XDD ENVIRONMENTAL

Do it Right, Do it once

The 34th Annual International Conference on Soils, Sediments, Water and Energy

Avoiding the Epic Fail – PFAS Treatability Testing

Presented by

Michael Marley

October 17, 2018

Outline

- Role of treatability studies in remedial design
- Treatability case studies
- Why PFAS treatability Studies?
- PFAS treatability case studies
- Collaborative treatability testing research underway
- Approximate study costs and test durations

Why Conduct Treatability Studies?

You Needed This:

- ❑Certainty of success
- ❑Select right site-specific technology
  - ➢ Determine failure mechanisms
  - ➢ Adverse reactions / byproducts
- ❑Determine correct amount of reagents to be applied

But What You Got Was….

Treatability Studies - Design

Example 1 – Bioremediation SOP[1] vs. SOA[2]

Superfund Site SC: Mixed source / plume with chlorinated solvents and petroleum hydrocarbons

Aerobic Biodegradation: Comparison of oxygen release products for petroleum plume

- Evaluated oxygen release compounds on the market
- Provided vendors with site specific data and requested recommended dosing of product = SOP
- Based on responses – tested all products at MAXIMUM dosage recommended by any of the vendors*

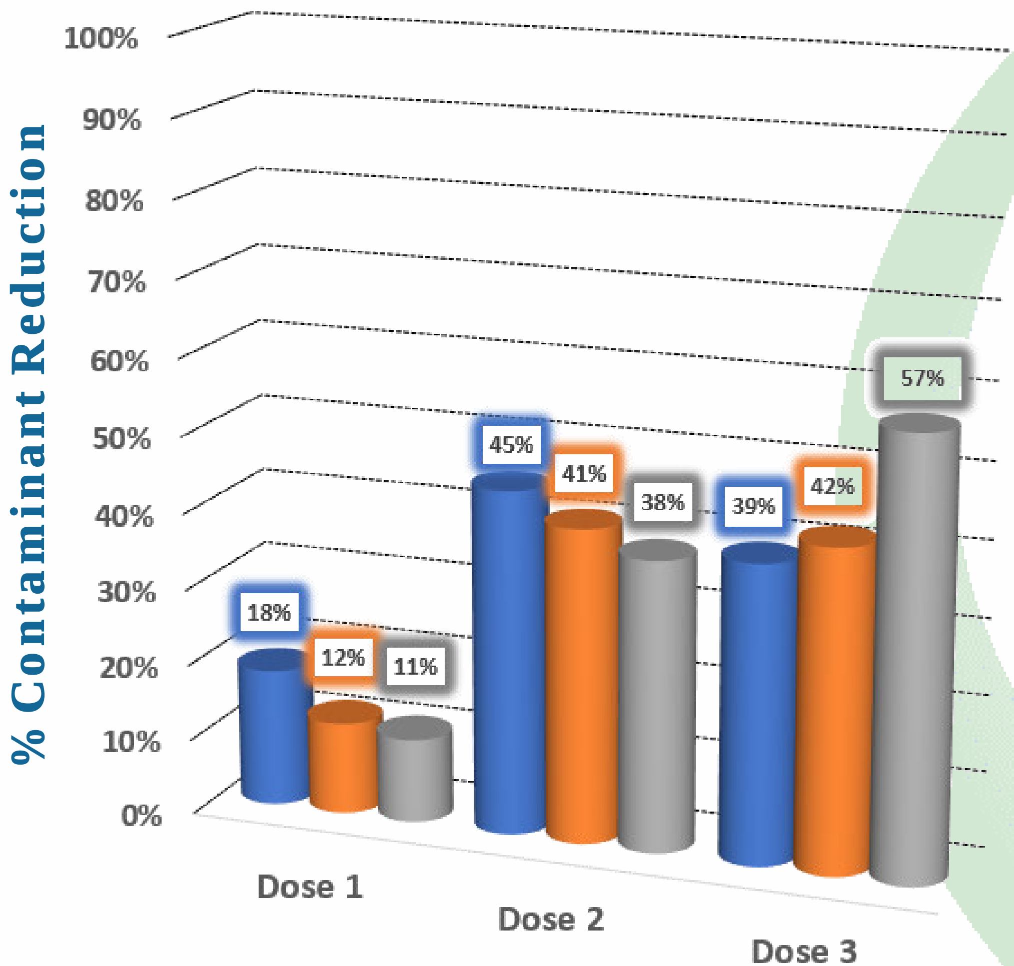
* = Some vendors recommended treatability study be performed

1 = State of practice

2 = State of art

Example 1: Oxygen Release Compound Performance

Vendor Design Estimates (objective >90% Reduction with Single Dose)



All Products Failed, Even After 3 Applications at the SOP Maximum Dose Recommendation – Treatability (SOA) Identified Dose for Certainty of Success

