TREATMENT AND REMEDIATION PANEL

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OBJECTIVES:

- **Summarize the challenges associated with treatment of PFAS-contaminated soil and groundwater**
- **Introduce potential viable PFAS remediation approaches**

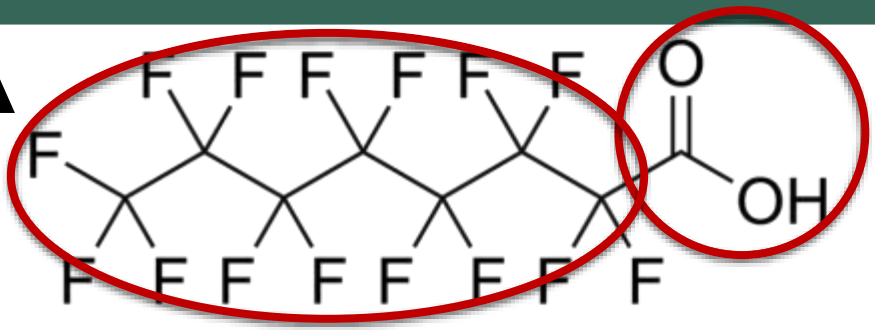
INTRODUCTION

- Perfluorinated Compounds
  - Perfluorinated alkyl acids (PFAAs)
    - PFOA, PFOS
    - PFBA, PFBS
    - PFHxA, PFHxS
  - Intermediates or Precursors
    - N-MeFOSE
    - N-EtFOSE
    - 6:2 FTS
  - Range of properties with chain length and functional group(s) – hydrophobicity, electrostatic, reactivity

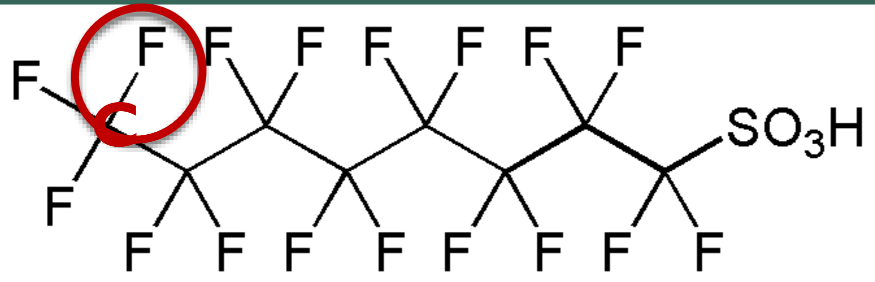
Guidelines (ng/L), EPA 2016	
PFOA	70
PFOS	

INTRODUCTION

PFOA



PFOS



	Formula	Vapor Pressure	Aqueous Solubility	Log K_{oc}	Degradation
PFOA	$C_8HF_{15}O_2$	0.1 kPa (20°C) 10 mm Hg (25°C)	4.1 g/L (22°C) 9.5 g/L (25°C)	2.06	Stable
PFOS	$C_8F_{17}SO_3^-$	3.31×10^4 Pa at 20°C	570 mg/L	2.57	Stable
PFHxS	$C_6F_{13}SO_3$	0.61Pa (25°C)^{ES}	6.2 mg/L^{ES} 22 mg/L^{ES}	3.5^{ES}	Stable
PFBS	$C_4F_9SO_3$	0.29 mm Hg at 20°C	8900 mg/L^{ES} 344mg/L^{ES}	2.2^{ES} 1.9^{ES}	Stable
6:2 FTS	$F(CF_2)_6CH_2CH_2SO_3^-$	0.115Pa(25°C)^{ES} 0.00086 mm Hg (25°C)^{ES}	11 mg/L^{ES} 2mg/L^{ES}	4.0^{ES}	Biodegradable under specific conditions

ES = estimated from EPISuite (U.S. EPA http://www.epa.gov/opptintr/exposure/pubs/episuite.htm)

