Application Note

Environmental

Determination of 40 PFAS in Soil Following EPA 1633 Method Guidance

Using the Agilent Captiva EMR PFAS Food I passthrough cleanup and LC/MS/MS detection

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Abstract

This application note describes the development and validation of a multiresidue method for analyzing 40 per- and polyfluoroalkyl substances (PFAS) in soil. The method employs QuEChERS extraction followed by enhanced matrix removal (EMR) mixed-mode passthrough cleanup using Agilent Captiva EMR PFAS Food I cartridges (680 mg), and subsequent LC/MS/MS detection. It features streamlined and efficient sample preparation, sensitive LC/MS/MS analysis, and reliable quantitation based on neat standard calibration curves. Validated was performed in accordance with U.S. Environmental Protection Agency (EPA) Method 1633 quality control guidance for quantitative analysis for PFAS in environmental solids[1], meeting all specified quantification acceptance criteria.

Introduction

The determination of PFAS residues in environmental solid, such as soil and sediment, is a critical approach for monitoring and regulating environmental PFAS contamination. In 2021, the U.S. EPA published Method 1633 for the quantitative analysis of 40 PFAS compounds in aqueous, solid, biosolid, and tissue samples using LC/MS/MS.[1] The method involves extraction of solid samples with basic methanol (MeOH) followed by matrix cleanup using carbon-based materials and weak anion exchange (WAX) solid phase extraction (SPE). The original matrix cleanup process was further streamlined by using a dual-phase SPE cartridge containing both carbon and WAX sorbents—either stacked or blended. This approach effectively consolidated two cleanup steps into one, reducing the risk of contamination, enhancing method reproducibility, and saving time. The improved method for PFAS in soil and sediment was demonstrated using blended Agilent Bond Elut PFAS WAX/Carbon S SPE cartridges.[2]

The QuEChERS extraction followed with EMR mixed-mode passthrough cleanup demonstrated as a streamlined approach with acceptable quantitation performance in environmental PFAS analysis in complex matrices such as biological tissue.[3,4] The objective of this study was to apply this approach to the analysis of 40 PFAS analytes in solid and to validate the method in accordance with EPA Method 1633 quality control guidance to meet the acceptance criteria. LC/MS/MS detection and quantitation were performed using the Agilent 6495D system.

Experimental

Chemicals and reagents

Native PFAS, isotopically labeled EIS, and NIS stock solutions were obtained from Wellington Laboratories (Guelph, Ontario, Canada). The concentrations of individual compounds in these stock solutions vary and are detailed in Appendix Table 1 from a previous application note.[4] Methanol (MeOH), acetonitrile (ACN), and isopropyl alcohol (IPA) were purchased from VWR (Radnor, PA, USA). Acetic acid and ammonium acetate were procured from MilliporeSigma (Burlington, MA, USA).

Solutions and standards

Native PFAS, EIS, and NIS spiking solutions were prepared by diluting the corresponding stock solutions with MeOH. The concentration of native PFAS targets in the native spiking solution was ≥ 25 ng/mL in MeOH. EIS compounds were prepared in two spiking solutions: EIS spiking I at ≥ 5 ng/mL and EIS spiking II at ≥ 25 ng/mL in MeOH. NIS compounds were spiked at ≥ 5 ng/mL in MeOH. These concentrations reflect the lowest concentration compounds in the stock solutions; other compounds in the mixture were present at proportionally higher concentrations based on their respective stock solution levels.

The native PFAS spiking, EIS spiking I, and NIS spiking solutions were used to prepare neat calibration standards at the following concentrations for native PFAS targets: 0.025, 0.05, 0.1, 0.2, 0.5, 1, 2.5, 5.0, and 10.0 ng/mL in ACN containing 1% acetic acid (AA). EIS and NIS compounds were spiked at 0.1 ng/mL. As with the spiking solutions, these calibration levels correspond to the lowest concentration compounds, with others proportionally higher.

All standards were stored at 4 °C and used within two weeks. For routine calibration curve generation, aliquots of the calibration solutions were transferred to vials with polypropylene (PP) inserts for instrument injection.

The ACN with 1% AA extraction solvent was prepared by adding 10 mL of glacial acetic acid to 990 mL of ACN and stored at room temperature. LC mobile phase A was 5 mM ammonium acetate (NH_4OAc) in water, and mobile phase B was ACN. Needle wash solvents included IPA, water, and ACN.

