Assessing HydraSleeve Samplers for Acquiring Representative PFAS Concentrations in Aqueous Environments

Bench-Scale Study

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1. Introduction

1.1 Background

Per- and polyfluoroalkyl substances (PFAS) are man-made substances often referred to as the "forever chemicals" because they do not naturally breakdown in the environment. PFAS have been found to be ubiquitous in the environment and detrimental to human health, and therefore subject to regulation, environmental monitoring, and remedial action. The remedial action levels are extremely low compared to other environmental contaminants, often in the double-digit parts per trillion (ng/L) range. Because the Maximum Concentration Levels (MCLs) are so low, sampling for PFAS requires an elevated level of rigor in the procedures, and confidence in equipment used, for obtaining the samples.

The HydraSleeve is a passive grab sampler used to obtain a representative "whole-water" sample from an interval in groundwater monitoring wells and surface water. The HydraSleeve captures a sample that includes the aqueous medium, and everything dissolved or suspended in the medium at the time of sampling, so it can be applied universally for sampling any contaminant. Over 1 million samples have been collected using HydraSleeves, to comply with groundwater monitoring and remediation requirements since the year 2000. Since 2016 approximately sixty-thousand High Density Polyethylene (HDPE) HydraSleeves have been used to collect samples of groundwater with suspected or actual per- and polyfluoroalkyl substances (PFAS) contamination.

The expanding use of the HDPE HydraSleeves for PFAS sampling has been supported by many private, site-specific studies, such as those comparing field samples collected using HydraSleeves to samples collected using low-flow pumping methods. However, because of the sensitive and costly nature of sites contaminated with PFAS, these field test results are rarely made public. In light of these confidentiality and funding concerns, the current study provides publicly available evidence about the accuracy of the HydraSleeves as a PFAS sampling method.

1.2 Study Objectives

This study was conducted to provide a controlled-environment evaluation of the use of the HDPE HydraSleeve for obtaining representative concentrations of PFAS at low-ng/L concentrations in aqueous environments. HDPE HydraSleeve samples were collected from a controlled test chamber filled with PFAS-spiked water. A third-party laboratory used EPA Draft Method 1633 to analyze the HydraSleeve samples and Control volumes of the water in the test chamber for PFAS concentrations. Results from the HydraSleeves were compared to Control results to determine whether the PFAS concentrations from HydraSleeve samples accurately represented the actual PFAS concentrations in the chamber where the samples were collected. The study also tested whether HDPE HydraSleeves leached PFAS into samples or adsorbed PFAS from samples to determine if HydraSleeves present potential sources for results bias.

2. Materials

The HydraSleeves and related materials and procedures used in this study were selected and used according to the guidance in the HydraSleeve Standard Operating Procedure manual, linked here. A short summary of their function is included below for reference. More information and details on these materials and procedures, as well as procedural and assembly variations for different conditions and product subtypes, can be found in that SOP. The test chamber was constructed specifically for the purpose of controlled comparison study and is not a part of the SOP.

2.1 HDPE HydraSleeve "SuperSleeve" Samplers

HydraSleeves are a type of passive grab sampler for use in obtaining representative samples of groundwater and other aqueous environments. The HydraSleeves used in these tests were the 1-liter sample volume HydraSleeve (1.7x~38"), SuperSleeve models, constructed of High-Density Polyethylene (HDPE), for sampling PFAS in water. HydraSleeves are flexible, flattened tubes that are sealed at the bottom and have a reed valve below the unsealed top end. The sleeves are deployed empty, and hydrostatic pressure keeps the sampler closed and empty during deployment and residence. When

the samplers are pulled upward through the water column during retrieval, the top of the HydraSleeve opens, allowing the sampler to "sleeve" around the stationary water column to capture a core of water inside. When the HydraSleeve is full, hydrostatic pressure collapses the reed-valve, sealing the sample inside and isolating it from the surrounding water for the rest of the retrieval process.

This process of sample collection where the HydraSleeve fills and is sealed occurs in a discrete sample interval that starts at the initial position of the top of the installed HydraSleeve and extends upwards for a distance that is approximately the length of the sampler. Water from outside of the sample interval is not captured in the HydraSleeve or represented in the sample. To fill laboratory containers with a HydraSleeve sample, the sleeve is punctured with a polypropylene discharge straw, and the sample water is drained through the straw into the laboratory containers. *Note: HydraSleeves are single-use samplers and must be replaced after each sampling event.*

2.2 Suspension Tethers & Accessory Items for HDPE HydraSleeves Deployment

Two factory-made suspension tethers were used to convey the samplers in and out of the test chamber and to hold the samplers in place between installation and removal. The tethers were the standard factory construction supplied as an option to purchasers of HydraSleeves. Tethers are constructed of braided polypropylene rope with the following items installed: stainless steel connection rings, polyamide snap connectors, Nylon™ zip-ties, and an aluminum ID Tag. Stainless steel weights were connected to the bottom of each tether to pull the sampler and tether downward through the water column and into place. The following items were also attached to the tether and HydraSleeve assembly in this study, according to best practice noted in the SOP. *Note: For field use, suspension tethers are usually well-dedicated and reusable, with the related accessories to reduce disposal and decontamination procedures required.*

- **Standard Top Collar Assembly:** A reusable, two-piece threaded PVC adaptor that attaches to the top of the HydraSleeve to facilitate attachment of the HydraSleeve to the suspension tether.

- **Weighted Top Collar Assembly:** A reusable, two-piece threaded top collar assembly made of PVC and stainless steel that attaches at the top of the HydraSleeve to facilitate attachment of the HydraSleeve to the suspension tether. The optional weight compressed the sleeve against the bottom of the well, allowing the sample interval to start close to the bottom of the well or chamber.

- **Spring Clip:** A stainless steel clip, shaped like a downward facing "U", that attaches to the connection rings on the suspension tether and clips into the top collar assembly (standard or weighted) at the top of each HydraSleeve, above the reed-valve.

