C1-C10 PFAS Analysis in Human Plasma and Serum

Integrating Ultrashort-Chain Compounds into PFAS Biomonitoring

By Shun-Hsin Liang and Justin Steimling

Abstract

Human exposure to ultrashort-chain (C1 to C3) PFAS and their potential adverse health effects are poorly understood, partly due to a lack of analytical methods to properly monitor their occurrence. This study introduces an innovative methodology for the simultaneous analysis of C1 to C10 carboxylic and sulfonic acid PFAS, along with four alternative compounds, in human plasma and serum samples. The chromatographic analysis was conducted using a polar-embedded, reversed-phase LC column for accurate and robust quantification.

Related Products

- *PFAS delay column (cat. # 27854)*
- *Ultra IBD 3 µm, 100 mm x 2.1 mm (cat.# 9175312)*
- *PFAS 28 calibration standard (cat.# 30734)*
- *Big Mouth Step screw-thread vials (cat.# 24626)*
- *Polypropylene vial inserts (cat.# 24518)*
- *Survival kit for HPLC, stainless steel (cat.# 25097)*

Introduction

While concerns about the adverse effects of long-chain per- and polyfluoroalkyl substances (PFAS) on human health have led to increased biomonitoring, less is known about the potential toxicity of ultrashort-chain PFAS. Ultrashort-chain PFAS are ubiquitous in environmental aquatic systems and can occur at very high concentrations, so determining exposure levels is important, particularly for vulnerable populations. Since both human plasma and serum are widely used for biomonitoring longer-chain PFAS, developing methods that include shorter chain PFAS is critical to gaining a more comprehensive understanding of the relationship between PFAS exposure and adverse health outcomes.

Ultrashort-chain PFAS are small, highly polar compounds with carbon chain lengths shorter than C4 (Figure 1). Their high polarity creates a challenge for analytical practices that are based on reversed-phase liquid chromatography, primarily due to insufficient chromatographic retention. To improve analytical performance, the following method was developed on an Ultra IBD column because its polar-embedded stationary phase provides stronger retention of polar compounds, even in the presence of the various salts, electrolytes, and buffers that are inherently found in human plasma and serum.

In this study, a simple and reliable workflow was developed for the simultaneous analysis of C1 to C10 perfluoroalkyl carboxylic and sulfonic acids, along with four alternative PFAS, in human plasma and serum. The samples underwent a simple, single-step protein precipitation procedure and were analyzed with a user-friendly LC-MS/MS method. Method accuracy and precision were evaluated with fortified fetal bovine serum. In addition, the method's suitability for real-world samples was confirmed by accurately measuring targeted PFAS with known concentrations in NIST standard reference human plasma (NIST SRM 1950) and serum (NIST SRM 1957).

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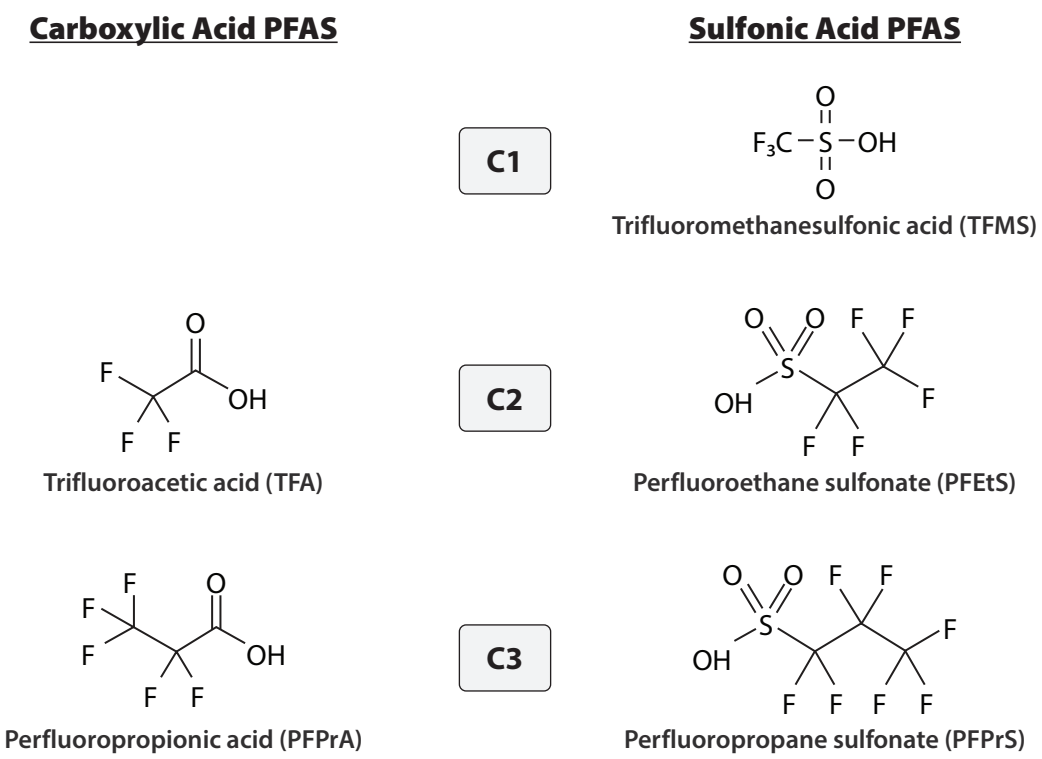
Figure 1: Structures of C1 to C3 PFAS



