Protecting tomorrow—together, we can do it.

PFAS analysis compendium

thermo scientific

Solve more PFAS contaminant challenges together

Introduction

Worldwide demand for quick, simple, precise, and regulatory-compliant per- and polyfluoroalkyl substance (PFAS) testing is becoming more significant than ever. Compliance standards and regulatory requirements continue to evolve and are now more stringent than ever, due to our increased knowledge and heightened awareness of the harmful effects of these so-called 'forever chemicals' on both our environment and human health. It is estimated that more than 15,000 PFAS compounds have been identified from a variety of sources, however, it is unknown how many additional variations exist due to unintentional transformation products. The polluting of rivers and lakes through to the safety our drinking water and or food means that detecting these chemically stable compounds has never been more important.

Regulatory overview

Global regulatory bodies are investigating the prevalence of PFAS compounds in a variety of matrices. The main PFAS under scrutiny are PFOA (perfluorooctanoic acid) and PFOS (perfluorooctanesulfonic acid), due to their toxicity, persistence and widespread use, followed by the numerous different combinations and permutations of PFAS compounds introduced since the discovery of the original synthetic polymer back in the 1940s.

In the Stockholm Convention for persistent organic pollutants (POPs), PFOA has been restricted since 2009 and PFOS banned since 2019, with a ban on PFHxS and its derivatives, implemented in 2022. Other regional agencies include the United States Environmental Protection Agency (EPA), in Europe REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) and the EU DWD (European Drinking Water Directive EU2020/2184) lay out restrictions as does the European Food Safety Authority (EFSA) citing maximum residue levels (MRLs). Global regulations are rapidly evolving, encompassing more matrices and added target PFAS compounds for analysis.

PFAS problems

Human exposure to PFAS substances is widespread and its effects through bioaccumulation are still being studied. PFAS is and has been used in a large number of household items and products and as such exposure can come from different sources. This includes food packaging materials, commercial household products, non-stick cookware, certain workplace environments and even water-resistant clothing and cosmetics. Each of these sources presents unique challenges to analytical testing laboratories.

Analytical challenges

This compendium was compiled with PFAS testing laboratories in mind. Labs must meet new challenges posed by regulatory agencies that have been adding an increasing number of PFAS to their targeted methodologies with required low part-per-trillion (ppt) reporting limits based on health advisory information. In addition, laboratories are often tasked to screen for unknown PFAS, referred to as non-targeted analysis (NTA). This allows for PFAS 'fingerprinting' for sites that have been contaminated with chemical mixtures and could contain thousand of compounds beyond any targeted analyte scope.

The optimal method choice will vary depending on the matrix and goals of the respective analysis. Another challenge faced by laboratories involved in PFAS testing is background contamination. This can be especially problematic with sampling equipment and lab equipment that may be already contaminated with PFAS compounds either through manufacturing or handling. Manual sample preparation is often a readily available option, however automated sample preparation solutions that can be adapted to a wide variety of matrices reduce labor cost and background contamination due to less sample handling with the added benefit of faster throughput. We understand the need for laboratories to have ready-to-go complete workflow solutions that address both current and future PFAS testing challenges.

Discover strategies to help you with the detection and quantification of known PFAS through targeted LC-MS/MS analysis on our range of UHPLC systems, along with our comprehensive portfolio of reagents and consumables specifically selected for your most demanding PFAS applications.

The discovery and identification of unknown PFAS compounds can be challenging when reference standards are not available. Technology is available that enables untargeted and retrospective analyses, allowing you to advance your own PFAS testing capabilities. Screening of samples for total adsorbable organic fluorine (AOF) using combustion ion chromatography (CIC) can provide valuable insight into potentially 'hot' samples that may be contaminated with PFAS. CIC can be used in combination with non-targeted methods using high resolution accurate mass (HRAM) to identify unknowns with greater confidence and lead to better understanding of PFAS in your samples.

Now is the time to future proof your PFAS testing laboratory, with robust, high-throughput workflows that meet and exceed stringent standards. From water and soil testing to a wide variety of other matrices, our PFAS testing solutions are the way forward.

Discover new approaches to challenging PFAS testing issues from industry experts. Understand how a combination of automation, a wide range of advanced technologies, and proven workflow solutions can be applied to improve productivity and certainty in your results.

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PFAS in water

The presence of PFAS in ground, surface, and wastewater supplies has become a major concern worldwide and therefore accurate measurement of PFAS in our water systems is critical.

First, several techniques are available for detecting and quantifying PFAS in water, an often-complex analysis. Several regulatory methods require samples to be collected in polypropylene bottles before carrying out solid phase extraction (SPE) and triple quad mass spectrometry analysis. Additionally, there are numerous considerations that need to be accounted for when analyzing PFAS in water, including water type, calibration range, detection limit, screening, and quantification.

Finally, many testing labs may use manual workflows to manage PFAS analysis for water sources, leading to increased time and work. To improve overall lab throughput and productivity, automation of analytical procedures using SPE and liquid chromatography with tandem mass spectrometry (LC-MS/MS) methods is crucial.

In the next section, you can find links to various application notes detailing PFAS testing in water, including new methods from experts in the PFAS testing field and how automation can improve productivity and certainty in your results.

With our full portfolio of chromatography solutions, Thermo Fisher Scientific can help support your PFAS testing. To learn more, visit Solutions for PFAS Testing.

Matrix				Regulatory/Guidance	Title
Drinking water	Surface water	Groundwater	Wastewater		Click on note titles to jump to page
	●	●	●	EPA 1633	Quantitation of per- and polyfluoroalkyl substances (PFAS) in aqueous samples by LC-MS/MS following EPA Draft Method 1633
			●		EUROLAB adopts Orbitrap high-resolution accurate-mass (HRAM) solution for both targeted and untargeted contaminant analysis
●				EPA 537.1	Determination of per- and polyfluorinated alkyl substances (PFAS) in drinking water using automated solid-phase extraction and LC-MS/MS
●				EPA 537.1	Secondary validation study for EPA Method 537.1 using automated SPE followed by LC-Q Exactive Orbitrap MS
●				EPA 537	A comparison between HRAM Orbitrap technology and MS/MS for the analysis of polyfluoroalkyl substances by EPA Method 537
	●	●	●	EPA 8327	Direct analysis of selected per- and polyfluorinated alkyl substances (PFAS) in ground, surface, and waste water by LC-MS/MS
	●	●		EPA 1621	AOF by combustion IC – non-targeted complemental determination of PFAS in aqueous samples
			●	EPA 1621	Detecting the elusive forever chemicals using combustion ion chromatography

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APPLICATION NOTE 002348

Quantitation of per- and polyfluoroalkyl substances (PFAS) in aqueous samples by LC-MS/MS following EPA Draft Method 1633

Kevin J. McHale, Thermo Fisher Scientific, Somerset, NJ, USA

Goal

To demonstrate the measurement of 40 per- and polyfluoroalkyl substances (PFAS) in 500 mL water samples at or below the method detection limits (MDLs) reported in U.S. EPA Draft Method 1633 by LC-MS/MS on the Thermo Scientific™ TSQ Quantis™ Plus mass spectrometer.

