Getting Ahead of the Curve

Risk Management Strategies for Perfluoroalkyl Substances

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Acknowledgments

- Rachel Jacobson and H. David Gold of Wilmer Hale
- Patrick Gwinn, Nicholas Shonka, Phil Goodrum, and Janet Anderson of Integral Consulting Inc.

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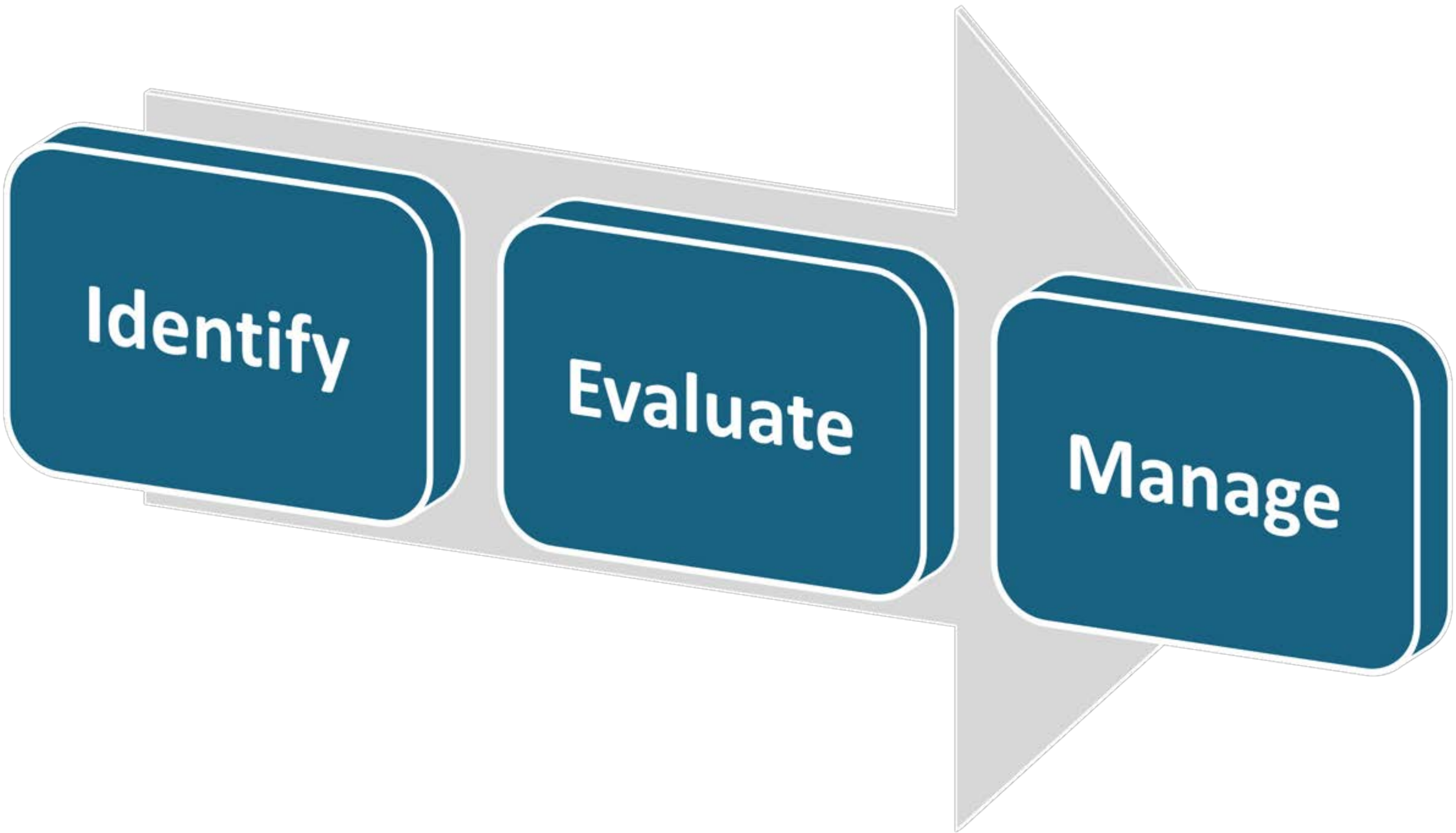
Overview