Example 2 –Peer Review –Diagnosis of ISCO Failure, by Others

- SOP Treatability Design using Peroxide Flawed – was "considered a success" as TCE was ND in test reactor
  - Half-life < 5hrs (from data analysis of peroxide concentration and gas generated) –not evaluated or reported
    - <5hrs half-life inadequate for oxidant distribution in the field – essentially gas generation outside well location, oxygenating the aquifer and diluting / stripping TCE
  - Loss of TCE in treatability can be accounted for by TCE vapor concentration measured in off-gas, and theoretical gas volume generated / released from mass of peroxide added
    - Gas generation was not measured / reported
  - 21 pore volumes of reagent solution used in treatability tests
    - Common lab issue
    - Not representative of field applications

Why PFAS Treatability Studies?

- Treatability studies are perhaps even more important for PFAS than for other contaminants because:
  - Target PFAS and remedial goals are changing fast
  - Complications posed by PFAS precursors
  - Part per trillion cleanup levels
  - Potential requirement for remediation treatment trains.
  - Analytical limitations
- Each potential remedial technology requires treatability
  - Effectiveness for PFAS present
  - Byproduct formation
  - Costing for application

Analytical Challenges

- Low detection limits required
- Cross-contamination
- Deciding which analytes to quantify of the many that exist
- Standards not available for many analytes
- Widely varying chemical/physical characteristics of PFAS
- Fast-changing regulatory requirements and analytical methods

Common PFAS Remedial Technologies In Use

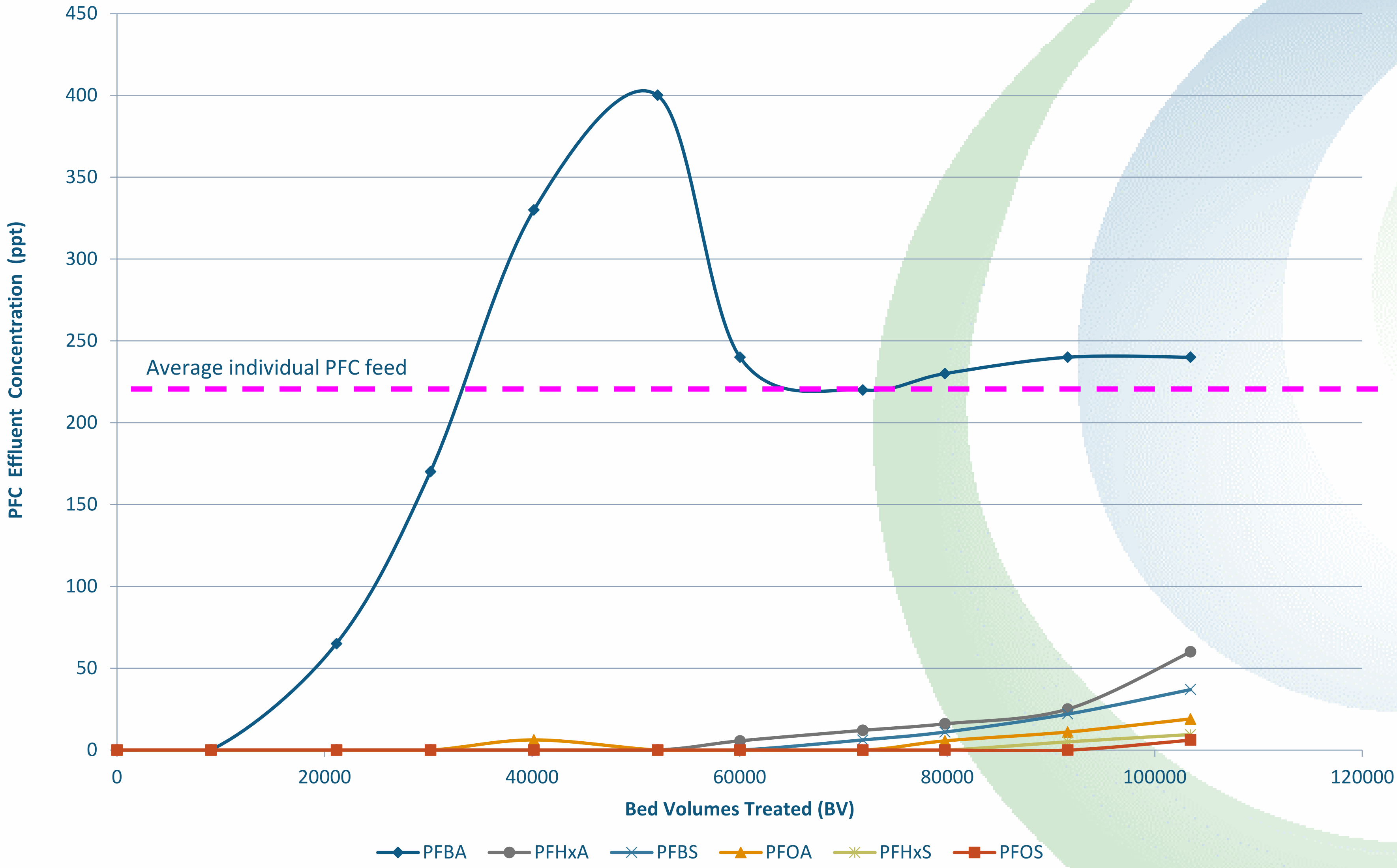
Adsorption/Ion Exchange

(most commonplace, non-destructive, produces concentrated PFAS waste)

