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Moving beyond monitoring legacy per and polyfluoroalkyl substances PFAS screening strategies for the growing list

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Introduction

Per/Polyfluoroalkyl substances (PFAS), are compounds that have uniquely desirable properties for use in various industries. However, their wide-ranging use leads to emission into the environment, and as PFAS are persistent and bioaccumulate in the environment and wildlife, they are contaminants of concern. Monitoring PFAS precursors present in an environmental sample may impact decisions in treatment processes at remediation sites and help deduce possible degradation products that could exist in the environment. Consequently, scientists are contributing newly identified PFAS structures and spectra to various publicly available databases: growing the list of precursors and degradation by-products, some listing thousands of PFAS.

Traditionally, methods such as USEPA 537 and ASTM 7979 are designed to monitor a small and discrete number of PFAS compounds, thought to be end-products of degradation processes occurring in environmental systems. LC-MS/MS technology is usually employed to quantify commonly monitored PFAS end-products. Without standards, adding target compounds to an LC-MS/MS method is restrictive and it would be logistically difficult to monitor all possible PFAS without knowing them and having standards.

The total fluorinated compounds in a sample may be underestimated by not monitoring the precursor compounds of which these compounds are formed from. Some countries decided to phase out specific classes of PFAS manufacturing and use, which has led manufactures to find alternative classes of PFAS, leading to new precursors and degradation products being found in environmental samples.

LC/Q-TOF technology allows the simultaneous quantification of commonly monitored PFAS whilst acquiring untargeted data that can be screened for suspected PFAS precursors (Figure 1).

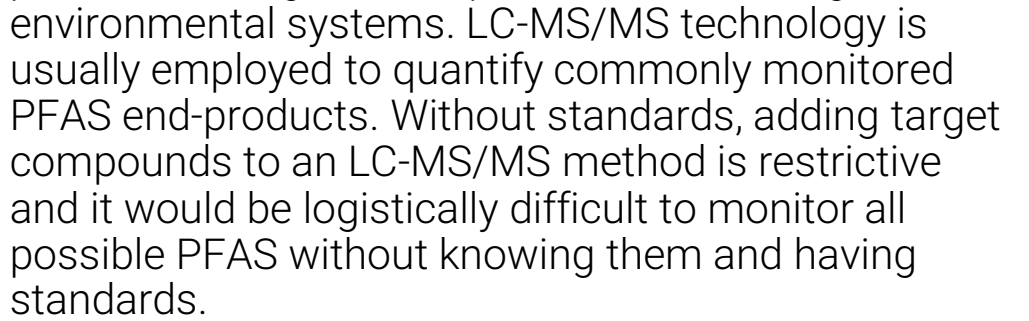

Figure 1. Target quantitation and suspect screening workflow.

The non-target nature of the data acquired also allows for retrospective detection of new PFAS as the scientific community learns more about these emerging contaminants.

Experimental

Standards Preparation

Standards were from Wellington Laboratories in methanol and were diluted from 5000 ppt to 5 ppt in water.

Sample Preparation

Samples were blind spiked with different PFAS. 5 mL of each sample was diluted with 5 mL methanol, filtered with 0.45 µm nylon discs, acidified with acetic acid before injection, as described previously[1].

Instrumental Analysis

The LC method was as previously described.[1] The Agilent 6546 LC/Q-TOF system (Figure 1) was run in AllIons MS/MS acquisition mode as described in Table 1 to collect both precursor ion (used for quantitation of targets) and fragment ion data for qualitative confirmation.

Table 1: LC/Q-TOF Instrument parameters

High Speed Pump (G7120A)	Solvent A2: 5mM ammonium acetate in water Solvent B2: 100% acetonitrile Flow Rate: 0.4 mL/min Max Pressure Limit: 1300 bar Gradient:	Time (min) 0.00 1.00 9.00 10.00 12.00 14.00 15.00	%B 3.00 (Start) 25.00 85.00 97.00 97.00 3.00 3.00 (Stop)
Multisampler (G7167B)	Injection Volume: 30 µL Multiwash: Seat back flush and needle wash with 5s each of 100% isopropanol, then 100% acetonitrile, then 100% water		
Multicolumn Thermostat (G7116B)	Column Temperature: 30°C Column: Agilent InfinityLab Poroshell HPH-C18 2.1 × 100 mm, 1.9 µm (p/n 695675-702)		
6546 Q-TOF System (G6546A)	Gas Temp: 320°C Gas Flow: 8 L/min Nebulizer: 35 psi Sheath Gas Temp: 350°C Sheath Gas Flow: 11 L/min Negative ionization mode Collisions Energy: 0, 10, 20 V Mass range: 50-1100 m/z Acquisition Rate 6 spectra/sec		

