Investigating Electrochemical and Catalytic Approaches for In Situ Treatment of PFAS in Groundwater

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Abstract

Objectives

The overall goal of SERDP Project ER-2424 "Investigating Electrocatalytic and Catalytic Approaches for In Situ Treatment of Perfluoroalkyl Contaminants in Groundwater" is to develop and assess the use of electrocatalytic and catalytic approaches for treatment of poly- and perfluoroalkyl substances (PFAS) in groundwater. Two parallel approaches are being employed as part of this research effort: an oxidative electrochemical approach and a reductive approach that employs the use of UV-sulfite induced hydrated electrons. Both the oxidative and reductive approaches show continued promise.

Approach

A series of bench-scale batch experiments have been performed to evaluate the electrochemical oxidation of PFAS. Initial experiments were performed using simple electrolytes, and individual PFAS compounds (e.g., PFOA, PFOS). To assess impacts due to geochemistry and contaminant mixtures, subsequent electrochemical experiments were performed in synthetic and natural groundwaters and with AFFF.

UV-sulfite reduction experiments were performed in parallel with the electrochemical experiments. Initial bench-scale batch experiments were performed using electrolyte and groundwater systems spiked with a single PFAS (e.g., PFOS, PFOA). Subsequent experiments were performed using AFFF-impacted groundwater.

Results To Date

Current results indicate mixed metal oxide anodes did not provide sustained PFAS treatment, as PFAS removal greatly diminished over time. However, sustained PFAS removal was observed using boron doped diamond anodes. Treatment occurred via a direct electron transfer mechanism, and hydroxyl radical generation had no observable impacts on PFAS removal rates. Treatment was effective in AFFF-impacted groundwater with substantial defluorination. Perchlorate generated during treatment (from chloride present in the groundwater) was effectively treated by a subsequent biological reduction. Oxidation pathways of precursor compounds are being determined.

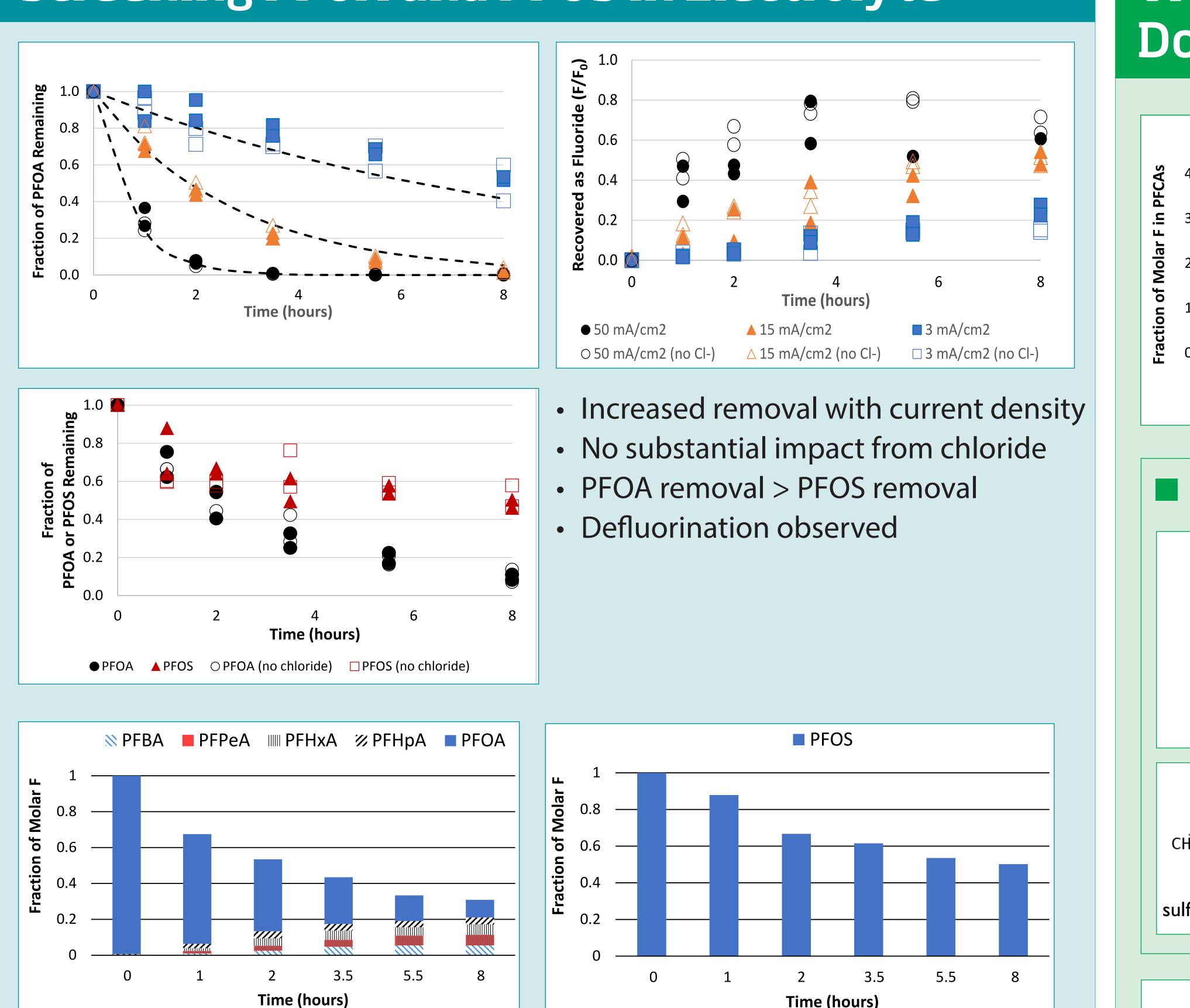
Preliminary results using UV-induced hydrated electrons indicate both PFOA and PFOS are amenable to treatment, with substantial defluorination occurring. Effective treatment also was observed in AFFF-impacted groundwater. Longer-chained PFAS are removed more rapidly than shorter-chained PFAS; branched PFAS are removed more readily than linear PFAS. PFAS removal rates increase with increasing sulfite levels. Reaction kinetics are currently being evaluated.