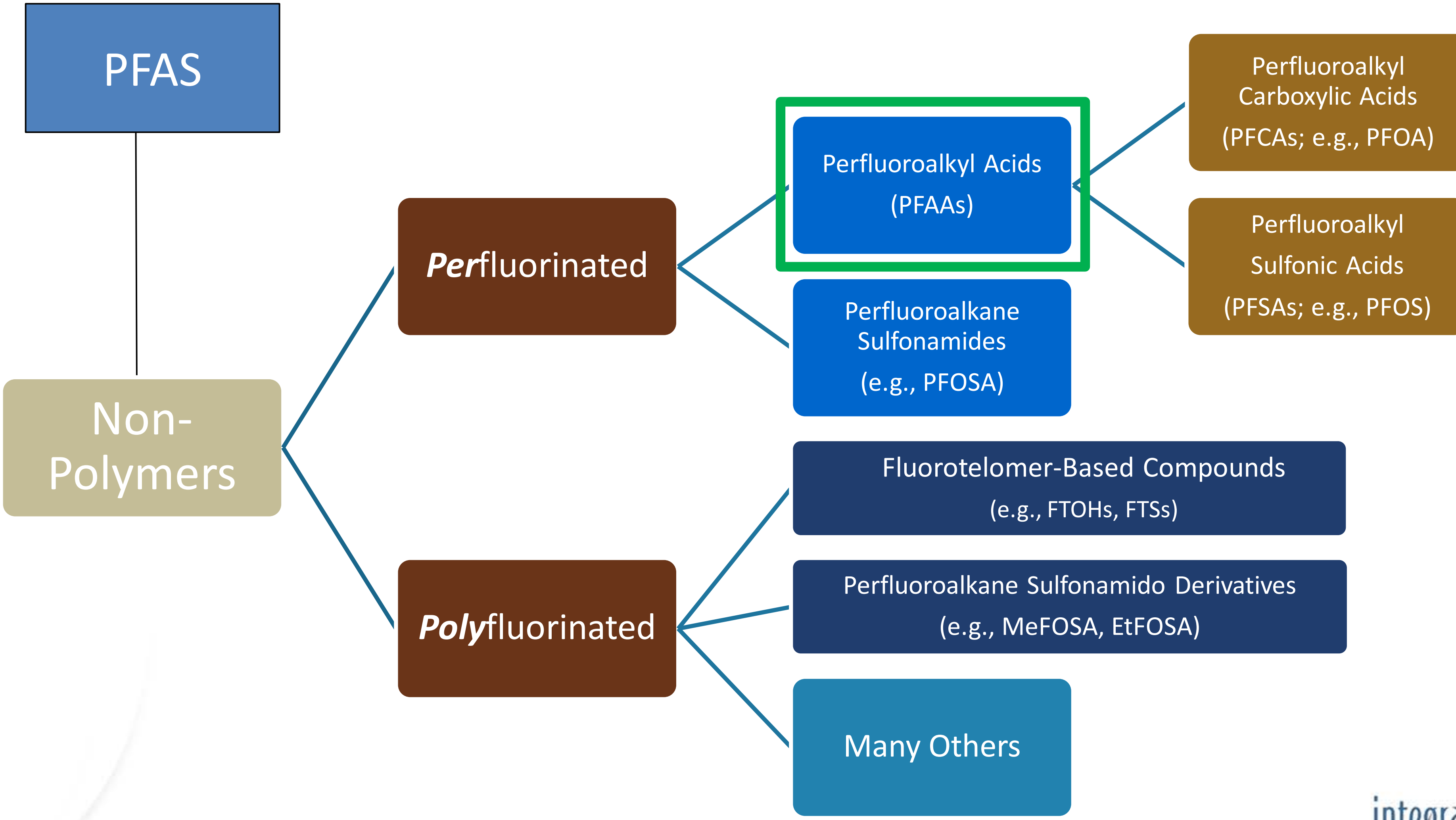
- Nomenclature and Classification Schemes
- Sources
- Regulatory Attention
- Treatment Technologies
- Management Strategies