Equipment and material

The study was performed using an Agilent 1290 Infinity II LC system consisting of an Agilent 1290 Infinity II binary pump (G4220A), an Agilent 1290 Infinity II high-performance autosampler (G4226A), and an Agilent 1290 Infinity II thermostatted column compartment (G1316C). The LC system was coupled to an Agilent triple quadrupole LC/MS system (G6495D) equipped with an Agilent Jet Stream iFunnel electrospray ion source. Agilent MassHunter workstation software was used for data acquisition and analysis.

Other equipment used for sample preparation included:

- Centra CL3R centrifuge (Thermo IEC, MA, USA)
- Geno/Grinder (Metuchen, NJ, USA)
- Multi Reax test tube shaker (Heidolph, Schwabach, Germany)
- Pipettes and repeater (Eppendorf, NY, USA)
- Agilent positive pressure manifold 48 processor (PPM-48; part number 5191-4101)
- Ultrasonic cleaning bath (VWR, PA, USA)

The 1290 Infinity II LC system was modified using an Agilent InfinityLab PFC-free HPLC conversion kit (part number 5004-0006), including an InfinityLab PFC delay column, 4.6 × 30 mm (part number 5062-8100).

Chromatographic separation was performed using an Agilent ZORBAX RRHD Eclipse Plus C18, 95Å, 2.1 × 100 mm, 1.8 µm (part number 959758-902) and a ZORBAX RRHD Eclipse Plus C18, 2.1 mm, 1.8 µm, 1200-bar pressure limit, and an Agilent UHPLC guard column (part number 821725-901).

The sample preparation and other consumables used included:

- Agilent Bond Elut QuEChERS EN extraction kit, EN 15662 method, buffered salts, ceramic homogenizers (part number 5982-5650CH)
- Agilent Captiva EMR PFAS Food I cartridges, 6 mL cartridges, 680 mg (part number 5610-2231)
- PP snap caps and vials, 1 mL (part numbers 5182-0567 and 5182-0542)
- PP screw cap style vials and caps, 2 mL (part numbers 5191-8121 and 5191-8151)
- Tubes and caps, 50 mL, 50/pk (part number 5610-2049)
- Tubes and caps, 15 mL, 100/pk (part number 5610-2039)

All the consumables used in the study were tested and verified for acceptable PFAS cleanliness.

LC/MS/MS instrument conditions

Instrument method conditions were identical to those described previously.[4]

Sample preparation procedure

Michigan reed sedge peat was purchased locally. This topsoil was selected as a representative and challenging matrix due to its high complexity and rich organic content. The percentage solid of the sample was determined as ~ 50% using the instructions provided in EPA Method 1633 (sec. 11.1.2).

For each sample, an aliquot of 5 g soil sample (dry-weight) was weighed into a 50 mL PP tube. Native PFAS and EIS standards were spiked into all prespiked quality control (QC) samples, while EIS was spiked to matrix blanks (MBs). For procedure blanks (PBs), 5 mL of water was used with EIS being spiked.

Table 1 summarizes the spiking details for prespiked samples. Due to a two-fold dilution introduced during sample preparation, final extract concentrations were corrected accordingly. To ensure accurate quantitation using neat calibration standards prepared in solvent, it was critical to maintain theoretical EIS and NIS concentrations equivalent to those in the calibration standards (0.1 ng/mL in the final ACN extract). After spiking, all solid samples were vortexed for 2 to 3 minutes and allowed to equilibrate for 30 minutes prior to extraction. The detailed extraction procedure is illustrated in Figure 1.

Following sample extraction and cleanup, sample eluent was vortexed and a 1 mL aliquot was transferred into a 2 mL PP vial. To this, an aliquot of 20 µL of NIS spiking solution (5 ng/mL) was added. The vial was capped and vortexed for 10 to 20 seconds to ensure thorough mixing. All prepared samples were then ready for injection into the LC/TQ system for analysis.

Table 1. Prespiked sample spiking with native PFAS targets and EIS compounds.