Experimental

Plasma and Serum Samples

Since PFAS-free human plasma and serum were not found during the screening of commercially obtained samples, charcoal-stripped fetal bovine serum (FBS) obtained from MilliporeSigma (Burlington, MA) was used as the blank matrix for method verification because it did not contain any of the analytes of interest except for TFA. To compensate for this, a TFA isotope, ^{13}C-TFA, was employed as a surrogate to assess method accuracy for TFA in FBS. NIST SRM 1950 (metabolites in human plasma) and NIST SRM 1957 (organic contaminants in non-fortified human serum) were purchased from NIST Store (Gaithersburg, MD). These SRMs are characterized by known concentrations of six or seven short-chain and long-chain PFAS.

Standard and Sample Preparation

TFA is commonly present in laboratory materials, such as pipette tips, glass and polypropylene HPLC vials, and polypropylene tubes. Following a comprehensive examination, the materials with the lowest TFA contamination levels were chosen for standard and sample preparation. Additionally, deionized water and reverse osmosis (RO) water generated at Restek were assessed to determine if they contained PFAS. The results revealed that RO water was free of PFAS contamination, with the exception of TFA, which was found to be present at very low levels. Consequently, RO water was used for the preparation of mobile phase and calibration standards.

The calibration standard solutions (100 µL) were prepared in RO water, supplemented with 1x phosphate-buffered saline (PBS), across a range of 0.05 to 40 ng/mL (ppb) in polypropylene HPLC vials. Initial testing revealed that early eluting compounds displayed slightly broader peak shapes in the human plasma and serum samples compared to the neat standard solutions prepared in 100% water. Therefore, PBS was incorporated into the standard solutions to mitigate this variability and ensure uniform chromatographic performance between standard and sample solutions.

Five isotopically labeled PFAS were used as quantitative internal standards (QIS) (Table I). A 5 µL aliquot of QIS working solution (40 ng/mL of $^{13}C_3$-PFBA; 20 ng/mL of $^{13}C_2$-PFHxA and $^{13}C_4$-PFOA; and 10 ng/mL of $^{13}C_5$-PFNA and $^{13}C_2$-PFDA) was added to the standard solutions, which were then mixed with 200 µL of methanol containing 1.5% formic acid.