Risk Management Framework

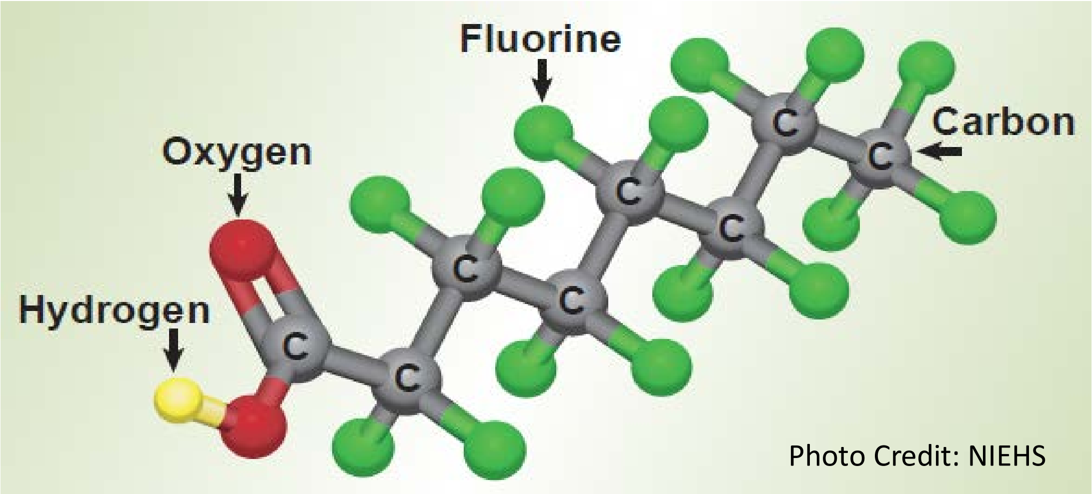



PFC
PFAA
PFAS
PFOA
PFOS
PFCA
PFSA

Per- and Polyfluoroalkyl Substances (PFAS)