- Carbon-based systems
  - Ex-situ activated carbon systems (GAC or PAC)
  - Biochar (biomass and charcoal) – less consistent and kinetically slower?
  - In-situ injectable carbon-based systems – * gaining interest *
  - Competition with organics for sorptive sites – may require pretreatment
- Synthetics resins – gaining traction due to capacity/effectiveness
  - Combination IX and adsorption
  - Faster kinetics and higher capacities = smaller reactor size
  - Higher product cost – requires site specific cost-benefit analysis
  - Ongoing work on single use IX and shorter chain PFAS sorption

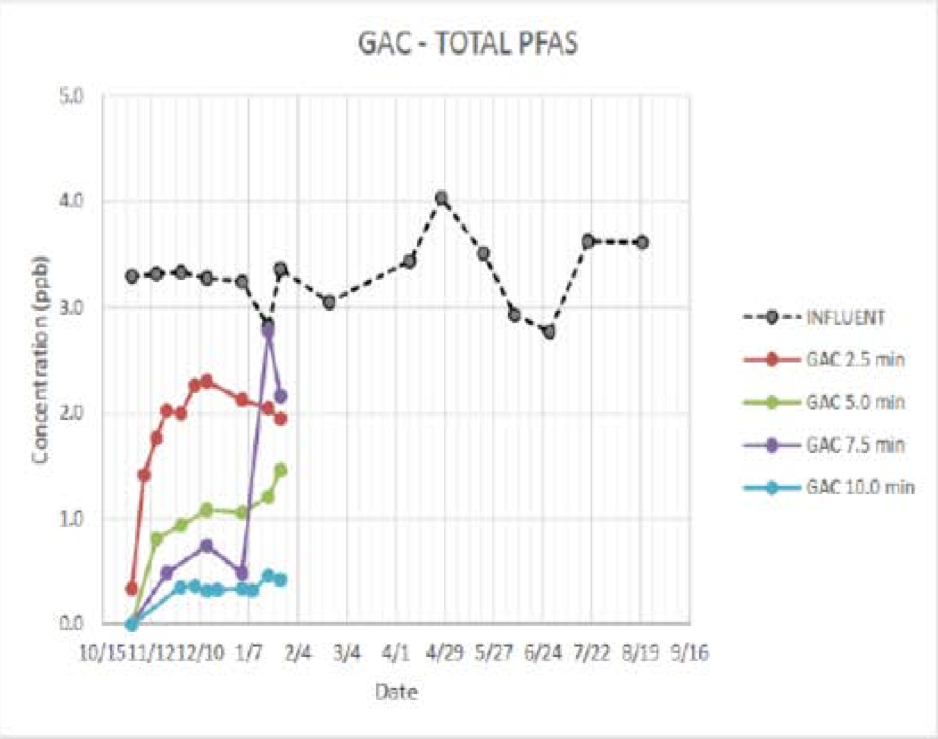
Treatability studies are needed

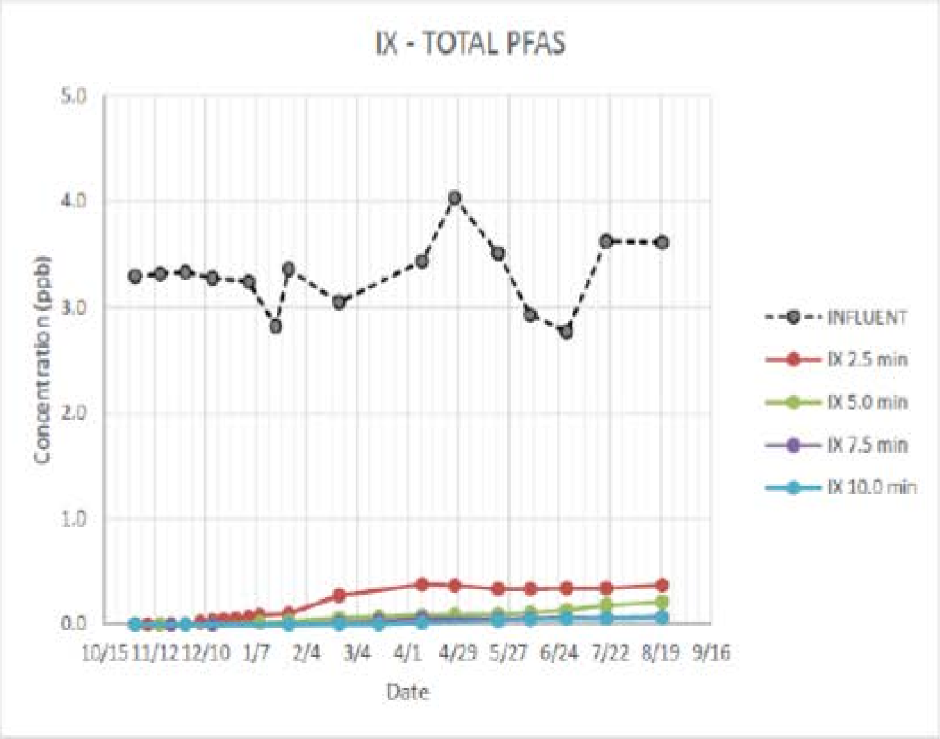
Removal of Various PFAS using Virgin Filtrasorb