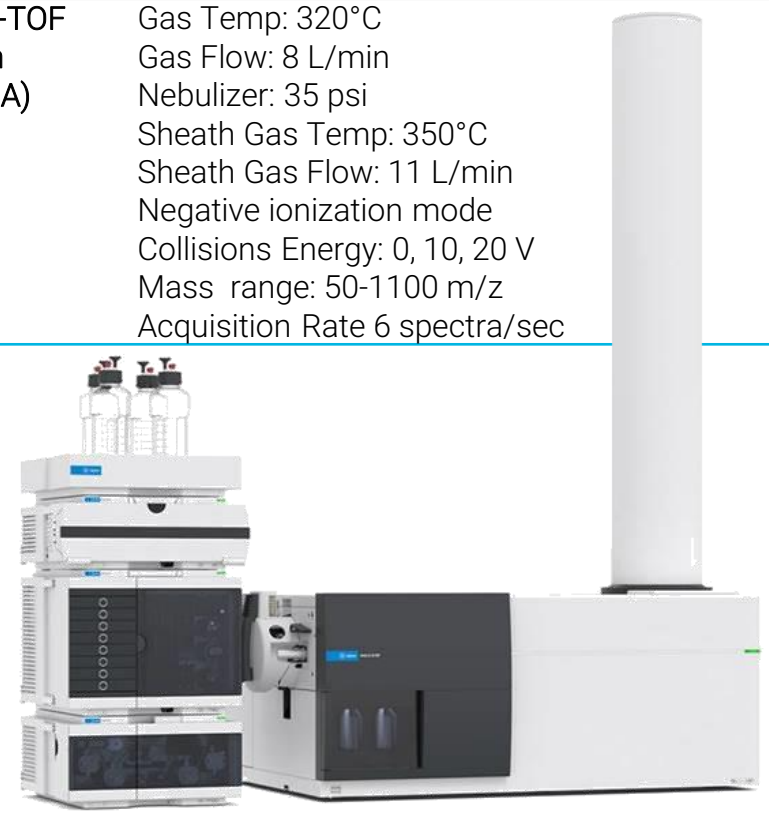

Figure 1. Agilent 6546 LC-Q/TOF system

Quantitative analysis

This study used a simple dilution (with methanol) and acidification extraction of non-potable water samples to quantify ~20 commonly monitored PFAS and determines the accuracy, recovery and estimated limits of detection on an LC/Q-TOF.

Agilent's SureMass[2] technology significantly increase the speed in processing time required to quantitate the accurate mass high resolution data.

Figure 2 shows the chromatographic separation of the target compounds, where the CE=0 producing the precursor ion. Good peak shape and separation was achieved with the 30 µL injection.