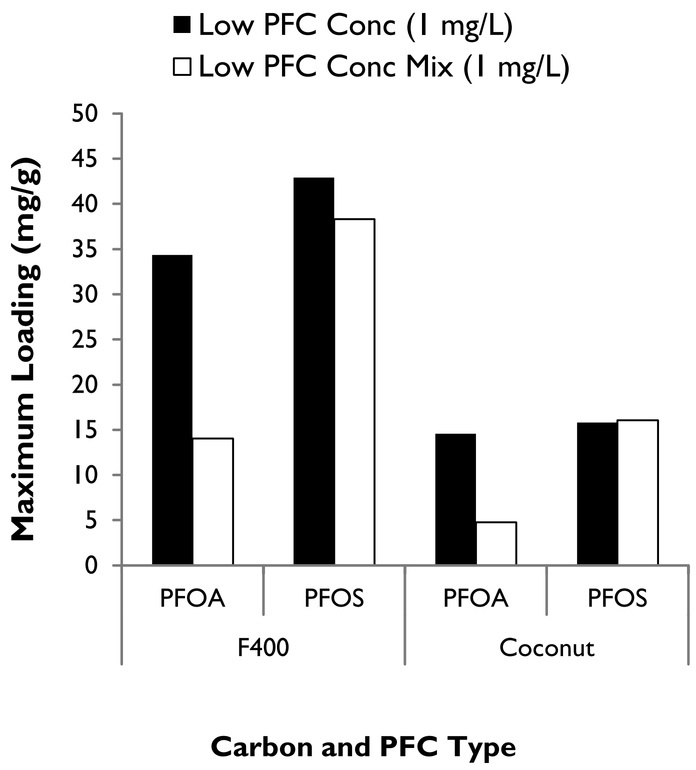
REMEDIATION OPTIONS

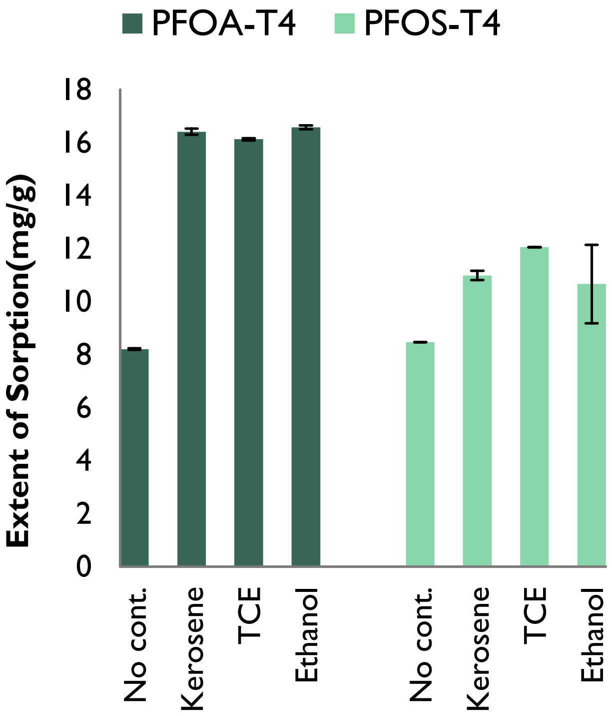
- Excavation → Incineration
  - Expensive
  - Contaminants must be treated off site
- Immobilization/Stabilization
- Filtration
  - Nanofiltration
  - Reverse Osmosis
- Sorption
  - Granular Activated Carbon (GAC)
  - Carbon nanotubes
  - Biomaterials
- Ion Exchange
  - Resins
  - Mineral materials (e.g., zeolites)
  - Polymers
- Precipitation/Flocculation/Coagulation
- Oxidation/Reduction
  - Chemical oxidation
  - Electrochemical, sonochemical, and photochemical
  - Plasma
  - Customized reductants