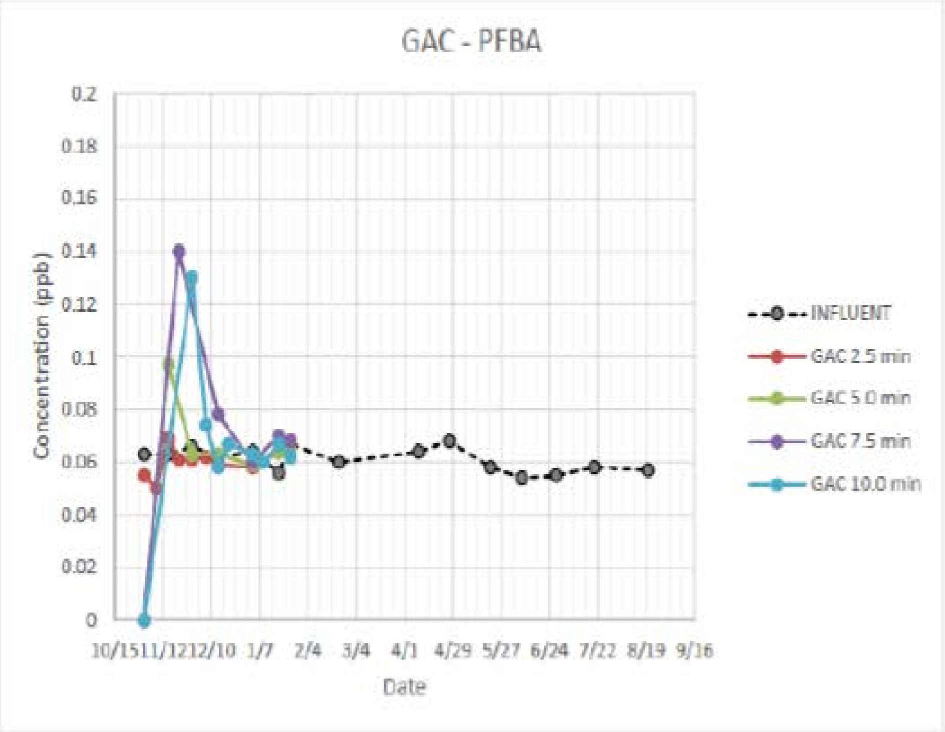
Public water supply well (in NH) side-by-side pilot: Sorbix LC1 resin vs. Calgon F400 GAC

