Derivatization Methods for Perfluoroalkyl Substances (PFAS) by Gas Chromatography/Tandem Mass Spectrometry
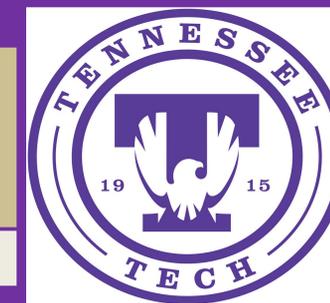
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Introduction

- PFAS are environmentally persistent, non-degradable, bioaccumulative, and potentially harmful. These "forever chemicals" are widely distributed across the globe, and methods are needed for the rapid and routine analysis in a variety of matrices
- Gas chromatography with mass spectrometry (GC/MS) is commonly used for the analysis of water samples, but PFAS compounds pose special problems in sample pretreatment, separation, and detection
- To develop a method for routine analysis of PFAS by GC, we present our work towards a sensitive, simple, and reliable analytical technique for the determination of perfluorocarboxylic acids (PFOA) by GC-MS/MS after amidation with 2,4- difluoroaniline (DFA)
- The optimized conditions for the synthesis of the derivatized analytes, as well as their GC retention properties and characteristic mass spectrometric fragments were reported. The overall instrument detection limit is determined from a calibration curve study and found to be acceptable for the analysis of surface water samples following appropriate solid-phase extraction and derivatization

Methods

- **PFOA Anilide derivative:** Standards of PFOA anilide derivatives were prepared in 1:2 methylene chloride (DCM) and methanol respectively, followed by an amidation reaction with 2,4-difluoroaniline (DFA) after coupling with N,N-dicyclohexylcarbodiimide (DCC) in the presence of 4-dimethylaminopyridine (DMAP) at ambient temperature
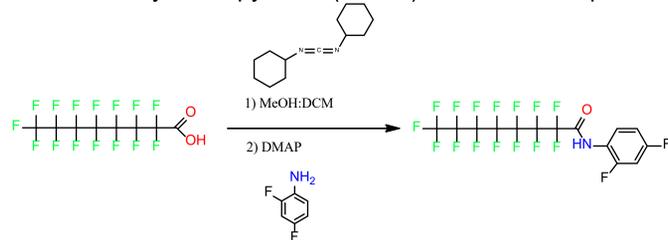
- **NMR Characterization:** Sequel to the synthesis of PFOA using DCC and DFA at equivalent ratio of (1.0:1.0:1.2), protons of the derivative formed were confirmed by NMR for both the intermediate (pre clean up), and final product (post clean up) using the Brucker 500 NMR
- **Clean up procedure:** Aliquots of products were dried under rotary evaporator, followed by the addition of 10 ml of ethyl acetate, 2 ml of hydrochloric acid, and 2 ml of saturated sodium carbonate solution. Stirred for 30 mins and the organic phase was collected after the addition of 2 ml sodium chloride, dehydrated with Sodium sulfate, filtered and dried under nitrogen prior to GC-MS/MS analysis of the organic phase
- **GC-MS/MS Analysis: GC-MS/MS** experiments were performed using Agilent GC-MS (8890 GC with 9000D triple quadrupole MS) with an electron ionization and data were acquired in the multiple reaction monitoring modes (MRM)

