MARKES international

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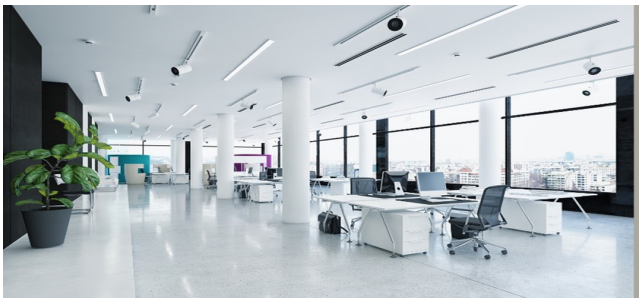
# Application Note 167

# Measurement of PFAS in indoor air and investigation of source materials


## Summary

This study investigates the performance of Markes' TD100-xr™ high through-put automated thermal desorption (TD) instrument coupled to a gas chromatograph (GC) and a triple quadrupole mass spectrometer (MS/MS) for PFAS analysis. This instrument combination enables measurement of per- and polyfluoroalkyl substances (PFAS) in indoor air at a detection limit as low as 1 pg for Me-FOSA. When using sampling chambers to test materials, the PFAS they release into the indoor air can be identified, along with quantifying the emission rate of such releases.

## Introduction

Per and polyfluorinated substances (PFAS) are known to be present in the air and dust in indoor environments,[1] the toxicology and bioaccumulation of these compounds means that understanding their presence and concentration in indoor air is important. The majority of people spend over 90% of their time indoors[2], making the quality of indoor air significant to our overall health.

PFAS compounds enter indoor air from a variety of everyday sources. Any item which has been treated to be non-stick, waterproof or stain proof is likely to contain PFAS, as well as many firefighting foams. For this reason, concentrations of many PFAS in indoor air are higher than in outdoor air.[3]

The toxic nature of some PFAS means their presence in air is a risk to human health. Perfluorooctanoic acid (PFOA), which is a perfluorinated carboxylic acid (PFCA), has been studied extensively. It 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.[4]

Unfortunately, the answer is not as simple as limiting use of PFOA. Some neutral PFAS species (n-PFAS) can degrade within the body and in the environment to form PFOA. These include fluorotelomer alcohols (FTOHs), fluorotelomer carboxylic acids (FTCAs) and perfluorooctanesulfonamides (FOSA).

In this study we demonstrate the use of thermal desorption (TD) coupled with gas chromatography (GC) and triple-quadrupole mass spectrometry (MS/MS) to measure n-PFAS and PFCAs in indoor air.

## Using TD with GC and MS/MS to monitor PFAS

When using TD, solid sorbents are employed to preconcentrate organic analytes from litres of air. Retained compounds are then injected directly (without dilution) into the GC capillary column in a flow of inert carrier gas. This combination of TD with GC and MS/MS maximises sensitivity, enabling the measurement of single-digit pg/m$^3$ concentrations in air.

The non-selective nature of the sorbents means that a targeted analysis method can easily be extended to give information on relevant untargeted species collected at the same time. Detailed repeat investigation of samples is also facilitated by using Markes' patented sample re-collection feature during initial analysis.

The process of re-collection is invaluable for method development/validation, troubleshooting and sample archiving. It also enables users to re-run samples with the same or different GC(–MS) methods or even use a completely different detector. This is particularly valuable when trying to identify unknowns in a sample. More information on re-collection can be found in Application Note 027.

A function of Markes' TD100-xr™ is the system's electrically-cooled focusing trap. Desorbed vapours from the sample collection tube are swept into the cooled trap for focusing. The trap is then heated rapidly (up to 100°C/s) in a reverse flow of carrier gas, 'backflushing' the analytes into the capillary GC column as a narrow band of vapour. Backflushing enables the use of multiple sorbents with increasing strength in the trap, facilitating the quantitative retention of very volatile compounds with only moderate electrical cooling (*e.g.* –30°C). Backflushed sorbent focusing traps also enable the analyst to selectively purge excess water from most samples, preventing subsequent analytical interference, and eliminating risk of ice blockages (a persistent issue with many cryogenically-cooled focusing systems).


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**Figure 1:** The TD100-xr – An automated, analytical thermal desorption system.

## Experimental

The aim was to develop and validate a method for sampling and analysing 19 target PFAS compounds across four different functional groups – perfluoroalkyl carboxylic acids/carboxylates (PFCAs), fluorotelomer alcohols (FTOHs), fluorotelomer carboxylic acids (FTCAs) and perfluorotoctane sulfonamides (FOSAs) – all of which may be found in the indoor environment.