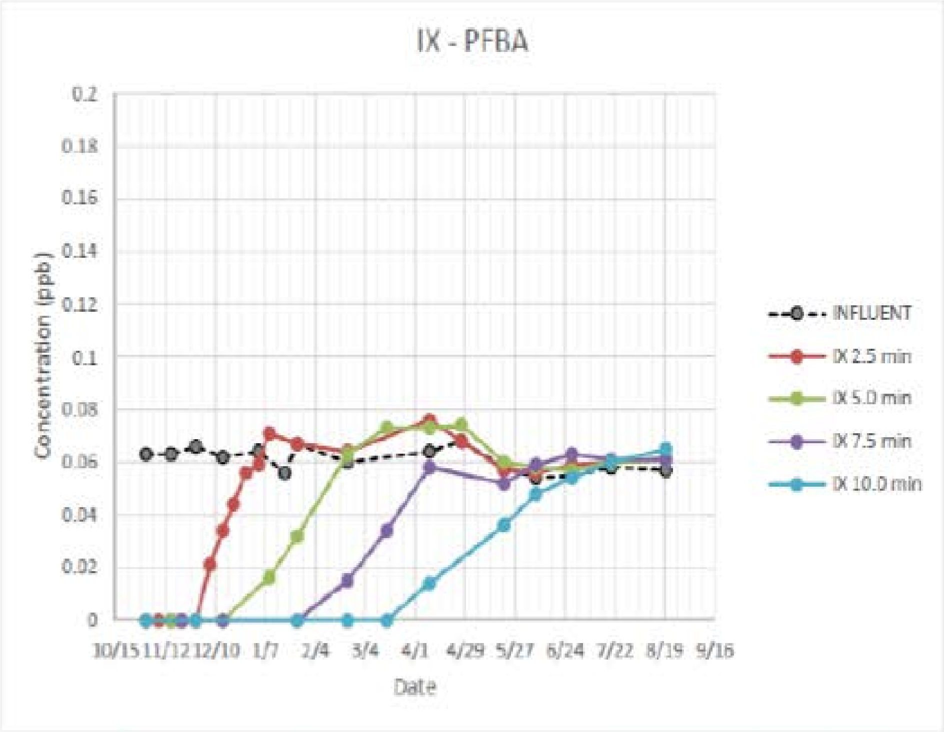
Removal comparison – Total PFAS





Short chain removal comparison - PFBA





Filtration / Separation

(Also produces concentrated PFAS waste)

Nano-Filtration (NF)

- PFAS have molecular weight cutoff (MWCO) of approximately 300 - 500 Daltons
  - >90% effective most PFAS
- Ultra and micro-filtration low effectiveness

Reverse Osmosis

- Polymers used have spaces on the order of 100 – 200 Daltons
- >90% effective most PFAS

Treatability studies are needed

Destructive Technologies

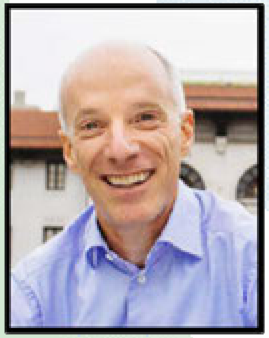
- Oxidative / reductive technologies – redox manipulation
  - Can treat many of the co-contaminants
  - Common theme is high energy and / or diverse reactive species needed and reaction time (e.g., electrochemical, plasma, photolysis)
  - Byproducts may be a concern
    - Formation of lower C Per's with higher mobility
    - Chloride to perchlorate
    - Bromide to bromate
  - PFAS range of applicability may be limited
    - Showing more promise for carboxylic' s (PFOA) than sulfonates (PFOS)
  - Treatment to ppt levels may require treatment train / polishing

Treatability studies are needed

Pretreatment of Precursors

Fighting the Unbeatable Foe: Remediation of Groundwater Contaminated by PFASs with In Situ Chemical Oxidation

Dr. David Sedlak
University of California, Berkeley



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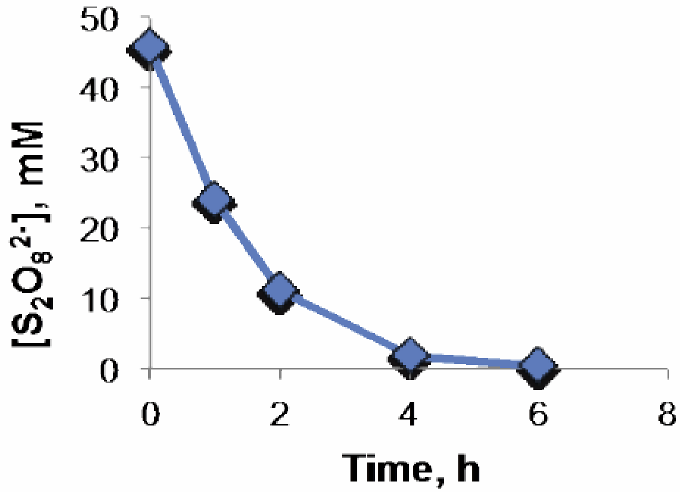
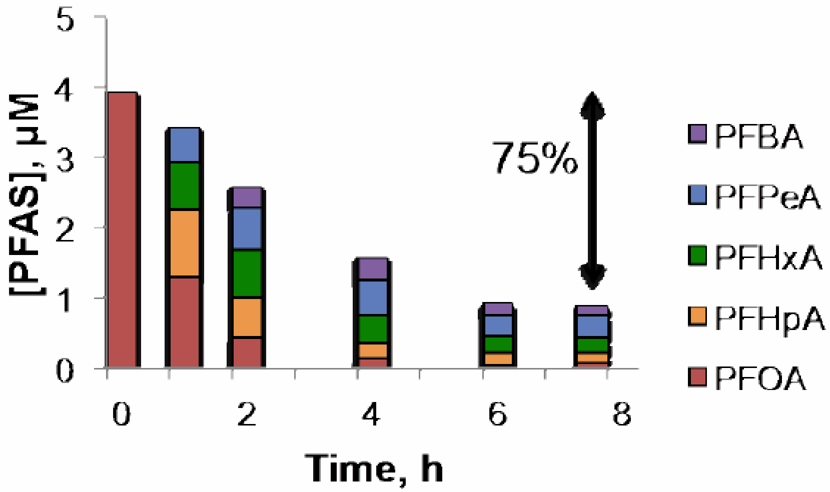
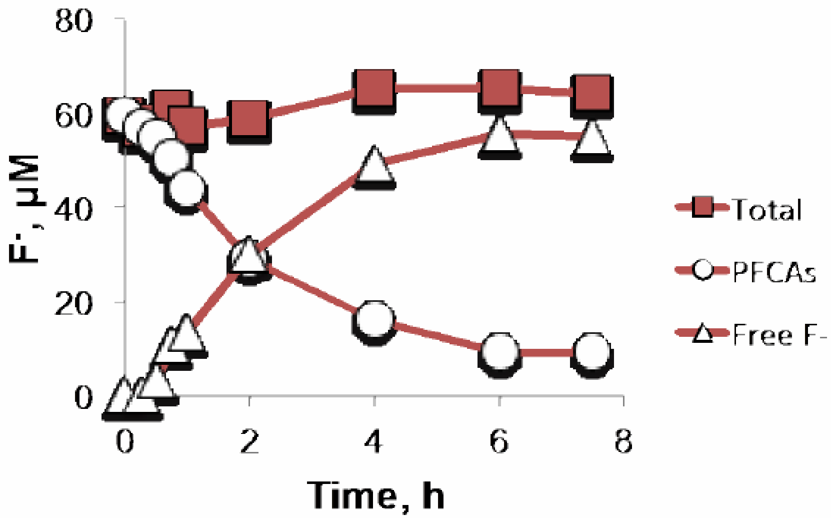
PFOA in Deionized Water