Samples	Native PFAS Targets Spiking				EIS Compounds Spiking				Replicates (N)
	Spiking Solution and Conc. (ng/mL)	Spiking Volume (µL)	Conc. in Sample (µg/kg)	Conc. in Sample Extract (ng/mL)	Spiking Solution and Conc. (ng/mL)	Spiking Volume (µL)	Conc. in Sample (µg/kg)	Conc. in Sample Extract (ng/mL)	
PB	NA	NA	NA	NA	EIS spiking solution II (25 ng/mL)	40	0.2	0.1	2
MB	NA	NA	NA	NA		40	0.2	0.1	7
QC-LOQ	PFAS spiking solution (25 ng/mL)	10	0.05	0.025		40	0.2	0.1	6
QC-Low (12.5x LOQ)		40	0.2	0.1		40	0.2	0.1	6
QC-Mid (125x LOQ)	PFAS stock solution (250 ng/mL)	40	2	1		40	0.2	0.1	6

NA = not applicable

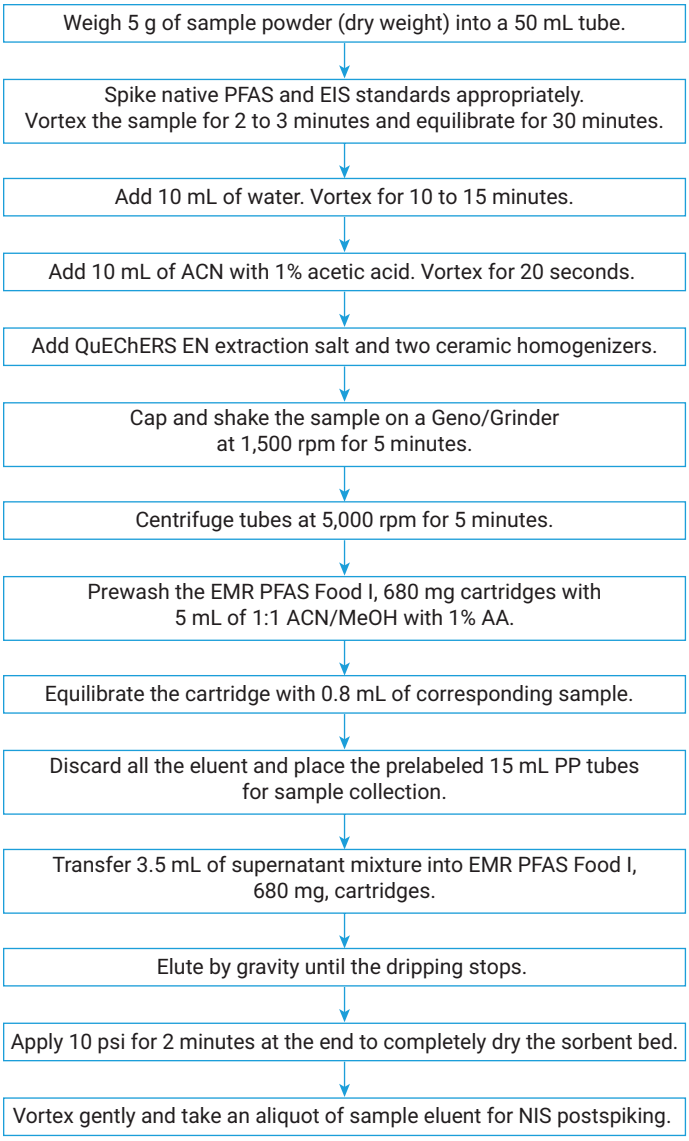

Figure 1. Solid sample preparation procedure using QuEChERS extraction followed by EMR mixed-mode passthrough cleanup on the Agilent Captiva EMR PFAS Food I, 680 mg cartridge.

Results and discussion

LC/TQ instrument method

Good peak distribution and separation across the retention time window, along with baseline separation for critical PFOS isomers and isobaric cholic acids potentially coming from matrix, were demonstrated previously.[4]

Environmental solid matrix

An environmental solid matrix refers to solid materials—such as soil, sediment, sludge, and other waste substances—that serve as a medium for environmental contaminants or pollutants. However, according to the definition in EPA Method 1633[1], the applicable solid matrices are soil, biosolids, and sediment. Due to the inherent complexity of biosolids, the method and its associated quality control guidance for analyte determination in biosolids are treated separately from those for soil and sediment. Therefore, for the purposes of this study, the solid matrices considered under method applicability are restricted to soil and sediment. Complex topsoil matrix was employed for method validation and performance demonstration. The validated method can then be extended to other environmental solid matrices such as sediment.

Sample preparation procedure

The sample preparation workflow using QuEChERS extraction followed by EMR mixed-mode passthrough cleanup significantly streamlined the overall process. The ACN-based solvent extraction followed with salt partitioning, enhanced extraction efficiency and matrix cleanup by retaining polar co-extractives in the aqueous phase. Compared to the extended extraction procedure in EPA Method 1633, the QuEChERS approach shortened the process time without compromising the extraction efficiency. Additionally, solvent usage was reduced from a total of 25 mL to 10 mL per sample, and the drying step prior to SPE loading was eliminated.