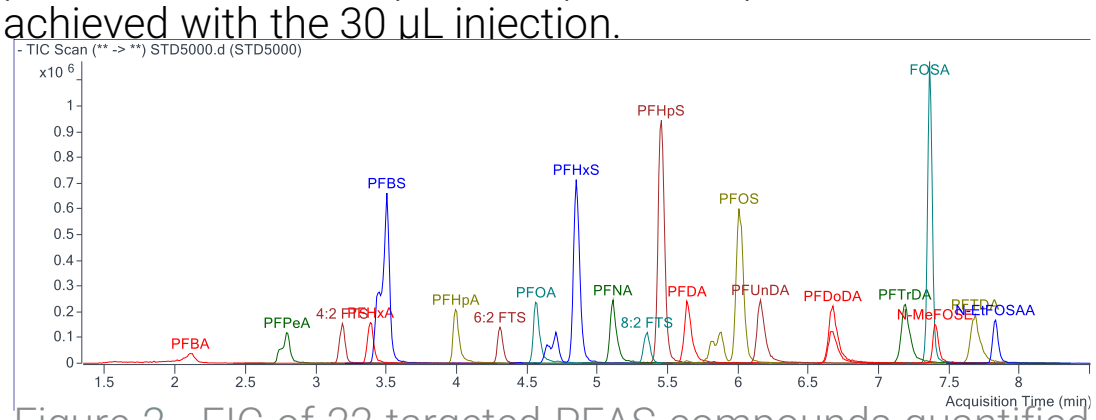

Figure 2. EIC of 22 targeted PFAS compounds quantified by LC/Q-TOF

EICs of the select targets ranging in RT and chemical diversity (Figure 3: from top to bottom PFBA, PFOS, PFOA and N-MeFOSE) at the lower limit of quantitation (LLOQ) along with a calibration for each compound showing linearity achieved. The detection limits of the 6546 LC/Q-TOF system was close but not as low as equivalent triple quadrupole results.[1]