### Standards

Most of the components of interest were purchased as individual standards from Wellington Laboratories Inc., Canada, at a concentration of 50 ng/µL. They were then combined and diluted to create a 5 ng/µL stock standard. The PFCAs were sourced as a mixture at 2 ng/µL and used as a stock standard. Serial dilution of these stock standards produced the range used in calibration and further tests.

To spike sorbent tubes with standards, 1 µL of each standard was injected using a Calibration Solution Loading Rig™ (CSLR™) onto the sorbent tube in a flow of nitrogen at 100 mL/min. Samples were purged for 60 minutes to simulate real air sample collection and completely remove methanol. Markes' TC-20™ unit was used to purge up to 20 tubes simultaneously, significantly speeding up the spiking process. The TC-20 was also used to re-condition the sorbent tubes in nitrogen prior to sampling, freeing up the analytical instrument and saving helium.

### Sampling

Air samples were collected from a workplace and residential building. The volumes taken varied depending on the location, but all samples were collected at a flow rate of 100 mL/min using an ACTI-VOC™ Plus air sampling pump. The workplace contained spaces dedicated to offices (singular occupancy and open plan), analytical laboratories, kitchen areas, storage areas and a factory.

Samples of test materials were cut and weighed into aluminium sample boats before being placed in the Micro-Chamber/Thermal Extractor™. Once sealed into individual microchambers the samples are incubated at a user-defined temperature and purged with gas, sweeping any evolved vapours into connected sorbent tubes. Although pure air is normally used as the purge gas (dry or humidified) to simulate real-world conditions, nitrogen was chosen in this case to evaluate emissions without oxidation.

**Sampling:**

| | |
|---|---|
| Temperature: | Varied |
| Flow rate: | 50 mL/min |
| Sampling time: | 30 minutes |

**TD:**

| | |
|---|---|
| Sorbent tubes: | PFAS Extended volume tubes (C3-AAXX-5426; stainless steel, conditioned and capped, Markes International) |
| System: | TD100-xr™ Advanced |
| Flow path: | 200°C |
| Automatic dry purge: | 1 min at 50 mL/min |
| Tube desorption: | 300°C for 10 min at 50 mL/min |
| Trap purge: | 1 min at 50 mL/min |
| Focusing trap: | PFAS focusing trap (U-T24PFAS-2S, Markes International) |
| Focusing trap low: | –30°C |
| Elevated trap purge: | 25°C |
| Focusing trap high: | 300°C (4 min) |
| Trap heat rate: | MAX |
| Outlet split: | 6:1 |
| Internal standard: | Toluene-$D_8$ |

**GC:**

| | |
|---|---|
| Column: | TG-200MS, 30 m × 0.25 mm × 1.0 µm |
| Carrier gas: | Helium |
| Column flow: | 1.2 mL/min, constant flow |
| GC oven: | 35°C for 2 min, 15°C/min to 280°C, hold for 5 min |

**MS/MS**

| | |
|---|---|
| Source: | 300°C |
| Transfer line: | 280°C |
| Acquisition mode: | Timed single-reaction monitoring (SRM) and full scan |
| Scan range: | m/z 35–650 |
| SRM: | SRM transitions (see Appendix for details). |

## Results and discussion

### 1. Standards

*Chromatography*

Figure 2 shows the chromatogram for a sorbent tube spiked with a PFAS mid-point concentration standard. The 19 target species are labelled. There is excellent separation of the compounds and sharp Gaussian peaks for each species. The wide range of compound chemistries within the PFAS standard made column choice a critical factor during method development.

*System and method blank*

As demand for analytical methods requiring lower detection limits grows, analytical blank levels are more often the limiting factor than instrument sensitivity.

In 2017, the US Environmental Protection Agency (US EPA) responded to this by moving away from determining method detection limits using system detection limits alone, and starting to include blank levels.

Blank levels were carefully investigated as part of this study. System flow path blanks were tested first by desorbing the unsampled focusing trap through the valve and heated transfer line under standard analytical conditions. No background was detected for any of the PFAS target species during this part of the study, demonstrating that the flow path of the instrument was inherently PFAS-free. Multiple sorbent tubes were then assessed to determine the analytical method blank. Five of the target compounds were found to be at or just above the 'challenge' level (half the lowest concentration standard). In the results table (see Table A1 in the Appendix), the MDLs for these compounds reflect the level at which they were found in the method blank. A more detailed discussion of system and method blank characterisation can be found in Application Note 166: Measuring PFAS pollution in ambient air using TD–GC–MS/MS.