The EMR mixed-mode passthrough cleanup further simplified the matrix removal process, offering efficient and selective cleanup. For soil and sediment matrix, lipids/fats are not a significant challenge. Instead, the humic acids and pigments are the main matrix challenge. Therefore, Captiva EMR PFAS Food I, 680 mg, cartridges were applied to enhance the soil matrix cleanup. This approach replaced the traditional SPE workflow—consisting of conditioning, equilibrating, loading, washing, and eluting—with a prewashing, equilibrating, and loading passthrough procedure.

Originally developed for PFAS analysis in food matrices, the QuEChERS-EMR workflow demonstrated strong potential for application to environmental solid matrices. In a comparison study, an analyst required only 2 to 3 hours to prepare a batch of 10 to 15 samples using the QuEChERS-EMR method, whereas the traditional SPE-based method took 5 to 7 hours for the same sample quantity. This represents time savings of over 50%. Solvent and consumable usage were also reduced by 50% or more, contributing to improved laboratory productivity and cost efficiency.

Quantitation method

The quantitation approach used in EPA Method 1633 is based on the calibration curves prepared in solvent with the use of both isotopic EIS and NIS compounds. The EIS compounds are used for target quantitation and NIS compounds are used for EIS recovery calculations. The use of EIS and NIS provides a much more accurate quantitation on native PFAS analytes, as well as the simultaneous method critical performance assessment, including recovery and matrix effect, in the same batch.

The 400-fold dynamic range of calibration curves were established for all 40 PFAS analytes, with the LOQ spanning from 0.025 to 0.625 ng/mL in extraction solvent, which is ACN with 1% AA. All the neat calibration curves were established using linear regression with $1/x^2$ weight, generating a $R^2 > 0.99$ or relative standard error (RSE) < 20%.

Method validation

The developed method was validated for the quantitative determination of 40 PFAS targets in the solid matrix, specifically soil and sediment. Due to a two-fold dilution introduced during sample preparation, the effective calibration range in the actual solid matrix is twice that of the neat standards. Because PFAS concentrations vary across the stock solution, the dynamic calibration ranges differ among analytes and are summarized in Table 2.

Method accuracy and precision were evaluated using three levels of prespiked QC samples, at six replicates for each level. Additionally, seven replicates of matrix blanks were prepared and analyzed. All PFAS compounds positively detected in the matrix blanks were confirmed based on retention time and qualifiers ions and were employed to correct for matrix background in the calculation of spiking recoveries.

Table 2. Parameters for 40 PFAS quantitation in solid using QuEChERS-EMR method, and comparison with MDLs and LOQs reported EPA 1633 results.[1]

Target	RT (min)	Quantification Reference IS	Calc. Range (µg/kg)	Detected in MB (µg/kg)	Calc. MDL (µg/kg)	Pooled MDL by EPA 1633 (µg/kg)	Calc. LOQ or Exper. LOQ (µg/kg)	Estimated LOQ Range by EPA 1633 (µg/kg)
PFBA	3.29	$^{13}C_4$-PFBA	0.2–80	0.01	0.006	0.15	0.2	0.64–1.6
PFMPA	3.81	$^{13}C_4$-PFBA	0.1–40	ND	0.006	0.07	0.1	0.32–0.8
3:3 FTCA	3.99	$^{13}C_5$-PFPeA	0.25–100	0.002	0.008	0.23	0.25	0.8–5.0
PFPeA	4.36	$^{13}C_5$-PFPeA	0.1–40	0.047	0.012	0.07	0.04	0.32–0.8
PFMBA	4.61	$^{13}C_5$-PFPeA	0.1–40	ND	0.01	0.05	0.1	0.32–0.8
4:2 FTS	4.92	$^{13}C_2$-4:2 FTS	0.2–80	ND	0.021	0.2	0.2	0.64–1.5
NFDHA	5.43	$^{13}C_5$-PFHxA	0.1–40	ND	0.013	0.2	0.1	0.32–0.8
PFHxA	5.29	$^{13}C_5$-PFHxA	0.05–20	0.039	0.005	0.06	0.014	0.16–0.4
PFBS	5.43	$^{13}C_3$-PFBS	0.05–20	0.021	0.006	0.05	0.01	0.16–0.4
HFPO-DA	5.72	$^{13}C_2$-HFPO-DA	0.2–80	ND	0.013	0.25	0.2	0.64–1.6
5:3 FTCA	6.02	$^{13}C_4$-PFHpA	1.25–500	ND	0.04	0.86	1.25	4–10
PFEESA	6.05	$^{13}C_4$-PFHpA	0.1–40	ND	0.004	0.08	0.1	0.32–0.7
PFHpA	6.57	$^{13}C_4$-PFHpA	0.05–20	0.007	0.001	0.05	0.05	0.16–0.4
PFPeS	6.89	$^{13}C_4$-PFHpA	0.05–20	0.004	0.003	0.08	0.05	0.16–0.4
ADONA	7.10	$^{13}C_8$-PFOA	0.2–80	ND	0.015	0.23	0.2	0.64–1.5
6:2 FTS	7.41	$^{13}C_2$-6:2 FTS	0.2–80	ND	0.061	0.39	0.2	0.64–1.5
PFOA Isomers	7.80	$^{13}C_8$-PFOA	0.05–20	0.107	0.005	0.07	0.008	0.16–0.4
PFHxS Isomers	8.22	$^{13}C_3$-PFHxS	0.05–20	0.019	0.003	0.08	0.05	0.16–0.4
7:3 FTCA	9.11	$^{13}C_3$-PFHxS	1.25–500	0.033	0.024	0.87	1.25	4–10
PFNA Isomers	9.27	$^{13}C_9$-PFNA	0.05–20	0.053	0.002	0.14	0.006	0.16–1.3
PFHpS	10.12	$^{13}C_9$-PFNA	0.05–20	ND	0.003	0.07	0.05	0.16–0.4