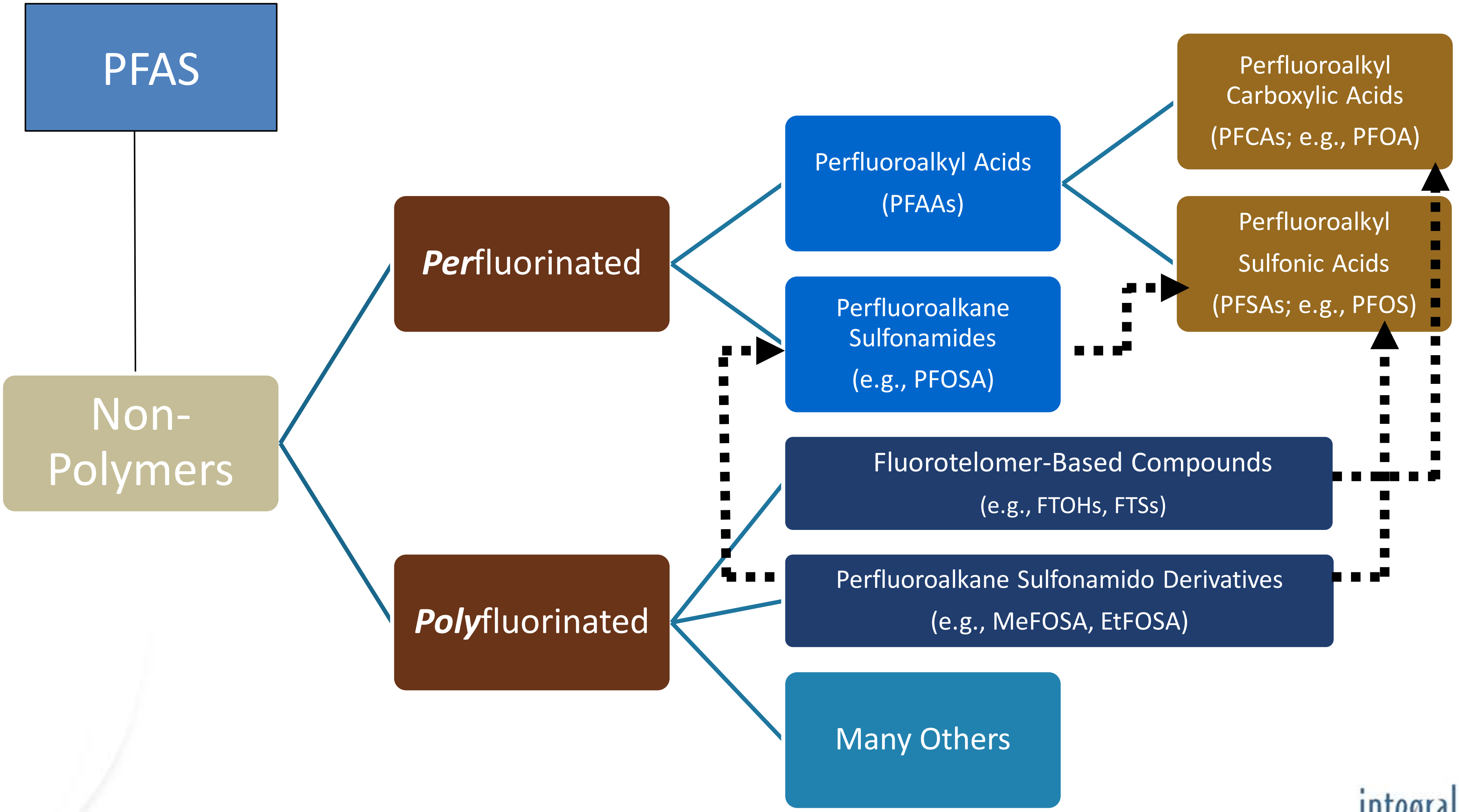


Perfluoroalkyl Acids (PFAAs)