*Linearity*

Due to the concentrations of the stock standards, different compound classes were calibrated over different ranges, but a minimum of six calibration points were used for each of the compounds (Table 1). All calibration curves for compounds were linear down to 10 pg except the FTCAs – including perfluorohexyl ethanoic acid (FHEA) and perfluorooctyl ethanoic acid (FOEA) – which were linear up to 100 pg on-tube. Linearity ($R^2$) values for all compounds were $R^2$ >0.99 (see Table A1 in the Appendix for individual values).

| Compound class | Concentration range (pg/µL) | No. of calibration points |
|---|---|---|
| Perfluorocarboxylic acids (PFCAs) | 10–2000 | 8 |
| Fluorotelomer carboxylic acids (FTCAs) | 100–5000 | 6 |
| Fluorotelomer alcohols (FTOHs) | 10–5000 | 9 |
| Perfluorooctanesulfonamides (FOSAs) | 10–5000 | 9 |

**Table 1:** Calibration ranges (due to the concentrations of the stock standards, different compound classes were calibrated over different ranges).

*Method detection limits (MDLs)*

The concentration of individual PFAS species in indoor air varies depending on the sources. In contrast to ambient air, with reported concentrations in the range of <800 pg/m$^3$,[5] indoor air studies have determined individual compounds at levels above 600 ng/m$^3$.[1] Therefore, while sensitivity may be the most important factor for many PFAS analytical methods, it should not be a practical concern for indoor air at the moment.

The method detection limit for this study was calculated by comparing seven method blanks with seven sorbent tubes that were spiked with a standard at a 'challenge level' in accordance with US EPA guidance.[6] Using this approach, the average method detection limit was 16 pg.

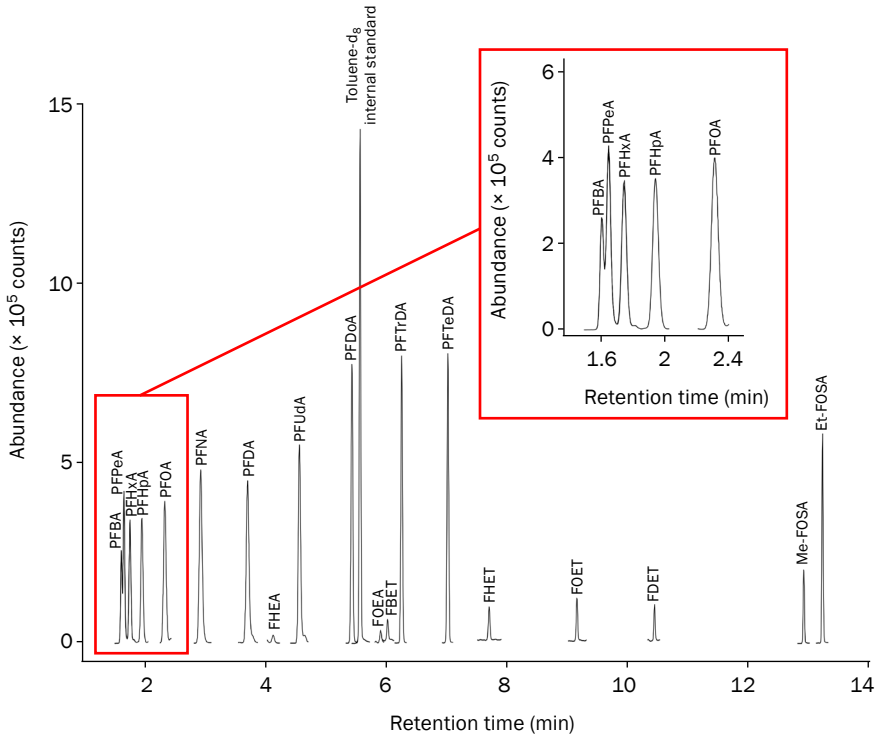


**Figure 2:** Mixed PFAS standard at 500 pg on-tube. The inset shows a close-up view of the chromatogram for the first five compounds, which are perfluoroalkylcarboxylic acids (PFCAs).