Conditions:
$[S_2O_8^{2-}]_0$ = 50 mM,
$[PFOA]_0$ = 4 μM
unbuffered (pH < 3) H_2O,
T = 85° C

Bruton and Sedlak, in review



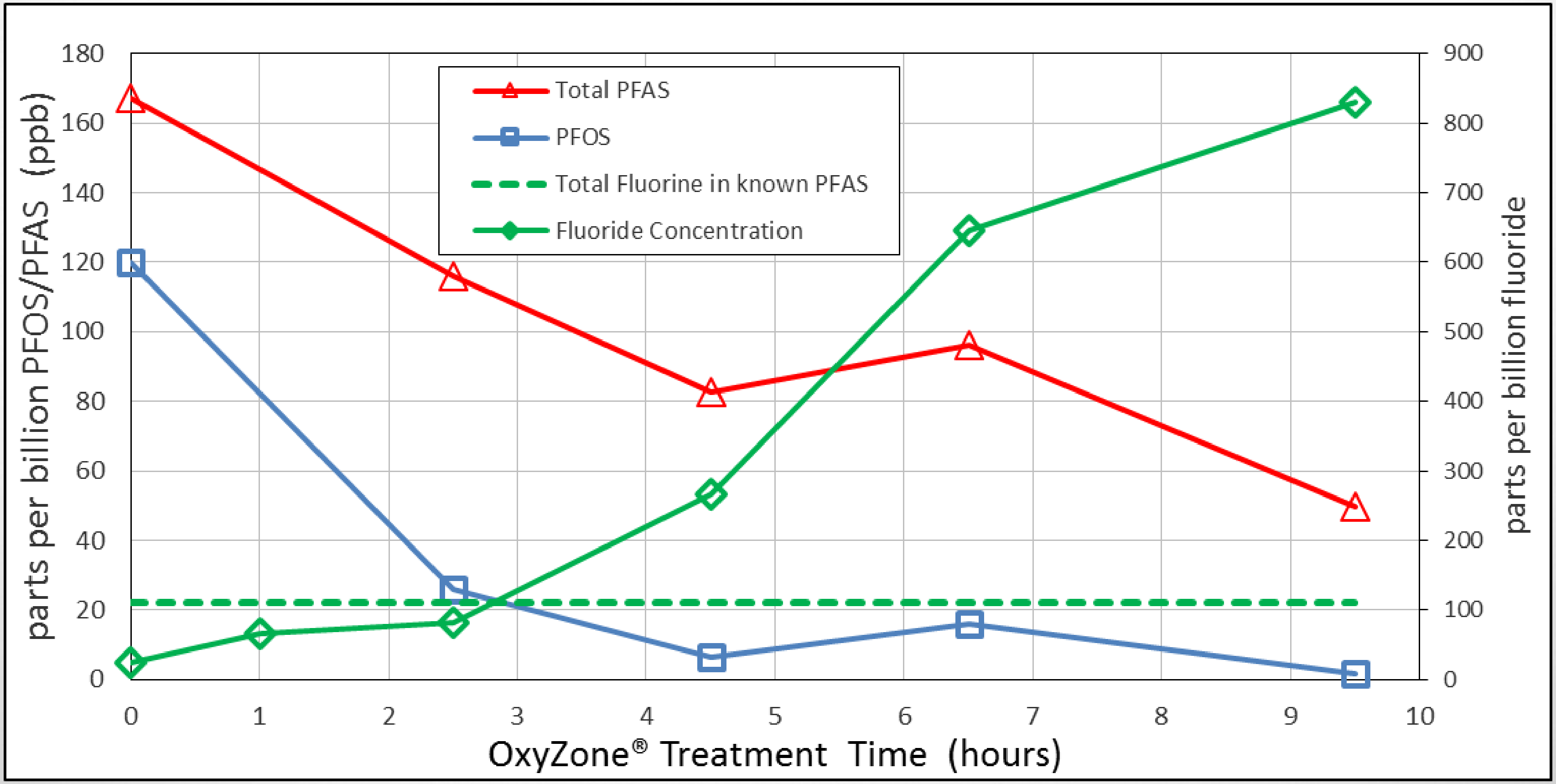
EnChem Engineering, Inc.