Target	RT (min)	Quantification Reference IS	Calc. Range (µg/kg)	Detected in MB (µg/kg)	Calc. MDL (µg/kg)	Pooled MDL by EPA 1633 (µg/kg)	Calc. LOQ or Exper. LOQ (µg/kg)	Estimated LOQ Range by EPA 1633 (µg/kg)
8:2 FTS	10.34	$^{13}C_2$-8:2 FTS	0.2–80	ND	0.015	0.31	0.2	0.64–1.5
PFDA	10.94	$^{13}C_6$-PFDA	0.05–20	ND	0.002	0.06	0.05	0.16–0.4
N-MeFOSAA Isomers	10.93	D_3-N-MeFOSAA	0.05–20	ND	0.008	0.08	0.05	0.16–0.4
PFOS Isomers	11.20	$^{13}C_8$-PFOS	0.05–20	0.189	0.027	0.07	0.085	0.16–0.4
N-EtFOSAA Isomers	11.20	D_5-N-EtFOSAA	0.05–20	ND	0.011	0.08	0.05	0.16–0.4
PFUnA	11.66	$^{13}C_7$-PFUdA	0.05–20	ND	0.005	0.12	0.05	0.16–0.5
9Cl-PF3ONS	11.81	$^{13}C_7$-PFUdA	0.2–80	ND	0.01	0.22	0.2	0.64–1.5
PFNS	11.94	$^{13}C_7$-PFUdA	0.05–20	ND	0.004	0.07	0.05	0.16–0.4
PFDoA	12.16	$^{13}C_2$-PFDoA	0.05–20	ND	0.004	0.06	0.05	0.16–0.4
PFDS	12.41	$^{13}C_2$-PFDoA	0.05–20	ND	0.003	0.08	0.05	0.16–0.4
PFTrDA	12.58	$^{13}C_2$-PFDoA	0.05–20	ND	0.002	0.07	0.05	0.16–0.4
11Cl-PF3OUdS	12.72	$^{13}C_8$-PFOS	0.2–80	ND	0.015	0.18	0.05	0.64–1.5
PFOSA Isomers	12.73	$^{13}C_8$-PFOSA	0.05–20	ND	0.004	0.04	0.05	0.16–0.4
PFTeDA	12.97	$^{13}C_2$-PFTeDA	0.05–20	ND	0.004	0.05	0.05	0.16–0.4
PFDoS	13.18	$^{13}C_8$-PFOS	0.05–20	ND	0.014	0.06	0.05	0.16–0.4
N-MeFOSE Isomers	13.98	D_7-N-MeFOSE	0.5–200	ND	0.029	0.36	0.5	1.6–4
N-MeFOSA Isomers	14.05	D_3-N-MeFOSA	0.05–20	ND	0.005	0.07	0.05	0.16–0.4
N-EtFOSE Isomers	14.26	D_9-N-EtFOSE	0.5–200	ND	0.018	0.35	0.5	1.6–4
N-EtFOSA Isomers	14.36	D_5-N-EtFOSA	0.05–20	ND	0.003	0.07	0.05	0.16–0.4

ND = Not detectable

Method detection limit (MDL) was calculated following the procedure published by U.S. EPA[5] using Equation 1.

