Current Insights on Reaction Kinetics and Mechanisms of PFAS Destruction during Hydrothermal Alkaline Treatment (HALT)

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Hydrothermal Alkaline Treatment (HALT)

- PFAS destruction process in **subcritical water**
  - Temperature: 200 to 350 °C
  - Pressures: 10 to 25 MPa
  - Reaction times: 1.5 to 30 min
  - NaOH concentrations: 0.1 to 5 M-NaOH
- Highly effective at breaking down long-chain, short-chain and ultra-short chain PFAS
- Final products of reaction are inert salts (*e.g.*, sodium fluoride, sodium carbonate, sodium sulfate)

Technical Development To-Date

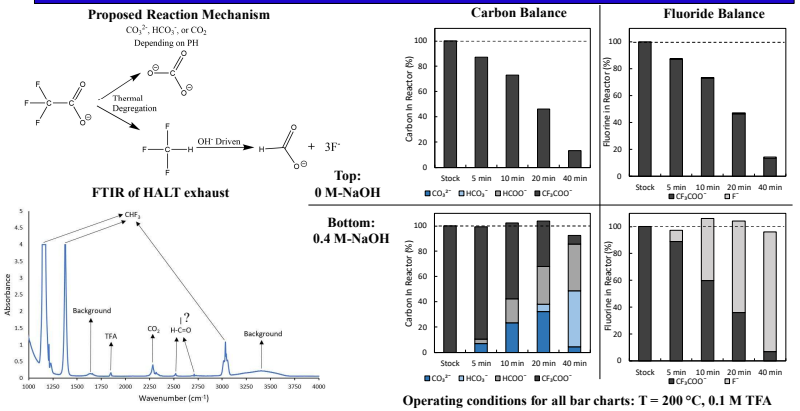
Feedstock	Testing Done	Total DRE (%)
Dilute AFFF	Pilot-Scale	>99%
Concentrated AFFF	Lab-Scale	>99.99%
Fire training pond water	Pilot-Scale	>99.9%
Landfill leachate	Lab-Scale	>99%
Sorbent regen. brine	Pilot-Scale	>99.9%
Foam fractionate	Pilot-Scale	>99.9%

- Pilot Series system has been operated >200 hours for feasibility testing
- Steed Series (10 - 20 gallon per hour) units are being fabricated for field demonstrations in 2023 and 2024
- Efficacy demonstrated on several key feedstocks at-scale, with >99% destruction efficiency reliably achieved for concentrated feedstocks

Abstract

Hydrothermal alkaline treatment (HALT) is an emerging **PFAS destruction** process which facilitates **rapid and complete destruction** of all PFAS compounds. Current research has shown that a combination of thermal decomposition, hydrolysis, and OH^--driven reactions occur to convert PFAS species to final products of fluoride, carbonate, and sulfonate salts

Mechanism of Perfluorocarboxylic Acid Destruction in HALT



Operating conditions for all bar charts: T = 200 °C, 0.1 M TFA

- TFA is destroyed under HALT conditions with and without NaOH
- NaOH is required to achieve **full mineralization**, breaking down the fluoroform (CF_3H) intermediate
- Initial reaction step is a thermal step to cleave off the -COOH head group, which occurs around 150 to 250 °C

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HALT of Foam Fractionate in Pilot System

Analyte	Foamate (ppb)	HALT Effluent (ppb)	Destruction %
PFOS	**36,400**	**10.9**	**99.97%**
PFHpS	522	0.199	99.96%
PFHxS	6,260	3.34	99.95%
PFPeS	1,160	1.09	99.91%
PFBS	552	1.58	99.71%
PFOA	**484**	**0.047**	**99.99%**
PFHpA	334	ND	>99.993%
PFHxA	2,540	ND	>99.999%
PFPeA	196	ND	>99.98%
6:2 FTS	8,800	ND	>99.999%
Total PFAS	**58,280**	**17.16**	**99.97%**

- AFFF-impacted water from a fire training pond treated with bench-scale foam fractionator. Foamate treated with HALT
- >99.9% destruction of total PFAS
- >99% destruction of all individual PFAS
- No detectable intermediate products

Conclusions

- HALT destruction mechanisms are becoming better understood, with recent testing indicating thermal mechanisms are active for PFCAs
- **>99% destruction efficiency** can be reliably achieved for all PFAS in pilot-scale HALT reactor