Introduction

PFAS are per- and polyfluoroalkyl substances. They comprise a hydrophobic chain of C- F bonds and a hydrophilic end group. The chemical nature of the C-F bonds makes these compounds extremely stable. Hence, PFAS have been given the term "forever compounds". They have been in use for decades in a wide variety of industrial uses and for many everyday consumer products. Because of their ubiquitous nature and chemical stability, PFAS have made their way into all aspects of the environment, including the water and soil and some even in the air. With contact with the environment, PFAS become integrated into plants, animals, and humans. Once in biological organisms, PFAS do not efficiently breakdown. This leads to bioaccumulation of PFAS, which has shown evidence of certain health effects in humans, including possible increased risk of cancer and infertility.

The U.S. EPA has taken a more active approach to monitoring PFAS in the environment in recent years. In March 2023, the EPA proposed the National Primary Drinking Water Regulation (NPDWR) to establish legally enforceable levels of six PFAS in drinking water, including PFOA and PFOS at 4 ng/L. Previously developed methods EPA 537.1 and EPA 533 were established to measure PFAS in drinking water, including the six PFAS designated under the NPDWR. More recently, EPA Method 1633 was developed, in conjunction with the Department of Defense, to measure PFAS in non-potable water, (bio)solids, and tissue samples for the intended use of regulating PFAS via the Clean Water Act (CWA). The third draft of EPA Method 1633 was released in December 2022 following a multi-laboratory validation study in spiked wastewaters.

Conclusion

Following the protocols in 1633, the TSQ Quantis Plus mass spectrometer has demonstrated MDLs at, or in most cases, below those listed in EPA Draft Method 1633 for aqueous samples. For extractions of mid-level fortified samples, results well within the recovery range of 70–130% and RSDs <20% were obtained, with the exception of 6:2FTS.

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EUROLAB adopts Orbitrap high-resolution accurate-mass (HRAM) solution for both targeted and untargeted contaminant analysis

Thermo Fisher Scientific, EUROLAB

Introduction

EUROLAB, Srl focuses on the analysis of client samples for contaminants that impact product safety and environmental waters. Traditional contaminant monitoring strategies have involved targeted screening and quantitation of specific compounds. However, targeted methods address only a small portion of the potential universe of contaminants present in the environment and consumer products. The rise in unknown compounds that can have toxic effects is driving the need for advanced monitoring strategies that go beyond targeted screening and quantitation to comprehensive methods capable of revealing all compounds present in a sample. In addition to the challenges of comprehensive sample characterization, regulatory agencies continually lower contaminant levels and add new contaminants to monitor as toxicological evidence expands.

Conclusion

With the ever increasing numbers of contaminants that must be screened and quantified at increasingly lower concentrations, and in a wider variety of sample matrices, the need for powerful and accurate high-resolution

LC-MS instruments will continue to rise. Comprehensive characterization of samples for unknown emerging contaminants requires high-resolution full-scan LC-MS methods. Orbitrap HRAM methods not only increase the potential targets monitored, they reduce false positives and per-sample costs, save time, provide more confidence in compound identifications, and allow retrospective data analysis.

Orbitrap HRAM instruments provide a one-instrument solution for unknown identification, untargeted and targeted screening, and targeted quantitation that is accurate with a simplified user experience that does not require complicated, time-consuming method development and sample preparation. It is for these advantages that EUROLAB, Srl relies on their Q Exactive Focus mass spectrometers and Compound Discoverer software.

➡ View the full case study

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Determination of per- and polyfluorinated alkyl substances (PFAS) in drinking water using automated solid-phase extraction and LC-MS/MS

Changling Qiu, Xin Zhang, Rahmat Ullah, Wei Chen, Yan Liu Thermo Fisher Scientific, Sunnyvale, CA, USA

Goal
To demonstrate an efficient and reliable solid-phase extraction method with the Thermo Scientific™ Dionex™ AutoTrace™ 280 PFAS Solid-Phase Extraction instrument for the determination of per- and poly-fluorinated compounds in drinking water per U.S. EPA Method 537.1.

Introduction
Per- and polyfluorinated alkyl substances (PFAS) are a group of man-made chemicals including perfluorooctanoic acid (PFOA), perfluorooctanesulfonic acid (PFOS), and GenX chemicals that have been manufactured and used in a variety of industries globally. These compounds have a wide range of commercial product applications including industrial polymers, stain repellents, surfactants, waterproofing products, packaging, and aqueous film forming foams used for firefighting. PFAS are highly soluble in water, chemically stable, persistent in the environment, and can accumulate in the human body over time, leading to adverse human health effects. PFOA and PFOS are no longer manufactured in the U.S. due to their persistence and potential human health risks.

In November 2018, the United States Environmental Protection Agency (U.S. EPA) published Method 537.1 "Determination of selected per- and polyfluorinated alkyl substances in drinking water by solid phase extraction and LC-MS/MS". The method uses an offline solid-phase extraction (SPE) with liquid chromatography tandem mass spectrometry (LC-MS/MS) to extract, enrich, and determine 18 PFAS in drinking water. Currently most testing laboratories perform the sample extraction manually using a vacuum manifold, which is labor-intensive, time- consuming, and the flow rate through the cartridge is difficult to control. There is a high demand for automation of the SPE procedure.

Conclusion
This application note reports a method that can be used for the extraction and determination of 18 PFAS in drinking water with a PFAS-safe AutoTrace 280 extraction system and LC-MS/MS. The modified AutoTrace 280 extraction system ensures inertness and prevents PFAS from leaching into sample during extraction, while at same time delivering consistent and reliable performance. Both sample path cleaning in SPE and separation method precaution for the LC system maintained a low system background, meeting the EPA method requirement. The calculated LCMRLs ranged from 0.20 to 3.5 ng/L and the MDLs ranged from 0.30 to 2.5 ng/L, which were below or comparable to those values reported in U.S. EPA Method 537.1. At both 16.0 ng/L and 80.0 ng/L fortified concentration levels, all the recoveries were within the acceptable range of 70–130%. The calculated RSDs were all less than 10%, suggesting good precision. Thermo Scientific LC-MS/MS with the automatic extraction AutoTrace 280 PFAS system demonstrated an efficient, reliable, and sensitive method to fulfill the requirements of U.S. EPA Method 537.1.

