DEVELOPMENT OF ADVANCED CHEMICAL TREATMENT FOR PFAS IN CO-CONTAMINATED GROUNDWATER

INTERNATIONAL CLEANUP CONFERENCE
ADELAIDE 2019

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Co-Author Acknowledgements

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PFAS Treatment Technologies – Developing Destructive Technologies

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- Alkaline Ozone/Perozone
- Electrochemical Oxidation
- Non-Thermal Plasma
- Heat activated persulfate
- UV + Sulfite
- Vitamin B12 with titanium citrate
- Sonolysis

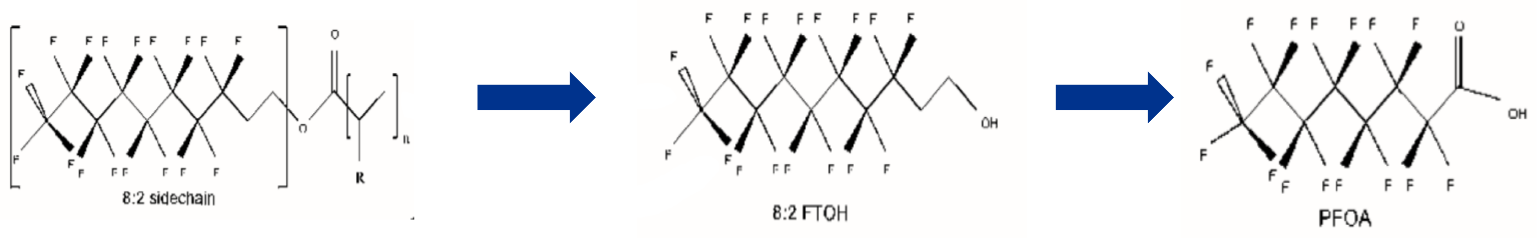
Advanced Alkaline Oxidation

- "Conventional" Advanced Oxidation (Ozone, UV/H_2O_2) has limited effectiveness
  - Oxidation can mineralize PFOA and carboxylic acids
  - Not as effective for PFOS and sulfonic acids

- Advanced Alkaline Oxidation enhances destruction
  - Promotes balance of both oxidizing and reducing radicals

Background - Precursors

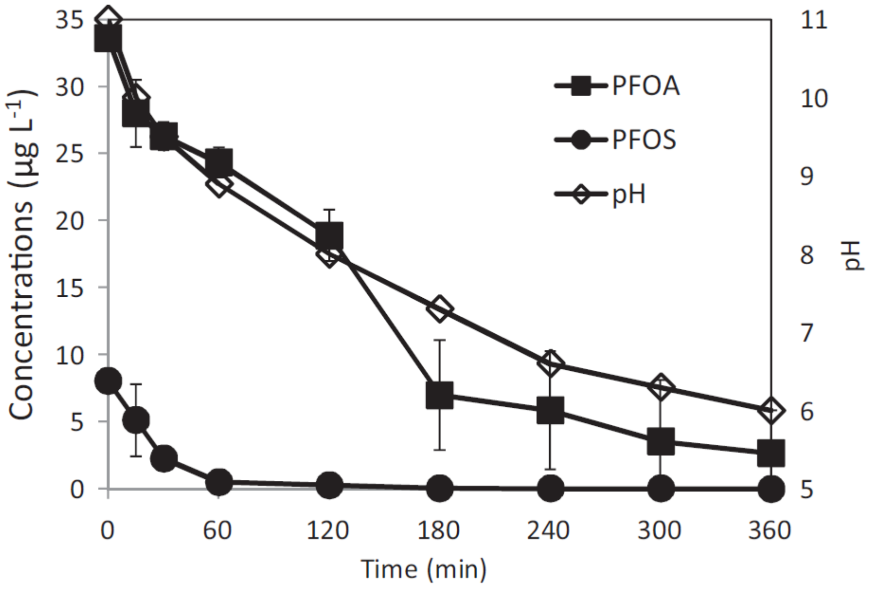
- 1000's of PFAS compounds created – very few quantified analytically
- PFAS that can undergo transformation to form terminal end products
  - Alkyl chain not fully fluorinated
  - Creates weak link
  - Can transform to biotic or abiotic mechanisms
  - Precursors may constitute a majority of fluorinated chemical mass at some sites