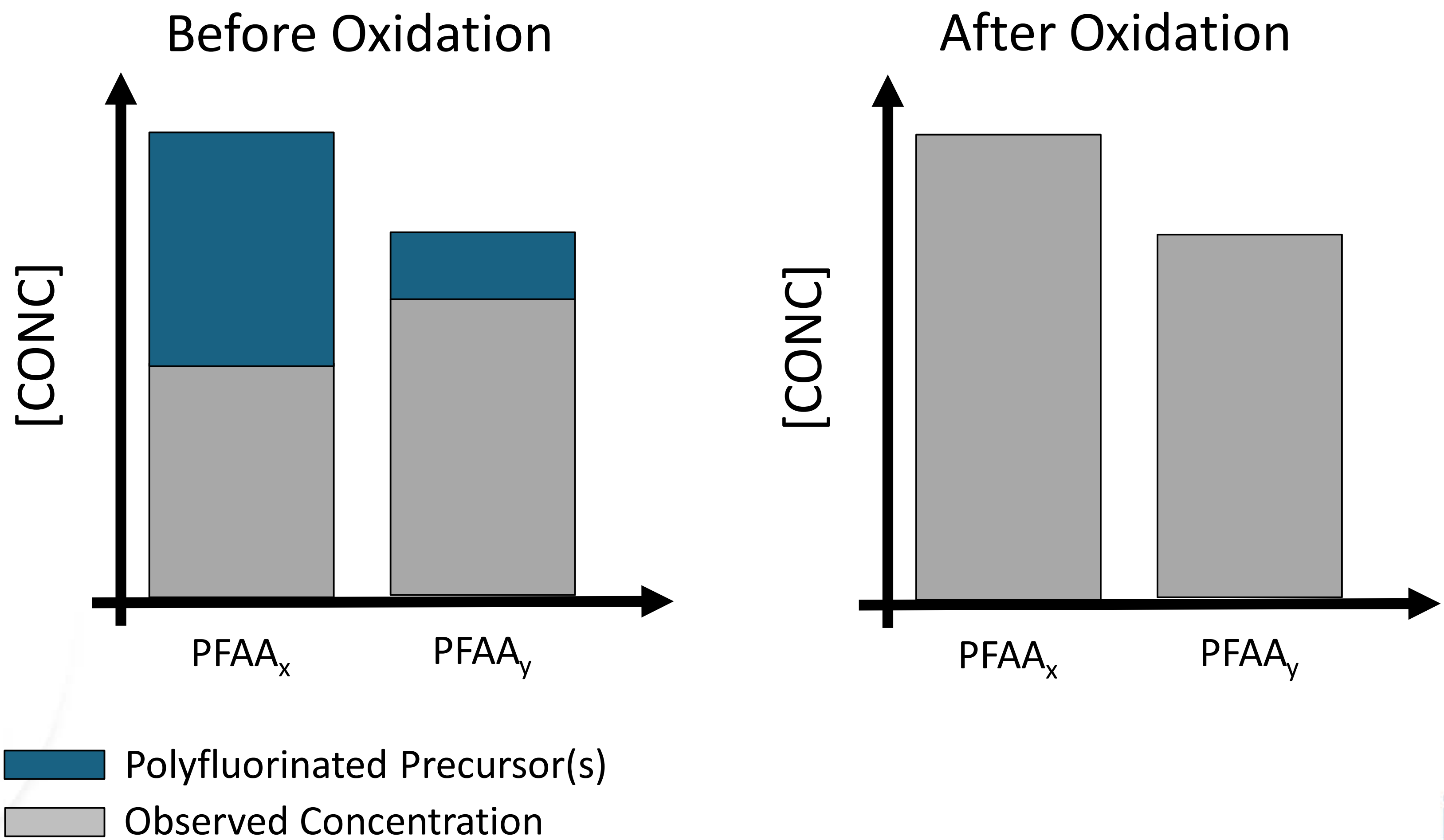
Carbons	PFAS	Acronym
C4	Perfluorobutanesulfonic acid	PFBS
C6	Perfluorohexanoic acid	PFHxA
C6	Perfluorohexanesulfonic acid	PFHxS
C7	Perfluoroheptanoic acid	PFHpA
C8	Perfluorooctanoic acid	PFOA
C8	Perfluorooctanesulfonic acid	PFOS
C9	Perfluorononanoic acid	PFNA
C10	Perfluorodecanoic acid	PFDA
C12	Perfluorododecanoic acid	PFDoA
C13	Perfluorotridecanoic acid	PFTrDA
C14	Perfluorotetradecanoic acid	PFTA
Precursor	Polyfluorotelomer sulfonate	8:2 FTS

Per- and Polyfluoroalkyl Substances (PFAS)

