wetsus
european centre of **excellence**
for sustainable **water technology**

Improvement of thermo-chemical destruction processes for PFAS removal from sewage sludge

Esther de Kroon
esther.dekroon@wetsus.nl

Motivation

Per- and polyfluoroalkyl substances (PFAS) are ubiquitously used for many industrial applications due to its thermal and chemical stability, provided by the strong C-F bond. The same quality, however, result in accumulation in the environment, as well as in wastewater treatment plants, where they are present in sewage sludge[1]. Excess sewage sludge is typically treated in sludge thermal treatment processes, such as incineration or gasification.

Although partial degradation may occur at operating temperatures (±850-1100 °C), stable fluorinated by-products can form. Full mineralization requires process conditions typically not achieved in current industrial sludge thermal treatment systems[2]. The lack of standardized sampling and analytical methods across solid, liquid and gas phases further limits the closure of PFAS and fluorine mass balances, impeding the assessment of degradation efficiencies and identification of harmful by-products. As a result, PFAS behaviour, degradation pathways and emission risks during such large-scale sludge thermal processes remain poorly understood[3].

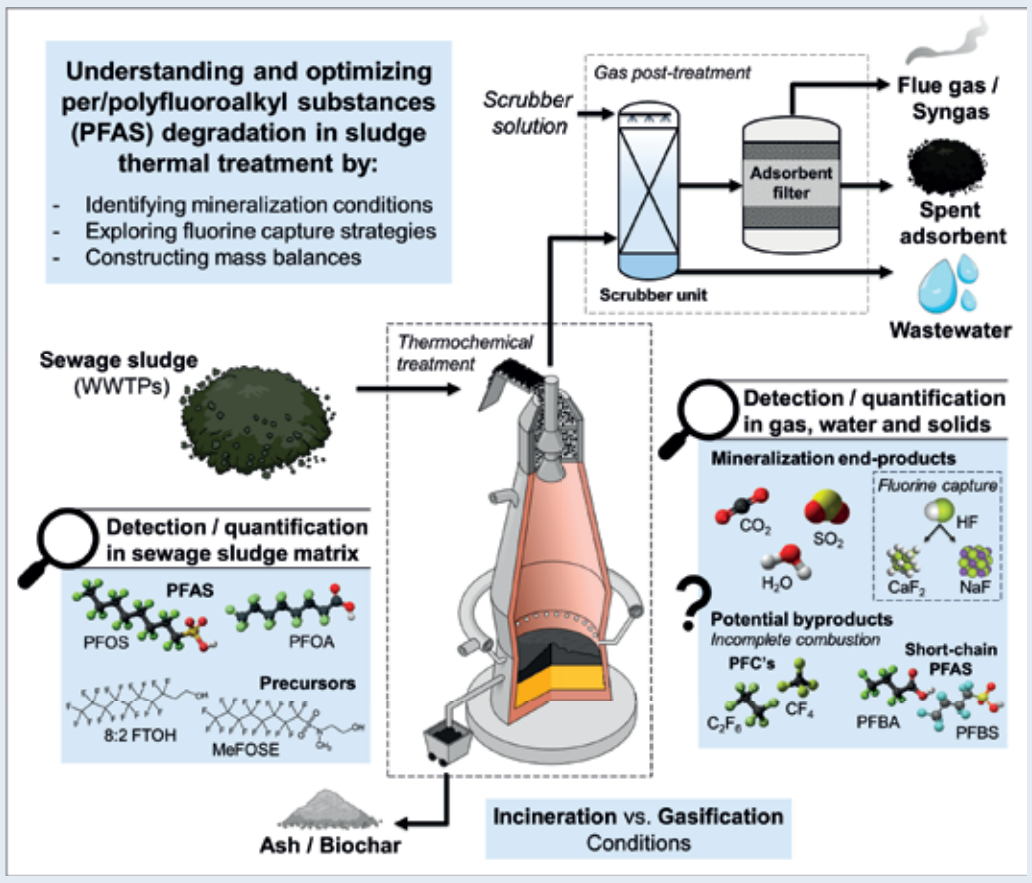

Fig 2. Graphical abstract of thermochemical PFAS degradation in sludge matrices, presenting a simplified overview of sludge thermal treatment.

