ECWS-9 2025 Conference

The 9th International Electronic Conference on Water Sciences

11–14 November 2025 | Online

MDPI

Hybrid Ultrasonic-Oxidative Treatment of PFASs in Firefighting Foams and Enriched Foam Waste

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INTRODUCTION & AIM

Per- and polyfluoroalkyl substances (PFAS) are highly persistent and toxic contaminants commonly linked to aqueous film-forming foams (AFFF), a major source of soil and groundwater pollution. Foam fractionation (FF) is commonly used to concentrate PFAS from AFFF solutions, yet the resulting PFAS-rich foams present disposal challenges. Ultrasonic degradation has emerged as a promising remediation strategy, as the extreme cavitation conditions generated during sonication promote both radical-mediated and pyrolytic breakdown of PFAS. This study aims to evaluate the influence of oxidants, ferric chloride ($FeCl_3$), sodium persulfate (PS) ($Na_2S_2O_8$), and hydrogen peroxide (H_2O_2), on the ultrasonic degradation of PFAS, including PFOA and PFOS, AFFF, and FF.

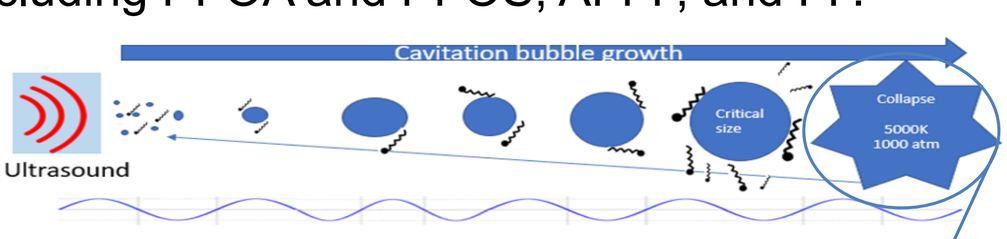
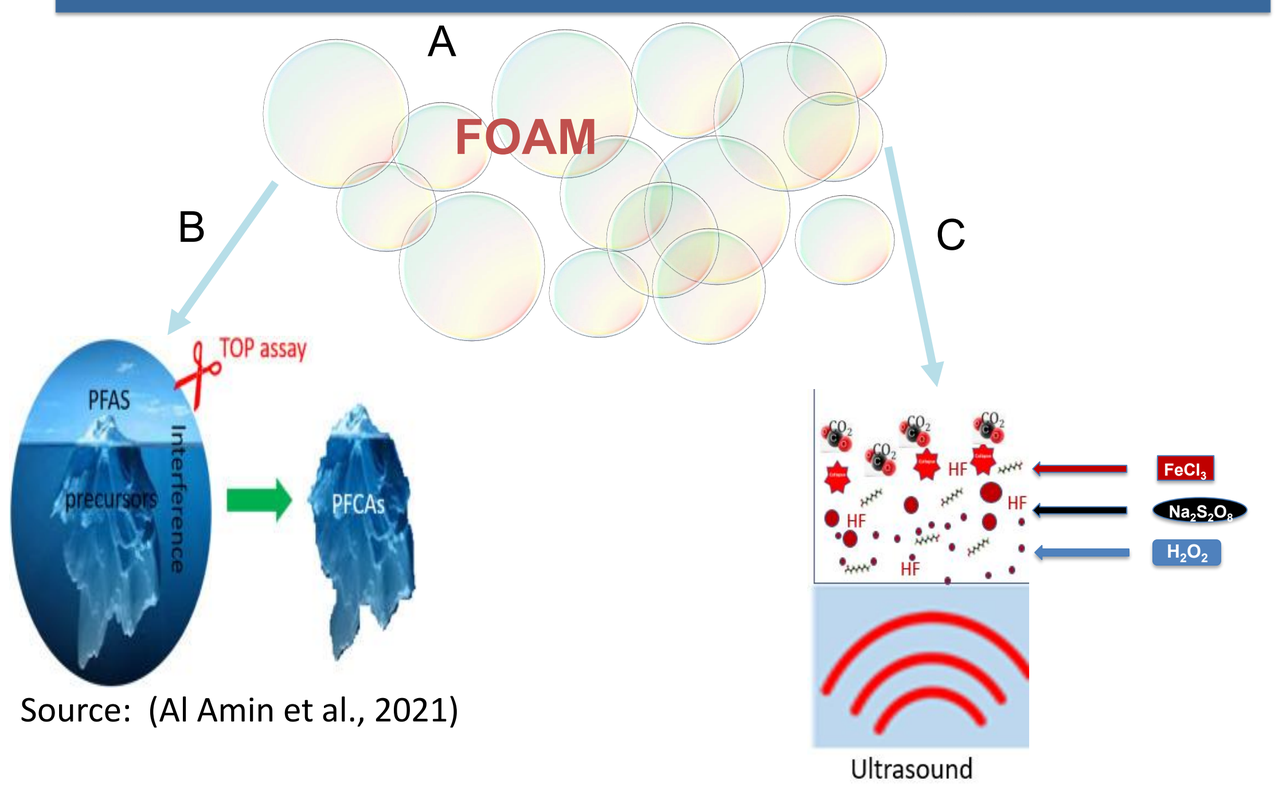