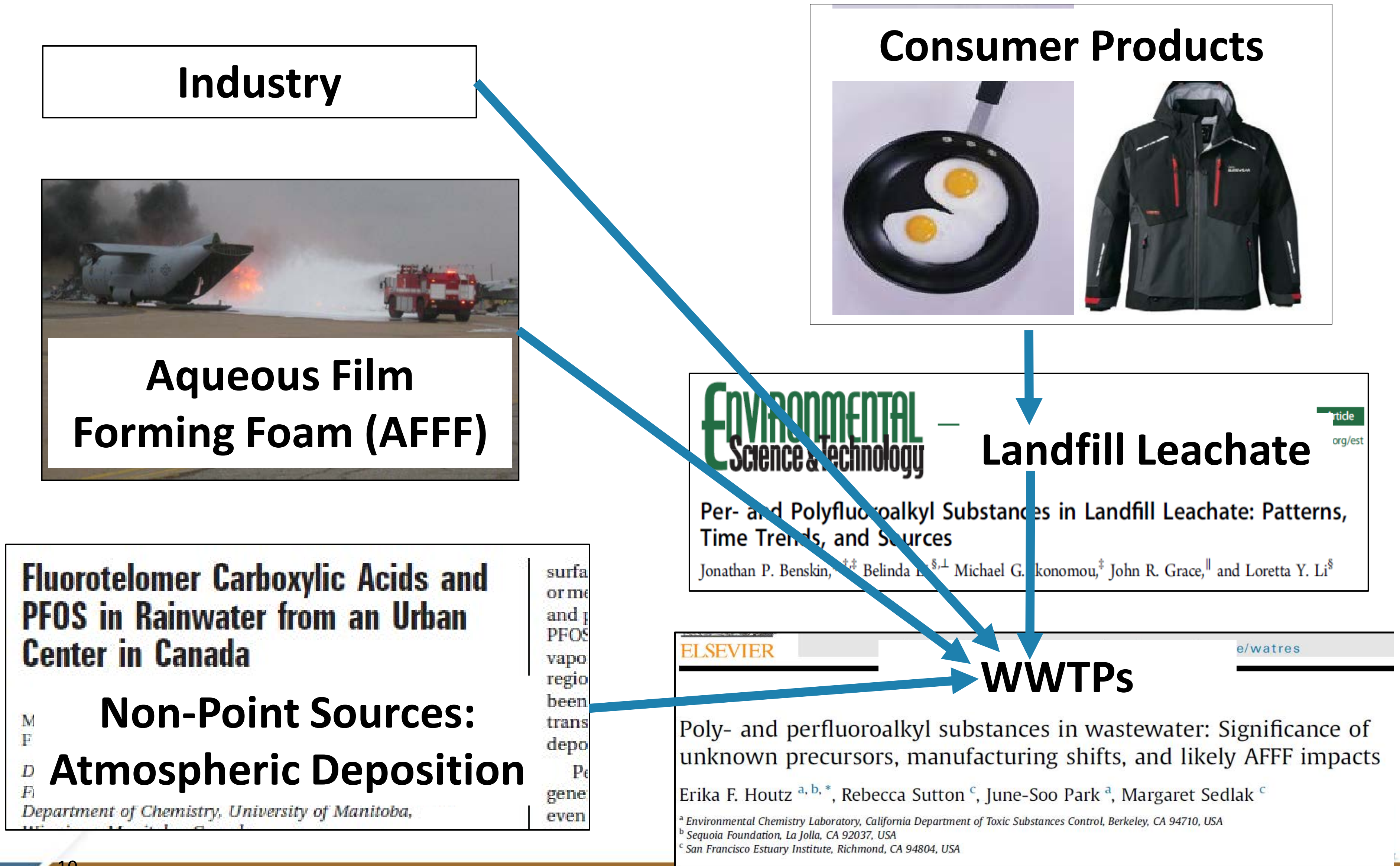


Precursor Biotransformation

- All polyfluorinated PFASs are potential “Precursors” to PFAAs



Sources of PFAS



PFAA Chemical Properties

- Chemical properties common to PFAAs are:
  - Water soluble
  - High mobility
  - Low volatility
  - Resistant to degradation
- Carbon chain length:
  - The longer the tail, the greater the hydrophobicity
  - Focus has been on long-chain PFAAs (8+ carbons)

Not Your Traditional Persistent Compounds

	PFOA	Dioxins & PCBs
Highly water soluble	YES	NO
Binds well to soil & sediments	NO	YES
Degrades in environment to some extent	NO	SOMEWHAT
Bioaccumulates in fish	NO	YES
Bioaccumulates in lipids	NO	YES
Drinking water is major exposure route	YES	NO

Source: NJDEP. 2013. Perfluorinated chemicals (PFCs) – Emerging drinking water contaminants. DRBC Toxics Advisory Committee, West Trenton, NJ. Gloria Post. June 5.

