Per- and Polyfluoroalkyl Substances – Industry Update and Facility Management Considerations

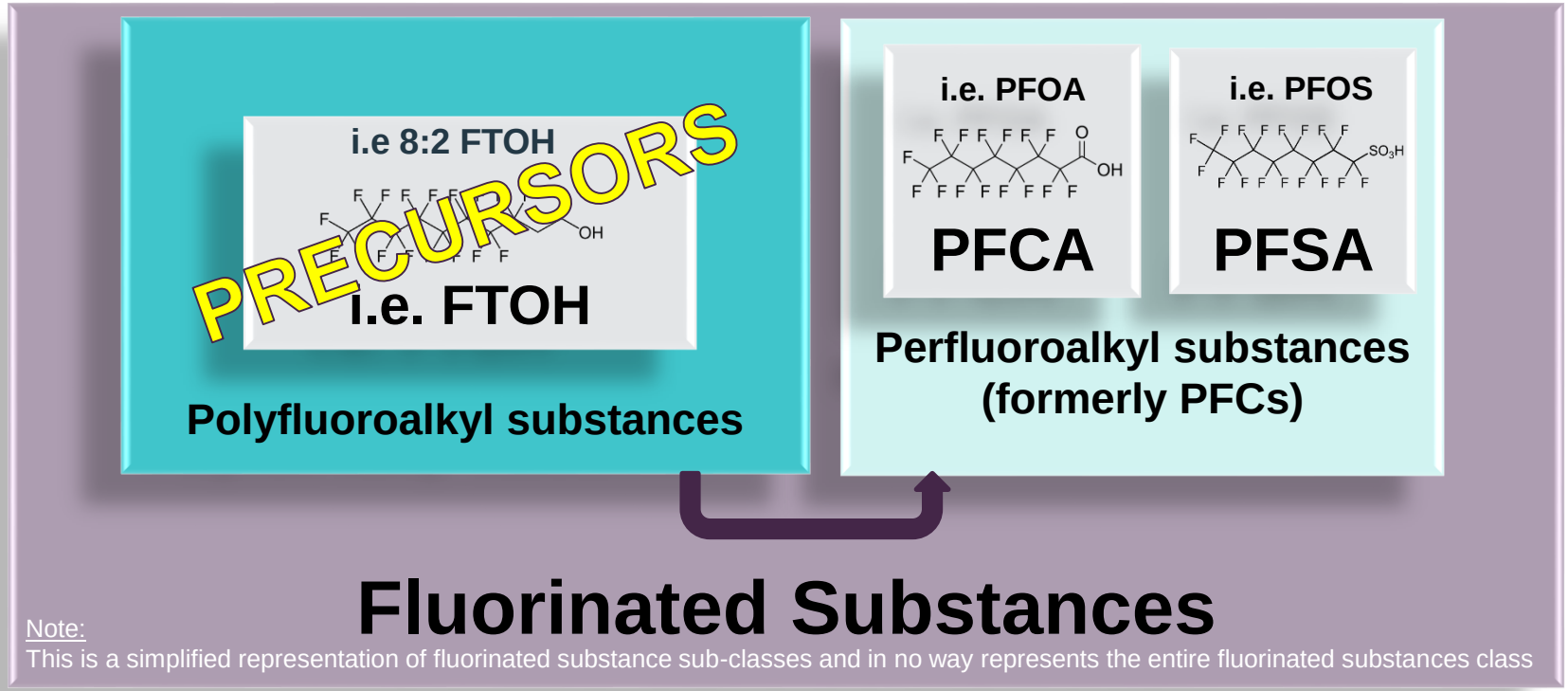
Shalene Thomas, Emerging Contaminant Program Manager

Agenda

1. PFAS- Review- What are they? Where are they?
2. The PFAS Conceptual Site Model (CSM), A Case Study
3. Remediation Alternatives and Research
4. Facility Management Considerations

PFAS- Review- What are they? Where are they?