Source: van Zelm, R., Env. Tox. and Chem., 27:11, 2216-2223, 2008

Preliminary Bench-Scale Studies – Alkaline Perozone

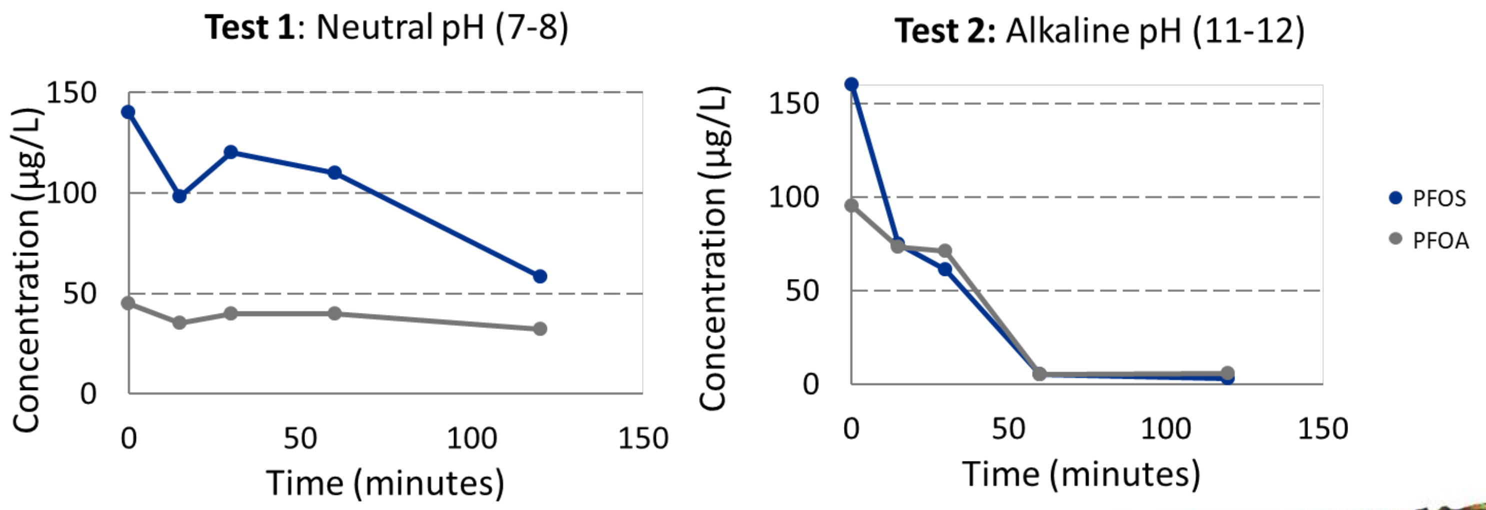
- Academic work published in 2012
- Used perozone (hydrogen peroxide + ozone) in a two-step process at unconventional pH values
- pH decreases commensurate with PFOA reduction
- Removal of PFOS > PFOA



Source: Lin, A. et.al., 2012, J Haz Mat

Preliminary Bench-Scale Studies – Alkaline Ozone Bench-Test Results

- Significant reduction of PFOS and PFOA at an alkaline pH
  - Testing on mix of PFOA and PFOS only
- Data corroborates results observed during 2012 Lin Study
- Supports need for alkaline conditions



Courtesy of Piper Environmental Group

Site Sample Bench-Scale Study

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- Testing conducted by APT Water in bench-scale HiPOx reactor.
- **Objective:**
  - **Assess advanced alkaline oxidation for treatment of AFFF contaminated groundwater**
- Round 1 Screening Tests
  - Ozone versus perozone
  - Alkaline versus natural pH
  - Single versus dual pH steps
  - Various H2O2:O3 mole ratios
- Round 2, 3, 4
  - Select best case for repeated optimization

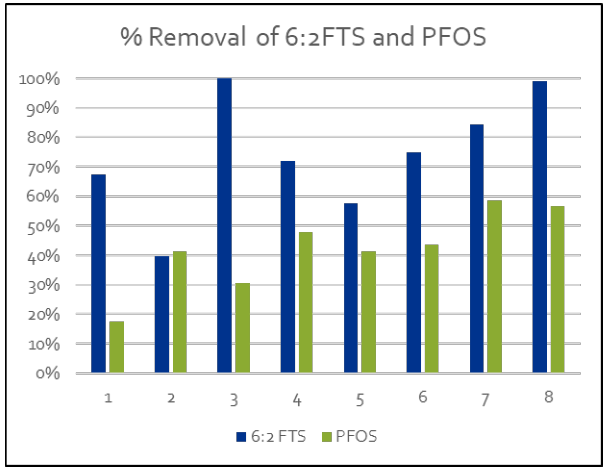

APTwater, LLC HiPox Bench-Scale Reactor

Initial Test	Ozone Dose (mg/L)	Pre-Treatment pH	H_2O_2:O_3 Mole Ratio	Final pH
1	2,000	natural	0	natural
2	2,000	natural	0	11
3	2,000	natural	0.50	natural
4	2,000	natural	0.25	11
5	2,000	natural	0.50	11
6	15% of 2,000	natural	0	11
	85% of 2,000	11		
7	15% of 2,000	natural	0.25	11
	85% of 2,000	11		
8	15% of 2,000	natural	0.50	11
	85% of 2,000	11		

