Application proof note | AP004098

Combustion-IC

Screening of per- and polyfluoroalkyl substances (PFAS) in textiles: Utilizing a new combustion-ion chromatography system for total organic fluorine (TOF) analysis

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Keywords

Cindion combustion/absorption module, Dionex Inuvion IC system, Dionex IonPac AS24 column, AB 1817, organofluorine compounds, CIC, C-IC, combustion, pyrolysis, combustion ion chromatography

Introduction

Per- and polyfluoroalkyl substances (PFAS) are widely used across various industries and comprise thousands of compounds. These amphipathic substances are commonly found in textile products, such as clothing, carpets, and household items, to impart waterproofing, oil and dirt resistance, heat protection, and enhanced durability. The State of California Department of Toxic Substance Control has identified treatments of converted textiles or leathers as significant sources of human and ecological PFAS exposures, especially via inhalation during product use. In addition to textiles, PFAS contributes to environmental contamination through the disposal of these and other consumer products, such as food packaging materials and cosmetics.

In recent years, several US states have introduced or proposed regulations to limit PFAS use in various products, including textiles. Notably, California Assembly Bill 1817 (AB 1817) prohibits the manufacturing, sale, and distribution of textiles containing total organic fluorine (TOF) exceeding 100 parts per million (ppm) starting in January 2025, with a further reduction to 50 ppm by January 2027. Use of PFAS in textiles is also under scrutiny in Europe. For example, Denmark's Ministry of the Environment plans to ban PFAS in clothing, shoes, and waterproofing agents intended for consumers starting July 1, 2026, with broader EU-wide regulation expected by 2027.

In application note 003571, we developed a method to measure TOF in textiles using combustion-ion chromatography (C-IC).[1] This application proof note demonstrates the determination of TOF in textiles using a new and enhanced C-IC system. The Thermo Scientific™ Cindion™ Combustion Ion Chromatography System combines the Thermo Scientific™ Dionex™ Inuvion™ Ion Chromatography System, featuring reagent-free ion chromatography (RFIC), with the Thermo Scientific™ Cindion™ Combustion/Absorption Module. The system is optimized for increased combustion efficiency by incorporating a Z-fold combustion tube to introduce oxygen at multiple points. As a result, the combustion tube and furnace are shorter, and combustion times are reduced. This also results in a smaller footprint, saving valuable bench space. Additionally, the entire C-IC system is controlled by a single software solution—the Thermo Scientific™ Chromeleon™ Chromatography Data System (CDS)—which streamlines data processing and system management. With excellent sensitivity and versatility, the C-IC workflow enables direct IC analysis of total inorganic fluorine (TIF), allowing for the calculation of TOF by subtracting TIF from total fluorine (TF). Unlike surface-sensitive techniques, such as particle-induced gamma-ray emission (PIGE), which are limited to surface measurements and are affected by sample thickness, the C-IC method analyzes the entire sample, providing results independent of sample thickness.

Method

IC conditions	
IC system	Dionex Inuvion IC system with Thermo Scientific™ Dionex™ AS-AP Autosampler
Columns	Thermo Scientific™ Dionex™ IonPac™ AS24 Analytical Column (2 x 250 mm) (P/N 064153) Thermo Scientific™ Dionex™ IonPac™ AG24 Guard Column (2 x 50 mm) (P/N 064151)
Eluent	8 mM KOH from 0-6 min, 8-75 mM KOH from 6-9 min, 75 mM KOH from 9-12 min, 8 mM KOH from 12-20 min
Eluent source	Thermo Scientific™ Dionex™ EGC 500 KOH Cartridge (P/N 075778) with Thermo Scientific™ Dionex™ CR-ATC 600 Continuously Regenerated Anion Trap Column (P/N 088662)
Flow rate	0.3 mL/min
Injection volume	25 µL
Column temperature	30°C
Detection	Suppressed conductivity, Thermo Scientific™ Dionex™ ADRS 600 Anion Dynamically Regenerated Suppressor, 2 mm (P/N 088667), recycle mode, 56 mA current
Run time	20 min

Combustion and absorption conditions			
Combustion system	Cindion C-IC system combustion/absorption module		
Furnace temperature	Heater 1:1050°C, Heater 2: 1050°C		
Gases	Oxygen (primary): 300 mL/min Oxygen (Turbo): 100 mL/min Argon carrier: 100 mL/min		
Absorption solution	7 mL DI water		
Boat program	Position (mm) 75 150	Wait time (s) 60 250	Boat speed (mm/s) 3 1

Sample analysis

Given that textile samples can degrade or change over time, and the identical samples such as S1 are no longer available, we compared the TOF result for S1-S6 from AN003571 using both the method described above and the C-IC method described in AN003571 using the Nittoseiko C-IC system. TOF in samples S1-S6 was calculated by subtracting the TIF from the TF.

In this study, TF was measured using the combustion method, while TIF was determined by directly injecting water-extracted samples into the ion chromatograph using the Dionex AS-AP Autosampler. Detailed instructions for setting the 2-in-1 system are provided in technical note 003853.[2]

Table 1 summarizes TOF results obtained using the Cindion C-IC system. Figure 1 shows representative IC chromatograms for TF and TIF for sample S1. The TOF values obtained from the Cindion C-IC system closely matched those from the Nittoseiko C-IC system (Table 2), ranging from 100% to 105% of the corresponding values. This consistency confirms the reliability of this new method on the improved instrument platform.