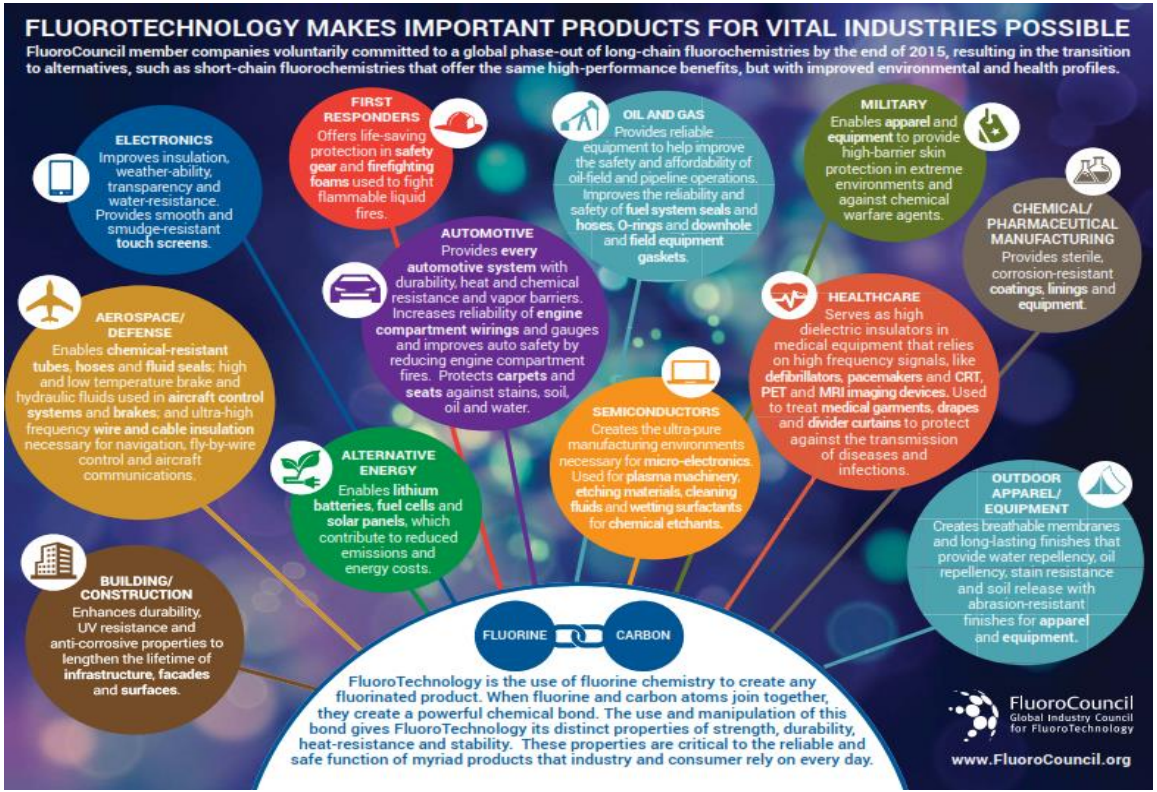
PFAS –What are they?



Note:
This is a simplified representation of fluorinated substance sub-classes and in no way represents the entire fluorinated substances class

[1] RC Buck et al. Guide to PFASs in the Environment- Integr Environ Assess Manag 7, 2011

Where are they? Uses and Sources



PFAS Properties

Chemical Properties	PCB (Arochlor 1260)	PFOA	PFOS	TCE	Benzene
Molecular Weight	357.7	414.07	538	131.5	78.11
Solubility	0.0027 mg/L @24°C	**3400–9500 mg/L @25°C**	519 mg/L @20°C	1100 mg/L @ 20°C	1780 mg/L @20°C
Vapor Pressure (25°C)	4.05×10^{-5} mmHg	**0.5-10 mmHg**	**2.48×10^{-6} mmHg**	77.5 mmHg	97 mmHg
Henry's Constant	4.6×10^{-3} atm-m^3/mol	0.0908 atm-m^3/mol	**3.05×10^{-6} atm-m^3/mol**	0.0103 atm-m^3/mol	0.0056 atm-m^3/mol
Organic Carbon Part. Coeff. (Log K_{oc})	4.8-6.8	2.06	**2.57**	2.42	2.15

The PFAS Conceptual Site Model (CSM)
A Case Study

The Case Study: Data Summary

- Over 100 US DoD Installations in our PFAS program

- **TODAY'S FOCUS**
- 22 Installations
- 125 potential PFAS release areas of AFFF
- 405 soil borings
- 769 monitoring wells

AFFF = Aqueous Film Forming Foam

Media and Constituents

7 Media of Concern

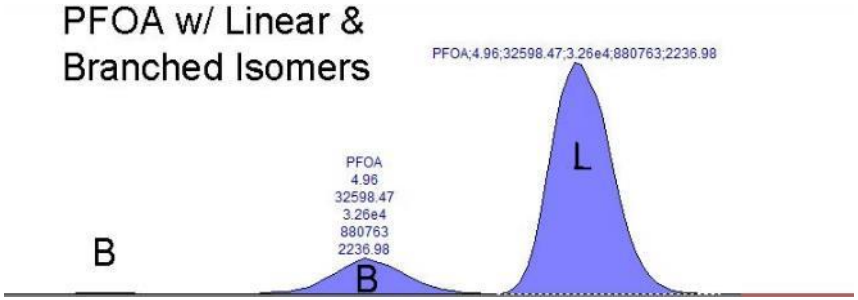
- Soil
- Groundwater
- Stormwater
- Porewater
- Sediment
- Surface water
- Fish tissue