Experimental System



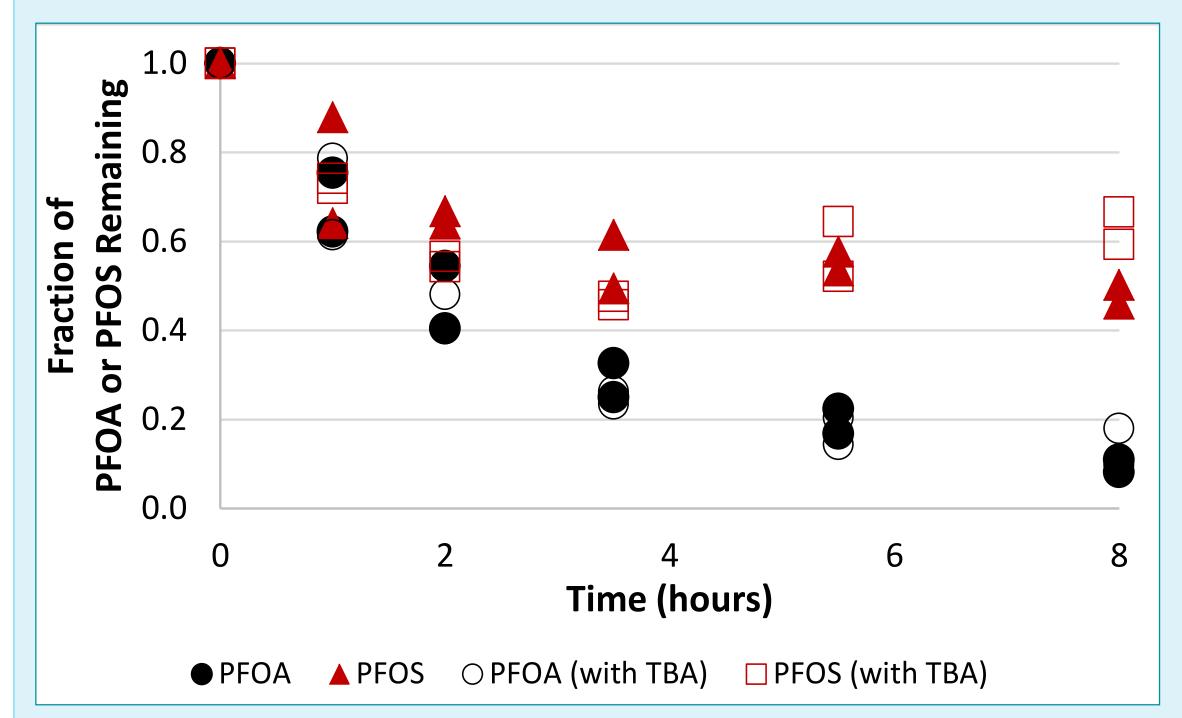
Boron Doped Diamond Anode (ADT)