Regulations and Regulatory Approaches

- Disparate regulations nationally and internationally
- Focus on PFAAs, and mostly long-chain
- General confusion over precursors and degradation pathways
- Tendency to sum PFAS, without data suggesting that this is appropriate or necessary

Chemical Research in Toxicology
PERSPECTIVE
pubs.acs.org/crt

Why Toxic Equivalency Factors Are Not Suitable for Perfluoroalkyl Chemicals

Jeffrey M. Peters*,† and Frank J. Gonzalez‡

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Current New England GW/DW Values

Location	Agency / Dept	Year	Standard / Guidance	Type	Must Comply	To Be Considered	Concentration (µg/L)		
							PFOA	PFOS	PFBS
USEPA	Office of Water	2016	HA	DW		X	0.07[a]	0.07[a]	
	Regions		RSL[b]	GW		X	0.4*	0.4*	380
Connecticut	DPHE	2016	AL	DW		X	0.07[c]	0.07[c]	
Maine	CDC	2016	Health-based MEG	DW		X	0.07[a]	0.07[a]	
	DEP	2016	RAG	GW	X		0.13	0.56	
	DEP	2016		RW		X	0.05	1.2	
Massachusetts	DEP	2017	EPA HA	DW		X	0.07[a]	0.07[a]	
New Hampshire	DES	2016	AGQS	GW	X		0.07[a]	0.07[a]	
Vermont	DEC/DOH	2016	PGWES	GW/DW	X		0.02[a]	0.02[a]	

Notes:

* = draft/proposed values

[a] Applies to the individual results for PFOA and PFOS, as well as the sum of PFOA + PFOS.

[b] Anticipated from EPA. Calculated using the EPA RSL calculator using EPA OW RfDs, HI of 1, residential exposure assumptions.

[c] Connecticut has additive guidance - sum of PFOA, PFOS, PFNA, PFHxA, and PFHpA