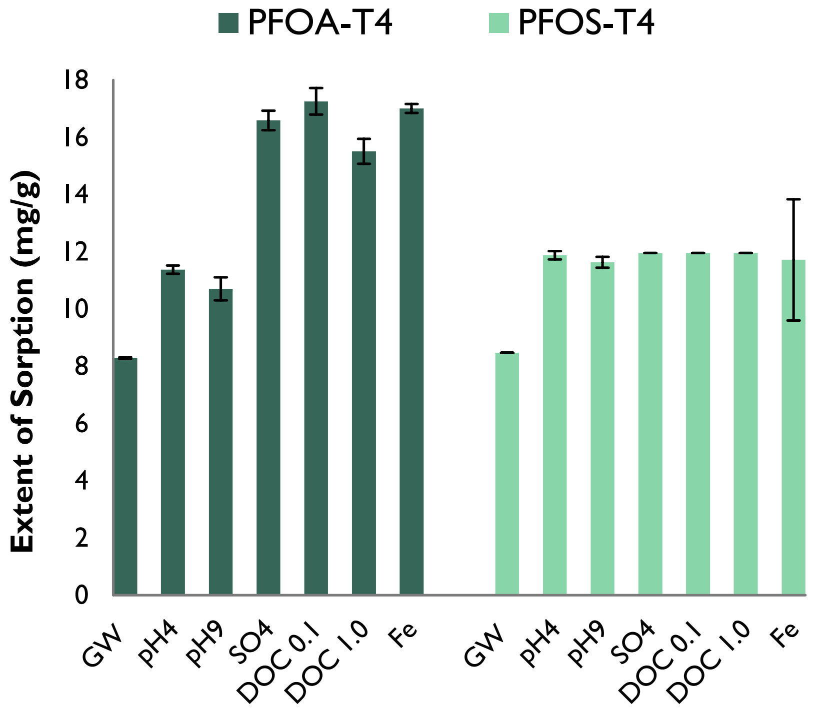
TREATMENT TRAINS and COMBINED REMEDIES!

SORPTION BY GAC

SORPTION – GAC







Sorption under site-specific conditions…

ION EXCHANGE

Sustainable Removal of Poly- and Perfluorinated Alkyl Substances (PFAS) from Groundwater Using Synthetic Media

Nathan Hagelin, Amec Foster Wheeler; Steve Woodard, ECT

Media Selection

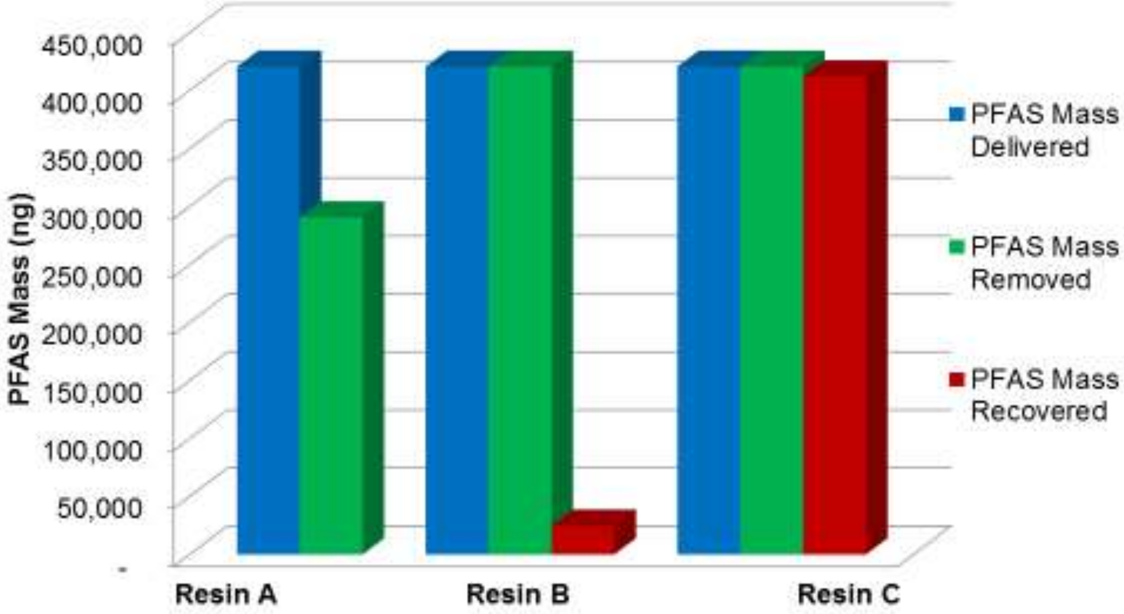
- Synthetic media (resins) removes various contaminants from liquids, vapor or atmospheric streams
- Isotherm testing to identify potentially effective media
- Potential for indefinite reuse via regeneration