For the assessment of method accuracy and precision, 100 µL aliquots of FBS were fortified at 0.4, 2, 10, and 30 ppb with non-labeled PFAS and isotopically labeled ^{13}C-TFA, which served as a surrogate for the determination of TFA recovery. The fortified FBS samples were mixed with 5 µL of QIS working solution and 2 µL of extracted internal standard (EIS) working solution (50 ng/mL of $^{13}C_3$-PFPrA, $^{13}C_4$-PFBA, $^{13}C_5$-PFPeA, $^{13}C_5$-PFHxA, $^{13}C_4$-PFHpA, $^{13}C_8$-PFOA, $^{13}C_9$-PFNA, $^{13}C_6$-PFDA, $^{13}C_3$-PFHxS, and $^{13}C_8$-PFOS). A 200 µL aliquot of methanol containing 1.5% formic acid was then added to the fortified FBS samples followed by vortexing for 30 seconds at 3000 rpm. After centrifugation at 4200 rpm for 10 minutes, approximately 150 µL of supernatant was transferred to a polypropylene vial insert (cat.# 24518), placed in a glass HPLC vial (cat.# 24626), and subsequently injected for LC-MS/MS analysis. This single-step protein precipitation in clean polypropylene HPLC vials was used to minimize background PFAS contamination and to ensure accurate measurement of target analytes. Non-fortified human plasma and serum samples were also prepared using the same procedure that was used for the fortified FBS samples.

Analytical System

PFAS analysis was performed by LC-MS/MS under the conditions shown below. A PFAS delay column was installed between the mixer and injector to prevent any potential PFAS contamination upstream of the injector from coeluting with PFAS in the samples.

System: Waters ACQUITY UPLC I-Class and Xevo TQ-S triple quadrupole mass spectrometer

Columns:

- Analytical column: Ultra IBD, 100 mm x 2.1 mm, 3 µm (cat.# 9175312)
- PFAS delay column (cat.# 27854)

Injection volume: 5 µL

Mobile phase A: 5 mM ammonium formate, 0.1% formic acid in water

Mobile phase B: Acetonitrile

Flow rate: 0.3 mL/min

Temperature: 40 °C

Gradient:

Time (min)	%B
0.00	20
7.00	95
9.00	95
9.01	20
11.00	20

Ion mode: Negative ESI

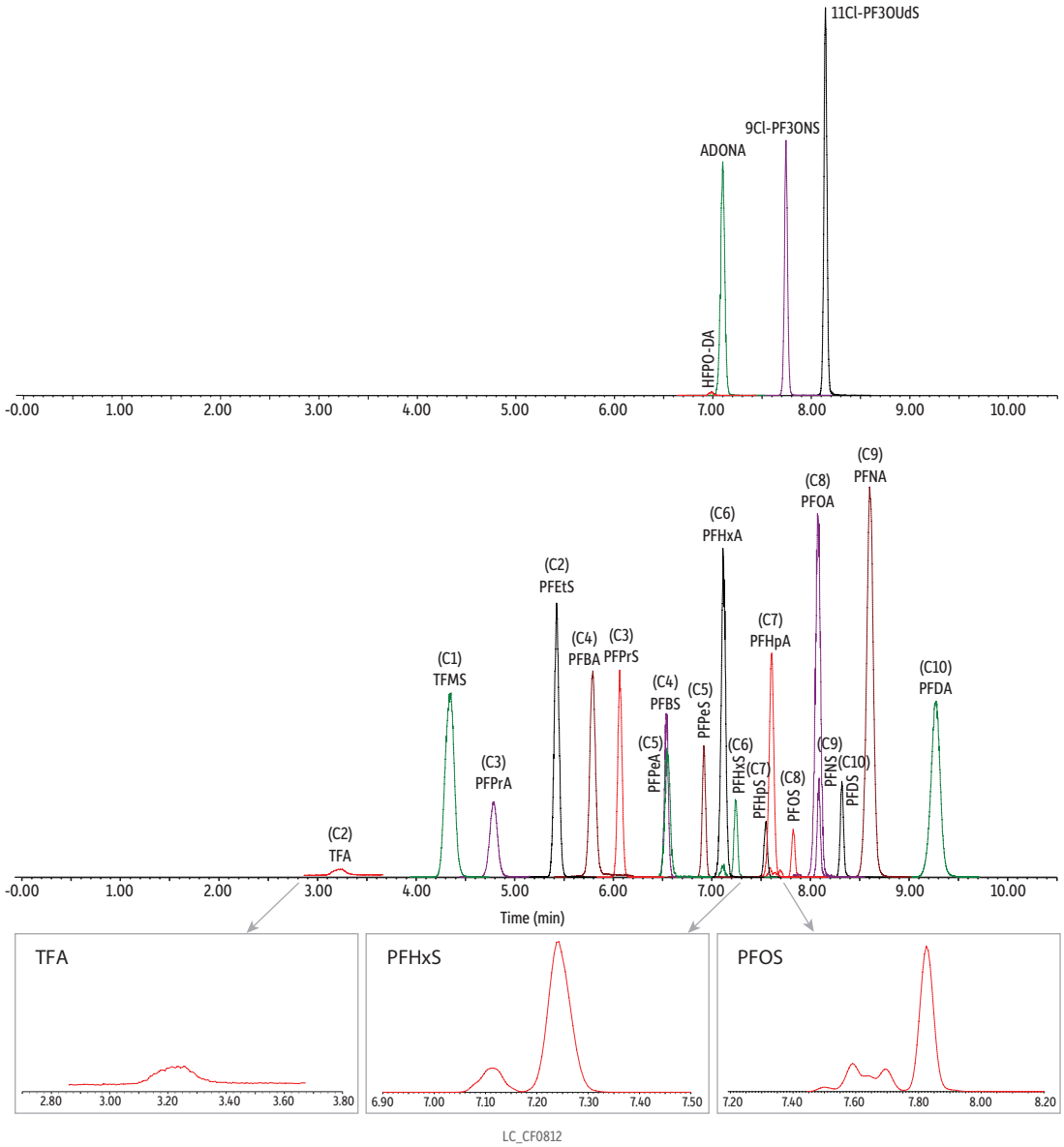
Mode: Scheduled MRM

Results and Discussion

LC-MS/MS Method Development

After exploring various mobile phases and chromatographic conditions, a final method (Figure 2) was established for the analysis of C1 to C10 PFAS in human plasma and serum. The polar embedded Ultra IBD column provided strong retention and good separation of early eluting, ultrashort-chain PFAS analyzed under reversed-phase conditions. More important, the extensive retention of ultrashort-chain PFAS, especially for the first-eluted analyte (TFA), led to reduced matrix interferences. Matrix impact was further minimized by using stable isotopes as internal standards to correct for any matrix interference during quantification. The MS/MS transition parameters and internal standards used for each analyte are provided in Table I.

Figure 2: Analysis of a 10 ppb PFAS Standard



Column	Ultra IBD (cat.# 9175312)
Dimensions:	100 mm x 2.1 mm ID
Particle Size:	3 µm
Pore Size:	100 Å
Temp.:	40 °C
Standard/Sample	PFAS 28 calibration standard (cat.# 30734)
Diluent:	1:2 water:methanol
Conc.:	10 ng/mL
Inj. Vol.:	5 µL
Mobile Phase	
A:	Water, 5 mM ammonium formate, 0.1% formic acid
B:	Acetonitrile

Time (min)	Flow (mL/min)	%A	%B
0.00	0.3	80	20
7.00	0.3	5	95
9.00	0.3	5	95
9.01	0.3	80	20
11.00	0.3	80	20

Max Pressure: 275 bar

Detector	Waters Xevo TQ-S
Ion Mode:	ESI-
Mode:	MRM
Instrument	Waters ACQUITY UPLC I-Class
Sample Preparation	The standard solution (100 µL) was prepared in reverse osmosis water supplemented with 1x phosphate-buffered saline at 10 ng/mL (ppb) in a polypropylene HPLC vial followed by mixing with 200 µL of methanol containing 1.5% formic acid.
Notes	A PFAS delay column (cat.# 27854) was installed before the injector. The peaks of confirmation ions are not displayed in this chromatogram.