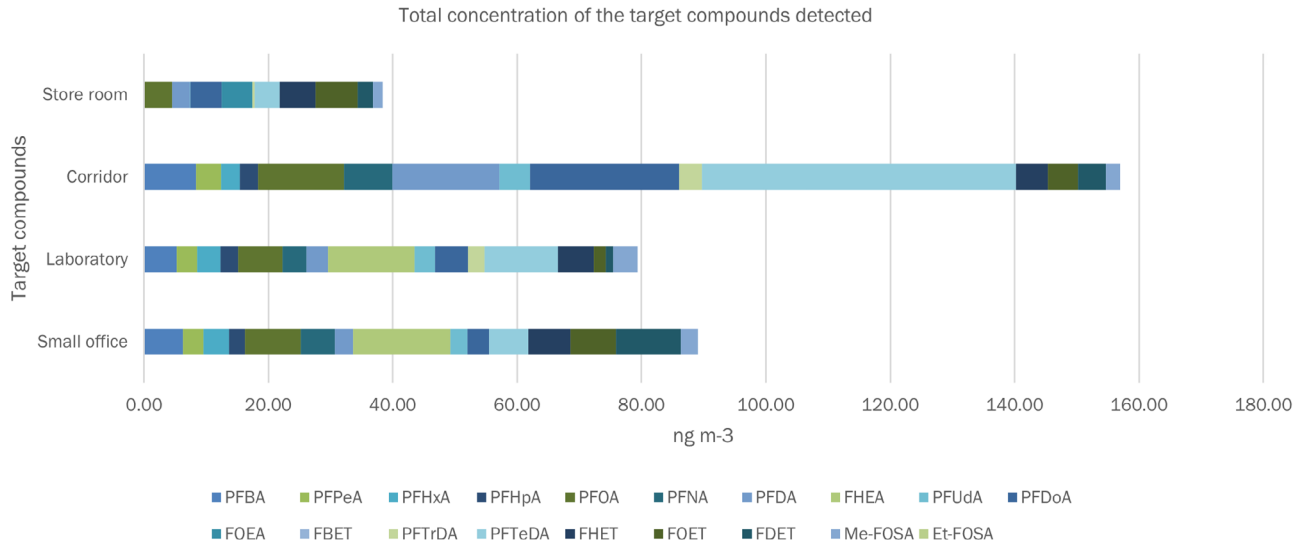


**Figure 3:** Total concentration of each of the target compounds detected in each individual work space. The concentration of PFTeDA quantified in the air of the corridor (50 ng/m3) contributes greatly to the total concentration detected in that environment

Breakthrough volumes for the compounds targeted in this work were shown to be greater than 500 L of air on the sorbent tubes used (see Application Note 158). Applying this volume of air, the average pg/m$^3$ method detection limit expressed as an air concentration would be in the order of 32 pg/m$^3$.

Much lower air sample volumes can be used for monitoring PFAS in indoor air because the levels of PFAS are higher. At a volume of 20 L, the average MDL is 780 pg/m$^3$ or ~0.8 ng/m$^3$ (see Table A1 in the Appendix for individual values).

## 2. Real air samples

*Air in a mixed workplace*

Indoor environments have many uses. Within this study we collected 20 L air samples within a residence and a workplace. A toluene-$D_8$ internal standard (IS) was added to each sample tube, after sampling but before analysis, to ensure high data quality was maintained across all samples.

Table 2A (see Appendix) shows which PFAS compounds were detected and their concentrations. The results show that nearly all of the compounds monitored were found in at least one of the sampling locations, with the exception of FBET and Et-FOSA. The compound class with the highest concentrations was the carboxylic acids – PFOA, PFDA, PFDoA and PFTeDA.

When comparing four workplace environments (Figure 3), the location with the highest overall PFAS levels for the 19 species measured was the corridor (156.95 ng/m$^3$) and the lowest was the store room containing painted materials (38.35 ng/m$^3$). The total PFAS concentration in the analytical laboratory was 79.35 ng/m$^3$, which was similar to the single-occupancy office environment (89.10 ng/m$^3$). The presence of the target compounds in the laboratory atmosphere makes a clear case for a stringent blank regime when carrying out PFAS analysis and for using instrumentation that maintains sample integrity. The analytical caps (with DiffLok™ technology) stay on the sorbent throughout an automated sequence preventing both artefact ingress and analyte loss.

*Air in a residential property*

Samples were also taken from a residential property which was undergoing major renovations. PFAS compounds are known to be included in building materials such as paints, flooring, sealants and adhesives, glass and ceramics, and even lightbulbs.[7] This is in addition to the PFAS found in everyday items in the home.