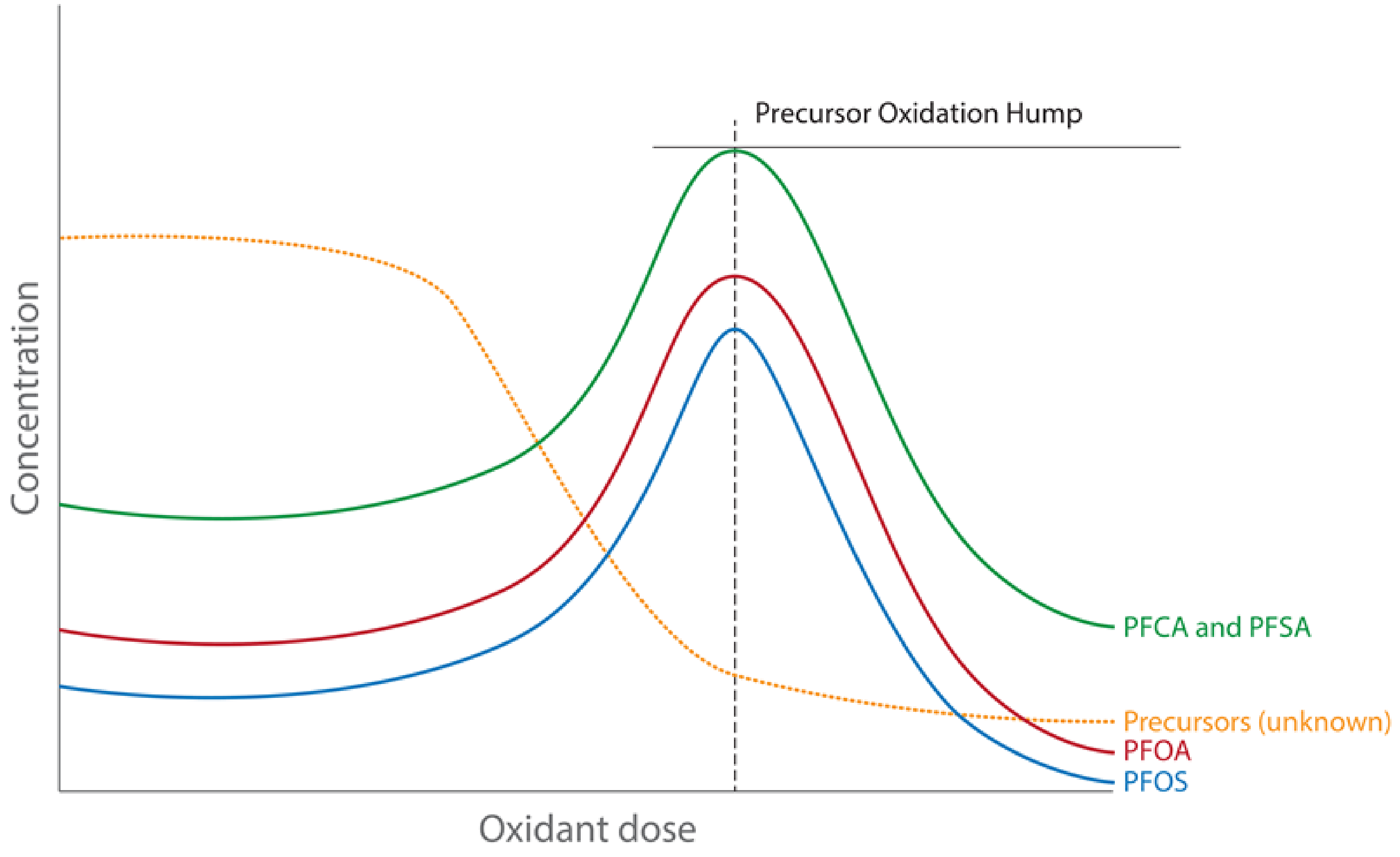
Screening Results

pH	COD (mg/L)	TOC (mg/L)	Total VOCs (µg/L)	Total PFAS (ng/L)	6:2: FTS (ng/L)	PFOA (ng/L)	PFOS (ng/L)	PFBS (ng/L)	PFHxA (ng/L)	PFHxS (ng/L)
5.28	8.5	0.56 J	220	1,613	575	151	46	28	420	261