▶ View the full application note

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APPLICATION NOTE 65499

Secondary validation study for EPA Method 537.1 using automated SPE followed by LC-Q Exactive Orbitrap MS

Ali Haghani, Andy Eaton, Eurofins Eaton, Monrovia, CA, USA;
Richard Jack, Maciej Bromirski, Thermo Fisher Scientific, San Jose, CA, USA

Goal

To demonstrate method performance for the per- and polyfluorinated alkyl substances (PFAS) analysis using Thermo Scientific™ Orbitrap™ high-resolution mass spectrometry as an alternative to conventional triple quadrupole instruments for determination of PFAS in drinking water matrices using EPA Method 537.1.

Introduction

Within the last decade, liquid chromatography-tandem mass spectrometry (LC-MS/MS) sensitivity has increased by at least a factor of ten and is therefore sensitive enough for quantitation of targeted compounds for validated methods. The ease of use for detecting polar compounds makes LC-MS/MS the technique of choice for analysis of compounds of emerging concern (CECs) in environmental samples. However, with the development of high-resolution accurate mass (HRAM) spectrometers, sensitivity rivals that of triple quadrupole MS instruments and, in addition, mass resolution provides the added benefits of accurate quantitation along with unknown screening capabilities. HRAM using Orbitrap technology combines the sensitivity of a triple quadrupole analyzer for quantitation with the confidence of full scan data for quantitative identification and confirmation similar to MS/MS instruments that participated in a method validation study.

This application note highlights the Thermo Scientific™ Q Exactive™ Hybrid Quadrupole-Orbitrap™ mass spectrometer used as one of the outside laboratory validations for updating EPA Method 537 r1.1 - *Determination of Selected Per- and Polyfluorinated Alkyl Substances in Drinking Water by Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry (LC-MS/MS).*

EPA 537 Rev. 1.1, first published in 2009 to determine 14 different PFAS in drinking water, has been updated to EPA Method 537.1 and includes four more PFAS. These new PFAS that have been replacing PFOA and PFOS in manufacturing processes are GenX chemicals, specifically the hexafluoropropylene oxide dimer acid, as well as 11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3OUdS), 9-chlorohexadecafluoro- 3-oxanone-1-sulfonic acid (9Cl-PF3ONS), and 4,8-dioxa-3H-perfluorononanoic acid (ADONA). EPA Method 537.1 can be used by EPA's Regions and other government and commercial environmental laboratories to measure PFAS in finished drinking water.

Conclusion

The method referenced in this application note is rugged and reproducible and shows excellent quantitative performance of the Q Exactive Orbitrap mass spectrometer in PRM mode for EPA Method 537.1 with enhanced selectivity and specificity.

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A comparison between HRAM Orbitrap technology and MS/MS for the analysis of polyfluoroalkyl substances by EPA Method 537

Ali Haghani, Andy Eaton, Eurofins Eaton Analytical, Inc. Monrovia, CA, USA;
Richard F. Jack, Ed George, Dipankar Ghosh, Thermo Fisher Scientific, San Jose, CA, USA

Goal
To demonstrate a liquid chromatography – high-resolution, accurate-mass (LC-HRAM) methodology using Thermo Scientific™ Orbitrap™ technology as a sensitive, accurate, and reliable quantitative alternative to the use of triple quadrupole mass spectrometers while simultaneously determining unknown perfluorinated compounds in the same drinking water extracts.

Introduction
The unique water-, oil-, grease-, stain- and heat-resistant properties of perfluoroalkyl substances (PFASs) have led to their widespread use in diverse industrial applications and multiple consumer products for over fifty years.

Perfluoroalkyl substances are compounds for which all hydrogens on all carbons (except for carbons associated with functional groups) have been replaced by fluorines, e.g., perfluoroalkyl acids (e.g., PFOA, PFOS). Polyfluoroalkyl substances are compounds for which all hydrogens on at least one (but not all) carbons have been replaced by fluorines, e.g., fluorotelomer-based compounds. The carbon-hydrogen linkages allow for biotic and abiotic degradation in the environment. However, the C–F bond is considered the strongest single bond in organic chemistry with a bond enthalpy of 481 kJ/mol in CH_3F, which is substantially higher than that of other bonds. This pronounced bond strength is reflected in the notorious environmental and chemical stability of these compounds.

Conclusion
Based on the EPA method flexibility rule, QA/QC requirements and guidance within EPA Method 537, HRAM Orbitrap technology should be permissible for potential compliance monitoring if PFASs become regulated compounds in US drinking waters. Q Exactive HRAM Orbitrap instrumentation in the PRM scan mode can be used for quantitation with performance like a triple quadrupole in SRM mode with added specificity, selectivity, and comparable sensitivity.

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Direct analysis of selected per- and polyfluorinated alkyl substances (PFAS) in ground, surface, and waste water by LC-MS/MS

Cristina C. Jacob, Claudia P.B. Martins, Alan R. Atkins, Richard F. Jack, Thermo Fisher Scientific, San Jose, CA, USA

Goal

To demonstrate method performance for the PFAS analysis at low levels (ng/L) in a wide variety of non-drinking water matrices by direct analysis and submit data package for EPA 8327 interlaboratory method validation.

Introduction

Per- and polyfluoroalkyl substances (PFAS) are a group of man-made chemicals that includes perfluorooctanoic (PFOA), perfluorooctyl sulfonic acid (PFOS), and hexafluoropropylene oxide dimer acid (HFPO-DA, which is part of GenX process). PFAS compounds have been manufactured since the 1940s. The most well-known PFAS compounds, PFOA and PFOS, have been the most extensively produced and studied for chemical properties and toxicological effects. Both chemicals are very persistent in the environment and accumulate in the human body over time. It is well documented that exposure to PFAS can lead to adverse human health effects and are found in food packaging material as well as food processing equipment. Plants can accumulate PFAS when grown in PFAS-containing soil and/or water. These compounds are also found in a wide variety of consumer products such as cookware, food containers (e.g., pizza boxes), and stain repellants. Additional products that lead to routes of exposure include clothing with stain- and water-repellent fabrics, nonstick products (e.g., Teflon), polishes, waxes, paints, and cleaning products. Another major source of PFAS are fire-fighting foams, which are a primary component of groundwater contamination at airports and military bases. More exposure comes from workplace environments, including production facilities or industries (e.g., chrome plating, electronics and manufacturing, or oil recovery).