In this study we sampled 70 L of air from a residence which was undergoing renovations. Table A3 (see Appendix) shows which PFAS compounds were detected and at what concentration. The results show that fluorotelomer alcohols had the highest concentrations, and fewer individual PFAS

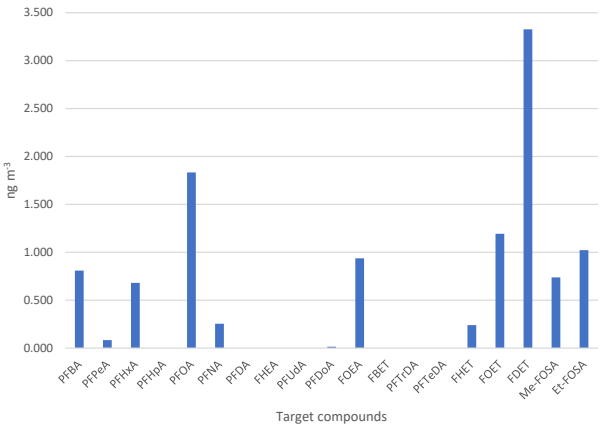


**Figure 4:** Compounds detected in the residential air sample

species were identified compared to the workplace. The total concentration of PFAS identified was also significantly lower than in the workplace environment – 11.15 ng/m$^3$ compared to an average of 90.94 ng/m$^3$.

Figure 4 shows the compounds detected in the residential air sample. Unlike the office samples, the FTOHs and FOSAs are more prominent than the PFCAs. The PFCAs present are all the more volatile species, with no acids with a chain length longer than $C_9$ detected.

## 3. Materials

To demonstrate how a material could be sampled to determine the rate of PFAS release, a child's waterproof coat was sampled using Markes' Micro-Chamber/Thermal Extractor.

Samples of the coat material were prepared and tested using the Micro-Chamber/Thermal Extractor as described above. Tests were carried out at ambient temperature to simulate the indoor environment (see EN ISO 16000-series methods and other similar standards[8–10]).

Table A4 (see Appendix) shows which PFAS compounds were detected from the samples, their concentration and the emission rate for each. Figure 5 clearly shows the compound with the highest concentration in the sample was the fluorotelomer alcohol 2-perfluorooctyl ethanol (8:2), with 3.9 ng being released per gram of material at ambient temperature. The bulk emission rate was then calculated by dividing the concentration by the sampling time in minutes. For FTOH 8:2, the emission rate was 0.131 ng/g/min. The emission rate is very important as it would form the basis of any emissions limits placed on PFAS containing materials in future.

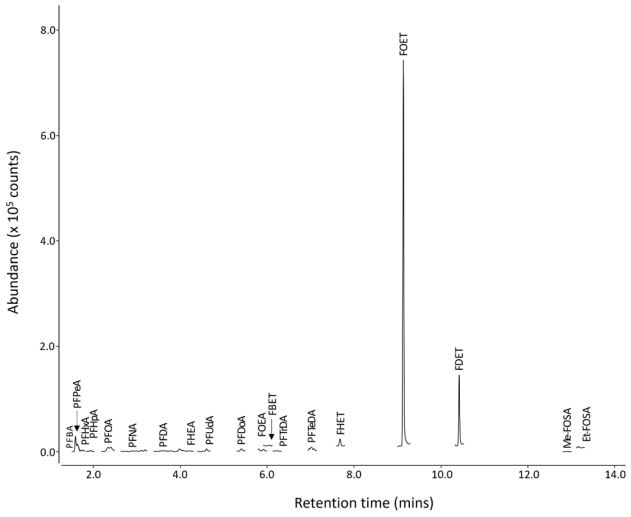


**Figure 5:** SRM chromatogram for the child's waterproof coat at ambient temperature. Although other PFAS are present, the highest emissions are clearly from FTOH 8:2 (FOET) and FTOH 10:2 (FDET).

## 4. The benefit of using MS/MS

Certain countries and individual US states have already banned the use of PFAS in certain products. Given the persistence of PFAS in the environment and existing health fears, increased testing is inevitable. Triple quadrupole MS/MS detectors are rarely used in current air analysis or emission testing methods, but are likely to be necessary for trace-level PFAS.