Ion Exchange

Polymeric

Carbonaceous

Adsorption and Regeneration of Leading Resins from Column Testing



REDOX MANIPULATION

- **Sonolytic**
- **Electrochemical**
- **Chemical Oxidation and Reduction**
- **Plasma**
- **Combinations…**

Plasma-based water treatment: Efficient transformation of perfluoroalkyl substances (PFASs) in prepared solutions and contaminated groundwater

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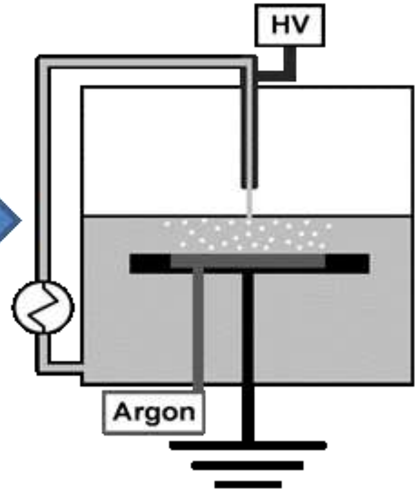
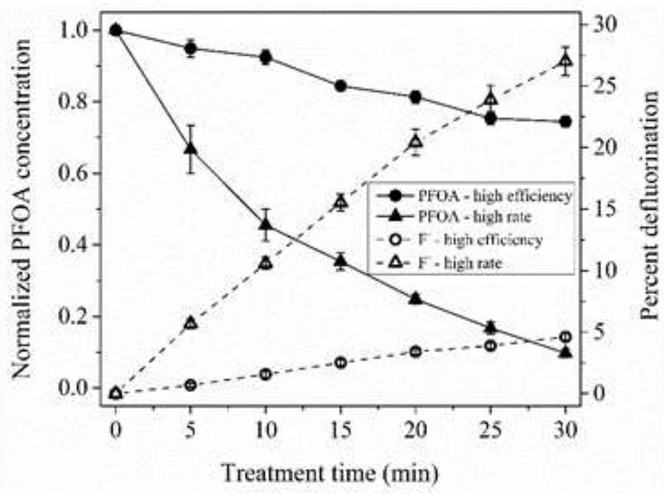
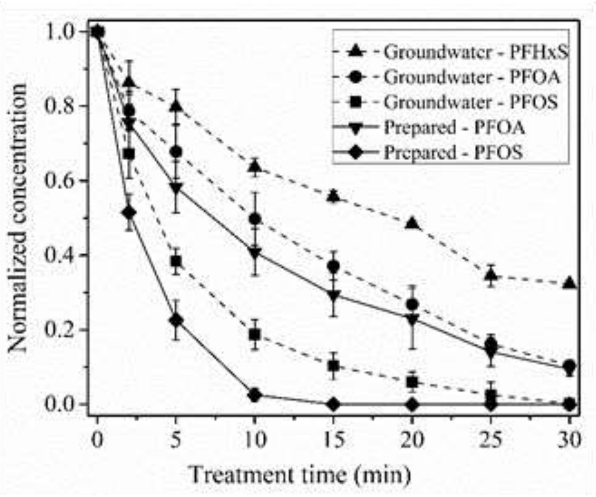
Bench-scale enhanced contact plasma reactor



Plasma produces aqueous electrons and H radicals which are capable of chemically degrading PFASs

G. R. Stratton, F. Dai, C. L. Bellona, T. M. Holsen, E. R. V. Dickenson and S. Mededovic Thagard, "**Plasma-based water treatment: Demonstration of efficient perfluorooctanoic acid (PFOA) degradation and identification of key reactants**" Environmental Science & Technology, 2016, accepted.





Major byproducts: fluoride ions, fluorinated gases and shorter-chain PFAAs

Courtesy of Selma Mededovic Thagard, Clarkson University

CHALLENGES AND LIMITATIONS

- Mixtures, precursors, co-contaminants
- Managing materials
  - Sorption
  - Sludge
- Incomplete mineralization
- Energy intensity
- Technical challenges to *in situ* treatment
- Limited field-scale examples

SURVEY!

- OBJECTIVE: Improve understanding of the similarities and gaps between state of the science and the state of the practice of managing PFAS sites
  - goo.gl/zakRX3