2.3 Test Chamber for Comparison Study

A test chamber was constructed of an 8-inch diameter by 8-foot-long PVC pipe that was capped at the bottom and vertically mounted. A sampling port was installed at the approximate midpoint to allow the direct collection of the chamber water as a Control for comparison. Ports were installed near the bottom and top of the chamber and connected to a low-volume peristaltic recirculating pump with silicone tubing. The top of the chamber was fitted with a compression well-cap to seal the chamber from outside air during testing. The chamber was filled to a height of approximately 7.5 feet using approximately 74.1 liters of potable tap water. This water column was spiked with a blend of 40 PFAS obtained from AccuStandard, Inc. (New Haven, CT.), and the water in the chamber was recirculated for approximately 27 hours from top to bottom using the low volume peristaltic pump to ensure thorough initial mixing. A stabilization period of 42 hours was allowed for the PFAS in the test chamber to equilibrate with the test-chamber materials before placing the HydraSleeves in the chamber.

3. Procedures

3.1 HydraSleeve and Tether Materials Quality Test Procedures

Equipment rinsate tests are widely recommended when sampling for PFAS to determine if PFAS is present on the sampling equipment that could potentially leech into the sample. The HydraSleeve rinsate tests and the tether soak tests were conducted in accord with these recommendations, to validate that the HydraSleeves and suspension tethers are not a source for PFAS that could bias sample results. Results from both tests were compared to results from a Control sample of the water used for rinsing and soaking.

3.1.1 Rinsate Test (HDPE HydraSleeves)

Rinsate tests were performed on three 1.7 x 38-inch (1L) HDPE HydraSleeves. Each of the three HDPE HydraSleeves were filled with laboratory-produced, PFAS-free, deionized water. The water was held in the sleeves for approximately 5-minutes, in accordance with the HydraSleeve SOP recommendation to sample the sleeves immediately after retrieval. Each sampler was then punctured, and its contents drained via discharge straw into two lab-provided, 500mL HDPE sample containers.

3.1.2 Soak-Test (Suspension Tethers)

A soak test was performed on suspension tether components and accessories used with the HydraSleeve. The tether materials were soaked, rather than rinsed, because the surface area of the tether materials was small, and a longer contact time with the deionized water would be more likely to reveal if low levels of PFAS leaching were to occur.

A one-foot-long section of 3/16-in diameter polypropylene braided rope was placed in a 1-Liter, HDPE laboratory-provided sample bottle along with other tether components consisting of two 0.50-inch diameter stainless-steel connection rings, one 1-inch diameter stainless-steel hanging ring, one stainless-steel spring clip, two nylon zip-ties, one polyamide snap-connector, and one 1-inch diameter, stainless-steel ID Tag. Laboratory-provided PFAS-free, deionized water was used to fill the bottle, the bottle was capped and shaken for 30 seconds, and then left to soak for one hour. At the end of the soaking period the liquid was poured into two laboratory-provided, 500mL HDPE sample bottles.

3.1.3 Rinse Water Control

As a Control for comparing the results of the rinsate test and the soak test, two additional 500mL HDPE lab containers were filled with additional lab-provided DI water from the same lot that was used for the two quality tests.

3.2 Comparison Test Procedures

In order to evaluate the extent to which HydraSleeve samples provide an accurate representation of the surrounding aqueous environment, samples were collected from the PFAS-spiked the test chamber using HydraSleeves, and the HydraSleeve sample results were compared to two baseline/Control results from the water surrounding the sleeves in the chamber. The samples were tested for concentrations of 40 commonly sampled PFAS. In addition to a comparison using HydraSleeves discharged immediately after retrieval as recommended, a delayed-discharge test was performed to ascertain whether a sample is affected by prolonged/extended residence in a HydraSleeve after retrieval from the sampling environment.

3.2.1 HydraSleeve Setup & Deployment

The HDPE HydraSleeve comparison test was performed using 6 of the 1.75-inch x 38-inch x ~1.1L HDPE HydraSleeve “SuperSleeves,” which were deployed and retrieved following the guidance of the Standard Operating Procedure linked in the Materials section above. Three HydraSleeves were attached side-by-side to each of two bottom-weighted polypropylene suspension tethers using stainless-steel spring-clips and top collar assemblies. Two samplers on each tether were fitted with PVC Top Collars and one sampler on each tether was fitted with a PVC/Stainless-steel Top Collar Weight to provide weight to compress the sleeves against the bottom of the test chamber and allow sufficient water column for sampling.

The tethers and empty HydraSleeves were lowered into in the test chamber that had previously been spiked with PFAS compounds at low (ng/L) concentrations. The top of the HydraSleeves were positioned about 18-inches from the bottom of the test chamber, leaving approximately 6 feet of water column above the top of the sleeves. The tops of the tethers were attached to the underside of the compression cap using a snap connector and a stainless-steel ring. The compression cap at the top of the test-chamber was then sealed, and a low-volume peristaltic recirculation pump was turned on for three-hours to ensure the column was thoroughly mixed after installing the samplers, and then turned off. The HydraSleeves were left in-place undisturbed for 48 hours prior to sampling.

3.2.2 Collection of Controls

Two Control samples were collected as a way to gauge repeatability of results. The first Control sample was taken immediately prior to collecting the HydraSleeve samples, and the second Control sample was collected immediately after all the HydraSleeves had been removed from the test chamber and sampled. The same procedure was followed for both Controls:

Control samples representing the PFAS concentrations of the water in the chamber were collected from the discharge port at the midpoint of the test chamber, which approximately corresponded with the midpoint of where the HydraSleeve samples would be collected. Samples were discharged into two laboratory-provided, 500mL HDPE sample bottles. Care was taken so that the Control water did not contact any materials other than the test chamber and the HDPE sample bottles.