Table I: MS Transitions and Analytes Retention Times

Compounds	Retention Time (min)	Precursor Ion	Product Ions*	Cone (V)	Collision (V)	Quantification Internal Standard
Target Analytes						
TFA	3.25	113.03 [M-H]-	69.01	10	10	$^{13}C_3$-PFBA
PFPrA	4.81	162.97 [M-H]-	119.02	10	8	$^{13}C_3$-PFBA
PFBA	5.80	213.03 [M-H]-	168.98	14	8	$^{13}C_3$-PFBA
PFPeA	6.56	262.97 [M-H]-	218.97	2	6	$^{13}C_2$-PFHxA
PFHxA	7.13	313.10 [M-H]-	268.97/118.99	2	8/20	$^{13}C_2$-PFHxA
PFHpA	7.62	363.16 [M-H]-	319.09/169.06	8	10/18	$^{13}C_4$-PFOA
PFOA	8.10	413.10 [M-H]-	368.96/168.90	2	10/16	$^{13}C_4$-PFOA
PFNA	8.62	463.10 [M-H]-	419.01/219.02	4	10/16	$^{13}C_5$-PFNA
PFDA	9.29	513.17 [M-H]-	469.16/219.06	4	12/16	$^{13}C_2$-PFDA
TFMS	4.37	148.97 [M-H]-	79.93/98.92	62	18/18	$^{13}C_3$-PFBA
PFEtS	5.44	198.90 [M-H]-	79.92/98.91	38	22/22	$^{13}C_3$-PFBA
PFPrS	6.08	248.97 [M-H]-	79.92/98.91	2	24/24	$^{13}C_3$-PFBA
PFBS	6.55	298.97 [M-H]-	79.97/98.89	2	26/26	$^{13}C_2$-PFHxA
PFPeS	6.93	349.10 [M-H]-	79.98/98.98	6	32/30	$^{13}C_2$-PFHxA
PFHxS	7.24	398.90 [M-H]-	79.97/98.89	56	32/34	$^{13}C_2$-PFHxA
PFHpS	7.56	449.17 [M-H]-	79.98/98.97	4	42/38	$^{13}C_2$-PFHxA
PFOS	7.82	499.03 [M-H]-	79.92/98.90	8	40/40	$^{13}C_4$-PFOA
PFNS	8.09	549.10 [M-H]-	79.92/98.83	12	42/40	$^{13}C_4$-PFOA
PFDS	8.32	599.17 [M-H]-	79.98/98.83	8	44/46	$^{13}C_5$-PFNA
HFPO-DA	7.01	285.03 [M-COOH]-	169.02/185.02	2	6/16	$^{13}C_2$-PFHxA
ADONA	7.11	376.90 [M-H]-	250.93/84.97	22	12/26	$^{13}C_2$-PFHxA
9Cl-PF3ONS	7.75	530.78 [M-H]-	350.85/82.96	12	26/24	$^{13}C_2$-PFHxA
11Cl-PF3OUdS	8.15	630.78 [M-H]-	450.80/82.95	8	26/32	$^{13}C_5$-PFNA
Extracted Internal Standards						
$^{13}C_3$-PFPrA	4.81	165.97 [M-H]-	120.96	10	11	$^{13}C_3$-PFBA
$^{13}C_4$-PFBA	5.80	217.03 [M-H]-	171.98	2	8	$^{13}C_3$-PFBA
$^{13}C_5$-PFPeA	6.56	267.97 [M-H]-	222.99	2	6	$^{13}C_2$-PFHxA
$^{13}C_5$-PFHxA	7.13	318.03 [M-H]-	272.93	2	7	$^{13}C_2$-PFHxA
$^{13}C_4$-PFHpA	7.62	366.90 [M-H]-	321.93	2	10	$^{13}C_4$-PFOA
$^{13}C_8$-PFOA	8.10	420.97 [M-H]-	375.94	2	10	$^{13}C_4$-PFOA
$^{13}C_9$-PFNA	8.62	471.97 [M-H]-	426.87	4	8	$^{13}C_5$-PFNA
$^{13}C_6$-PFDA	9.29	518.90 [M-H]-	473.87	4	13	$^{13}C_2$-PFDA
$^{13}C_3$-PFHxS	7.24	401.90 [M-H]-	79.97	2	32	$^{13}C_2$-PFHxA
$^{13}C_8$-PFOS	7.82	506.84 [M-H]-	79.97	4	48	$^{13}C_4$-PFOA
Quantitative Internal Standards						
$^{13}C_3$-PFBA	5.80	215.97 [M-H]-	171.97	10	8	
$^{13}C_2$-PFHxA	7.13	314.97 [M-H]-	269.93	8	8	
$^{13}C_4$-PFOA	8.10	416.87 [M-H]-	371.88	2	8	
$^{13}C_5$-PFNA	8.62	467.87 [M-H]-	422.89	16	10	
$^{13}C_2$-PFDA	9.29	514.87 [M-H]-	469.84	8	10	

*Quantifier ion/qualifier ion. No qualifier ion was used for TFA, PFPrA, PFBA, and PFPeA because only one product ion could be identified for each.