Figure 1. Schematic representation of the formation and collapse of bubbles by ultrasound.

- (A) Pyrolysis into PFAS radicals & headgroup ……..…(Major)
- (B) H_2O + » → H• + •OH
- •OH + PFAS radicals → CO_2,… (Sonochemistry)….(Minor)

METHOD



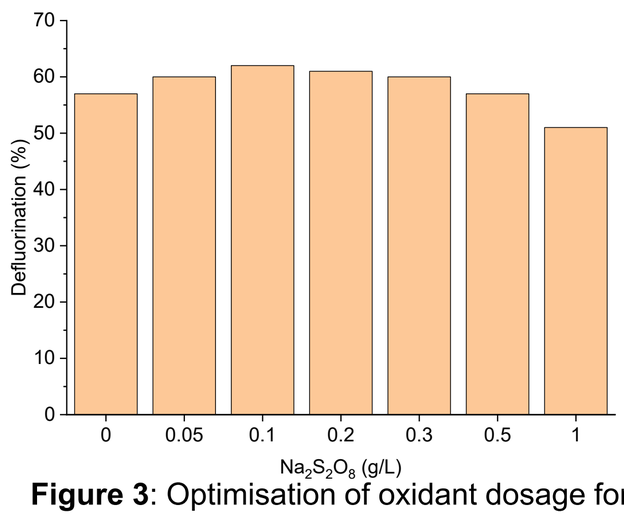
Source: (Al Amin et al., 2021)

Figure 2. Schematic representation of AFFF/FF foam (A), total oxidisable precursor (TOP) assay (B), the ultrasonication system (C).

Operational conditions

Dilution	Frequency (kHz)	Power density (W/mL)	Time (h)
1000x	580	0.1875	4

RESULTS & DISCUSSION



PS was used because it effectively generate SO_4•⁻, which complement •OH

- Enhancement peaks at 0.1 g/L
- At higher conc., surplus PS may act as a scavenger, quenching $SO_4^{-\bullet}$ radicals or recombining to form less reactive species, thus diminishing the radical pool available for PFAS attack

Figure 3: Optimisation of oxidant dosage for ultrasonic PFAS degradation using $Na_2S_2O_8$