Because both Controls were collected using the same location and procedure, any differences between the results from the two Controls should only reflect variations in the chamber water caused by removing the samplers, exposure to air, influences of sample handling, or contribution from the laboratory environment. Therefore, Laboratory results from the two Control samples can be compared to each other and used as a baseline of expected and acceptable variability between actual sample results and Controls.

3.2.3 HydraSleeve Retrieval and Sampling

After the first Control sample was collected, the HydraSleeves were retrieved according to instructions in the SOP. Each tether was pulled upward through the water column a distance of about 38-inches, at a rate of about 1 foot per second. When the HydraSleeves were filled, one sampler at a time was removed from the chamber and suspended in the air on a tripod for sample collection.

Each 1L sleeve was punctured with a discharge straw and drained into two laboratory-provided, 500mL HDPE bottles. The first four (4) HydraSleeves were each sampled within 5 minutes of being removed from the chamber, as is typical for field sampling and in accordance with the manufacturer's instructions to discharge the samplers immediately after recovery. The remaining two sleeves were used for the delayed discharge test below.

3.3 Delayed Discharge Test Procedure

The two remaining HydraSleeves were sampled at delayed intervals following retrieval from the sample chamber. One HydraSleeve was suspended in the air for 15 minutes before the sample was discharged to the lab bottles. The other HydraSleeve was suspended in the air for 20 minutes before the sample was discharged to the lab bottles.

3.4 Sample Container Shipment & Laboratory Procedure

The 500mL HDPE sample bottles (for all tests) were provided by the test laboratory in accordance with the recommendations of EPA Method 1633-draft for PFAS analysis of aqueous solutions. Each HDPE sample bottle was labeled and put on ice, in a cooler, immediately after the sample or Control was collected. The coolers were shipped to Enthalpy Analytical Laboratories, LLC, El Dorado Hills, CA, for analysis for the entire suite of 40 PFAS using EPA Method 1633-Draft.

4. Analysis and Results

4.1 HydraSleeve Rinsate Test Results

Method 1633-draft analyses of the rinsate test sample and the soak test sample showed non-detect results across all 40 PFAS in all samples, validating that HDPE HydraSleeves and manufacturer provided suspension tethers do not contain these PFAS. Therefore, the use of HDPE HydraSleeves and these factory-provided tether materials for sampling PFAS in water will not bias results to indicate higher concentrations than the actual concentrations in the water, even at low ng/L levels. All results from the Method 1633-draft PFAS analysis of samples from the rinsate and soak tests and the Control sample of the laboratory produced, PFAS-Free deionized water used in the tests are shown in Appendix A.

4.2 HydraSleeve Comparison Test Results and Analysis

Six test samples were recovered from the test chamber water, one from each of six HDPE HydraSleeves. Two Control samples of the chamber water surrounding the HydraSleeves were also collected directly from chamber via a discharge port. Each of these eight total samples was analyzed by Enthalpy Analytical Laboratories for the entire suite of 40 PFAS using Method 1633 Draft. The water in the chamber was not analyzed before the PFAS blend was added or before the first Control was acquired, because the purpose of the test was to show how HydraSleeve test samples compared to Control samples of the water at the point in time the samples were collected. All results from the test and Control sample analyses are presented in Table 1.

4.2.1 Non-Detect, "j" Qualifier- Flagged, and Outlier Results

Several PFAS in the test chamber had concentrations below the RL and/or the MDL in at least one Control sample, as shown in Table 1. Because non-detect results (below the MDL) do not produce numerical concentration values, non-detect results were excluded from the comparison analysis. Results below the reporting limit (RL) but above the MDL were flagged by the laboratory with a "j" qualifier, indicating laboratory-estimated concentration values. Lab estimated results were included in our comparison analyses but are described below for reference, along with an outlier.

- All HydraSleeve and Control sample results for 5:3 FTCA (MDL 6.86 ng/L) and HFPO-DA (MDL 1.73 ng/L) were non-detect, indicating that the test-chamber concentrations were too low for laboratory detection. These compounds were excluded from comparative analysis.

- All HydraSleeve sample results for 7:3 FTCA, MeFOSE, and EtFOSE were j-flagged as estimated values. Results from one Control sample for 7:3 FTCA and one Control sample for MeFOSE were also estimated (j-flagged) values, while the other Control in each case was non-detect. The lab-estimated results for the HydraSleeve samples and the Controls, were included for comparative analysis. The ND Controls were excluded.

- One Control for 3:3 FTCA was significantly lower than the other Control for an undetermined reason. This result is an outlier, because the other Control sample and all the HydraSleeve samples for 3:3 FTCA produced results with values similar to each other. To be conservative, the outlier value was included in the comparative analyses.

4.2.2 Comparison Results Overview

The data shows in Table 1 that the results from the six HydraSleeve samples are close in value to all the other HydraSleeve samples and to the test chamber Control samples for each PFAS that was detected in the chamber (See Appendix B for descriptive statistics). Results were also similar between HydraSleeve samples and Control samples in showing that the concentration for a given PFAS was below the MDL and/or the reporting limit (RL), as discussed below.

Of the 228 PFAS results from HydraSleeve samples, including those sampled by immediate and delayed discharge, 130 individual PFAS results (57%) were less than 2 ng/L different from the average of the two Control samples (one taken

before HydraSleeve sampling, and one taken after HydraSleeve sampling). Over 81% of the HydraSleeve results were less than 4 ng/L different than the average of the Controls, and 91% of the HydraSleeve results were less than 6 ng/L different from the average of the Controls. This confirms the repeatability and precision, as well as overall accuracy, of the HydraSleeve for sampling low levels of PFAS.

Figure 1 highlights the comparison results for three specific PFAS (PFOS, PFOA, and PFNA) that are sometimes considered "Priority" PFAS (e.g., by the state of New Jersey) and have specific MCLs /GWQS of 13-14 ng/L. For each of these three PFAS, the concentration average of the HydraSleeve samples was within 0.5 ng/L of the Control sample average.