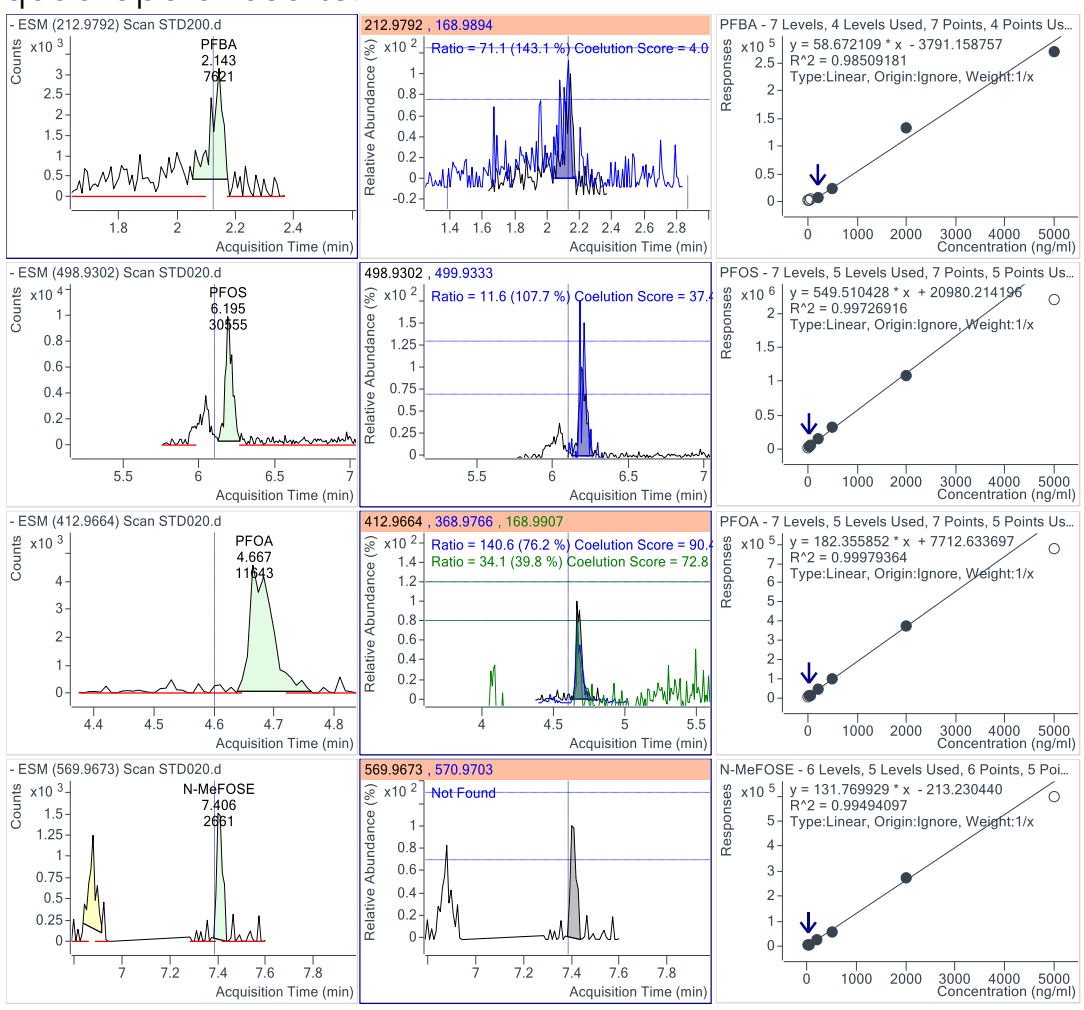

Figure 3. EICs and calibration curves of select targets

Predicting PFAS retention times

The sample preparation procedure was designed to extract a wide range of PFAS, rather than selecting PFAS via weak anion exchange (WAX) techniques commonly used. In combination with non-targeted data acquisition allowed us to screen against a large customer database of PFAS compounds to identify additional PFAS that were not in our original target list.

Presently, the availability of PFAS standards is very limited relative to the number of PFAS that could be present in the environment. So, without standards putative identifications rely on knowledge of fragment annotation and physiochemical properties. Software, such as Agilent's Molecular Structure Correlator can be used to correlate MS/MS spectra with chemical structures. Using predicted physiochemical properties to predict a RT is another useful tool to confirm a putative identification.