In-House Bench Scale Treatability Testing on Groundwater (from Virginia FTA site)

PFAS Contaminated Site GW Spiked with Additional PFOS and PFOA (6 hrs. treatment)				
Specific PFAS	**Initial concentration**	**Intermediate** (3 hrs.) **concentration**	**Final** (6 hrs.) **Concentration**	**Net Change**
PFOS: (8 carbon sulfonate)	138 ppb	25 ppb	3 ppb	95% decrease
PFOA: (8 carbon acid)	33 ppb	22 ppb	6 ppb	97% decrease
PFHpS: (7 carbon sulfonate)	7 ppb	4 ppb	0.4 ppb	97% decrease
PFHpA: (7 carbon acid)	6 ppb	< 0.4 ppb	< 0.4 ppb	67% decrease
PFHxA: (6 carbon acid)	15 ppb	43 ppb	30 ppb	net increase
PFHxS: (6 carbon sulfonate)	68 ppb	99 ppb	14 ppb	79% decrease
PFPeA: (5 carbon acid)	11 ppb	< 2 ppb	< 2 ppb	91% decrease
PFBS: (4 carbon sulfonate)	9 ppb	14 ppb	10 ppb	no change
PFBA: (4 carbon acid)	3 ppb	6 ppb	5 ppb	small increase

In-House Bench Scale Lab Results

Actual AFFF Site Contaminated Groundwater -
High Undetected PFAS showed 750% Fluoride Recovery