Equation 1. $MDL = SD \times 3.314$

Where SD is the standard deviation of matrix blanks or prespiked LOQ samples. For analytes with positive detections in matrix blanks exceeding 30% of the LOQ level, the SD of seven matrix blanks was applied. For analytes with no detection or with positive detections below 30% of the LOQ level, the SD was derived from six replicates of LOQ samples.

The method's validated LOQ was determined based on the lowest prespiking concentration that met the acceptable criteria for accuracy, precision, and selectivity. In cases where positive detections in matrix blanks interfered with the experimental LOQ spike, the LOQ was instead calculated using Equation 2.[5]

Equation 2. $LOQ_{cal} = SD_{MB} \times 10$

Table 2 summarizes the method MDLs and LOQs obtained using the QuEChERS-EMR approach, alongside the MDLs and LOQs for solid matrices reported in EPA Method 1633.[1] The results demonstrate that the method achieved lower MDLs and LOQs than the reported values for all 40 analytes, indicating enhanced sensitivity and suitability of the new method.

Recoveries of EIS and NIS compounds were evaluated across all 25 matrix samples in the validation batch. Figure 2 presents the average recoveries of these compounds in the solid matrix samples prepared using the QuEChERS-EMR approach. The red dotted lines indicate the acceptance limits for recoveries and RSDs specified in EPA Method 1633 for solids. The purple line displays the recoveries of EIS compounds (24, shown on the left) and NIS compounds (seven, shown on the right), and the purple columns represent the RSDs of EIS and NIS compounds.

Since all EIS and NIS compounds are isotopically labeled ISTDs, they are inherently absent from any natural occurrence in the matrix blank. All EIS and NIS compounds demonstrated recoveries within the established acceptance criteria. The recovery range of 89 to 125% for EIS compounds—excluding 4:2 FTS, 6:2 FTS, and 8:2 FTS—indicates excellent analyte recovery throughout the extraction and matrix cleanup processes. The elevated recoveries (138 to 139%) observed for the FTS compounds are attributed to the typical enhancement effect with this class in the matrix, compounded by the absence of correction due to lack of corresponding NIS compounds from this class. Additionally, the recoveries of 108 to 119% for postspiked NIS compounds confirm that acceptable matrix effects were achieved throughout the entire sample preparation procedure.