Table 1	**HDPE HydraSleeve PFAS Recovery Test (ng/L)**								
	HydraSleeve Sample ID						**Control Sample ID**		
PFAS Analyte	**10M-8066 (HS)**	**10M-8116 (HS)**	**10M-8086 (HS)**	**10M-8106 (HS)**	**10M-8096 (15 Minutes)**	**10M-8076 (20 Minutes)**	**10M-C8056 (Control-Before)**	**10M-C8136 (Control-After)**	**Lab RL***
11Cl-PF3OUdS	29.00	24.40	20.00	24.30	21.90	21.20	22.20	28.20	6.06
3:3 FTCA	51.20	35.70	40.30	39.70	44.40	44.70	47.20	15.50	8.08
4:2 FTS	109.00	103.00	106.00	109.00	101.00	101.00	103.00	96.70	6.06
5:3 FTCA	ND	ND	ND	ND	ND	ND	ND	ND	40.40
6:2 FTS	93.80	89.20	93.20	97.70	91.20	89.00	90.00	91.60	6.13
7:3 FTCA	11.40 (j)	4.30 (j)	5.00 (j)	4.63 (j)	6.97 (j)	7.01 (j)	10.10 (j)	ND	40.40
8:2 FTS	103.00	87.80	93.90	101.00	89.20	95.10	92.50	95.20	6.20
9Cl-PF3ONS	31.40	30.90	27.10	31.00	28.40	28.30	30.60	34.60	6.31
ADONA	21.60	21.00	20.10	22.20	20.20	20.00	20.10	22.70	6.39
EtFOSA	5.58	3.99	4.24	4.04	3.89	3.61	5.87	3.32	1.62
EtFOSAA	34.10	34.80	33.30	35.70	30.30	33.10	38.30	39.90	1.62
EtFOSE	11.30 (j)	10.60 (j)	10.60 (j)	10.5 (j)	9.50 (j)	10.10 (j)	13.60 (j)	11.50 (j)	16.20
HFPO-DA	ND	ND	ND	ND	ND	ND	ND	ND	6.75
MeFOSA	8.35	5.48	6.03	6.46	5.59	5.41	6.79	3.59	1.62
MeFOSAA	45.60	47.40	44.60	48.10	43.60	47.20	49.60	51.20	1.62
MeFOSE	6.54 (j)	2.92 (j)	3.99 (j)	3.47 (j)	3.80 (j)	3.82 (j)	4.41 (j)	ND	16.20
NFDHA	25.80	25.80	23.10	26.40	25.60	25.20	26.70	25.50	3.23
PFBA	148.00	142.00	141.00	155.00	142.00	146.00	148.00	143.00	6.47
PFBS	27.20	26.40	26.40	29.70	26.10	26.00	25.90	24.90	1.43
PFDA	37.40	33.30	34.90	38.00	33.30	33.90	34.30	38.00	1.62
PFDoA	42.90	41.90	35.50	44.60	39.80	38.80	38.90	45.00	1.62
PFDoS	21.30	19.00	15.70	20.30	18.20	19.00	16.60	23.60	1.57
PFDS	27.20	22.60	19.30	23.80	21.90	22.40	20.60	27.00	1.56

Table 1 Continued Below

PFAS Analyte	10M8066 (HS)	10M8116 (HS)	10M8086 (HS)	10M8106 (HS)	10M8096 (15 Minutes)	10M8076 (20 Minutes)	10MC8056 (Control-Before)	10MC8136 (Control-After)	RL*
PFEESA	29.30	26.90	25.40	28.40	26.50	26.50	28.10	26.30	2.88
PFHpA	42.50	41.10	41.20	44.20	40.50	41.00	42.00	43.20	1.62
PFHpS	25.30	24.20	23.90	27.10	24.30	27.40	25.20	26.30	1.54
PFHxA	40.20	37.00	36.00	40.00	38.50	40.80	38.90	37.10	1.62
PFHxS	25.20	23.00	22.70	24.90	22.80	23.50	24.30	23.50	1.48
PFMBA	24.80	23.70	24.40	26.10	23.90	25.20	24.70	24.30	3.23
PFMPA	23.70	24.50	22.00	23.70	21.30	23.70	24.20	24.60	3.23
PFNA	42.60	39.90	36.90	40.30	38.10	38.10	40.90	38.00	1.62
PFNS	22.10	19.00	17.30	20.60	18.30	19.90	18.50	22.60	1.56
PFOA	36.30	35.10	35.70	38.40	36.30	35.20	37.40	35.10	2.02
PFOS	24.10	24.10	22.90	25.90	23.90	26.00	24.20	25.30	1.51
PFOSA	35.40	41.60	40.30	42.50	40.90	39.70	44.00	44.00	1.62
PFPeA	89.90	103.00	104.00	112.00	104.00	109.00	105.00	95.30	3.23
PFPeS	25.50	23.10	24.20	25.60	24.00	24.40	26.40	24.70	1.52
PFTeDA	29.70	29.50	26.60	31.10	27.40	26.70	27.20	32.00	1.62
PFTrDA	32.50	32.00	27.70	33.60	31.00	28.30	29.70	33.30	1.62
PFUnA	41.30	35.90	33.30	36.40	32.20	33.90	35.00	39.30	1.62

*Table 1: *The Lab RL shown in Table 1 are the maximum values for each analyte out of the eight samples tested by the lab. See Appendix A for Lab MDLs. "(j)" values are lab qualifiers indicating estimated results above the MDL and below the RL. "ND" indicates a non-detect result. (Section 4.2)*