Linearity

With quadratic regression (1/x weighted), all analytes showed acceptable linearities with r2 >0.995 and deviations <20%. Table II shows the specific linear range for each analyte, ranging from 0.05 ppb to 40 ppb, with variation occurring at the lowest calibration concentration.

Accuracy and Precision

Accuracy and precision for most analytes were assessed at 0.4, 2, and 10 ppb. However, for HFPO-DA and TFA, the evaluation was conducted at 2, 10, and 30 ppb because 0.4 ppb was below the linear range of these compounds. Three batches of samples were prepared and analyzed on different days, totaling nine replicates at each fortification level. The average recoveries and relative standard deviations (%RSD) are presented in Table II. All analytes exhibited recovery values within the range of 82.3–115% across the three fortification levels. Satisfactory method precision was demonstrated with %RSD values ranging from 0.965 to 11.3%. Additionally, the results indicated that all EIS had recovery values within 20% of the nominal concentration. The use of EIS as an additional quality control measure enhanced the reliability and robustness of the method.

Based on the results of the accuracy and precision experiments, the method LOQ was set as the lowest concentration of the standard calibration curve for each analyte. The method LOD was estimated from the analysis of fortified FBS and was defined by a peak signal-to-noise ratio of 3:1.

Measurement of C1–C10 and Alternative PFAS in NIST 1950 and 1957 SRMs

Six preparations of each SRM were analyzed with the developed LC-MS/MS method. The results indicated that all measured EIS concentrations fell within 20% of the nominal concentration. Moreover, Table III illustrates that the average experimental concentrations of most PFAS closely matched the reference concentrations, with deviations within 20%. Although the measured PFDA concentration in NIST SRM 1957 exhibited a slightly higher deviation of 26%, it remained within the deviation range of the reference concentration. These results demonstrated that the established method was suitable for accurate measurement of PFAS—including ultrashort-chain PFAS—in both human plasma and serum samples. In addition to the reference PFAS, other measurable PFAS were also reported in Table III.

Table II: Linearity, LOD, Accuracy, and Precision Results for Fortified Fetal Bovine Serum Samples

			Average Recovery (%RSD)			
			Fortified Concentration (ng/mL)			
Analytes	Linearity Range (ng/mL)	LOD (ng/mL)	0.4	2	10	30
^{13}C-TFA	0.50 - 40	0.1250*	—	90.6 (9.28)	98.0 (2.99)	100 (10.7)
PFPrA	0.25 - 40	0.0102	108 (2.53)	115 (0.965)	105 (6.99)	—
PFBA	0.10 - 40	0.0222	104 (5.57)	109 (1.75)	104 (1.51)	—
PFPeA	0.10 - 40	0.0125	97.4 (3.25)	93.3 (4.19)	89.1 (5.57)	—
PFHxA	0.10 - 40	0.0098	99.2 (2.46)	109 (4.65)	102 (6.31)	—
PFHpA	0.10 - 40	0.0050	86.7 (5.37)	99.2 (2.04)	89.2 (1.80)	—
PFOA	0.10 - 40	0.0051	94.8 (8.24)	107 (5.30)	95.6 (3.35)	—
PFNA	0.10 - 40	0.0012	96.2 (1.44)	111 (1.87)	99.1 (2.62)	—
PFDA	0.10 - 40	0.0083	93.6 (1.93)	102 (2.03)	95.5 (3.64)	—
TFMS	0.05 - 40	0.0070	89.4 (7.33)	88.8 (3.80)	91.9 (3.19)	—
PFEtS	0.05 - 40	0.0020	98.0 (2.62)	103 (1.47)	99.3 (2.26)	—
PFPrS	0.05 - 40	0.0030	98.1 (8.18)	108 (4.23)	98.9 (4.15)	—
PFBS	0.05 - 40	0.0124	88.0 (8.84)	94.1 (4.95)	86.5 (6.17)	—
PFPeS	0.10 - 40	0.0031	94.8 (4.57)	100 (8.05)	94.3 (5.43)	—
PFHxS	0.10 - 40	0.0115	85.8 (7.88)	96.0 (10.0)	92.2 (8.98)	—
PFHpS	0.10 - 40	0.0088	92.5 (6.75)	99.8 (6.45)	93.4 (5.74)	—
PFOS	0.10 - 40	0.0200	97.8 (8.66)	97.9 (7.01)	95.9 (3.37)	—
PFNS	0.10 - 40	0.0129	92.1 (7.98)	94.2 (4.43)	91.9 (2.78)	—
PFDS	0.10 - 40	0.0111	92.6 (8.20)	82.3 (3.48)	87.6 (3.55)	—
HFPO-DA	0.50 - 40	0.1875	—	99.9 (11.3)	91.1 (8.95)	90.4 (6.13)
ADONA	0.10 - 40	0.0035	90.4 (7.14)	106 (4.67)	95.7 (4.25)	—
9Cl-PF3ONS	0.10 - 40	0.0031	95.8 (4.20)	93.7 (5.12)	93.8 (6.71)	—
11Cl-PF3OUdS	0.10 - 40	0.0023	106 (5.10)	84.5 (4.20)	97.2 (4.86)	—