Of particular note, drinking water can contain PFAS and can be associated with domestic and specific workplace facilities. Living organisms, including fish, animals and humans, have been shown to have accumulations of PFAS compounds and thus can build up and persist over time. For these reasons, most people have been exposed to PFAS.

Conclusion

The method referenced in this application note shows excellent quantitative performance of the Thermo Scientific™ TSQ Altis™ mass spectrometer for PFAS direct analysis in the low ng/L range in non-drinking water matrices.

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AOF by combustion IC – non-targeted complemental determination of PFAS in aqueous samples

Eleonora von Abercron, Udo Neist, Inge Klocke, Dr. Sebastian Georgii, Prof. Dr. Hubertus Brunn, Hessian State Laboratory, Wiesbaden, Germany; Dr. Detlef Jensen, Thermo Fisher Scientific GmbH, Dreieich, Germany

Goal

To develop an automated method to determine a range of perfluorinated alkyl substances (PFAS) by combustion IC within environmentally relevant matrices and compare the results with existing highly specific methods based on liquid chromatography mass spectrometry (LC-MS/MS).

Introduction

PFAS are human-made chemicals, which have been manufactured since the 1940s. The most well-known PFAS compounds, perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS), have been extensively studied for their chemical properties and toxicological effects. PFAS are used in a wide variety of consumer products, such as nonstick cookware, food containers, stain- and water-repellent fabrics, polishes, waxes, paints, and cleaning products. Other sources of PFAS are firefighting foams, which are primary groundwater contaminants at airports and military bases. Further environmental exposure to PFAS comes from industrial production facilities (e.g., chrome plating, electronics, manufacturing, or oil recovery). Living organisms, including plants, animals, and humans, can accumulate PFAS compounds in their tissue, which can build up over time and impact their health.

Several national and international standardization and regulatory bodies have developed methods specifically for the determination of PFAS in aqueous samples. These methods are mostly based on solid-phase extraction (SPE) followed by LC-MS/MS detection for only a select number of PFAS.

Conclusion

The described AOF approach extends the analytical toolset to determine PFAS in environmental samples, such as surface water, groundwater, and wastewater. While LC-MS/MS and gas chromatography tandem mass spectrometry (GC-MS/MS)-methods use a specified set of PFAS for the evaluation, the adsorption process for the AOF method ensures the extraction and determination of more components—PFAS and other fluorinated compounds—than the previously mentioned approaches.

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Detecting the elusive forever chemicals using combustion ion chromatography

Thermo Fisher Scientific

Introduction

Per- and polyfluorinated alkyl substances (PFAS) and their precursors are used in many human-made products, including non-stick cookware, food containers, polishes, and waxes. Their resistance to water, oil, and heat also makes them useful for many industrial processes and in firefighting foams, the byproducts of which can easily enter waterways. Although useful, PFAS are harmful environmental pollutants; the most widely researched PFAS chemicals, PFOA, and PFOS, have been linked with immunological problems, cancer, and developmental issues in animal studies, and there is evidence that they can lead to adverse health outcomes in humans.PFAS bioaccumulate and once present in food chains, can be difficult to remove. This persistence and bioaccumulation have dubbed PFAS the 'forever chemicals.'

Accurate measurement of environmental pollutants is key to detecting pollution and protecting waterways, particularly if they are used as a source for human consumption, but PFAS often elude detection. As the numbers of undetected PFAS and their precursors continue to rise, it is more important than ever that techniques are developed to screen for the presence of PFAS molecules, especially those that are not detected by targeted approaches.

Conclusion

AOX and AOF by CIC provide a fast, precise, and more accurate alternative to existing standardized techniques, by delivering greater automation and increased speed. These benefits deliver reduced error rates, time savings, and more accurate determinations. Moreover, along with being a replacement technology for combustion sample preparation and analytical titrations, CIC can be used as a complementary technique. Because CIC provides a simpler and more cost-effective method, it is an ideal pre-screening tool to identify suspicious samples which may contain additional PFAS compounds that were not included in the targeted LC-MS/MS method. The suspicious samples can then undergo an unknown screen using high-resolution accurate mass (HRAM) mass spectrometry. CIC helps make this process more cost-effective and saves time because it identifies which samples should be screened using HRAM, avoiding the need to screen all samples.

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PFAS in other matrices

Although the main sources of PFAS compounds are water, these compounds can also exist in other matrices, such as soil, air and food.

In this section, you'll discover strategies to help you with either targeted analysis of known PFAS compounds or the discovery of unknowns, from a variety of matrices, with Thermo Scientific chromatography solutions. To learn more, visit Solutions for PFAS Testing. To learn more, visit Solutions for PFAS Testing.

Soil

Matrix			Regulatory/Guidance	Title
Sediments	Sludges	Soils		Click on note titles to jump to page
●	●	●	EPA 1633	Quantitation of per- and polyfluoroalkyl substances (PFAS) in aqueous samples by LC-MS/MS following EPA Draft Method 1633
		●		Extraction and analysis of poly- and perfluoroalkyl substances (PFAS) from soil

Air

Matrix		Regulatory/Guidance	Title
Ambient	Indoor air		Click on note titles to jump to page
●			High-throughput analysis of both neutral and ionic PFAS in ambient air using thermal desorption coupled to gas chromatography – mass spectrometry (TD-GC-MS/MS)
	●		Analysis of PFAS in indoor air using thermal desorption coupled to gas chromatography – mass spectrometry (TD-GC-MS/MS)

Food

Matrix		Regulatory/Guidance	Title
Food contact materials	Food		Click on note titles to jump to page
●			The effect of particle size reduction techniques on extraction and recovery of 16 PFAS in food-contact paper packaging matrices
	●	CAM C-010.01	Detection and quantitation of PFAS in animal tissue using Orbitrap Exploris 120 high-resolution mass spectrometer

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Quantitation of per- and polyfluoroalkyl substances (PFAS) in aqueous samples by LC-MS/MS following EPA Draft Method 1633

Kevin J. McHale, Thermo Fisher Scientific, Somerset, NJ, USA

Goal

To demonstrate the measurement of 40 per- and polyfluoroalkyl substances (PFAS) in 500 mL water samples at or below the method detection limits (MDLs) reported in U.S. EPA Draft Method 1633 by LC-MS/MS on the Thermo Scientific™ TSQ Quantis™ Plus mass spectrometer.