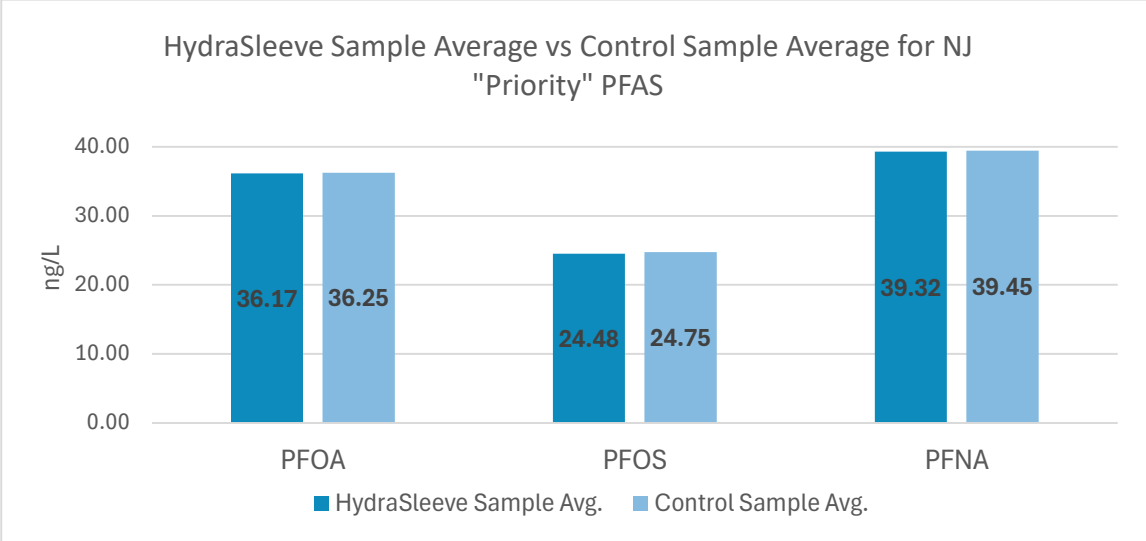


Figure 1: Bar charts show the average concentration from 6 HydraSleeve samples of the 3 New Jersey Priority PFAS compared with the average of two Control samples for those PFAS. (Section 4.2.2)

4.2.3 Comparative Analysis Results

As shown in Table 1, the results from the six HydraSleeve samples are close in value to all the other HydraSleeve samples and to the test chamber Control samples for each PFAS that was detected in the chamber. The comparison of the HydraSleeve samples to the Control samples was assessed via 1:1 correlation.

The U.S. Geological Survey (Imbrigiotta, T. E., & Harte, P. T. 2020. Passive sampling of groundwater wells for determination of water chemistry (No. 1-D8).) suggests that "one of the more effective ways to compare concentration results is to plot the data on a 1:1 correspondence on an X-Y plot with the passive sampling (HydraSleeve) results on one axis and the active sampling (Control) results on the other axis. If the two sampling methods collect the same concentrations, the points will plot on or close to the 1:1 correspondence line." This analysis is presented below.

To determine an overall statistical correlation between results from HydraSleeves samples and results from Control samples, the average of all six HydraSleeve results for each of the 38 PFAS that were detected were plotted against the average of the two corresponding Control results (Figure 2). The resulting 1:1 plot of these 38 data pairs shows a very high positive correlation, having an R^2 value of .996, showing that overall, HydraSleeve samples provide statistically similar results to Control samples for the PFAS analyzed by Method 1633.

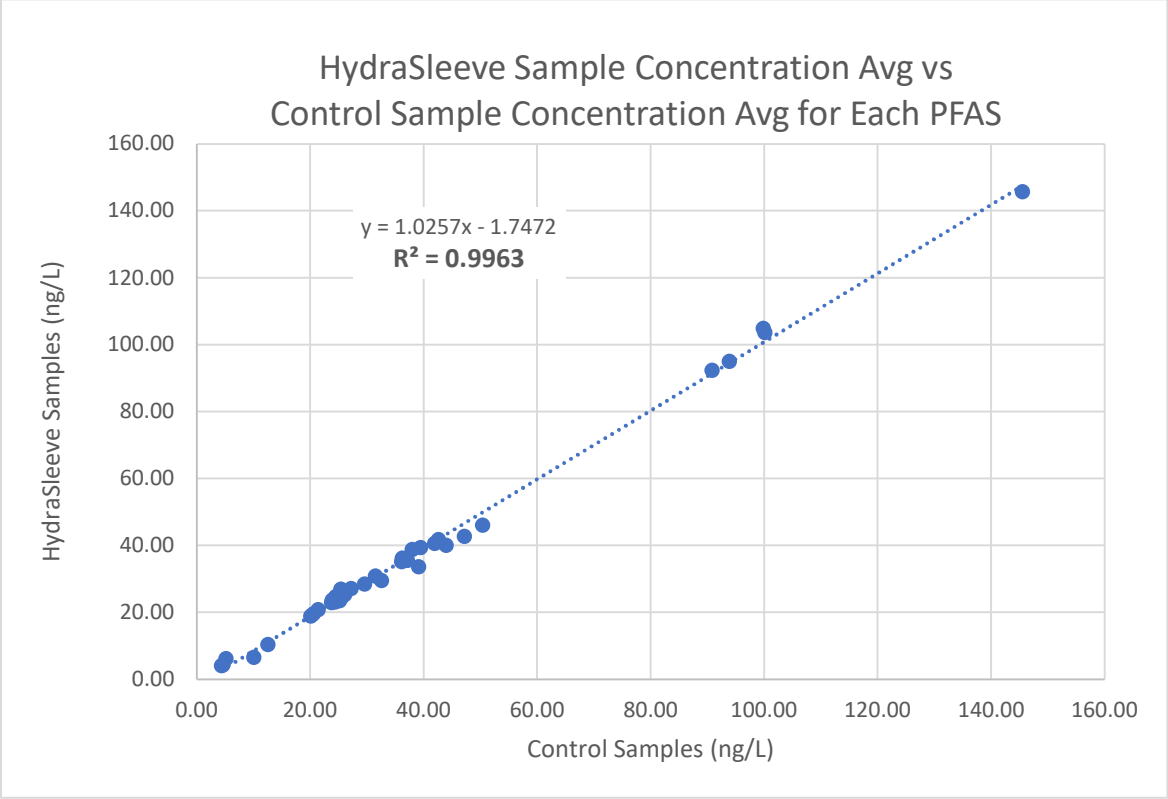


Figure 2: Each data point represents the average concentration from the 6 HydraSleeve Samples compared to the average concentration for the 2 Control samples for one of the 38 PFAS detected in the study. The samples from the HydraSleeves demonstrated 99.6% correspondence with the Controls. (Section 4.2.3)