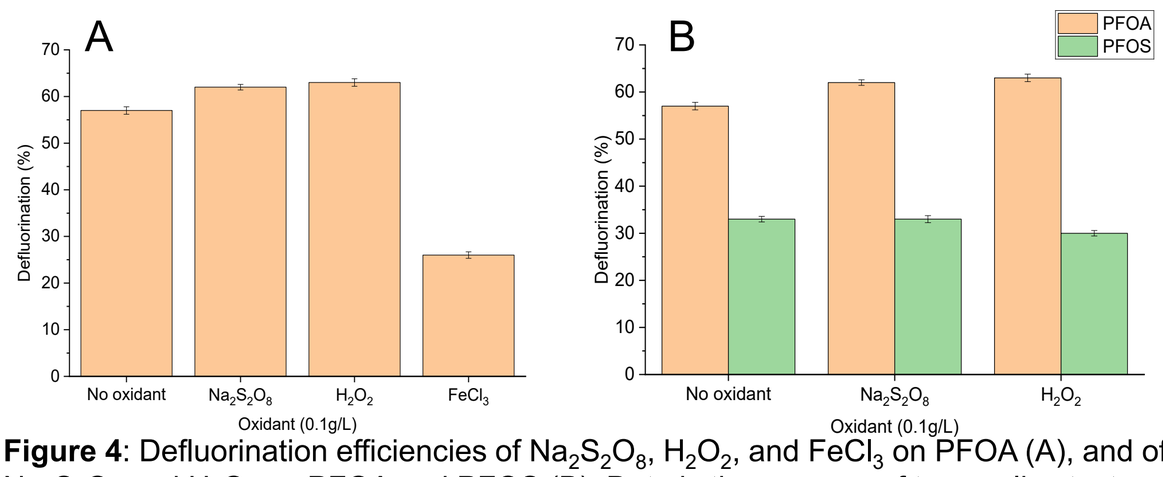


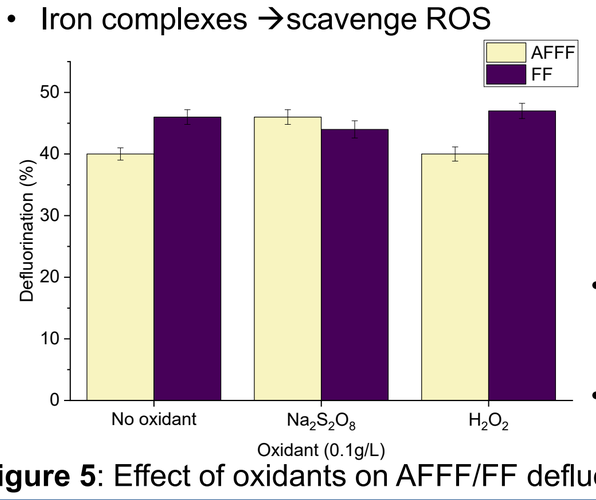
Figure 4: Defluorination efficiencies of $Na_2S_2O_8$, H_2O_2, and $FeCl_3$ on PFOA (A), and of $Na_2S_2O_8$ and H_2O_2 on PFOA and PFOS (B). Data is the average of two replica tests

$Na_2S_2O_8$ ≈ H_2O_2 > control

$FeCl_3$ < control

- Fenton-like reactions, less eff.
- Iron complexes →scavenge ROS

- Defl. (%): PFOA > PFOS
- PFOS larger size (-SO_3H vs -CO_2H) →(+1) -CF_2-
- $Na_2S_2O_8$ ≈ control > H_2O_2



- Control → AFFF > FF
- $Na_2S_2O_8$ → AFFF > FF > control
- H_2O_2 → AFFF ≈ control < FF

Possible reasons

- Differences in AFFF & FF compositions (surfactant, HC, solvents,…scavenge ROS
- Viscosity, foaming, surface tension,.. alter cavitation dynamics

Figure 5: Effect of oxidants on AFFF/FF defluorination. Data is the average of two replica tests

CONCLUSION

- Not all oxidants contribute equally under ultrasonic conditions
- Defl. (%): PFOA > PFOS → 15 F *vs* 17 F
- $Na_2S_2O_8$ & H_2O_2 enhance FF defluorination; only $Na_2S_2O_8$ for AFFF
- Components of PFAS-containing waste can influence defluorination

Acknowledgment

The authors acknowledge funding from the Australian Research Council (SR180200015), as well as support from the CRC for Contamination Assessment and Remediation of the Environment (CRC CARE) and the Global Centre for Environmental Remediation (GCER) at the University of Newcastle, NSW

REFERENCES