*For non-labeled TFA

Table III: Quantification of PFAS in NIST 1950 and 1957 SRMs

Analytes	Reference Conc. (ng/mL)	Experimental Avg. Conc. (ng/mL)	Experimental Precision (%RSD)	Relative Concentration (%)**
NIST SRM 1950				
PFOA	3.27 ± 0.06	3.12	3.70	95.4
PFNA	0.720 ± 0.028	0.85	0.74	117
PFDA	0.322 ± 0.007	0.30	3.47	91.6
PFHxS	3.25 ± 0.08	2.91	6.26	89.5
PFOS	10.64 ± 0.13	12.57	2.92	118
TFA	—	5.74	4.45	—
PFPrA	—	0.26	6.90	—
PFHpA	—	0.23	3.04	—
TFMS	—	0.08	3.95	—
PFPeS	—	0.15	4.31	—
PFHpS	—	0.36	4.90	—
PFDS	—	0.10	4.64	—
NIST SRM 1957*				
PFHpA	0.305 ± 0.051	0.28	2.16	92.1
PFOA	5.00 ± 0.44	4.21	1.91	84.2
PFNA	0.878 ± 0.077	0.77	1.38	87.9
PFDA	0.39 ± 0.12	0.29	2.69	74.4
PFHxS	4.00 ± 0.83	3.35	9.88	83.8
PFOS	21.1 ± 1.3	20.46	3.81	97.0
TFA	—	3.22	3.79	—
TFMS	—	0.07	0.10	—
PFPeS	—	0.10	7.97	—
PFHpS	—	0.48	6.20	—
PFDS	—	0.10	4.23	—

*The reference concentration for NIST SRM 1957 is presented as mass fraction (µg/kg).
**Relative concentration = (experimental concentration/reference concentration) x 100

Conclusions

A simple, reliable workflow was established in this study to incorporate ultrashort-chain PFAS analysis into a method that also included longer-chain PFAS that are commonly monitored in human plasma and serum. The method utilized a polar-embedded Ultra IBD column to increase chromatographic retention of these small polar analytes, and the results demonstrated that the method was rugged, accurate, and precise. Most important, this method can offer a valuable tool for gaining insights into human exposure to these emergent ultrashort-chain PFAS. Visit www.restek.com/PFAS for additional products, methods, and technical resources.

PFAS Delay Column

- Traps system-related PFAS, preventing interference and ensuring accurate trace-level analysis of PFAS in samples.
- Universal compatibility: works with
  - any HPLC or UHPLC up to 15,000 psi (1034 bar);
  - both FPP and SPP analytical columns; and
  - all stationary phases.
- Highly retentive of system-related PFAS; no breakthrough even with extended equilibration times.
- Easy installation with standard fittings.

Catalog No.	Product Name	Units
27854	PFAS Delay Column, 5 µm, 50 x 2.1 mm HPLC Column	ea.