4.3 Delayed Discharge Test Results

The PFAS concentrations from the HydraSleeve samples that were discharged after a 15-minute delay and after a 20-minute delay were each plotted against the Control sample average (Figure 3 and Figure 4, respectively), to evaluate whether the samples were still representative after extended exposure to the inside of the HDPE HydraSleeves. Both delayed-discharge samples still showed excellent 1:1 correspondence with the Controls for the 38 PFAS that were detected in this study, with an R^2 value of .995 for the 15-minute-delay sample and an R^2 of 0.996 for the 20-minute-delay sample. To further demonstrate the consistency of these delayed-discharge results with the immediate-discharge sample results, the average of the four immediate-discharge HydraSleeve samples for each PFAS were also plotted against the Control average for those PFAS in Figure 5, demonstrating an extremely similar R^2 value of 0.996.

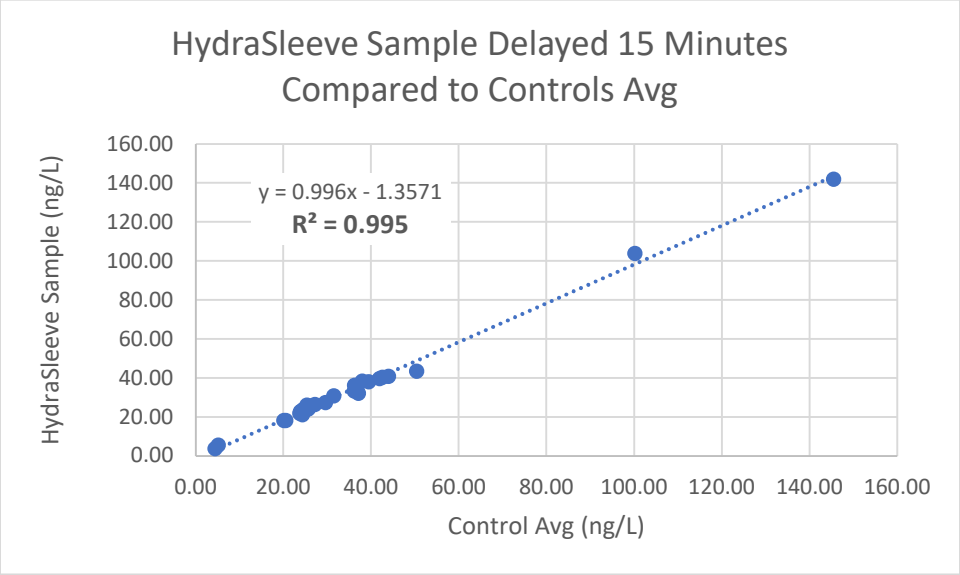
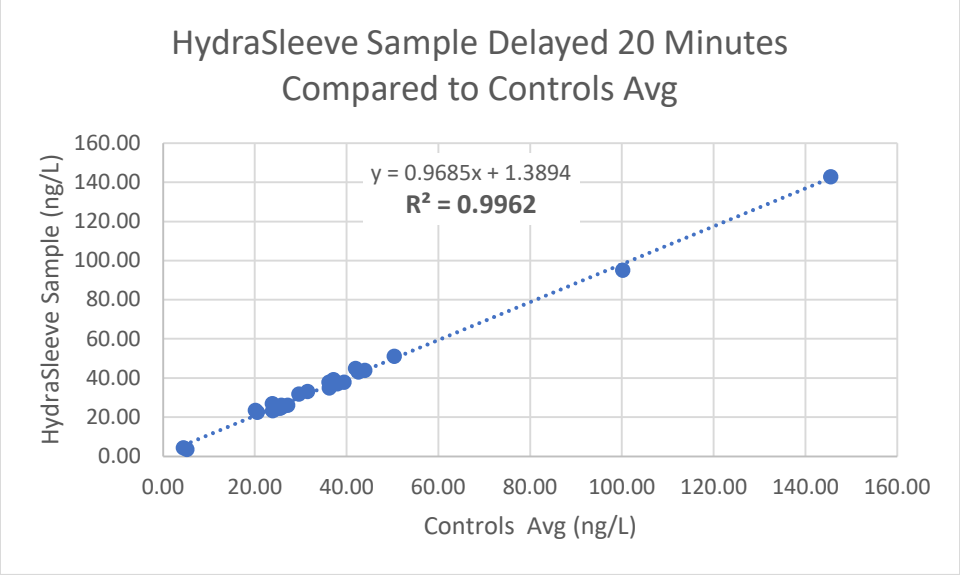


Figure 3 (above) and **Figure 4** (below): Scatter plots of concentrations from a delayed-discharge HydraSleeve sample compared to the average concentration for the 2 Control samples each of 38 PFAS. Figure 3 shows the 15-minute delay sample, and Figure 4 shows the 20-minute delay sample. (Section 4.3)