Introduction

PFAS are per- and polyfluoroalkyl substances. They comprise a hydrophobic chain of C-F bonds and a hydrophilic end group. The chemical nature of the C-F bonds makes these compounds extremely stable. Hence, PFAS have been given the term "forever compounds". They have been in use for decades in a wide variety of industrial uses and for many everyday consumer products. Because of their ubiquitous nature and chemical stability, PFAS have made their way into all aspects of the environment, including the water and soil and some even in the air. With contact with the environment, PFAS become integrated into plants, animals, and humans. Once in biological organisms, PFAS do not efficiently breakdown. This leads to bioaccumulation of PFAS, which has shown evidence of certain health effects in humans, including possible increased risk of cancer and infertility.

The U.S. EPA has taken a more active approach to monitoring PFAS in the environment in recent years. In March 2023, the EPA proposed the National Primary Drinking Water Regulation (NPDWR) to establish legally enforceable levels of six PFAS in drinking water, including PFOA and PFOS at 4 ng/L. Previously developed methods EPA 537.1 and EPA 533 were established to measure PFAS in drinking water, including the six PFAS designated under the NPDWR. More recently, EPA Method 1633 was developed, in conjunction with the Department of Defense, to measure PFAS in non-potable water, (bio)solids, and tissue samples for the intended use of regulating PFAS via the Clean Water Act (CWA). The third draft of EPA Method 1633 was released in December 2022 following a multi-laboratory validation study in spiked wastewaters.

Conclusion

Following the protocols in 1633, the TSQ Quantis Plus mass spectrometer has demonstrated MDLs at, or in most cases, below those listed in EPA Draft Method 1633 for aqueous samples. For extractions of mid-level fortified samples, results well within the recovery range of 70–130% and RSDs <20% were obtained, with the exception of 6:2FTS.

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Extraction and analysis of poly- and perfluoroalkyl substances (PFAS) from soil

Matthew S. MacLennan, Daniel Ng, David Hope, Pacific Rim Laboratories, Surrey, B. C. Canada

Introduction

Recent studies suggest that toxic and highly persistent poly- and perfluorinated alkyl substances (PFAS) are much more prevalent in tissue and soil than in water. The increasing length of perfluoroalkyl chain in PFAS is correlated strongly to lower water solubility/higher adsorption behavior of a particular PFAS molecule in the environment (i.e., migration of PFAS at soil/water/air interfaces) and in remediation/ filtration (i.e., choice of filtration media or sorbents).
There are over 6,000 PFAS commercially available, many of which have high environmental persistence and have been found in water and soils globally. This poses a significant challenge to developing analytical methods, especially for the extraction of a variety of PFAS from solid matrices such as soil. Previously, we reported unsatisfactory (0–50%) recovery of long-chain PFAS from soil using vortex/sonication.

In the present study, soil was spiked with 24 PFAS (C4-C14 acids, C4-C10 sulfonates, 4:2, 6:2 and 8:2 fluorotelomers, C8 sulfonamide) at 1 ng/g, which were allowed to absorb overnight into the soil samples. The soil samples were extracted using the Thermo Scientific™ Dionex™ ASE™ 350 Accelerated Solvent Extractor, which produced 70–130% recovery of all PFAS target compounds. Accelerated solvent extraction has outperformed commonly used, manual "shaking" extraction methods under the same conditions.

In the present study, soil was spiked with 24 PFAS (C4-C14 acids, C4-C10 sulfonates, 4:2, 6:2 and 8:2 fluorotelomers, C8 sulfonamide) at 1 ng/g, which were allowed to absorb overnight into the soil samples.

Conclusion

Accelerated solvent extraction can extract a variety of PFAS from soil including acids, sulfonates, fluorotelomer sulfonates, and sulfonamide compounds. Although the Dionex ASE 350 system utilized in this method contained Teflon lines, the lines had been used under a variety of different solvent conditions, effectively reducing the PFAS background contamination to a minimum. Isotopic dilution quantification was utilized for most analytes and demonstrated linearity for all PFAS studied in soil over the range of 1 ppb to 400 ppb. PFTrDA linearity is biased low which is partially due to PFTrDA being quantified via the internal standard method against $^{13}C_2$-PFTeDA and not an isotopically labeled analog of PFTrDA, but more strongly due to the effects of naturally abundant $^{13}C_2$-PFTeDA (from the native spiked levels) artificially increasing the recoveries of internal standard, thus underestimating the native levels of PFTrDA.

🔵➡ View the full application note

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High-throughput analysis of both neutral and ionic PFAS in ambient air using thermal desorption coupled to gas chromatography – mass spectrometry (TD-GC-MS/MS)

Laura Miles, Hannah Calder, Markes International Ltd, Bridgend, UK; Vladimir Nikiforov, Dorte Herzke, NILU-Norwegian Institute for Air Research, Fram Centre, Tromsø, Norway; Nicholas Warner, Daniel Kutscher, Thermo Fisher Scientific, Bremen, DE; Giulia Riccardino, Thermo Fisher Scientific, Milan, IT; Adam Ladak, Thermo Fisher Scientific, Hemel Hempstead, UK

Goal
The aim of this application note is to demonstrate a high-throughput method for the simultaneous analysis of neutral (FTOH, FOSA) and ionic (PFCA, FTCA) per- and polyfluoroalkyl substances (PFAS) in air using thermal desorption coupled to gas chromatography mass spectrometry.

Introduction
Per- and polyfluoroalkyl substances (PFAS) contain one or more alkyl radicals with all the hydrogens replaced by fluorine atoms. Traditionally, two groups of PFAS have been of the most concern and subject for control and monitoring. The first group includes ionic (or acidic) PFAS—the perfluorocarboxylic acids (perfluorooctanoic acid (PFOA) being the most infamous one) and perfluoroalkylsulfonates (perfluorooctanesulfonic acid (PFOS), the most infamous), where LC-MS-MS is the most commonly chosen analytical technique. The second group includes neutral (or volatile) PFAS—the fluorotelomer alcohols (FTOHs) and N-substituted fluoroalkylsulfonamides (FOSAs). For this group, GC-MS is the analytical method of choice. Detecting airborne concentrations of both ionic and neutral PFAS is critical for measuring atmospheric emission distribution and potential human exposure. Unlike water and soil matrices, there are fewer factors that slow the dispersal of PFAS after release into ambient air. These compounds can travel thousands of kilometers from the original point of emission, which could be chemical manufacturing sites, thermal waste treatment plants, or commercial applications of PFAS.