Screening PFOA and PFOS in Electrolyte



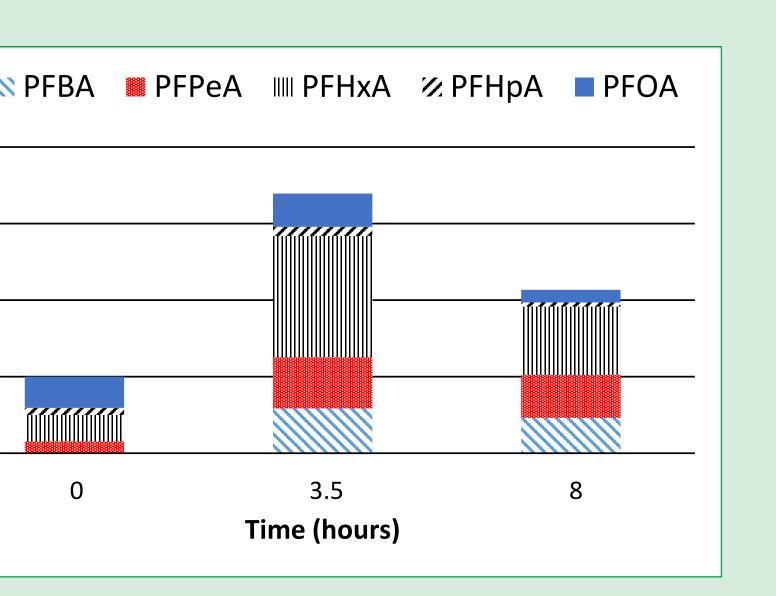
Shorter-chained carboxylates generated during PFOA oxidation, but no shorter-chained carboxylate or sulfonates observed during PFOS oxidation

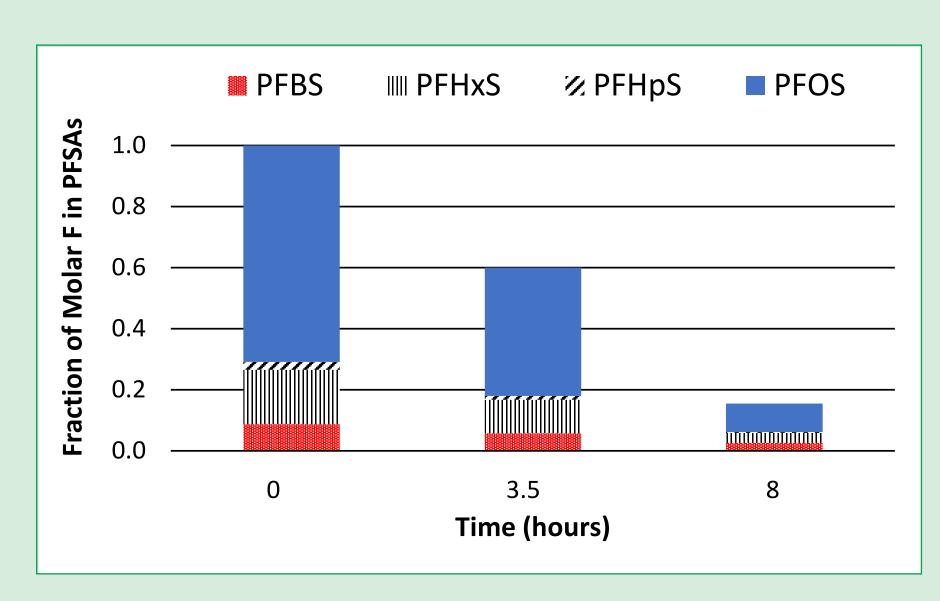
PFOA and PFOS Treatment in the Presence of Hydroxyl Radical Scavenger