ONGOING RESEARCH: PFAS

ALPHA ANALYTICAL, INC

GHD

TestAmerica

THE LEADER IN ENVIRONMENTAL TESTING

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UV/Oxidant Studies

PFAS impacted sample

0.64% Oxidant+UV

0.32% Oxidant+UV

High flow of Ozone + UV

Med flow of Ozone + UV

Low flow of Ozone + UV

Analyze for PFAS

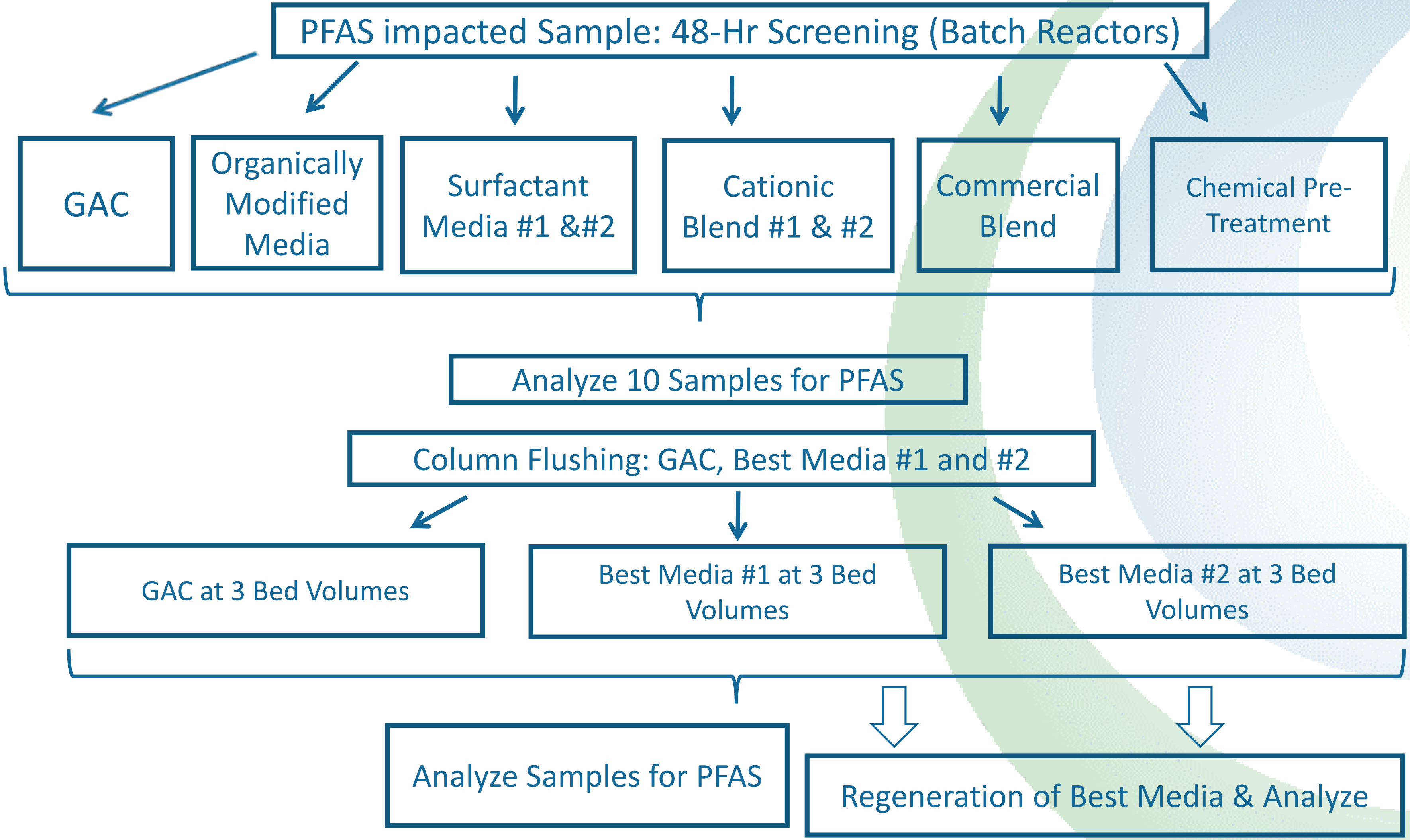
Best oxidant and dose tested at 3 UV exposure times

Best dose of ozone tested at 3 UV exposure times

Analyze for PFAS

Range of pH tested at Best Oxidant Dose / Ozone and UV time exposure

Adsorption / Ion Exchange Studies



Destruction (Electrochemical [EC]) Studies

PFAS impacted Sample:
1 Time Point (Batch Reactors)

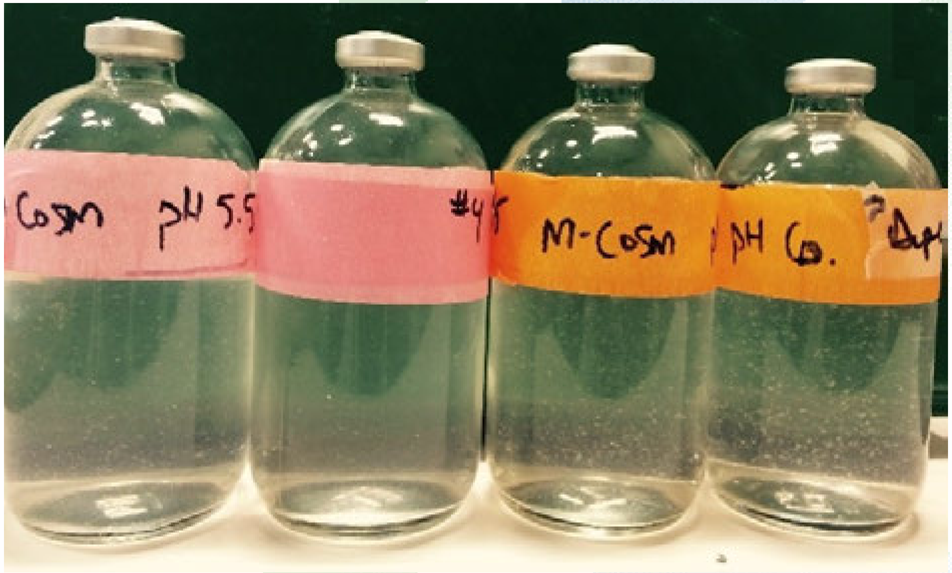
EC Only

EC with pre-treatment
(oxidant or other)

Analyze 4 samples for PFAS

Bench Scale Testing:
Duration, Media Requirements, Waste Handling, Costs

- Test Duration
  - ISCO: 2 days to 8 weeks
  - Bio: 2 to 6 months
- Media Requirements
  - Soil: 2 to 30 pounds
  - Groundwater: 1 to 20 liters
- Costs
  - $2,000 to $50,000 or greater (function of scope and sample numbers)



Questions?

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