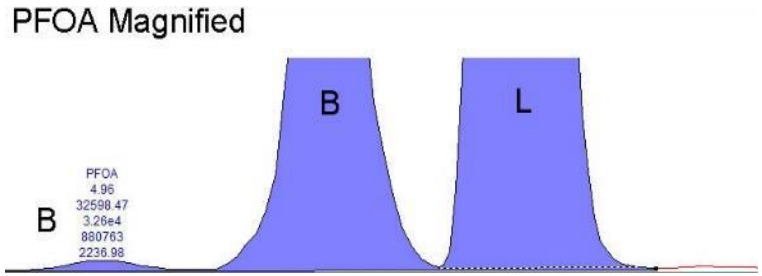
3 Functional Groups

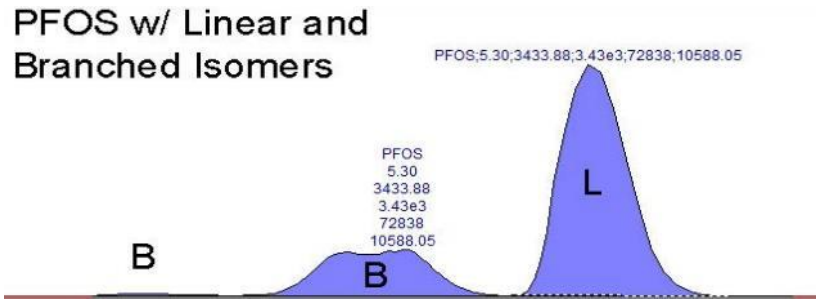
- 11 PFCAs
- 2 FTSs
- 3 PFSAs

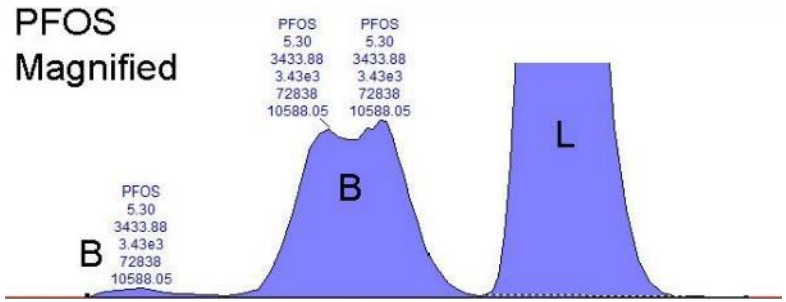
Short name	Formula	PFAS constituent (16)
PFBA	$C_4HF_7O_2$	Perfluorobutanoic acid
PFPeA	$C_5HF_9O_2$	Perfluoropentanoic acid
PFBS	$C_4F_9SO_3H$	Perfluorobutanesulfonic acid
PFHxA	$C_6HF_{11}O_2$	Perfluorohexanoic acid
PFHpA	$C_7HF_{13}O_2$	Perfluoroheptanoic acid
PFHxS	$C_6F_{13}SO_3H$	Perfluorohexanesulfonic acid
6:2 FTS	$C_8H_5F_{13}SO_3$	6:2 Fluorotelomer sulfonate
PFOA	$C_8HF_{15}O_2$	Perfluorooctanoic acid
PFOS	$C_8F_{17}SO_3H$	Perfluorooctanesulfonic acid
PFNA	$C_9HF_{17}O_2$	Perfluorononanoic acid
PFDA	$C_{10}HF_{19}O_2$	Perfluorodeconoic acid
8:2 FTS	$C_{10}H_5F_{17}O_3S$	8:2 Fluorotelomer sulfonate
PFUnA	$C_{11}HF_{21}O_2$	Perfluoroundecanoic acid
PFDoA	$C_{12}HF_{23}O_2$	Perfluorodecanoic acid
PFTrDA	$C_{13}HF_{25}O_2$	Perfluorotridecanoic acid
PFTeDA	$C_{14}HF_{27}O_2$	Perfluorotetradecanoic acid

Linear and Branched; what is important?