Technological challenge

The technological challenges related to PFAS degradation in sludge thermal treatment processes include:

- **Incomplete mineralization** under typical industrial conditions, enabling the formation of stable fluorinated by-products.
- **Matrix complexity**, as sludge composition affects PFAS degradation pathways and by-product formation.
- **Lack of standardized sampling and detection methods**, prevents reliable PFAS/fluorine mass balances.
- **Limited insights into PFAS behaviour** under oxidative vs. reductive conditions, and influence of catalysts, adsorbents and additives on degradation efficiencies and by-product formation.

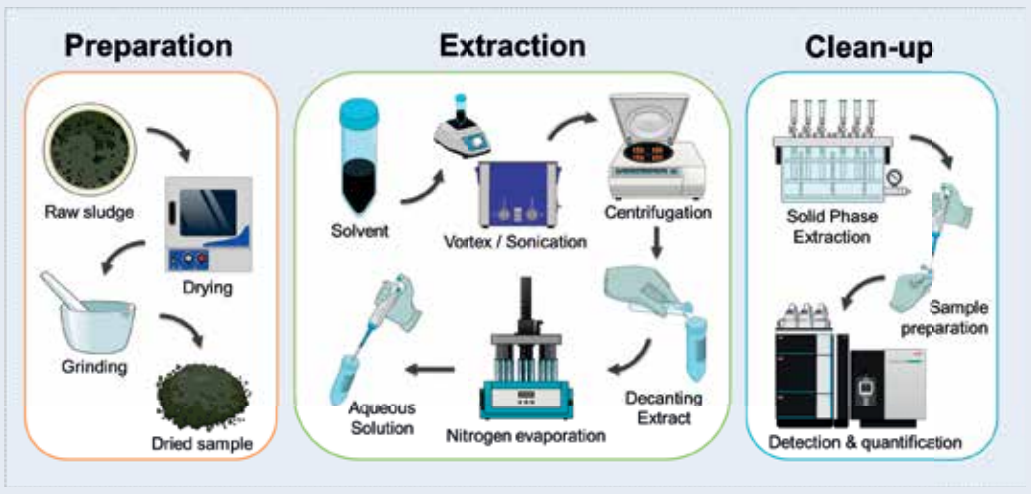

Fig 1. Impression of solid sample preparation, pretreatment and clean-up protocol for PFAS detection & quantification analysis.

Research goals

The main objective of this research is to establish a fundamental understanding and optimization of thermochemical PFAS degradation in sewage sludge thermal treatment processes, enabling complete mineralization while minimizing formation of harmful fluorinated by-products, by:

- **Conducting bench-scale parametric study** to quantify PFAS degradation, by-product formation and mass balances under controlled thermal conditions
- **Developing and validating sampling and analytical methods** for relevant PFAS compounds, its precursors, and fluorinated by-products across solid, liquid and gas phases.
- **Evaluating catalysts, additives and adsorbents** to enhance PFAS mineralization and promote fluorine capture.
- **Translating findings to demo- and full-scale systems** to assess scalability, validate mass balances and explore integration of other PFAS-rich waste stream treatment.

References

[1] Guo, Y. et al. Journal of Hazardous Materials (2025) vol. 498, 139989
[2] Hakeem, I. G. *et al.* Chemical Engineering Journal (2024) vol. 493, 152537
[3] Winchell, L. J. *et al.* Science of the Total Environment (2021) vol. 774, 145257

UPPWATER Dutch water tech
SBO-instituut Dutch Institute for Strategically Important Research

E. J. de Kroon MSc., ir. W. Wijdeveld MSc., dr. A. Larasati
dr.ir. A.G.J. van der Ham, prof.dr. S.R.A. Kersten
UNIVERSITY OF TWENTE.