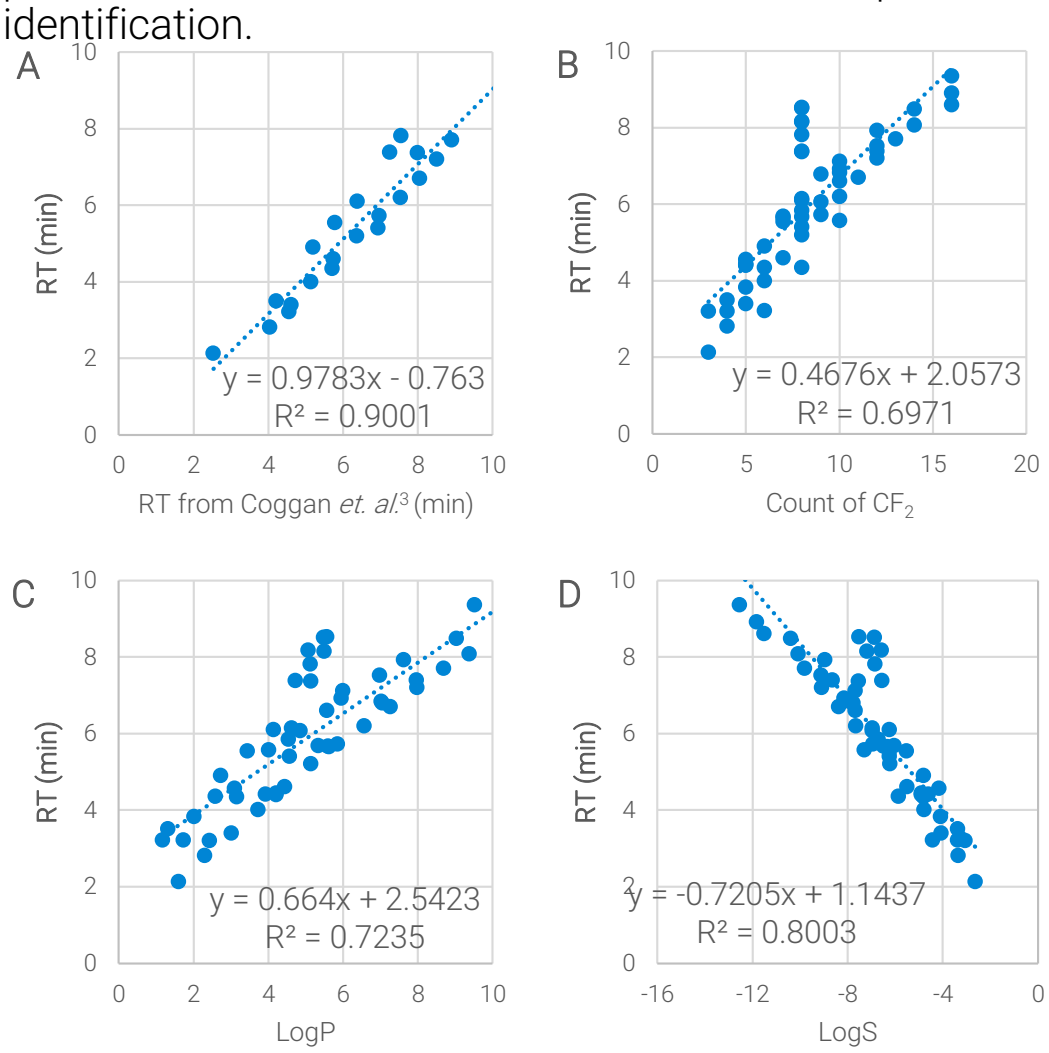

Figure 4. Correlation of other RT's and chemical properties to RT's measured in this study.

A model to predict RTs for a wide range of PFAS was developed by first projecting RT's from a validated method analyzing a chemically diverse set of PFAS[3] (Figure 4A), to increase the model training set size. Measured and projected RT's were then regressed on predicted physiochemical properties[4], including LogP (Figure 4C) and LogS (Figure 4D) as well as the number of -CF_2- subunits (Figure 4B) in the chemical structure. A weighted average of predicted RT's from individual regressions was calculated.

Screening Summary Report

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Sample name: 16AGW06 **Good** 4 **Warning** 17 **Error** 354

Status	Screening Summary Report	Formula	R.T.	R.T. Diff.	Match Score	Target Ion	Mass Accuracy	# of Qualified Ions	Final Conc.
!	(Heptafluoropropyl)trimethylsilane	C6H9F7Si	2.694	2.692		241.0289	3.95 PPM	2	
+	PFBA	C4 H F7 O2	2.079	0.041		212.9792	0.63 PPM	2	472.7851
+	PFPeA	C5 H F9 O2	2.777	0.031		262.9760	0.47 PPM	2	448.9793
!	4:2 FTS	C6 H5 F9 O3 S	3.162	0.048		326.9743	-0.22 PPM	1	880.0983
+	PFHxA	C6 H F11 O2	3.363	0.036		312.9728	-0.28 PPM	2	475.3056
!	PFBS	C4 H F9 O3 S	3.469	0.031		298.9430	-0.39 PPM	1	359.3393
!	3H-Perfluorobutanoic acid	C4H2F6O2	3.530	0.499		194.9886	-1.07 PPM	1	
!	Perfluorooctanesulfonate	C8HF17O3S	5.933	1.754		498.9302	-1.26 PPM	2	
+	6:2 FTS	C8 H5 F13 O3 S	4.266	0.076		426.9679	-0.59 PPM	2	911.3406
!	2H-Perfluoro(2-methylpentane)	C6HF13	3.956	0.505		318.9798	-0.97 PPM	2	
!	Perfluoro(2-ethoxyethane)sulfonic acid	C4HF9O4S	3.785	0.778		314.9379	0.46 PPM	2	
!	Perfluoropentanesulfonic acid	C5HF11O3S	4.165	0.729		348.9398	-0.65 PPM	2	
!	1-Hydroperfluoroheptane	C7HF15	4.511	0.662		368.9766	-0.44 PPM	2	
!	PFNA	C9 H F17 O2	5.058	0.143		462.9632	-0.38 PPM	2	303.9080
!	2,3,3,3-Tetrafluoro-2-(perfluoropentoxy)propan-1-ol	C8H3F15O2	4.526	0.718		414.9821	0.81 PPM	2	
!	1H-Perfluorohexane	C6HF13	3.956	1.326		318.9798	-0.97 PPM	2	
!	((Perfluorooctyl)ethyl)phosphonic acid	C10H6F17O3P	5.300	0.485		526.9710	4.37 PPM	1	
!	4-[3-(Perfluorobutyl)-1-propyloxy]benzyl alcohol	C14H13F9O2	6.167	0.221		383.0699	2.89 PPM	1	
!	(Perfluorooctyl)propanoyl chloride	C11H4ClF17O	5.927	0.137		508.9606	-2.22 PPM	1	
!	PFOS	C8 H F17 O3 S	5.933	0.167		498.9302	-1.23 PPM	2	63.0760
!	FOSA	C8 H2 F17 N O2 S	7.351	0.015		497.9462	-1.76 PPM	1	0.4484

Figure 5. Screening summary report for a waste water sample showing results

Suspect screening

A Personal Compound Database (PCD) containing predicted RT's was curated from US EPA's PFAS Inventory List. These suspect PFAS were appended to the MassHunter Quantitative 10.0 data analysis method, and screened for. The Screening Summary Report is shown in Figure 5 for a selected sample.