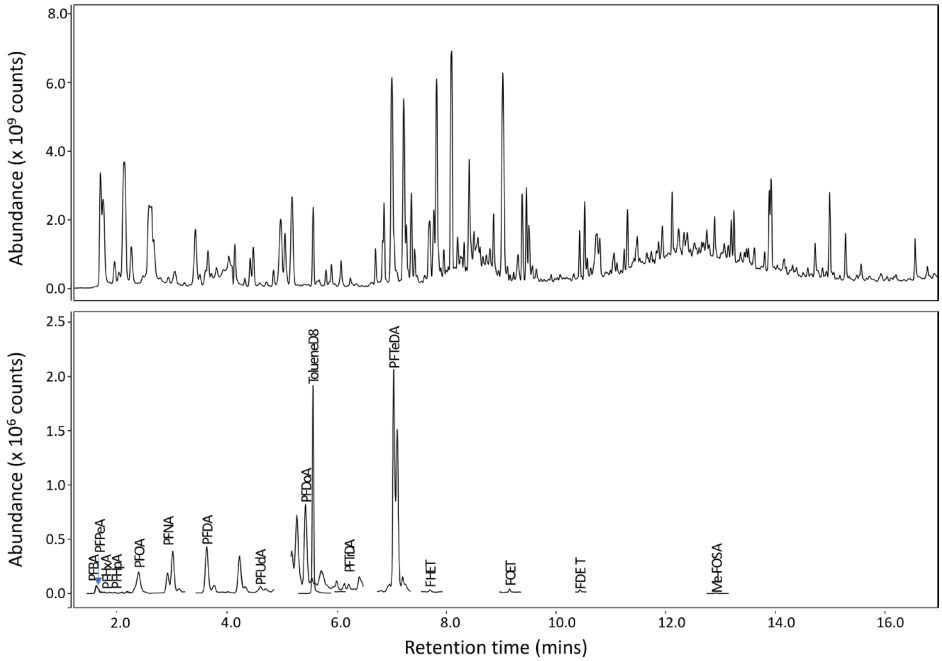


**Figure 6:** Chromatograms from the TIC (top) and SRM (bottom) of 20 L of indoor air sampled in a corridor. The PFAS compounds are at an abundance level of 10$^6$, compared to 10$^9$ for the VOCS which make up the background. Using MS/MS, compounds were confidently identified from each of our target classes (PFCAs, FTOHs, FTCAs, FOSAs).

Using re-collection, samples were run in TIC and SRM mode on the MS/MS. Figure 6 shows the chromatograms of the corridor sample from the workplace air testing. In this image, the difference in peak intensity between the targeted PFAS compounds and the untargeted compounds in the background is striking. If an MS/MS detector had not been used for this study, it's unlikely these compounds would have been identified with confidence.

## Conclusion

The TD–GC–MS/MS method developed for the 19 compounds targeted in this study delivered an average detection limit of 16 pg. Each compound gave a linear calibration and the analysis itself was highly repeatable (see Appendix). The technique is stable and sensitive enough to analyse the more volatile neutral PFAS species and volatile PFCAs in a single run.

Features of Markes' TD100-xr™, such as backflushing of the focusing trap and advanced water management, make the handling challenges associated with analysing PFAS manageable (such as the broad volatility range and the humidity of the materials analysed). The additional capability to perform sample re-collection provides checks that can easily be used to determine if the method is robust.

Indoor air quality is heavily influenced by material emissions. Markes' Micro-Chamber/Thermal Extractor™ enables analysts to validate whether a material is emitting PFAS and the emission rate. This result is directly comparable to reference chamber tests, and in the case of typical VOC testing can be used to predict whether products will pass.

## References


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### Trademarks



*Applications were performed under the stated analytical conditions. Operation under different conditions, or with incompatible sample matrices, may impact the performance shown.*