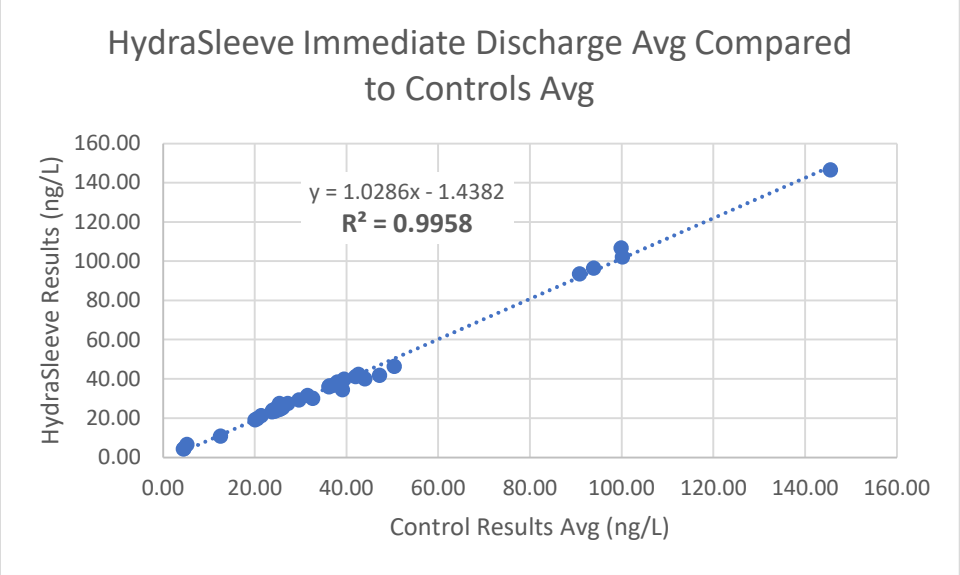


Figure 5: Scatter plot showing the average for 4 immediate-discharge HydraSleeve Samples compared to the average for the 2 Control samples each of the 38 PFAS detected in the study. (Section 4.3)

5. Conclusions

The study shows that HDPE HydraSleeves and manufacturer-provided suspension tether components do not leach PFAS into samples acquired using the HydraSleeve and therefore do not bias samples high, even at low-concentration, single-digit ng/L (parts per trillion), for the 40 PFAS analyzed using EPA Method 1633-draft.

The study also shows that HDPE HydraSleeves acquire samples that closely represent the test environment, as determined by their high positive correlations with Control samples taken directly from the test environment. In most cases the results from HydraSleeve samples were within 2-3 ng/L of the average of two Control results. In many cases, the individual PFAS concentrations were within the range of difference to the Control samples as the two Controls were to each other.

The study also demonstrated that allowing samples to reside in HydraSleeves for 20 minutes after sampling did not cause a noticeable change in concentration from HydraSleeves sampled within 5-minutes of sampling. This demonstrates that HDPE HydraSleeves do not adsorb PFAS from samples between the time of acquisition and discharge to sample bottles, even if the discharge is delayed for 20 minutes, and therefore do not bias samples low.

The test data demonstrates that sampling for PFAS using HydraSleeves produces samples with PFAS concentrations that are statistically representative of concentrations in water surrounding the sampler.

6. Reference

The Standard Operating Procedure for the HydraSleeve, including the HDPE “SuperSleeve” for PFAS and all other standard configurations and variations, can be found at https://www.eonpro.com/wp-content/uploads/2023/04/HydraSleeve-SOP-2.0-2023-1.pdf.

APPENDIX A: Rinsate & Soak Test Data

The entire data-set from the rinsate and soak tests are shown in the table below in ng/L (ppt). Each of the 40 tested PFAS is labeled in the left-hand column, and the results for that PFAS from individual tests are shown across the same row. Rinsate sample IDs (blue headers), tether soak sample IDs (green header), and the Control sample ID of the laboratory produced, PFAS-Free deionized water (gray header), are shown in the column headings. Results below the Method Detection Limit (MDL) are "Non-Detect" results and listed as "ND" in the table. The lab MDL and RL shown in Table 1 are the maximum of the five tests for each PFAS. Reading across each row facilitates comparing the HydraSleeve test results directly with the Control results.

Table of Rinsate and Soak Results	**HDPE HydraSleeve Rinsate Test (ng/L)**			**Tether Components 1-Hour Soak Test (ng/L)**	**Rinsate & Soak Control (ng/L)**	**Lab MDL* (ng/L)**	**Lab Reporting Limit* (ng/L)**
Sample ID> PFAS Analyte	10M8016	10M8026	10M8036	10M8146	10MC8046	MDL	RL
11Cl-PF3OUdS	ND	ND	ND	ND	ND	1.96	6.08
3:3 FTCA	ND	ND	ND	ND	ND	1.60	8.11
4:2 FTS	ND	ND	ND	ND	ND	1.29	6.08
5:3 FTCA	ND	ND	ND	ND	ND	6.86	40.50
6:2 FTS	ND	ND	ND	ND	ND	1.24	6.15
7:3 FTCA	ND	ND	ND	ND	ND	3.64	40.50
8:2 FTS	ND	ND	ND	ND	ND	1.90	6.22
9Cl-PF3ONS	ND	ND	ND	ND	ND	1.95	6.32
ADONA	ND	ND	ND	ND	ND	1.61	6.40
EtFOSA	ND	ND	ND	ND	ND	0.99	1.62
EtFOSAA	ND	ND	ND	ND	ND	0.70	1.62
EtFOSE	ND	ND	ND	ND	ND	2.58	16.20
HFPO-DA	ND	ND	ND	ND	ND	1.72	6.77
MeFOSA	ND	ND	ND	ND	ND	1.02	1.62
MeFOSAA	ND	ND	ND	ND	ND	0.70	1.62
MeFOSE	ND	ND	ND	ND	ND	2.63	16.20
NFDHA	ND	ND	ND	ND	ND	1.57	3.24
PFBA	ND	ND	ND	ND	ND	1.62	6.49
PFBS	ND	ND	ND	ND	ND	0.68	1.44
PFDA	ND	ND	ND	ND	ND	0.43	1.62
PFDoA	ND	ND	ND	ND	ND	0.23	1.62
PFDoS	ND	ND	ND	ND	ND	0.50	1.57