Perfluoro (2-ethoxyethane) sulfonic acid had a predicted retention time of 4.56 minutes and was putatively detected at 3.78 minutes in this sample, which is within an expected window given error in the prediction model. This suspect must be subject to further inspection to determine if the putative identifications is real. However, the predicted retention time, accurate mass results, stable isotope pattern provides much data for this inspection.

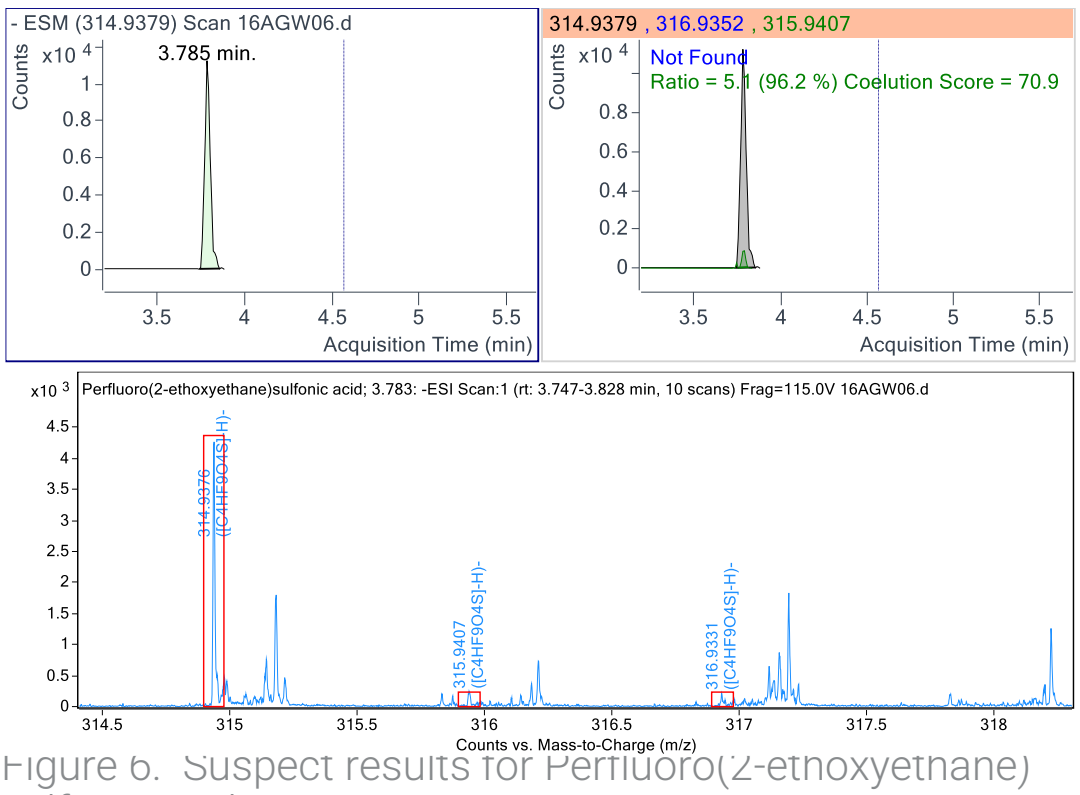

Figure 6. Suspect results for Perfluoro(2-ethoxyethane) sulfonic acid

MS/MS fragments, as they are determined, can also be added to the method to confirm the identification of existing data, due to the non-targeted data independent acquisition mode.

Conclusions

This work demonstrates the use of LC/Q-TOF MS for both quantitative targeted analysis and suspect screening in the same run.

- LC/Q-TOF with SureMass quantitation gives detection limits close to that of equivalent LC/TQ technology.
- The use of PCD and PCDL's (databases with MS/MS spectra) and SureMass provides suspect screening of PFAS compounds without the use of standards.
- Advantages of using physiochemical properties, known or predicted, to support a putative identification.

References

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