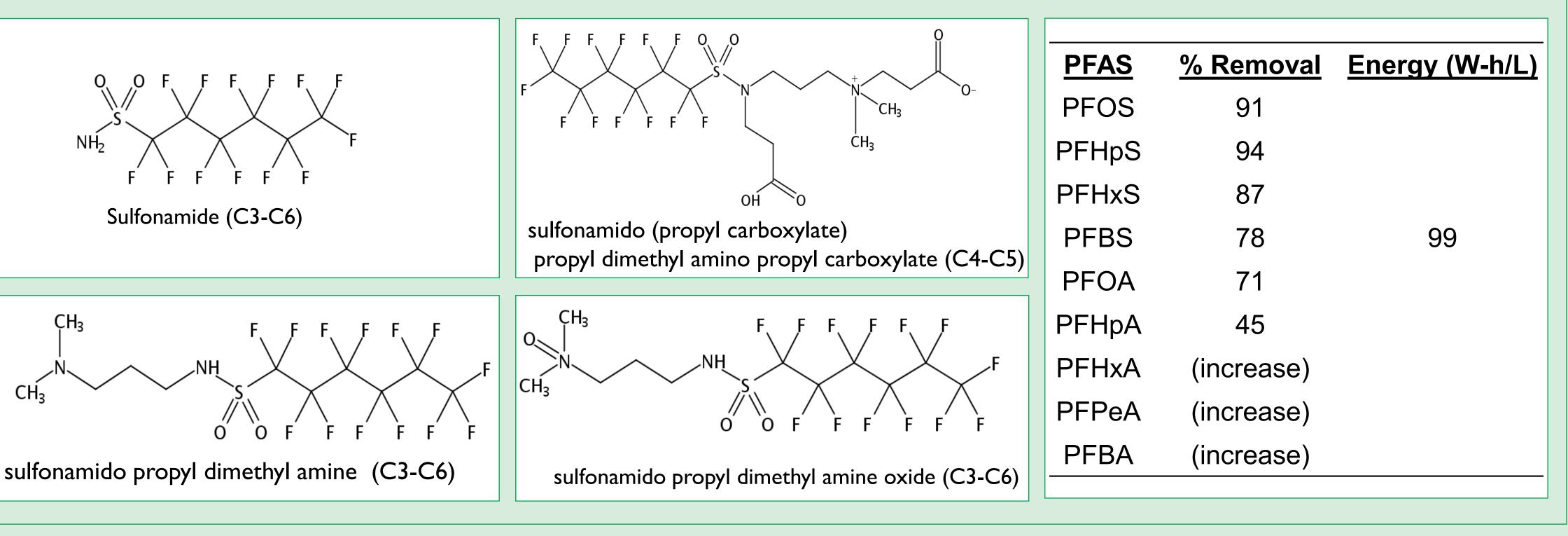
TBA, a hydroxyl radical scavenger, does not inhibit PFOA or PFOS removal, indicating that hydroxyl radicals do not play a role in treatment. These results also suggest that organic contaminants such as BTEX or chlorinated solvents likely will not adversely impact treatment.

