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Novel Approaches for Comprehensive PFAS Destruction: Integrating Analytical & Thermochemical Strategies

Aim

The aim of this study is to demonstrate how the integration of automated pyroprobe-GCxGC-HRMS and a custom-made muffle furnace setup can significantly improve mineralization efficiency while prioritizing safety measures, reducing manual labor, and minimizing loss of analytes and degradation products. Additionally, this project seeks to innovate by pioneering the utilization of two-dimensional GC and LC separation techniques to concurrently identify and quantify PFAS and their degradation products.

Justification

Since the 1940s, PFAS have been manufactured and used in a variety of industries in Europe and around the globe. The continuous PFAS production and consumption, faces a critical challenge concerning the mounting environmental and health risks associated with PFAS contamination. The absence of established guidelines for PFAS in drinking water further exacerbates this issue. Consequently, there is an urgent need for effective disposal methods and analytical techniques to address these challenges [1-3]

Various methods for PFAS degradation exist, including oxidation/reduction processes, photocatalysis, electrocatalysis, and thermal treatments, coupled with advanced analytical techniques like LC-MS, GC-MS, and HRMS for their analysis. However, most of these methods are complex, time-consuming, and inefficient in achieving complete mineralization [1,4].

This project proposes an innovative approach, utilizing an advanced online high-temperature pyrolysis setup (pyroprobe-GCxGC-HRMS) and a custom-made quartz muffle furnace for PFAS mineralization. The setup aims to achieve efficient degradation to inorganic fluoride at high temperatures over an extended duration. Additionally, the project explores the impact of various additives on mineralization efficiency at lower temperatures.

The research involves developing kinetic models to optimize PFAS destruction conditions, reducing the need for extensive experimental trials. Employing cutting-edge techniques like GCxGC-MS/MS and LCxLC-MS/MS will enable the comprehensive identification and quantification of diverse PFAS compounds and their degradation products across complex matrices.

The proposed sophisticated, automated pyroprobe-GCxGC-HRMS and homemade muffle furnace setup not only enhances mineralization efficiency but also ensures safety, reduces labor, and minimizes analyte and degradation product loss. Furthermore, the project pioneers two-dimensional GC and LC separation for simultaneous identification and quantification of PFAS and their degradation products, a groundbreaking approach for complex sample analysis.

This collaborative effort, involving leading analytical chemistry researchers, aims to establish comprehensive methodologies encompassing targeted, suspect/non-targeted, and total screening methods. This holistic study endeavors to transform our understanding of PFAS behavior and develop sustainable strategies for their effective mineralization and destruction, crucial for environmental and human health preservation.

Program

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DRIVING CHEMICAL TECHNOLOGY

1. Literature review on PFAS pyrolysis and GCXGC/LCXLC-MS/MS analysis
2. Online characterize the pyrolysised volatiles of PFAS using pyroprobe-GCxGC-HRMS and offline with homemade muffle furnace along with LCXLC-MS/MS
3. Investigate the effect of pyrolysis temperature, residence time and additives on the PVC pyrolysis.
4. Study the synergistic effect during PVC and PE co-pyrolysis.
5. Investigate the development of first-principles-based kinetic models, reducing future experimental needs and guiding optimal conditions for PFAS destruction.

References

1. Environ. Sci. Technol. 2023, 57, 6179−6187
2. Chemosphere 129 (2015) 87–99
3. Current Opinion in Environmental Science & Health 2023, 33:10045
4. Current Opinion in Environmental Science & Health 2023, 33:100459