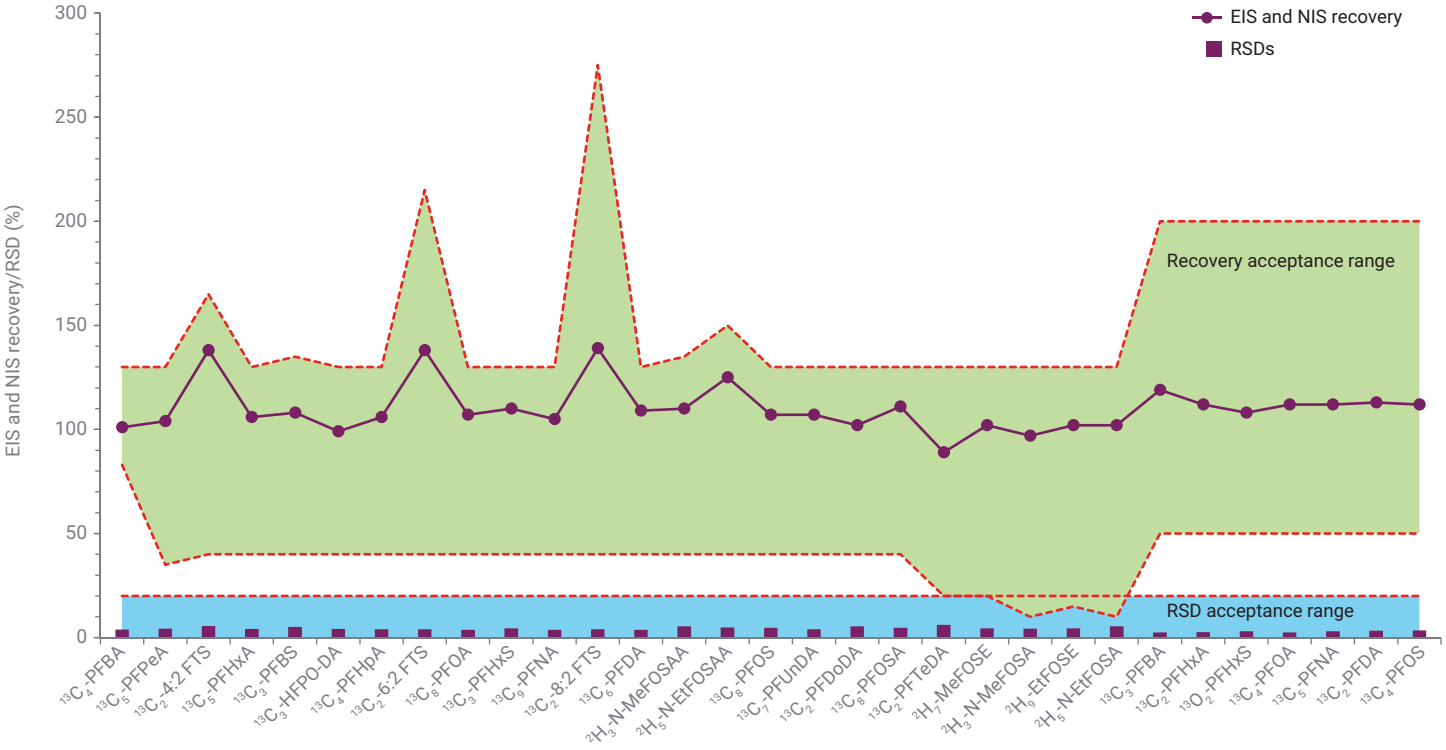

Figure 2. EIS and NIS compound average recoveries in solid validation batch using the QuEChERS-EMR method. The green band in the middle indicates the acceptable range of EIS and NIS recovery, while the blue band at the bottom shows the acceptable range of RSD. The purple line indicates the EIS and NIS recoveries, and purple columns represent the RSD results.

Figure 3 presents the quantitation accuracy and precision results for 40 PFAS targets in solid matrices, based on three levels of prespiked QC samples. The red dotted lines indicate the acceptance limits for recoveries and RSDs as specified in EPA Method 1633 for solids. The three lines represent the recoveries of native analytes, while the three sets of columns display the corresponding RSDs. All PFAS analytes demonstrated acceptable quantitation accuracy, with the exception of PFHpA at the LOQ level due to high positive detection contributed from matrix. Unexpected contamination of 6:2 FTS in low level spiked samples caused the failure of this compound in this level. Quantitation precision was acceptable for all analytes across the three speaking levels, with RSDs below 20%.