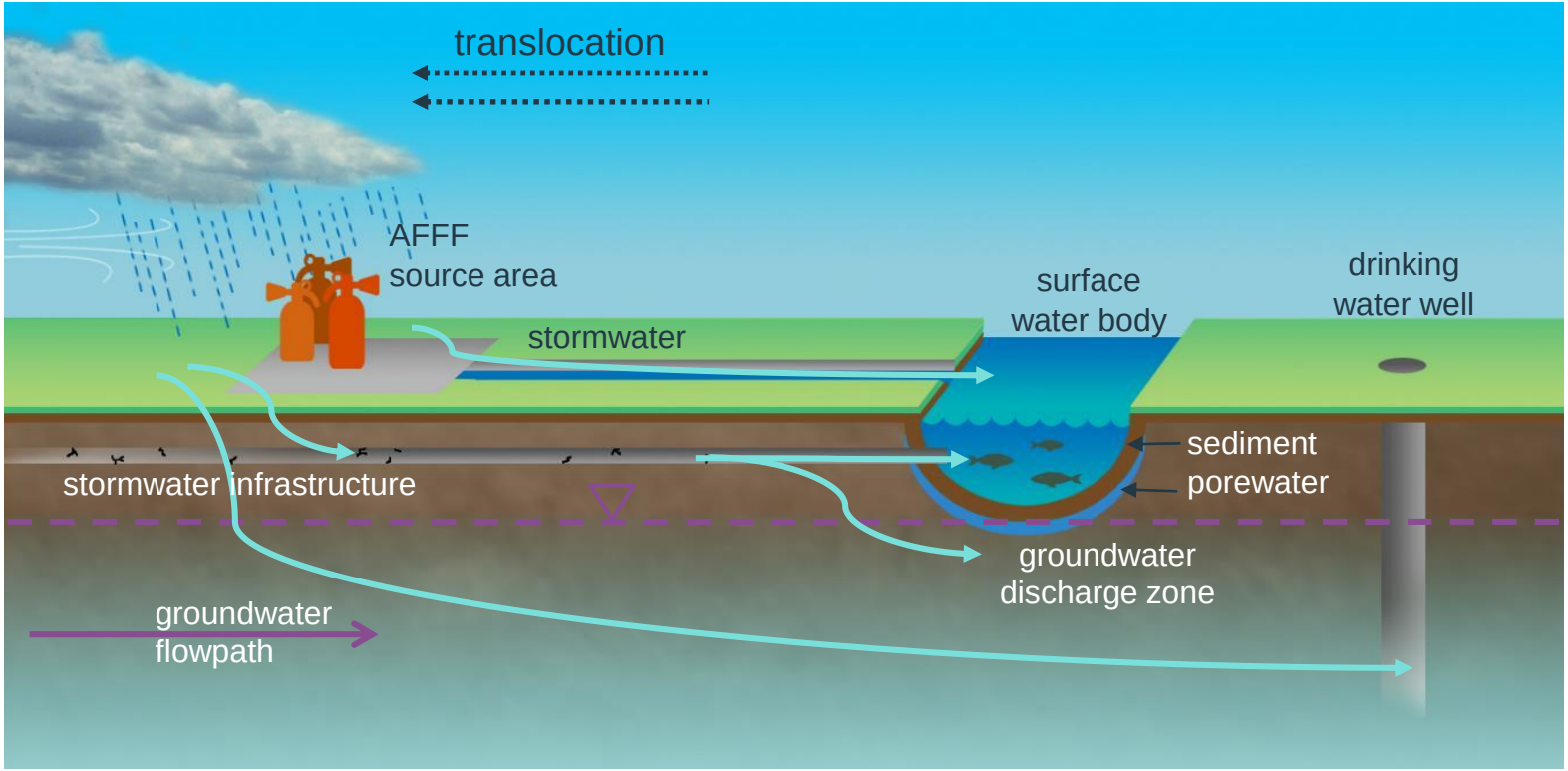








PFAS Migration Pathways



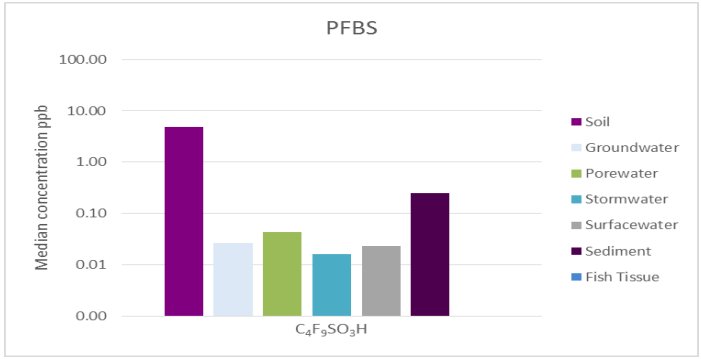
Data Summary

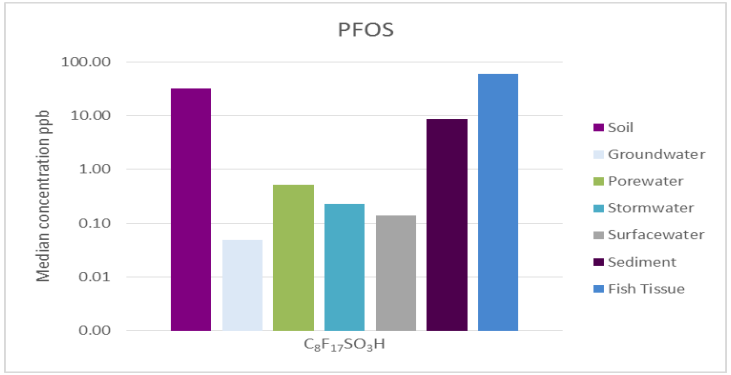
Summary data for 22 installations	# of samples	PFOS detects	Median / Maximum (ppb)	PFOS >HA	PFOA dectects	Median / Maximum (ppb)	PFOA>HA
Soil samples	1562	60%	32.4 / 108,000	NA	45%	0.514 / 697	NA
GW samples	1381	75%	0.050 / 7150	34%	67%	0.011 / 21.5	30%
Stormwater samples	80	96%	0.231 / 3.70	55%	68%	0.013 / 0.033	16%
Porewater samples	40	98%	0.052 / 4.30	83%	93%	0.011 / 0.052	85%
Sediment samples	123	76%	8.64 / 984	NA	47%	0.289 / 24.4	NA
Surface water samples	119	97%	0.138 / 2.40	67%	91%	0.0028 / 0.037	35%
Fish tissue samples	17	100%	59.1 / 457	NA	35%	0.576 / 1.28	NA

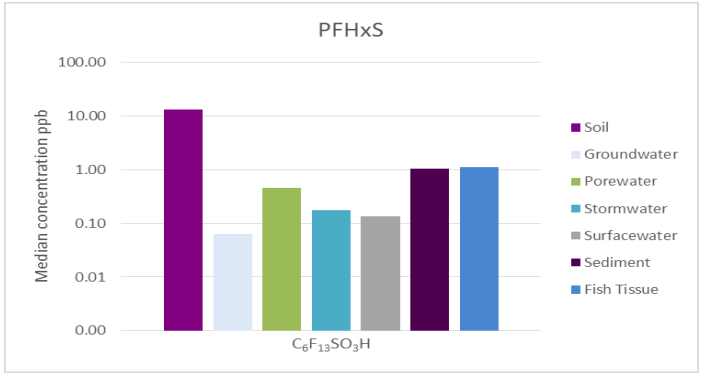
High frequency of detections for PFOS and PFOA