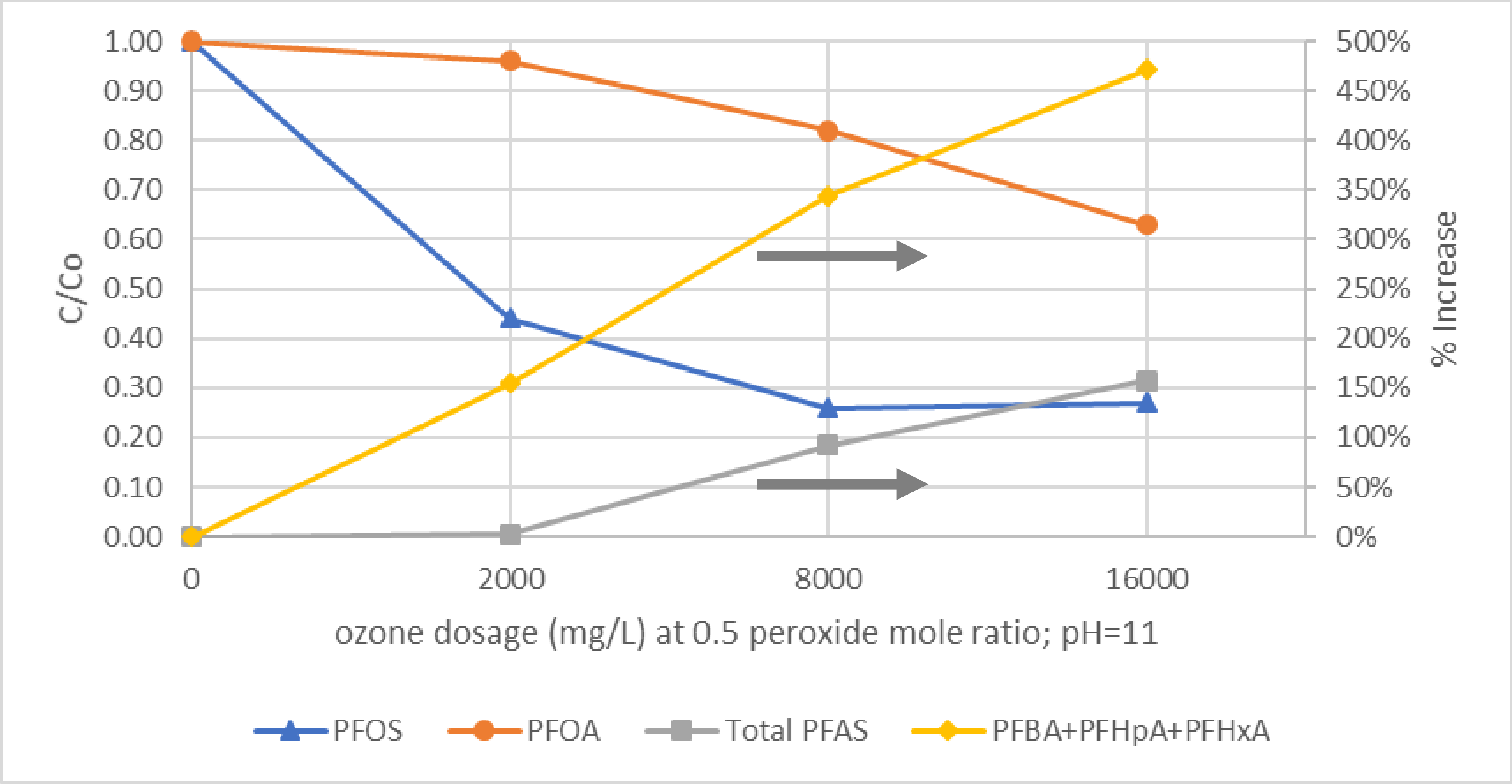
- Tests 1 and 2 – evaluate pH
  - Alkaline condition (T2) outperformed natural condition (T1)
- Tests 3, 4, and 5 – evaluate H_2O_2:O_3
  - Generally higher transformations of sulfonates observed at higher ratios
- Tests 6, 7, and 8 – evaluate single versus dual pH steps
  - The dual pH step tests generally performed better
- **Dual pH with 0.5 H_2O_2:O_3 test performed best (T8)**



Anticipated Results



Test Results



Summary & Path forward

- Alkaline perozone may be a valuable technology for treatment of PFAS
- Addressing real-world impacts with precursor load presents challenges
- Completing one last higher dosage to assess destruction curve
- Looking at further optimization
  - Longer oxidant contact time
  - Maintaining elevated pH
  - PFOS versus fluorotelomer-based AFFF

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Thank-you

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