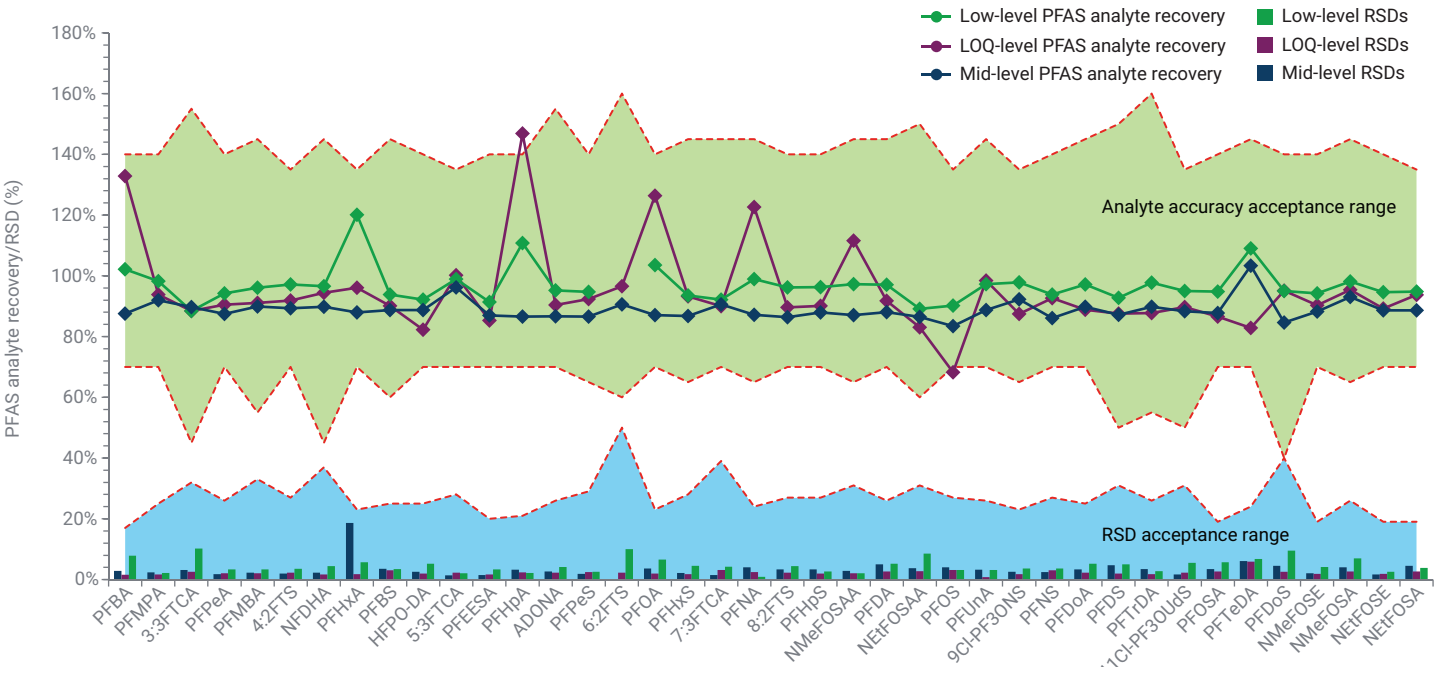

Figure 3. Quantitation accuracy (recovery%) and precision (RSD%) results for analysis of 40 PFAS targets in solids. Three lines indicate PFAS analyte recoveries, and three sets of columns represent the RSD results. Results are color-coded by spiking level: purple = LOQ-level, green = low-level, and blue = mid-level.

Conclusion

A simplified, rapid, and reliable method was developed and validated for the quantitation of 40 PFAS targets in soil using QuEChERS extraction followed by Captiva EMR PFAS Food I passthrough cleanup, with analysis performed via LC/MS/MS under EPA Method 1633 quality control guidelines. Compared to traditional SPE-based sample preparation approaches outlined in EPA Method 1633, the new method offers significant advantages: it reduces preparation time by over 50%, decreases solvent consumption by approximately 80%, and minimizes the use of consumables.

Validation in accordance with EPA Method 1633 quality control criteria confirmed acceptable recoveries for both EIS and NIS compounds, as well as accurate quantitation results of native PFAS analytes. Additionally, the method achieved MDLs and LOQs lower than those reported in EPA Method 1633 guidance. Overall, this approach provides an efficient, cost-effective, and high-performance alternative to conventional sample preparation approaches for PFAS analysis in soil and is extendable to sediment matrix.

When compliance with the SPE-based EPA Method 1633 is required, the standard method using Bond Elut PFAS Carbon S/WAX cartridges demonstrated excellent method performance.[2] For situations with more flexibility in method selection, the QuEChERS-EMR approach offers a streamlined sample preparation workflow that saves time and cost without compromising PFAS quantification performance.

References

1. U.S. Environmental Protection Agency. Method 1633, Revision A: Analysis of Per- and Polyfluoroalkyl Substances (PFAS) in Aqueous, Solid, Biosolids, and Tissue Samples by LC-MS/MS. EPA 820-R-24-007, December 2024. https://www.epa.gov/system/files/documents/2024-12/method-1633a-december-5-2024-508-compliant.pdf (accessed 2025-02-20).
2. Giardina, M. Determination of Per- and Polyfluoroalkyl Substances in Soil and Sediment, *Agilent Technologies application note*, publication number 5994-8290EN, **2025**.
3. Zhao, L.; Xu, C.; Parry, E.; Giardina, M. Determination of Per- and Polyfluoroalkyl Substances in Tissue Using QuEChERS Extraction Followed by Novel Enhanced Matrix Removal Mixed-Mode Passthrough Cleanup with LC-MS/MS Detection. *J. Chromatogr. A* **2025**, *1758*, 466150. DOI: 10.1016/j.chroma.2025.466150.
4. Zhao, L.; Parry E. Determination of 40 PFAS in Tilapia Tissue Following EPA 1633 Method Guidance, *Agilent Technologies application note*, publication number 5994-8232EN, **2025**.
5. Kim, K. R.; Owens, G. 6.21 – Potential for Enhanced Phytoremediation of Landfills Using Biosolids – A Review. *Comprehensive Biotechnology (3rd Edition)* **2011**, *6*, 276–284.

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