All installations compound highlights

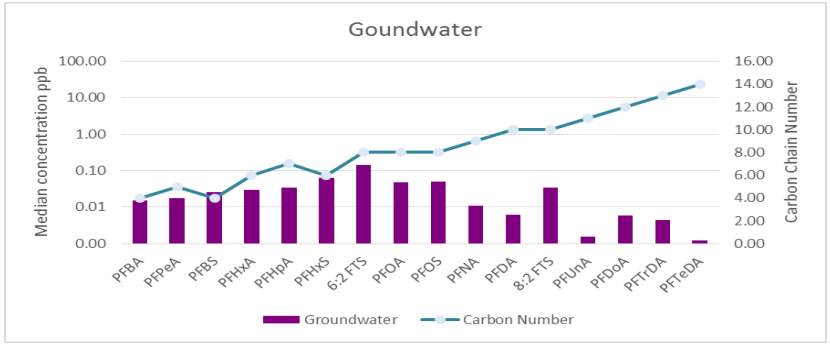
- PFSAs account for most of the mass
- Accumulated mass resides at GW-SW interface in pore water and sediment
- Some PFAS bioaccumulate in fish filet



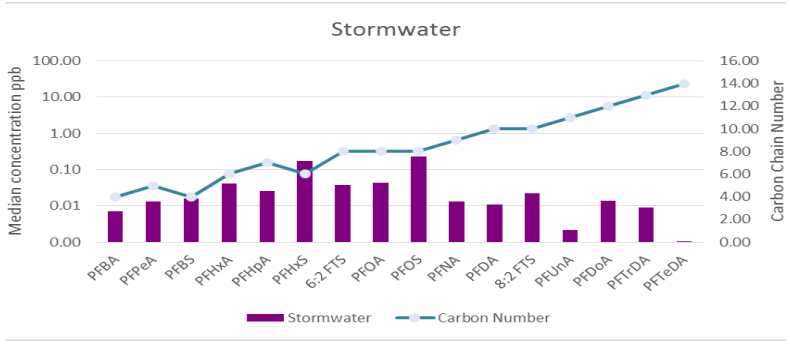




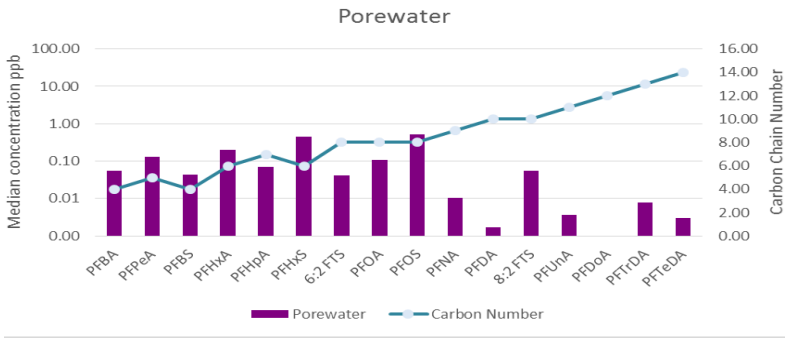
All Installations- Aqueous Media



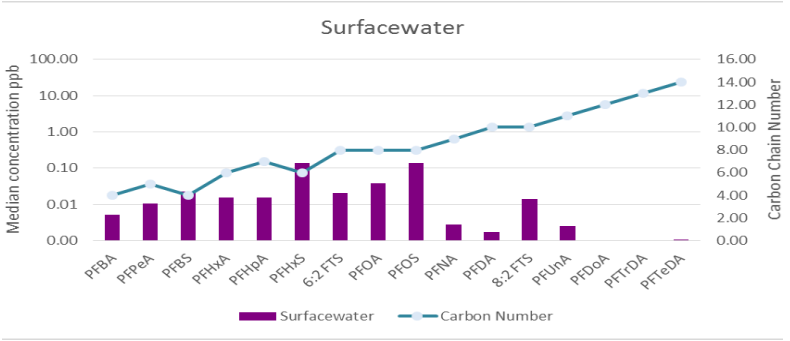
6:2 FTS highest in groundwater



PFHxS and PFOS dominate in ST, PW SW



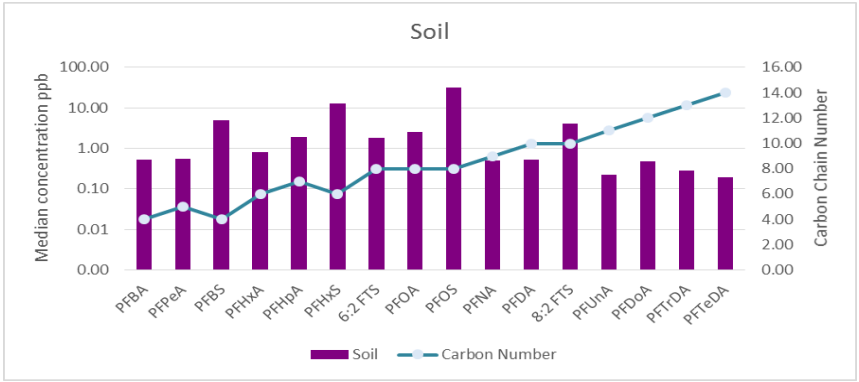
Low and mid-range C chain lengths dominate