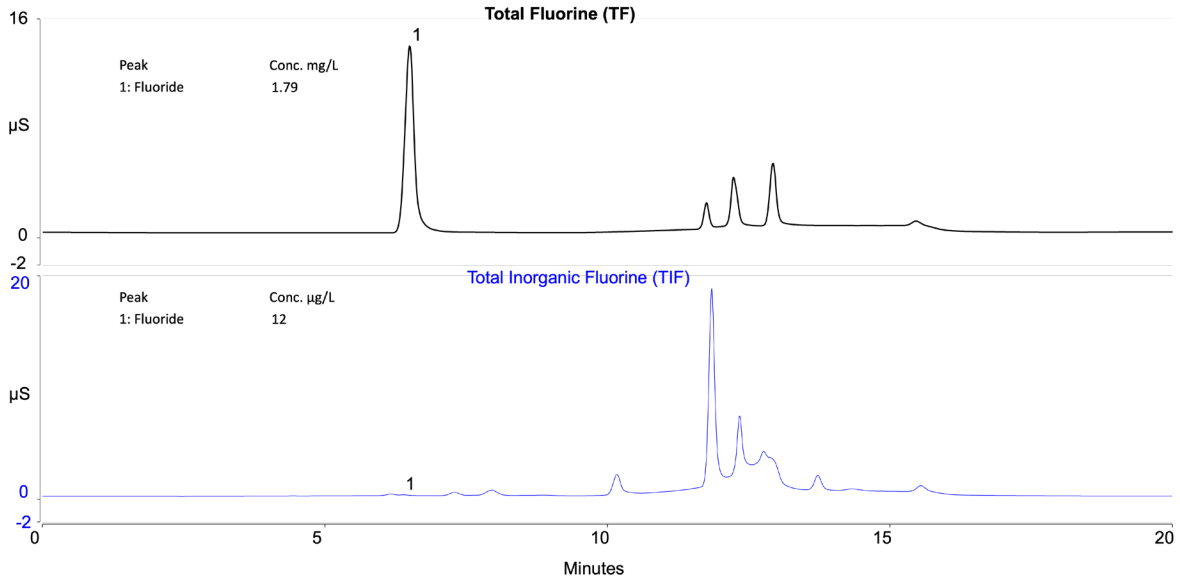

Figure 1. TF and TIF in sample #1.

Table 1. TOF in textile, ppm (µg/g) (n=3, RSD<8%) using the Cindion C-IC system.

Sample	Sample description	TF	TIF	TOF (TF-TIF)
1	Polyester Baby Bib	375	0.24	375.0
2	Polyurethane Laminate Pre-Cut Fabric, Waterproof and Breathable for Cloth Diapers	176	0.46	175.1
3	Polyester Waterproof & Stain Resistant Tablecloth	247	0.60	246.5
4	Waterproof Ripstop Nylon Fabric for Kite, Tent, Flag, Bag, Tarp Cover	1.1	0.13	1.0
5	Waterproof Canvas Fabric for Chair Cushion Furniture Cover	297	0.40	296.3
6	Waterproof Canvas Fabric for Indoor and Outdoor Use	186	0.19	185.5

Table 2. TOF in textile, ppm (µg/g) (n=3, RSD<8%) using the Nittoseiko C-IC system.

Sample	Sample description	TF	TIF	TOF (TF-TIF)
1	Polyester Baby Bib	373	0.21	372.8
2	Polyurethane Laminate Pre-Cut Fabric, Waterproof and Breathable for Cloth Diapers	169	0.46	168.5
3	Polyester Waterproof & Stain Resistant Tablecloth	235	0.53	234.5
4	Waterproof Ripstop Nylon Fabric for Kite, Tent, Flag, Bag, Tarp Cover	1.1	0.13	1.0
5	Waterproof Canvas Fabric for Chair Cushion Furniture Cover	286	0.44	285.6
6	Waterproof Canvas Fabric for Indoor and Outdoor	184	0.19	183.8

Note: Introducing an excessive amount of sample into the combustion-ion chromatography system can adversely affect combustion efficiency. If a peak appears disproportionately large relative to other analytes, reduce the sample weight incrementally until the TF results remain consistent or the fluoride concentration reaches the lowest calibration point.

Conclusion

The TOF results for samples S1-S6 show agreement between the Cindion C-IC system and the Nittoseiko C-IC system, confirming the accuracy and reliability of the new method. In AN003644, TIF was measured using four external injection channels, requiring manual sample changes after every four analyses and consuming large sample volumes. In contrast, the enhanced Cindion C-IC system offers a versatile 2-in-1 configuration that allows seamless switching between combustion- and standalone-IC modes. This integrated setup significantly improves workflow efficiency and ease of use. Overall, the TOF method described in this study provides a practical, efficient, and reliable tool for manufacturers aiming to comply with evolving PFAS regulations in textiles.

References

1. Jingli Hu, Neil Rumachik (2025) Application Note AN003571: Comprehensive screening of per- and polyfluoroalkyl substances (PFAS) in textiles; Utilizing combustion-ion chromatography for total organic fluorine (TOF) analysis, Thermo Fisher Scientific, Sunnyvale, CA, USA.

2. Jingli Hu, Neil Rumachik (2025) Technical Note TN003853: Configuring the Thermo Scientific Cindion C-IC system for a 2-in-1 operation: Seamless switching between combustion-IC and standalone-IC with an AS-AP autosampler, Thermo Fisher Scientific, Sunnyvale, CA, USA.

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