Conclusion
The results obtained in these experiments demonstrate that the TD100-xr Advanced coupled to the TRACE 1610 GC and TSQ 9610 mass spectrometer equipped with the AEI ion source delivers reliable analytical performance for analysis of PFAS in air, allowing for the analysis of the volatile neutral PFAS species and volatile ionic PFCAs in a single run.

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Analysis of PFAS in indoor air using thermal desorption coupled to gas chromatography – mass spectrometry (TD-GC-MS/MS)

Laura Miles, Hannah Calder, Markes International Ltd, Bridgend, UK; Nicholas Warner, Daniel Kutscher, Thermo Fisher Scientific, Bremen, DE; Daniela Cavagnino, Thermo Fisher Scientific, Milan, IT; Adam Ladak, Thermo Fisher Scientific, Hemel Hempstead, UK

Goal

The aim of this application note is to present a method for the simultaneous analysis of 19 per- and polyfluoroalkyl substances (PFAS) across four different functional groups (perfluoroalkyl carboxylic acids / carboxylates (PFCAs), fluorotelomer alcohols (FTOHs), fluorotelomer carboxylic acids (FTCAs), and perfluorotoctane sulfonamides (FOSAs)) in indoor air using thermal desorption coupled to gas chromatography-mass spectrometry. In addition, the PFAS emission rate from a common item was also evaluated by using a Markes International™ Micro-Chamber/Thermal Extractor™.

Introduction

Per- and polyfluoroalkyl substances (PFAS) contain one or more alkyl residues where all hydrogen atoms have been replaced by fluorine atoms. These compounds can be found in air as the results of emissions from industrial activities. However, these compounds are also found in indoor air, as they are widely used in consumer products, such as nonstick cookware, water-repellent clothing, stain resistant fabrics and carpets, some cosmetics, and products that resist grease, water, and oil. The presence of PFAS in indoor air can pose risks to human health; in particular perfluorooctanoic acid (PFOA) bioaccumulates in humans and other air-breathing mammals and has been linked to major health issues such as kidney cancer, testicular cancer, thyroid disease, pregnancy-induced hypertension, and high cholesterol.

Moreover some neutral PFAS species (n-PFAS) such as fluorotelomer alcohols (FTOHs), fluorotelomer carboxylic acids (FTCAs), and perfluorooctanesulfonamides (FOSA) can degrade within the body and in the environment to form PFOA.

Conclusion

The results obtained in these experiments demonstrate that the TD100-xr Advanced coupled to the TRACE 1610 GC and TSQ 9610 mass spectrometer equipped with AEI source delivers reliable analytical performance for analysis of PFAS in indoor air.

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The effect of particle size reduction techniques on extraction and recovery of 16 PFAS in food-contact paper packaging matrices

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Charles Yang, Thermo Fisher Scientific, San Jose, CA, USA

Goal
To investigate the effect of two particle size reduction techniques, ball milling and blade cutting-grinding, on the perfluoroalkyl and polyfluoroalkyl substances (PFAS) recovery of three types of food contact materials (microwave popcorn bags, molded fiber bowl, and wrappers) using the Focused Ultrasound Solid-Liquid Extraction (FUSLE) technique for extraction of 16 targeted fluorinated compounds.

Introduction
Paper and board (P&B) food contact materials (FCMs) have gained special attention lately due to the broad use of commercial additive blends and raw materials of known and unknown nature that have raised health and regulatory concerns.

Since P&B are used in a variety of applications, one of the challenges in paper production is to achieve specific technical functionalities. Therefore, the use of chemical additives is widely employed in the manufacturing process to achieve various performance requirements. Among these additives, processing aids and functional additives are some of the main categories. Processing aids are used to improve the efficiency of the paper making processes and are not intended to be transferred into the final product, although traces can be found.

Given the health and migration concerns associated with PFAS in FCM, it is imperative that adequate and good performance analytical methods be developed to quantify different PFAS accurately and efficiently in a variety of matrices.

Conclusion
Particle size reduction techniques for extraction and spike recovery of 16 PFASs including seven perfluorocarboxylic acids (PFCAs), five perfluoroalkylsulfonates (PFSAs), two chloroperfluoroether sulfonates (CI-PFESAs), one polyfluoroether carboxylate (PFECAs), and one hexafluoropropylene oxide dimer acid (GenX) on sampling of different cellulosic-based food contact materials were developed in the present study.

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Detection and quantitation of PFAS in animal tissue using Orbitrap Exploris 120 high-resolution mass spectrometer

Ed George, Maciej Bromirski, Charles Yang, Thermo Fisher Scientific, San Jose, CA, USA

Goal

To develop a robust method that can efficiently extract, identify and quantify target per- and polyfluoroalkyl substances (PFAS) at pg/g (parts-per-trillion) levels in animal tissues using a LC-Orbitrap high resolution mass spectrometer. Thirty-four target PFAS compounds were chosen based upon available reference standards that are cited in various regulated USEPA methods. Pork muscle meat was used as a test matrix to demonstrate applicability.

Introduction

PFAS were first developed in the 1940s and have been used by numerous industrial and commercial sectors for products that required thermal and chemical stability, water resistance, and stain resistance. Awareness of PFAS contamination in the environment first emerged in the late 1990s following developments in tandem LC-MS/MS instrumentation which enabled low-level target detection. Most regulations have been focused on environmental contamination of PFAS that have leached into water and soil samples from a variety of sources, such as landfills or aqueous film forming foam (AFFF) used to extinguish flammable liquid fires.

The need to analyze PFAS in other matrices is growing rapidly since these 'forever chemicals' are very stable and readily bioaccumulate in plant and animal tissues. Moreover, there are over 9000 known PFAS (with more PFAS being actively discovered) and only a very limited number of certified reference standards commercially available for routine targeted analysis. High-resolution accurate-mass (HRAM) analysis by LC-Orbitrap has an advantage over triple quadrupole MS because, in addition to quantification and identification of target PFAS, it also enables retrospective analysis of sample data files for other untargeted PFAS. The higher mass selectivity of HRAM MS, due to the low parts per million (ppm) mass accuracy and high mass resolution, can help to overcome matrix interferences observed in the analysis of animal tissue extracts. This work describes the development of a LC-HRAM method for the analysis of PFAS in pork meat. The method shows excellent sensitivity and specificity and is fit for purpose with the potential to be an excellent platform for expanded PFAS target compounds as well as into more complex matrices.