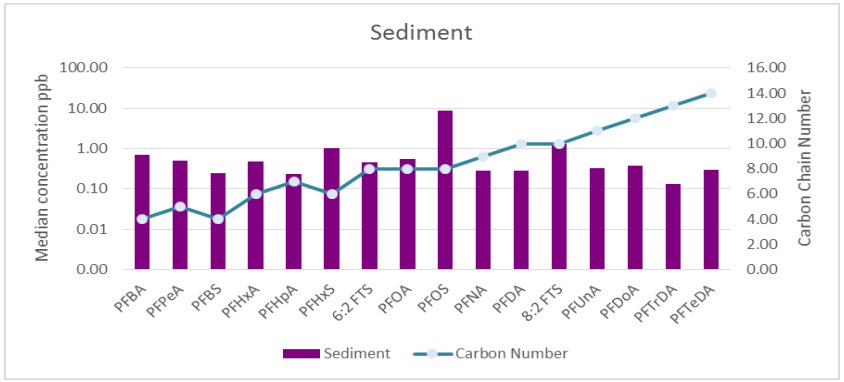


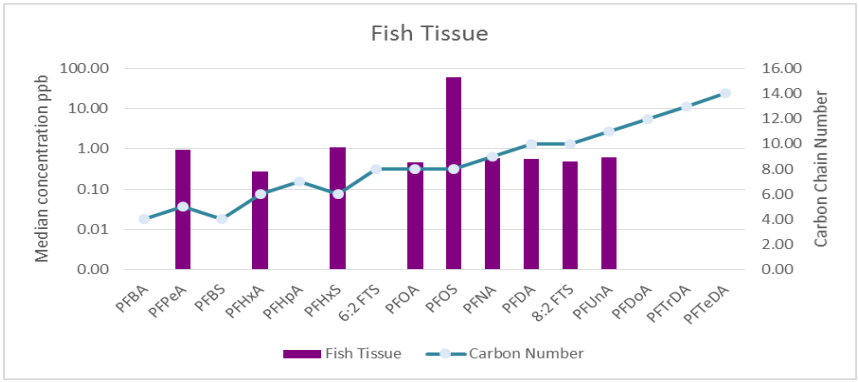
Widespread low-level detections in SW

All installations SO, SD, FT

- Longer chain compounds present in solid media
- PFOS, PFHxS dominate SO and SD
- PFOS 100X other PFAS in fish tissue







Remediation Alternatives and Research Efforts

PFAS Remediation Challenges

- PFASs soluble, recalcitrant may form large dilute plumes
- Limited commercially available/demonstrated technologies
  - High cost, non-destructive and may not address all PFASs
  - Treatment train may be required
- Emergency response mode – must use proven technology (GAC) to address completed exposure pathways
- Significant R&D ongoing – promising and challenging