Results

- Excellent fragmentation of the PFOA Anilide derivative chromatographic peak at RT 5.05 with high fragmentation intensities at 69, 100, 119, 128, 156, 206, and 525. on full scan mode, and target ions observed on MRM (525>156>206)
- Calibration curve linearity with $R^2 > 0.9$ for all prepared PFOA anilide derivative standards and the calculated Instrument detection limit (LOD) was 55 ppb.
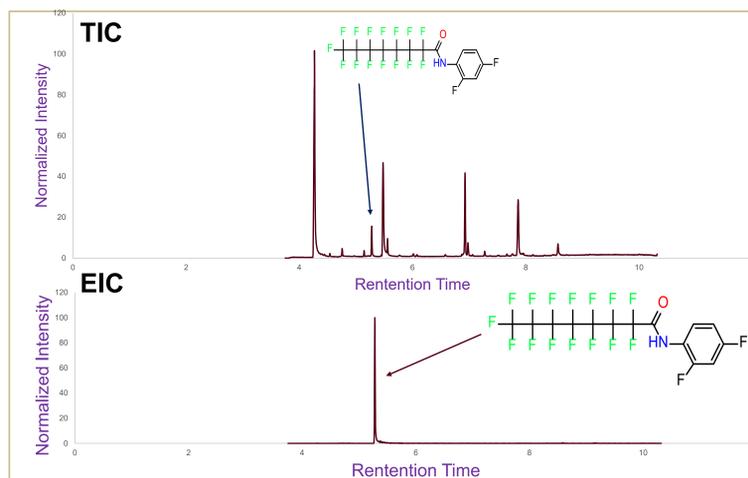
Figure 1: Reconstructed Total ion chromatogram (TIC) overlaid with a normalized Extracted ion chromatogram (EIC) of the PFOA anilide derivative at 525.2 m/z for the PFOA Anilide derivative at 1000 ppm.
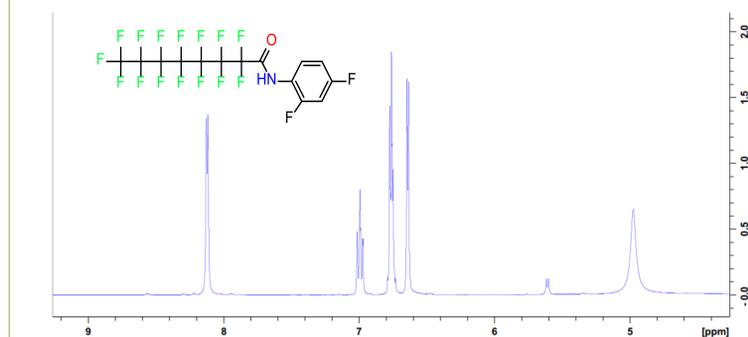
Figure 2: HNMR spectra for PFOA anilide derivative
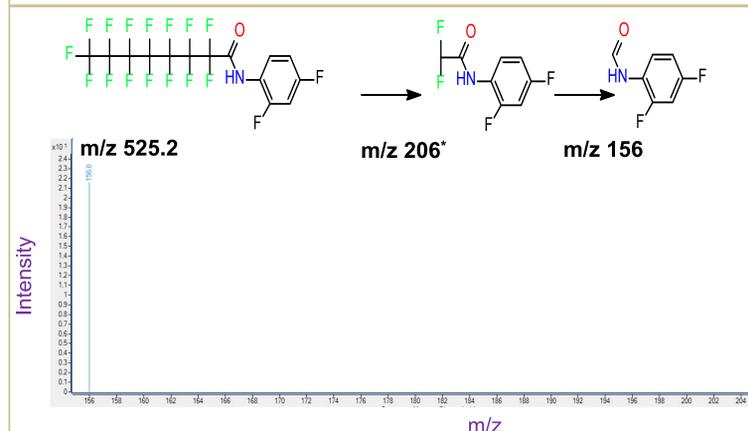
Figure 3: MS fragmentation (m/z) of PFOA Anilide derivative ions on electron ionization and acquired on MRM mode

$$y = 216.66x + 70654$$
$$R^2 = 0.9926$$
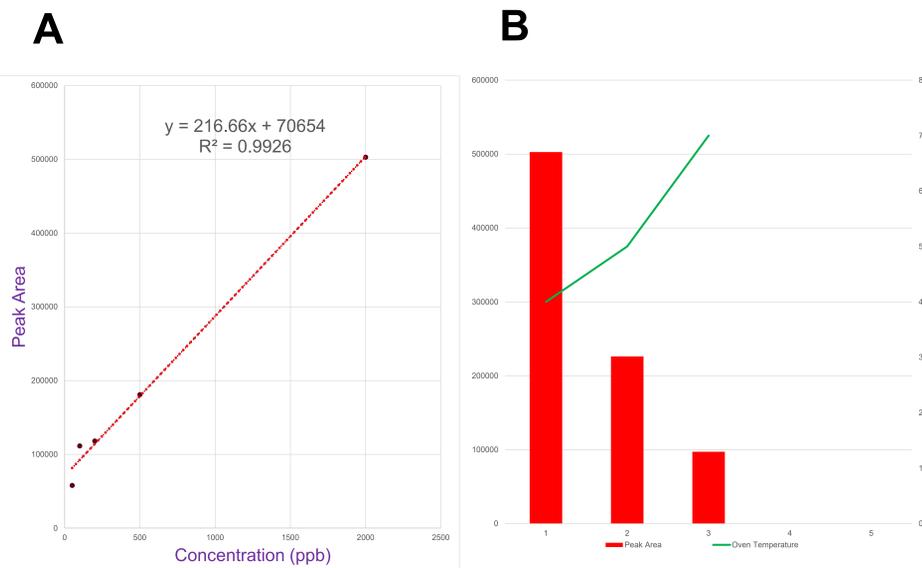
Figure 4: A. Calibration curve showing the mass spectrometry response across five different concentration (ppb) levels of the PFOA Anilide derivative. **B.** Gas chromatography initial oven temperature programming for optima separation of PFOA anilide derivative

Conclusions

- PFOA was successfully synthesized into anilide derivative suitable for GC separation.
- We managed to systematically modify and optimized the amidation reaction procedure, the instrument conditions, and established a detection limit based on the signal to noise ratio (SNR) of the lowest concentration closest to 3 (SNR ≥ 3) for both the instrument and the method
- The method is valid for application in water samples, following appropriate derivatization and solid phase extraction (SPE)

Acknowledgement

References

- Li, Z., & Sun, H. (2020). Cost-effective detection of perfluoroalkyl carboxylic acids with gas chromatography: optimization of derivatization approaches and method validation. *International journal of environmental research and public health*, 17(1), 100.