Conclusion

The Thermo Scientific™ Vanquish™ Flex UHPLC system using solvent sandwich injection technique coupled to the Thermo Scientific™ Orbitrap Exploris™ 120 mass spectrometer provided excellent quantitative sensitivity with qualitative confirmation in Full MS with DIA mode, with most PFAS LOQs in pork meat matrix less than 50 pg/g (16.7 pg/mL in the final extract), without the need for further extract concentration.

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Non-targeted PFAS analysis

PFAS compounds present numerous analytical challenges: from quantitation at low levels to identifying the growing number of new PFAS chemicals and their metabolites, giving rise to the fear of missing the next variant of emerging concern. Regulatory monitoring of PFAS has traditionally focused on the development of targeted quantitative methods by LC-MS/MS. These methods are limited in scope due to the lack of available certified reference standards. Over 15,000 known PFAS (with more PFAS being actively discovered) dictate the need for a comprehensive non-targeted analysis of PFAS by high-resolution accurate mass (HRAM). Compound Discoverer software is a turnkey solution, for the untargeted analysis of PFAS in complex matrices.

This section of the compendium describes applications using hardware and software specifically designed to look for PFAS compounds you might be missing. With extensive fragment libraries of over 40,000 PFAS and built-in visualization tools, Compound Discoverer software helps you characterize your samples easily. And if you want additional support, Thermo Fisher Scientific can help you streamline your workflows for more precise results. To learn more, visit Solutions for PFAS Testing.

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PFAS data processing: Forever chemicals do not need forever analysis with the right equipment and software

Thermo Fisher Scientific

Goal

In this Smart Note, we address critical considerations to help ensure your success when meeting the evolving needs for PFAS data analysis.

Introduction

Per- and polyfluoroalkyl substances (PFASs) were introduced in the 1940s and were rapidly incorporated into everyday products across multiple industries, from stain and water repellent materials to coatings, paints, and even foams used for fighting fires. Initially, these compounds were thought to be inert and were considered "wonder chemicals." Their usage was widespread, and now it is estimated that there are well over 10,000 possible PFAS compounds.

The most well-known PFAS compounds, perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS), have been extensively studied for their chemical properties and toxicological effects. Both chemicals are persistent in the environment and accumulate in the human body over time. Human exposure to PFASs can be traced to multiple sources, including water, soil, the food chain, processing equipment, and packaging materials.

Numerous strategies can be deployed to provide confidence in your results and ensure consumer safety.

Questions addressed

- Why are PFAS so hard to analyze?

- How can I increase my data processing efficiency and ensure that my analysis has a rapid turnaround time?

- How can I determine what and how many compounds are in potentially complex datasets, while ensuring confidence in these results?

- From unknown to known – how can I streamline identification of potential new contaminants?

- How can I transfer my compound identifications for high-throughput QQQ analysis?

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A comprehensive software workflow for non-targeted analysis of per- and polyfluoroalkyl substances (PFAS) by high-resolution mass spectrometry (HRMS)

Juan M. Sanchez, Ralf Tautenhahn, Thermo Fisher Scientific, San Jose, CA, USA

Goal
Provide an overview of the new untargeted PFAS analysis workflow capabilities within Thermo Scientific™ Compound Discoverer™ software.

Introduction
The ubiquity and toxicity of a highly stable group of small molecules collectively known as per- and polyfluoroalkyl substances (PFAS) recently garnered concerns among health and environmental regulatory agencies globally. Regulatory monitoring of PFAS has traditionally focused on the development of targeted quantitative methods by LC-MS/MS. These methods are limited in scope due to the lack of available certified reference standards. Over 9,000 known PFAS (with more PFAS being actively discovered) dictate the need for a comprehensive non-targeted analysis of PFAS by high-resolution accurate mass (HRAM).

Numerous individual techniques effective at discriminating PFAS in complex matrices by using intrinsic attributes such as signature product ions, progressive retention times tied to chain length, and CF_2-specific Kendrick mass defect are well documented in the literature.Additionally, fluorine's physicochemical attributes, such as a characteristic negative mass defect and the formation of homologous series containing predictable CF_2 patterns resulting from industrial PFAS synthesis techniques, may be exploited to simplify the detection and annotation of novel PFAS. Here we present a fusion of the most prominent untargeted PFAS analysis techniques leveraged within a single workflow using Compound Discoverer software as a turnkey solution.

Conclusion
Compound Discoverer software is a powerful platform providing a comprehensive turnkey solution for the untargeted analysis of PFAS in complex matrices. Access to the mzCloud spectral library to provide similarity searches—as well as the potential to leverage in silico fragmentation in positive mode and matching against a manually curated compound class library of PFAS signature product ions in negative mode—provides unparalleled capabilities. The incorporation of analysis techniques and best practices from the literature, compilation of PFAS databases, a custom scripting node for orthogonal discrimination, and a myriad of onboard visualization tools enables a simplified approach for analyzing this concerning class of small molecules. When challenged with analyzing PFAS, the untargeted PFAS workflow available in Compound Discoverer software version 3.3 SP2 can provide labs with an integrated solution to achieve meaningful insights.

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Thermo Scientific mzCloud Library for confident and accurate PFAS analysis
Thermo Fisher Scientific

Introduction

Global regulatory bodies are investigating for the prevalence of per- and polyfluoroalkyl substances (PFAS) compounds due to their toxicity, persistence and wide-spread use, especially as aqueous film forming foam (AFFF). PFASs are also used in a wide variety of industrial and household consumer products such as carpets and furniture, food packaging, cookware. Human exposure to PFAS residues has been implicated in the incidence of cancer, obesity, endocrine system disruption, and other adverse health effects. It is estimated that there are over 6000 possible PFAS compounds. Quantitation and screening for the prevalence of any of these compounds at low levels is especially challenging.

To assist you in delivering high quality identification of fluorochemicals, Thermo Fisher Scientific has produced a high-resolution, accurate-mass (HRAM) library of PFAS compounds to deliver ultimate confidence and confirmation in the data you report.

What makes this library especially powerful is that it is 100% curated with real standards on state-of-the-art Thermo Scientific™ Orbitrap™ technology. Though some libraries may have more compounds, these are based on estimated structures based on lower resolution QTOF instrumentation – lower quality data will give more errors and lower confidence in library searches.

