and Phone) _____

Container Quantity: _____ of _____ Y N

Chain of Custody #: _____ Y N

Tamper-Seal Tag #'s: _____ Y N
(Cap and Valve Tags) _____ Y N

AASI Office Use:
Received date: _____ Received by: _____

Container Condition Upon Arrival *(Circle)* : Good Damaged/Not Leaking Damaged/Leaking