# Appendix

| Compound name | Abbreviation | $t_R$ (min) | $R^2$ | Quantitation SRM transition | RSD (%) | MDL (pg) | MDL 20 L sample volume (pg/m$^3$) |
|---|---|---|---|---|---|---|---|
| **Perfluoroalkyl-carboxylic acids (PFCAs)** | | | | | | | |
| Perfluoro-n-butanoic acid | PFBA | 1.59 | 0.9985 | 131/69 | 4.52 | 5 | 250 |
| Perfluoro-n-pentanoic acid | PFPeA | 1.63 | 0.9966 | 131/69 | 3.80 | 2 | 100 |
| Perfluoro-n-hexanoic acid | PFHxA | 1.72 | 0.9970 | 131/69 | 3.25 | 23 | 1150 |
| Perfluoro-n-heptanoic acid | PFHpA | 1.93 | 0.9981 | 131/69 | 2.42 | 3 | 150 |
| Perfluoro-n-octanoic acid | PFOA | 2.31 | 0.9986 | 131/69 | 2.00 | 2 | 100 |
| Perfluoro-n-nonanoic acid | PFNA | 2.9 | 0.9983 | 131/69 | 1.48 | 46 | 2300 |
| Perfluoro-n-decanoic acid | PFDA | 3.66 | 0.9978 | 131/69 | 2.48 | 27 | 1350 |
| Perfluoro-n-undecanoic acid | PFUdA | 4.52 | 0.9974 | 131/69 | 3.67 | 4 | 200 |
| Perfluoro-n-dodecanoic acid | PFDoA | 5.39 | 0.9975 | 131/69 | 2.71 | 21 | 1050 |
| Perfluoro-n-tridecanoic acid | PFTrDA | 6.21 | 0.9974 | 131/69 | 3.00 | 3 | 150 |
| Perfluoro-n-tetradecanoic acid | PFTeDA | 6.98 | 0.9975 | 131/69 | 3.01 | 2 | 100 |
| **Fluorotelomer carboxylic acids (FTCAs)** | | | | | | | |
| 2-Perfluorohexyl ethanoic acid (6:2) | FHEA | 3.97 | 0.9953 | 131/69 | 5.75 | 64 | 3200 |
| 2-Perfluorooctyl ethanoic acid (8:2) | FOEA | 5.90 | 0.9983 | 131/69 | 2.65 | 52 | 2600 |
| **Fluorotelomer alcohols (FTOHs)** | | | | | | | |
| 2-Perfluorobutyl ethanol (4:2) | FBET | 6.01 | 0.9951 | 95/69 | 4.10 | 13 | 650 |
| 2-Perfluorohexyl ethanol (6:2) | FHET | 7.66 | 0.9971 | 95/69 | 2.61 | 18 | 900 |
| 2-Perfluorooctyl ethanol (8:2) | FOET | 9.12 | 0.9963 | 95/69 | 3.99 | 4 | 200 |
| 2-Perfluorodecyl ethanol (10:2) | FDET | 10.41 | 0.9937 | 95/69 | 4.08 | 6 | 300 |
| **Perfluorotoctane sulfonamides (FOSA)** | | | | | | | |
| N-Methylperfluoro-1-octanesulfonamide | Me-FOSA | 12.87 | 0.9953 | 94/30 | 0.83 | 1 | 50 |
| N-Ethylperfluoro-1-octanesulfonamide | Et-FOSA | 13.18 | 0.9953 | 108/80 | 5.29 | 1 | 50 |

**Table A1:** Method performance data for the individual compounds.

| | | | Concentration (ng/m$^3$) | | | |
|---|---|---|---|---|---|---|
| **Compound** | **Abbreviation** | **$t_R$ (min)** | **Office** | **Lab** | **Store** | **Corridor** |
| Perfluoro-n-butanoic acid | PFBA | 1.59 | 6.25 | 5.25 | ND | 8.40 |
| Perfluoro-n-pentanoic acid | PFPeA | 1.63 | 3.30 | 3.25 | ND | 3.95 |
| Perfluoro-n-hexanoic acid | PFHxA | 1.73 | 4.10 | 3.75 | ND | 3.10 |
| Perfluoro-n-heptanoic acid | PFHpA | 1.93 | 2.60 | 2.85 | ND | 2.85 |
| Perfluoro-n-octanoic acid | PFOA | 2.33 | 8.90 | 7.15 | 4.55 | 13.85 |
| Perfluoro-n-nonanoic acid | PFNA | 2.89 | 5.55 | 3.85 | ND | 7.75 |
| Perfluoro-n-decanoic acid | PFDA | 3.66 | 2.95 | 3.50 | 2.80 | 17.25 |
| 2-Perfluorohexyl ethanoic acid (6:2) | FHEA | 3.97 | 15.60 | 13.85 | ND | ND |
| Perfluoro-n-undecanoic acid | PFUdA | 4.60 | 2.75 | 3.30 | 0.05 | 4.95 |
| Perfluoro-n-dodecanoic acid | PFDoA | 5.40 | 3.45 | 5.35 | 5.10 | 23.95 |
| 2-Perfluorooctyl ethanoic acid (8:2) | FOEA | 5.90 | ND | ND | 4.95 | ND |
| 2-Perfluorobutyl ethanol (4:2) | FBET | 6.01 | ND | ND | ND | ND |
| Perfluoro-n-tridecanoic acid | PFTrDA | 6.22 | ND | 2.65 | 0.35 | 3.65 |
| Perfluoro-n-tetradecanoic acid | PFTeDA | 6.96 | 6.30 | 11.80 | 4.00 | 50.55 |
| 2-Perfluorohexyl ethanol (6:2) | FHET | 7.67 | 6.85 | 5.75 | 5.75 | 5.05 |
| 2-Perfluorooctyl ethanol (8:2) | FOET | 9.13 | 7.30 | 1.90 | 6.75 | 4.90 |
| 2-Perfluorodecyl ethanol (10:2) | FDET | 10.41 | 10.40 | 1.20 | 2.50 | 4.45 |
| *N*-Methylperfluoro-1-octanesulfonamide | Me-FOSA | 12.88 | 2.80 | 3.95 | 1.55 | 2.30 |
| *N*-Ethylperfluoro-1-octanesulfonamide | Et-FOSA | 13.19 | ND | ND | ND | ND |
| Total PFAS | | | 89.10 | 79.35 | 38.35 | 156.95 |