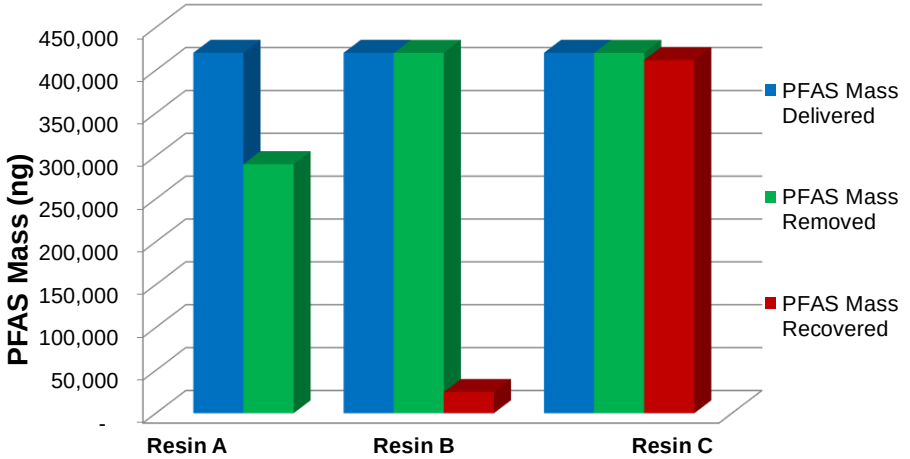
Ion-Exchange Media –First Study Set-Up

- Media Selection

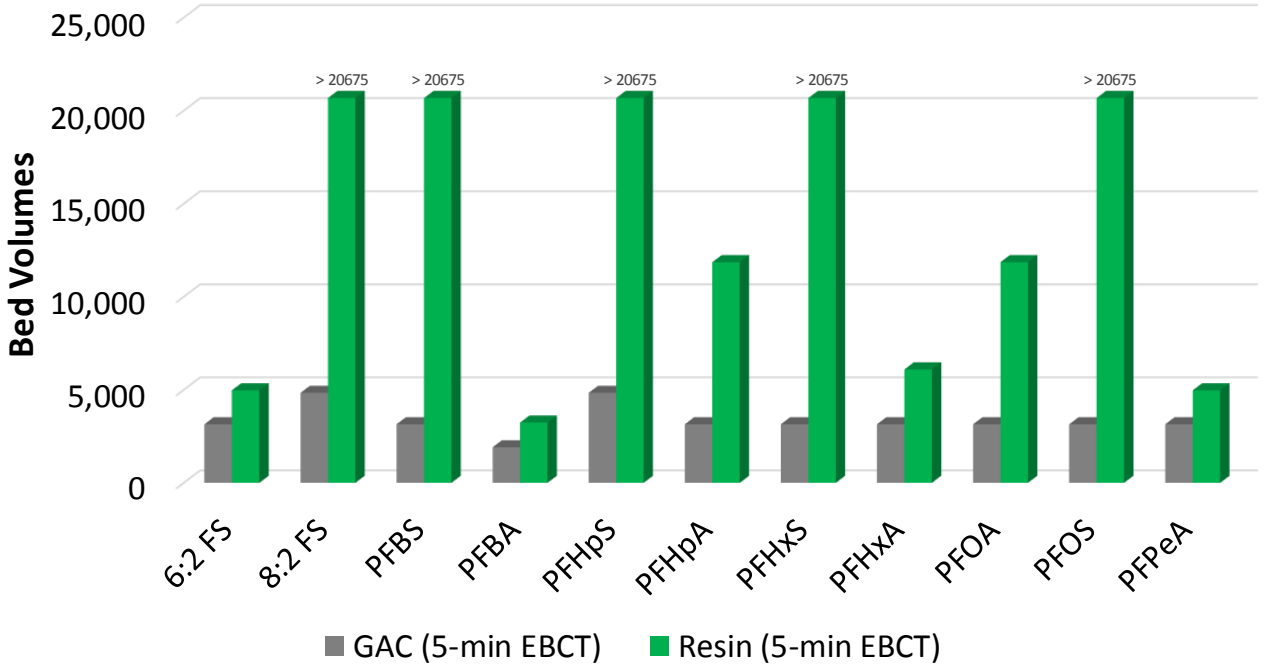


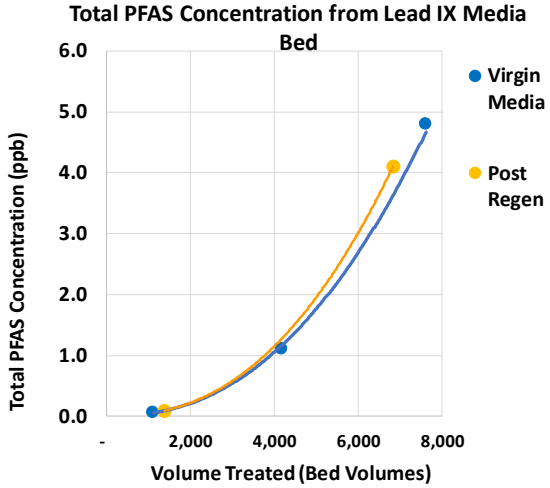
- PFAS Influent Concentrations

PFAS Compound	Average Influent Concentration (µg/L)
PFOA	0.291
PFOS	3.33
Other PFAS	3.11
Total PFAS	**6.73**



Ion-Exchange Media –First Study Results





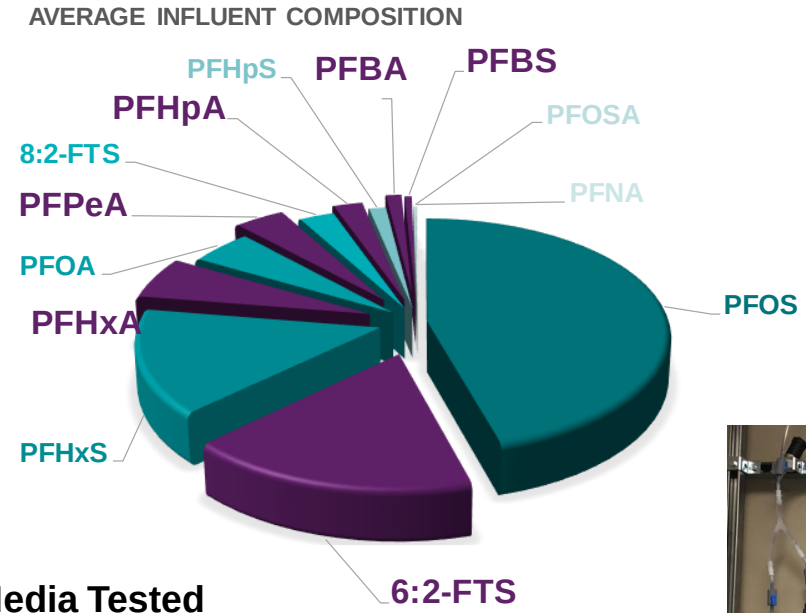
IX Regeneration Trial

Volume Treated Before Breakthrough: All Observed PFAS

Ion-Exchange Media –Second Study Set-Up

	% of Total PFAS Mass	Average Concentration (ug/L)	Fluorinated Carbon Chain Length
PFBA	**1.2%**	**0.408**	**3**
PFPeA	**3.8%**	**1.323**	**4**
PFBS	**0.5%**	**0.188**	**4**
PFHxA	**5.8%**	**2.032**	**5**
6:2-FTS	**17.2%**	**6.021**	**6**
PFHpA	**2.2%**	**0.762**	**6**
PFHxS	14.6%	5.111	6
PFOA	4.8%	1.663	7
PFHpS	1.3%	0.438	7
PFOS	45.5%	15.895	8
8:2-FTS	2.6%	0.909	8
PFOSA	0.2%	0.057	8
PFNA	0.1%	0.043	8
EtFOSE	0.0%	0.013	8
EtFOSA	0.0%	0.013	8
MeFOSE	0.0%	0.012	8
MeFOSE	0.0%	0.009	8
PFDA	0.0%	0.012	9
PFDS	0.0%	0.011	10
PFUnA	0.0%	0.009	10
PFDoA	0.0%	0.009	11
PFTrDA	0.0%	0.008	12
PFTeDA	0.0%	0.010	13
Total		**34.96**	

Short Chains



Column Set-up:

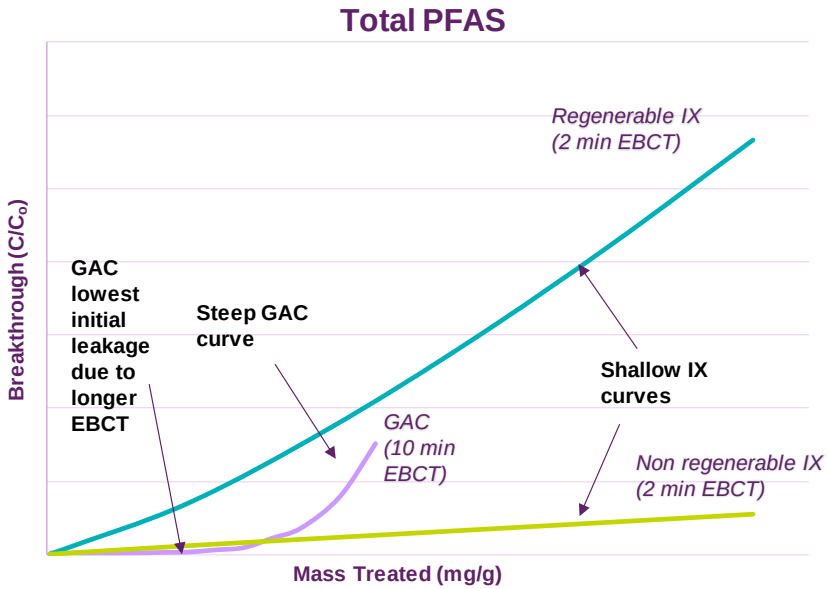
- GAC Column = 10 min EBCT
- IX Columns = 2 min EBCT

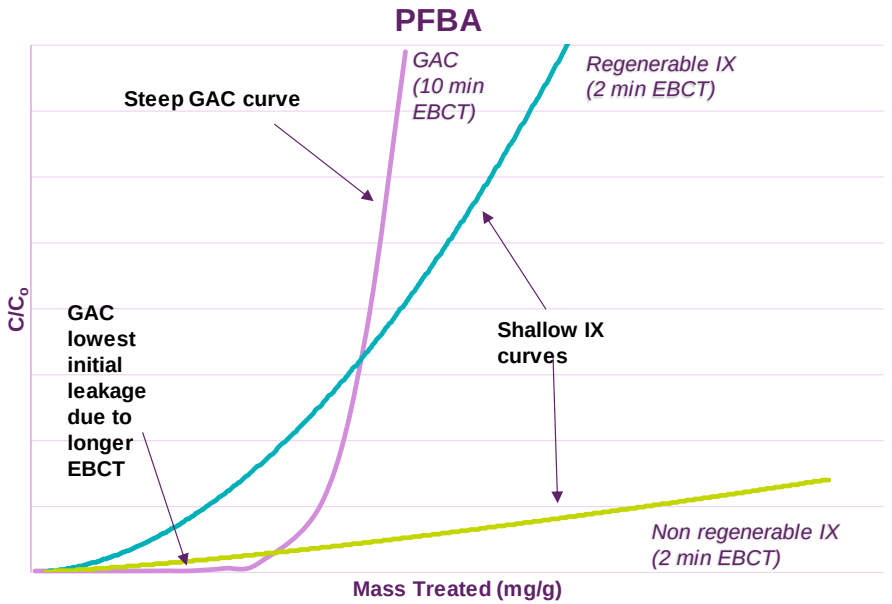
Media Tested

- One GAC
- Two regenerable IX media
- Three non regenerable IX media

Ion-Exchange Media –Second Study Results

- Illustrative curves for GAC and IX media for total PFAS from site-specific groundwater





Site-specific pilot testing required to determine media performance

Sustainable IX in Treatment Train with Plasma Destruction

Strategic Environmental Research and Development Program (SERDP)

Awarded: “Combined In Situ / Ex Situ Treatment Train for Remediation of PFAS Contaminated Groundwater”

Research Team:

Clarkson

ect2

NAVFAC

Environmental Security Technology Certification Program (ESTCP)

Pending: “Removal and Destruction of PFAS and Co-Contaminants from Groundwater”

Wrap-Up- What does this all mean?
Facility Management Considerations

Management Considerations

The “take-home” messages….

1. **Not all PFAS are created equally**
2. **Anticipate/plan for detections wherever historical use suspected.**
3. **Remediation is challenging; solutions are evolving and no “one size fits all”.**

Where to find us

Upcoming Conferences

- AEHS, Amherst MA- Oct 16-19
- SETAC Annual Conference, Minneapolis MN- Nov 16-18
- Battelle Chlorinated Conference, Palm Springs, CA –April 8-12

Industry Publications

- NGWA: Groundwater and PFAS: State of Knowledge and Practice- due out Fall 2017
- ITRC: PFAS Fact Sheets- 6 in total before the end of 2017
- Podcast: Understanding Emerging Contaminants and Regulatory Matters (https://itunes.apple.com/us/podcast/civil-engineering-podcast/id993416182?mt=2)
- Woodard, S. et al. 2017. Ion exchange resin for PFAS removal and pilot test comparison to GAC. Remediation 2017; 27:19-27.

Questions?

Shalene Thomas
Emerging Contaminant Program Manager
shalene.thomas@woodplc.com
(612) 252-3697

Thank you to collaborators:
Nathan Hagelin, Bill Malyk, Brandon Newman, Dave Woodward -Wood
Steve Woodard, Mike Nickelsen - ECT2
Michelle Crimi, Tom Holsen, Selma Mededov – Clarkson University
Tim Appleman- US Navy