Ultra IBD HPLC Column

The Restek IBD is a polar-embedded column that acts as a strong hydrogen bonder and may be the most versatile column available today. With a unique polar group, this column is very retentive and selective for acids. It also provides symmetrical peak shape for strong bases. Restek's IBD is compatible with 100% aqueous mobile phases and can be used under reversed-phase or HILIC conditions to retain very polar, ionic compounds in highly organic mobile phases.

Catalog No.	Product Name	Units
9175312	Ultra IBD HPLC Column, 3 µm, 100 mm x 2.1 mm	ea.

PFAS 28 Calibration Standard

Contains:
11-chloroeicosafluoro-3-oxaundecane-1sulfonic acid (11Cl-PF3OUdS) (763051-92-9)
1*H*,1*H*,2*H*,2*H*-Perfluorodecane sulfonic acid (8:2 FTS) (39108-34-4)
1*H*,1*H*,2*H*,2*H*-Perfluorohexane sulfonic acid (4:2 FTS) (757124-72-4)
1*H*,1*H*,2*H*,2*H*-Perfluorooctane sulfonic acid (6:2 FTS) (27619-97-2)
4,8-dioxa-3*H*-perfluorononanoic acid (ADONA) (919005-14-4)
9-chlorohexadecafluoro-3-oxanonane-1-sulfonic acid (9Cl-PF3ONS) (756426-58-1)
2-(Heptafluoropropoxy)2,3,3,3tetrafluoropropionic acid (HFPO-DA) (13252-13-6)
N-ethylperfluoro-1-octanesulfonamidoacetic acid (NEtFOSAA)* (2991-50-6)
N-methylperfluoro-1-octanesulfonamidoacetic acid (NMeFOSAA)* (2355-31-9)
Perfluoro-1-decanesulfonic acid (PFDS) (335-77-3)
Perfluoro-1-nonanesulfonic acid (PFNS) (68259-12-1)
Perfluoro-1-octanesulfonamide (FOSA) (754-91-6)
Perfluoro-1-pentanesulfonic acid (PFPeS) (2706-91-4)
Perfluorobutanesulfonic acid (PFBS) (375-73-5)
Perfluorobutanoic acid (PFBA) (375-22-4)
Perfluorodecanoic acid (PFDA) (335-76-2)
Perfluorododecanoic acid (PFD0A) (307-55-1)
Perfluoroheptanesulfonic acid (PFHpS) (375-92-8)
Perfluoroheptanoic acid ((PFHpA) (375-85-9)
Perfluorohexanesulfonic acid (PFHxS)* (355-46-4)
Perfluorohexanoic acid ((PFHxA) (307-24-4)
Perfluorononanoic acid (PFNA) (375-95-1)
Heptadecafluorooctanesulfonic acid (PFOS)* (1763-23-1)
Perfluorooctanoic acid (PFOA)* (335-67-1)
Perfluoropentanoic acid (PFPeA) (2706-90-3)
Perfluorotetradecanoic acid (PFTeDA) (376-06-7)
Perfluorotridecanoic acid (PFTrDA) (72629-94-8)
Perfluoroundecanoic acid (PFUnA) (2058-94-8)
*Technical grade compound containing both branched and linear isomers; see certificate for details.

Catalog No.	Concentration	Solvent	Volume	Units
30734	1 µg/mL	Methanol (1 mM KOH)/2-Propanol (98:2)	1 mL/ampul	ea.

Big Mouth Step Screw-Thread Vials

Catalog No.	Product Name	Units
24626	Big Mouth Step Screw-Thread Vials with Grad Marking Spot, 2.0 mL, 12 x 32 mm, 10 mm/425 Thread (Vial Only), Clear	100-pk.

Vial Inserts, Polypropylene

Catalog No.	Product Name	Units
24518	Vial Inserts, Polypropylene, Big Mouth w/Bottom Spring, 250 µL	100-pk.

Survival Kit for HPLC, Stainless Steel

For start-up and maintenance in all HPLC systems.

The stainless-steel survival kit contains a wide range of tubing, fittings, and tools necessary to set up and maintain your HPLC system: a selection of lengths and IDs of 1/16-inch tubing, nuts, ferrules, a ValvTool wrench, and a zero-dead-volume union.

Catalog No.	Product Name	Units
25097	Survival Kit for HPLC	kit

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Pure Chromatography

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