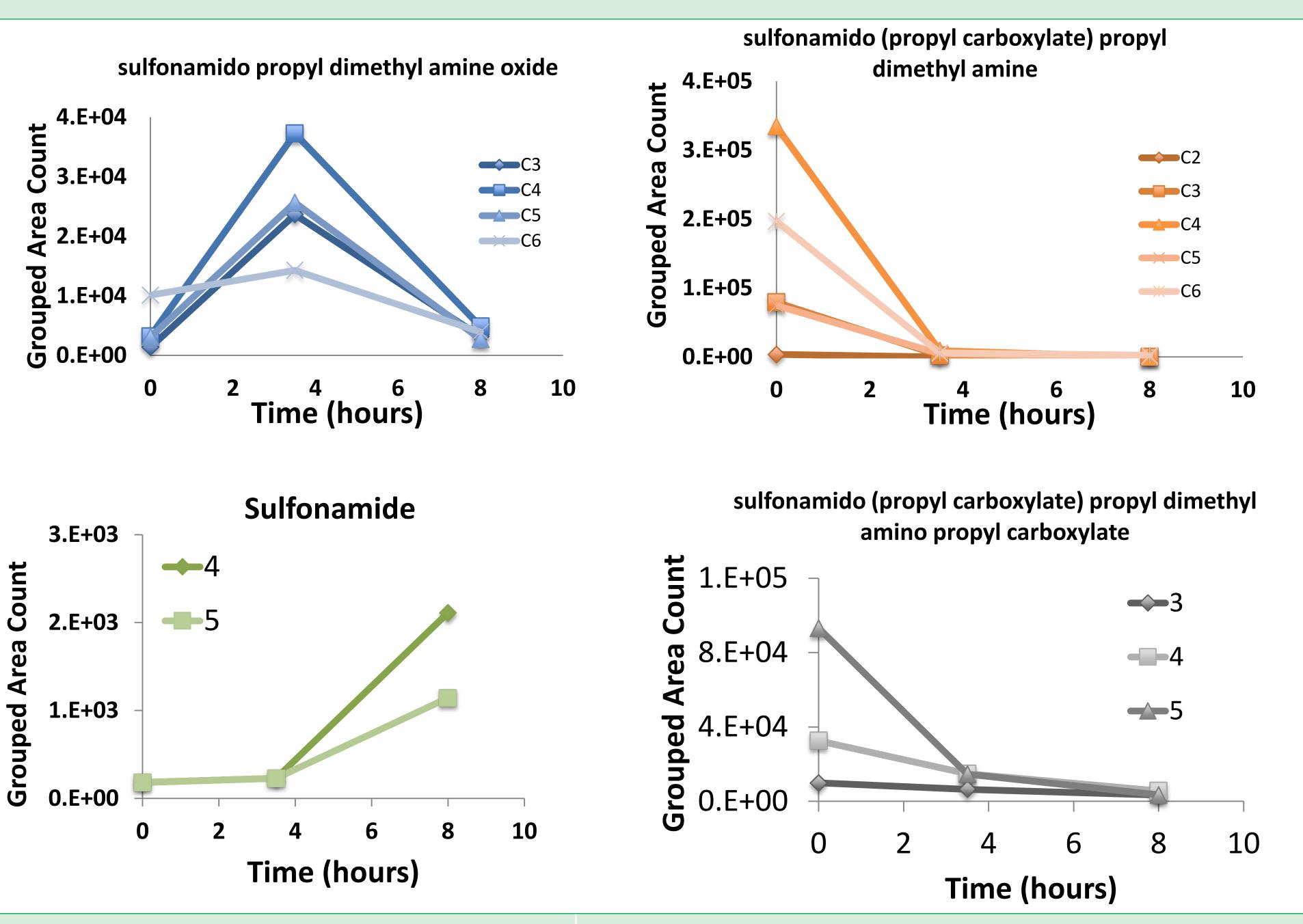
Treatment in Groundwater Spiked with 3M AFFF Boron **Doped Diamond Anode (Condias)**