Table of Rinsate and Soak Results Continued Below

Sample ID> PFAS Analyte	10M8016	10M8026	10M8036	10M8146	10MC8046	MDL	RL
PFDS	ND	ND	ND	ND	ND	0.57	1.56
PFEESA	ND	ND	ND	ND	ND	0.38	2.89
PFHpA	ND	ND	ND	ND	ND	0.28	1.62
PFHpS	ND	ND	ND	ND	ND	0.38	1.54
PFHxA	ND	ND	ND	ND	ND	0.28	1.62
PFHxS	ND	ND	ND	ND	ND	0.51	1.48
PFMBA	ND	ND	ND	ND	ND	0.46	3.24
PFMPA	ND	ND	ND	ND	ND	0.69	3.24
PFNA	ND	ND	ND	ND	ND	0.25	1.62
PFNS	ND	ND	ND	ND	ND	0.61	1.56
PFOA	ND	ND	ND	ND	ND	1.80	2.03
PFOS	ND	ND	ND	ND	ND	1.19	1.51
PFOSA	ND	ND	ND	ND	ND	0.40	1.62
PFPeA	ND	ND	ND	ND	ND	0.43	3.24
PFPeS	ND	ND	ND	ND	ND	0.49	1.52
PFTeDA	ND	ND	ND	ND	ND	0.24	1.62
PFTrDA	ND	ND	ND	ND	ND	0.26	1.62
PFUnA	ND	ND	ND	ND	ND	0.42	1.62

*The Lab MDL and RL shown in Table 1 are the maximum values for each analyte out of the five samples tested by the lab. There were no qualifiers in the data-set.

APPENDIX B: Descriptive Statistics for Comparative Study

Descriptive Statistics and Sample Characteristics for Comparison Test Data (ng/L)							
	Total Data for all 8 Samples (HydraSleeves + Controls) for Each PFAS				HydraSleeve Sample Data (*n*= 6)		Control Sample Data (*n*= 2)
PFAS Analyte	**Mean (ng/L)**	**Std. Deviation (ng/L)**	**Min. (ng/L)**	**Max (ng/L)**	**HS Mean (ng/L)**	**HS Std. Deviation (ng/L)**	**Control Mean (ng/L)**
11Cl-PF3OUdS	23.90	3.26	20.00	29.00	23.47	3.22	25.20
3:3 FTCA	39.84	10.94	*15.5	51.20	42.67	5.35	**31.35
4:2 FTS	103.59	4.24	96.70	109.00	104.83	3.71	99.85
6:2 FTS	91.96	2.90	89.00	97.70	92.35	3.28	90.80
7:3 FTCA	7.06	2.76	4.30	11.40	6.55	2.65	10.10
8:2 FTS	94.71	5.24	87.80	103.00	95.00	6.11	93.85
9Cl-PF3ONS	30.29	2.34	27.10	34.60	29.52	1.80	32.60
ADONA	20.99	1.07	20.00	22.70	20.85	0.91	21.40
EtFOSA	4.32	0.92	3.32	5.87	4.23	0.70	4.60
EtFOSAA	34.94	3.04	30.30	39.90	33.55	1.86	39.10
EtFOSE	10.96	1.24	9.50	13.60	10.43	0.60	12.55
MeFOSA	5.96	1.36	3.59	8.35	6.22	1.12	5.19
MeFOSAA	47.16	2.53	43.60	51.20	46.08	1.77	50.40
MeFOSE	4.14	1.16	2.92	6.54	4.09	1.26	4.41
NFDHA	25.51	1.09	23.10	26.70	25.32	1.15	26.10
PFBA	145.63	4.69	141.00	155.00	145.67	5.32	145.50
PFBS	26.58	1.42	24.90	29.70	26.97	1.40	25.40
PFDA	35.39	2.07	33.30	38.00	35.13	2.08	36.15
PFDoA	40.93	3.26	35.50	45.00	40.58	3.25	41.95
PFDoS	19.21	2.54	15.70	23.60	18.92	1.92	20.10
PFDS	23.10	2.81	19.30	27.20	22.87	2.59	23.80
PFEESA	27.18	1.30	25.40	29.30	27.17	1.43	27.20
PFHpA	41.96	1.27	40.50	44.20	41.75	1.37	42.60
PFHpS	25.46	1.34	23.90	27.40	25.37	1.54	25.75
PFHxA	38.56	1.73	36.00	40.80	38.75	1.93	38.00
PFHxS	23.74	0.96	22.70	25.20	23.68	1.10	23.90
PFMBA	24.64	0.76	23.70	26.10	24.68	0.89	24.50
PFMPA	23.46	1.19	21.30	24.60	23.15	1.22	24.40
PFNA	39.35	1.89	36.90	42.60	39.32	2.04	39.45
PFNS	19.79	1.87	17.30	22.60	19.53	1.71	20.55
PFOA	36.19	1.19	35.10	38.40	36.17	1.21	36.25
PFOS	24.55	1.08	22.90	26.00	24.48	1.22	24.75
PFOSA	41.05	2.78	35.40	44.00	40.07	2.49	44.00
PFPeA	102.78	7.11	89.90	112.00	103.65	7.59	100.15
PFPeS	24.74	1.05	23.10	26.40	24.47	0.95	25.55
PFTeDA	28.78	2.09	26.60	32.00	28.50	1.86	29.60
PFTrDA	31.01	2.24	27.70	33.60	30.85	2.37	31.50
PFUnA	35.91	3.08	32.20	41.30	35.50	3.25	37.15

*3:3 FTCA Minimum value of 15.5 ng/L from 1 Control sample is considered an outlier but is included in calculating the Control mean **31.35 ng/L.