**Table A2:** Concentration of compounds found across four sites in a workplace.

| Compound | Abbreviation | $t_R$ (min) | Concentration (ng/m$^3$) |
|---|---|---|---|
| Perfluoro-n-butanoic acid | PFBA | 1.59 | 0.81 |
| Perfluoro-n-pentanoic acid | PFPeA | 1.63 | 0.09 |
| Perfluoro-n-hexanoic acid | PFHxA | 1.73 | 0.68 |
| Perfluoro-n-heptanoic acid | PFHpA | 1.93 | ND |
| Perfluoro-n-octanoic acid | PFOA | 2.33 | 1.84 |
| Perfluoro-n-nonanoic acid | PFNA | 2.89 | 0.26 |
| Perfluoro-n-decanoic acid | PFDA | 3.66 | ND |
| 2-Perfluorohexyl ethanoic acid (6:2) | FHEA | 3.97 | ND |
| Perfluoro-n-undecanoic acid | PFUdA | 4.60 | ND |
| Perfluoro-n-dodecanoic acid | PFDoA | 5.40 | 0.01 |
| 2-Perfluorooctyl ethanoic acid (8:2) | FOEA | 5.90 | 0.94 |
| 2-Perfluorobutyl ethanol (4:2) | FBET | 6.01 | ND |
| Perfluoro-n-tridecanoic acid | PFTrDA | 6.22 | ND |
| Perfluoro-n-tetradecanoic acid | PFTeDA | 6.96 | ND |
| 2-Perfluorohexyl ethanol (6:2) | FHET | 7.67 | 0.24 |
| 2-Perfluorooctyl ethanol (8:2) | FOET | 9.13 | 1.20 |
| 2-Perfluorodecyl ethanol (10:2) | FDET | 10.41 | 3.33 |
| *N*-Methylperfluoro-1-octanesulfonamide | Me-FOSA | 12.88 | 0.74 |
| *N*-Ethylperfluoro-1-octanesulfonamide | Et-FOSA | 13.19 | 1.02 |
| Total PFAS | | | 11.15 |

**Table A3:** Concentration of compounds found in 70L of residential air

| Compound | Abbreviation | $t_R$ (min) | Concentration (ng/g) | Emission rate (ng/g/min) |
|---|---|---|---|---|
| Perfluoro-n-butanoic acid | PFBA | 1.59 | 0.045 | 0.002 |
| Perfluoro-n-pentanoic acid | PFPeA | 1.63 | 0.008 | 0.000 |
| Perfluoro-n-hexanoic acid | PFHxA | 1.73 | ND | ND |
| Perfluoro-n-heptanoic acid | PFHpA | 1.93 | ND | ND |
| Perfluoro-n-octanoic acid | PFOA | 2.33 | 0.034 | 0.001 |
| Perfluoro-n-nonanoic acid | PFNA | 2.89 | ND | ND |
| Perfluoro-n-decanoic acid | PFDA | 3.66 | ND | ND |
| 2-Perfluorohexyl ethanoic acid (6:2) | FHEA | 3.97 | ND | ND |
| Perfluoro-n-undecanoic acid | PFUdA | 4.60 | ND | ND |
| Perfluoro-n-dodecanoic acid | PFDoA | 5.40 | 0.006 | 0.000 |
| 2-Perfluorooctyl ethanoic acid (8:2) | FOEA | 5.90 | 0.126 | 0.004 |
| 2-Perfluorobutyl ethanol (4:2) | FBET | 6.01 | ND | ND |
| Perfluoro-n-tridecanoic acid | PFTrDA | 6.22 | ND | ND |
| Perfluoro-n-tetradecanoic acid | PFTeDA | 6.96 | ND | ND |
| 2-Perfluorohexyl ethanol (6:2) | FHET | 7.67 | ND | ND |
| 2-Perfluorooctyl ethanol (8:2) | FOET | 9.13 | 3.943 | 0.131 |
| 2-Perfluorodecyl ethanol (10:2) | FDET | 10.41 | 0.814 | 0.027 |
| *N*-Methylperfluoro-1-octanesulfonamide | Me-FOSA | 12.88 | 0.042 | 0.001 |
| *N*-Ethylperfluoro-1-octanesulfonamide | Et-FOSA | 13.19 | ND | ND |

**Table A4:** Concentration of compounds found in a child's waterproof coat.