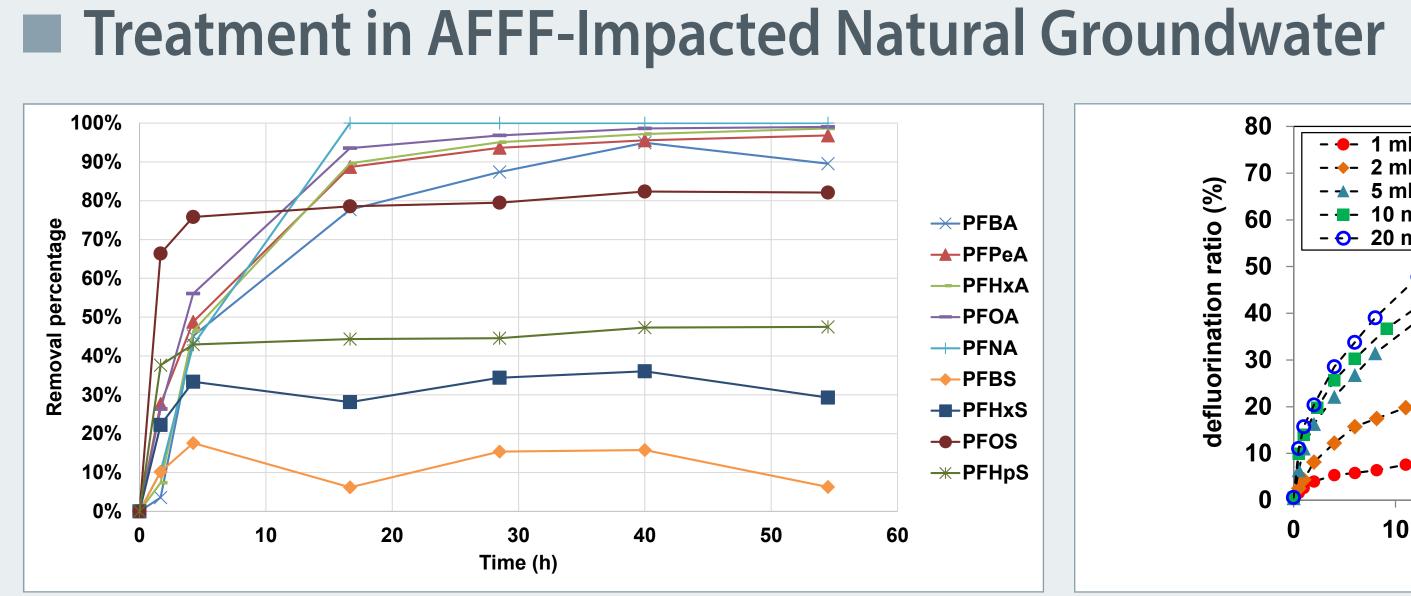
Precursor Structures Identified through HRMS