Conclusion

The current Thermo Scientific™ mzCloud™ library is capable of PFAS analysis with:

• 43 standards

• HRAM MS^n data on each standard in negative mode and 100% curated

• Highest possible quality for mass accuracy and spectral reproducibility with multiple energy levels

• Compound identification based on MS/MS or MS^n data

• Similarity searching based on MS/MS or MS^n data to find unknown PFAS compounds

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Chemicals and consumables for PFAS testing

At Thermo Fisher Scientific we can offer a wide range of consumables, reagents, and lab supplies suited PFAS testing. See the next few pages for recommended chemicals and consumables for PFAS.

Chemicals for PFAS testing

Our ultrahigh purity chemicals and reagents are suitable for both the sample preparation and analysis of PFAS compounds. The following products are suitable for targeted and non-targeted detection methods (including global ASTM regulations, Stockholm Convention on persistent organic pollutants (POPs), EU Drinking Water Directive, and US EPA Methods 537, 537.1, 533, 8327, and 1633).

We recommend using our UHPLC-MS grade solvents for PFAS analysis, whether you are using HPLC or UHPLC as part of your testing protocol. These products do not contain fluoropolymer liners in the caps, eliminating leachable background interfering with PFAS analysis.

Chemicals product description	Pack size	Part number
Acetonitrile, UHPLC-MS, Thermo Scientific Chemicals	1 L	A9561
	6 × 1 L	A9561CS
Methanol, UHPLC-MS, Thermo Scientific Chemicals	6 × 1 L	A4581CS
Water, UHPLC-MS, Thermo Scientific Chemicals	1 L	W81
	6 × 1 L	W81CS
Acetone, 99.9%, for residue analysis, Thermo Scientific Chemicals	1 L	423240010
Toluene, HPLC Grade, 99.7% min, Thermo Scientific Chemicals	1 L	610110040
Dichloromethane, for residue and pesticide analysis, Thermo Scientific Chemicals	1 L	326600010
	2.5 L	326600025

Chemicals product description	Pack size	Part number
Acetic acid, 99.7+%, ACS reagent, Thermo Scientific Chemicals	500 mL, 2.5 L	423225000
Formic acid, 99%, Thermo Scientific Chemicals	25 mL	270480250
	1 L	270480010
	2.5 L	270480025
Ammonium acetate, 97%, Thermo Scientific Chemicals	250 g	A16343.30
	1 kg	A16343.0B
	5 kg	A16343.0I
Ammonium hydroxide, ACS, 28.0–30.0% NH{3}, Thermo Scientific Chemicals	250 g	033285.30
	1 kg	033285.A1
	5 × 1 kg	033285.D9

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Chemicals and consumables for PFAS testing

Columns

For high retentivity and large volume direct injections, a fully porous column such as Thermo Scientific™ Acclaim™ C18 has excellent peak shape for PFAS testing. For methods where smaller sample injection volumes are employed, Thermo Scientific™ Accucore™ RP-MS is recommended.

Consumable type	Columns product description	Pack size	Part number
Isolator column	Accucore C18 Column, 2.6 µm, 2.1 × 50 mm	1	17126-052130
Guard cartridge	Acclaim 120 C18 Column C18, 5 µm, 10 mm v 2.1 mm, Guard Cartridge	2	069689
Guard holder	Acclaim Guard Cartridge Holder-Coupler Kit V-2	1	069707
Column	Acclaim 120 C18 Column, 2 µm, 150 mm × 2.1 mm	1	071399
Column	Acclaim 120 C18 Column, 2 µm 2.1 mm × 100 mm	1	068982
Guard cartridge	Accucore RP-MS, 10 mm × 2.1 mm GUARDS cartridges	4	17626-012105
Guard holder	UNIVERSAL UNIGUARD HOLDER FOR 2.1/3.0mm ID	1	852-00
Column	Accucore RP-MS, 2.6 µm, 100 mm × 2.1 mm column	1	17626-102130
Column	Accucore RP-MS, 2.6 µm, 150 mm × 2.1 mm column	1	17626-152130

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Chemicals and consumables for PFAS testing

Vials and well plates

To assure a robust method with accurate results, use a polypropylene or polyethylene vial. The importance of using highly inert materials for compounds containing chemical functional groups with strong electronegativity is imperative, particularly for analytes with lower concentrations like PFAS.

Consumable type	Screw vials and caps – for routine and research analyses	Pack size	Part number
Vials	0.4 mL Clear Polyethylene 9 mm Screw Microvials, Conical insert	100	6ESV9-04PP
Vials	1.5 mL Clear Polyethylene 9 mm Screw Microvials, Conical insert	100	6ESV9-1PP
Caps	Clear Polyethylene 9 mm Screw Caps with integral polypropylene membrane	100	C5000-50
Caps	Blue Polypropylene 9 mm Screw Caps with AVCS closure, Solid Aluminium Disk with Silicone sealing ring	100	C5000-56AL

Consumable type	Screw vials and caps – for routine and research analyses	Pack size	Part number
Vials	SureSTART 0.8 mL polypropylene snap top microvials, flat bottom	100	6ERV11-08PPFB
Vials	SureSTART 0.8 mL polypropylene snap top microvials, conical insert	100	6ERV11-08PPC
Vials	SureSTART 0.3 mL polypropylene snap top microvials, conical insert	100	6ERV11-03PPC
Caps	SureSTART 11 mm snap caps with blue polyethylene septa	100	6ERC11PE

Consumable type	Well plates and mats – for high throughput analysis	Pack size	Part number
Well plate	WebSeal 96-Well Deep Well Plates, Non-Coated Plastic, Round U-Bottom, 1000 µL	50	60180-P201
Well plate mat	WebSeal 96-Well Plate Sealing Mat, 7 mm Diameter, Round	100	60180-M179
Well plate	WebSeal 96-Well Deep Well Plates, Non-Coated Plastic, Square V-Bottom, 2000 µL	50	60180-P202
Well plate mat	WebSeal 96-Well Plate Sealing Mat, 8 mm Diameter, Square	100	60180-M121

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thermofisher.com/discreteanalysis

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thermofisher.com/data-management

Chromatography Data System (CDS) software
thermofisher.com/chromeleon

Due to the dynamic nature of guidance from regulatory agencies, regulations referenced in this compendium (and their respective links) are subject to change. Please contact your local sales representative for up-to-date regulatory information.

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