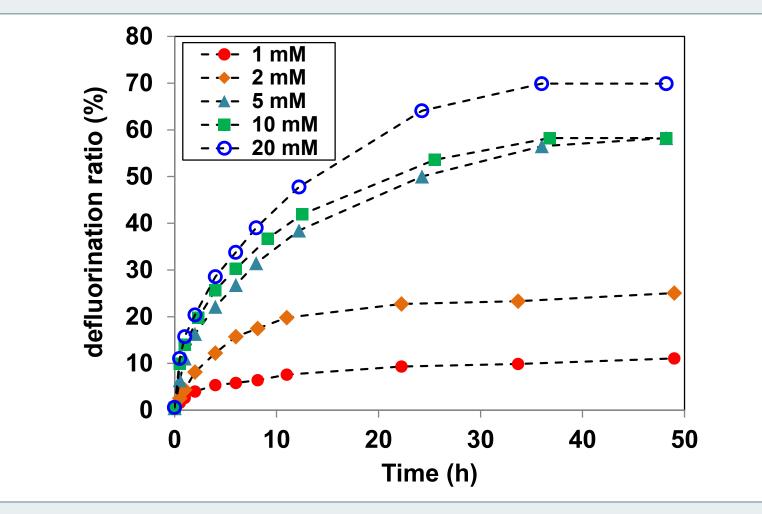




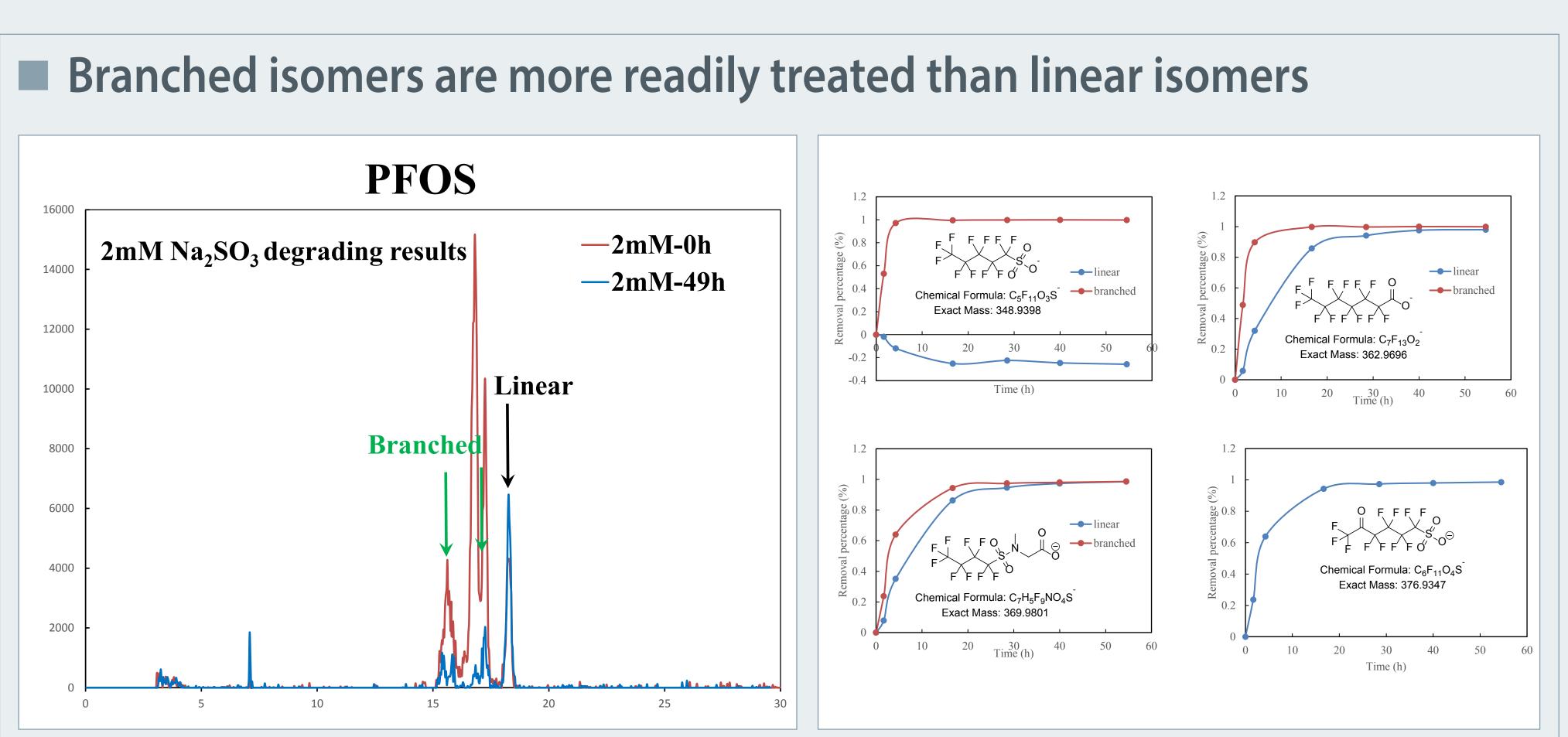


UV-Sulfite Process for Reductive Treatment of PFAS





- PFOA and PFOS both treated
- Longer-chain compounds showed Increased removal
- Substantial defluorination
- Increased PFAS removal and fluoride generation with increased initial sulfite dosage



Chloride, which gets oxidized during the electrochemical process, does not inhibit PFOA or PFOS oxidation

Ongoing and Future Efforts

- Assess treatment of precursor compounds in AFFF-impacted groundwaters (electrochemical and UV-sulfite treatments)
- Determine PFAS treatment kinetics during UV-sulfite treatment
- Evaluate BDD anode longevity