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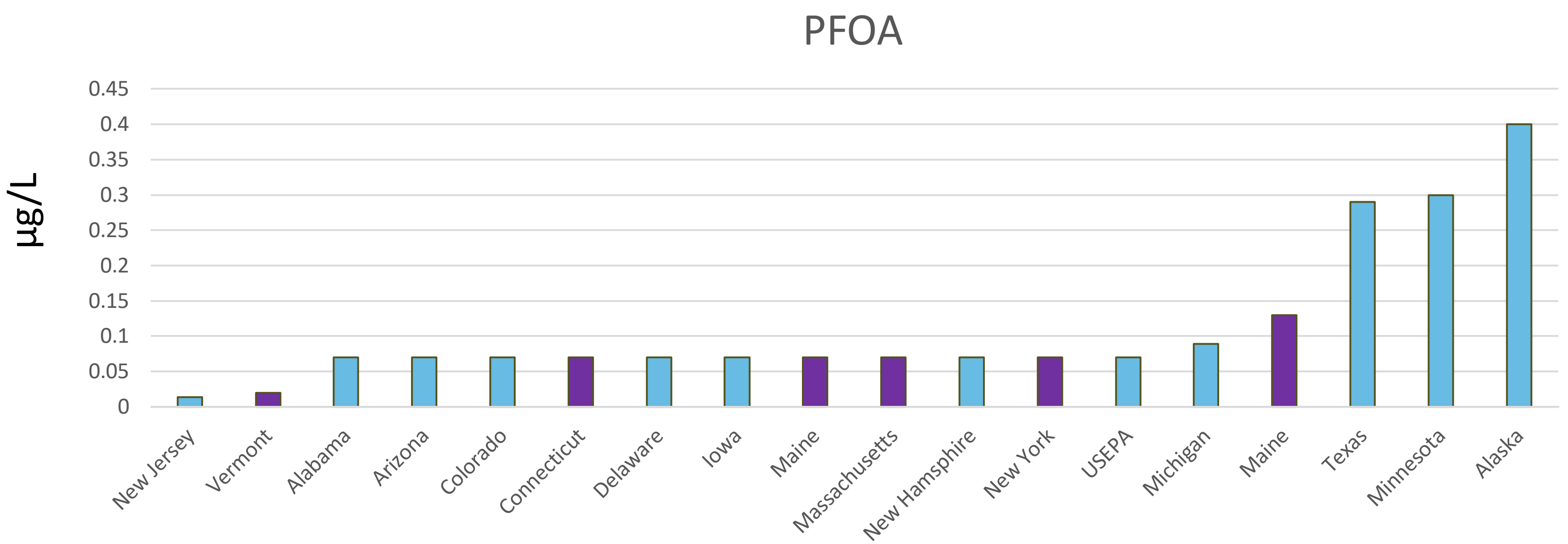
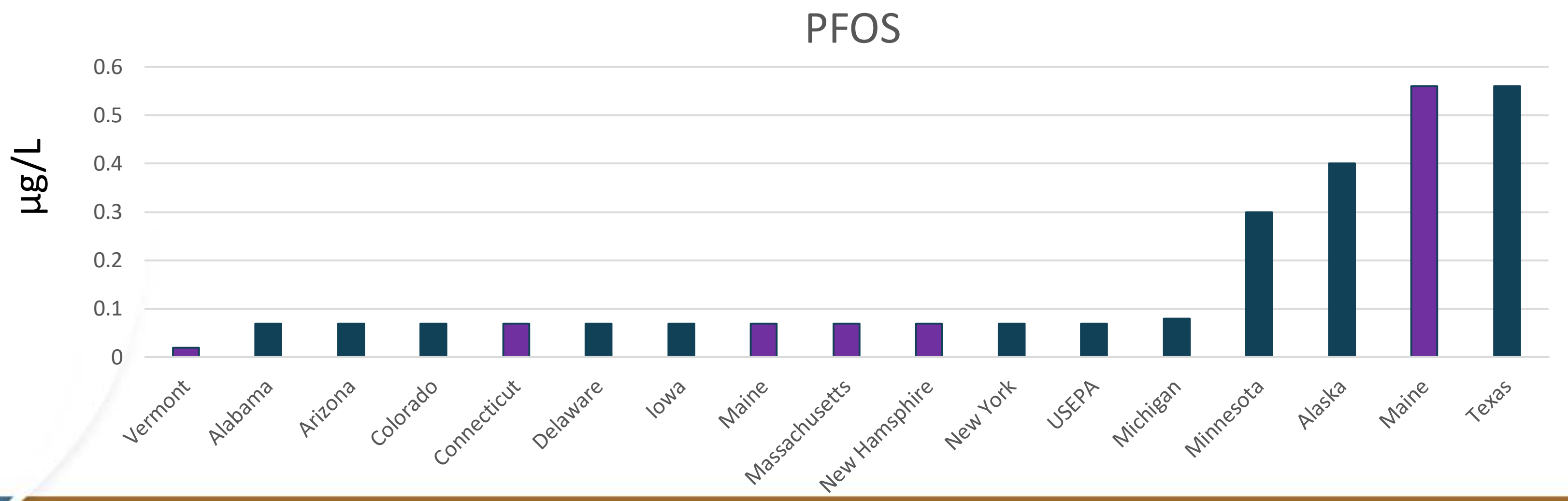
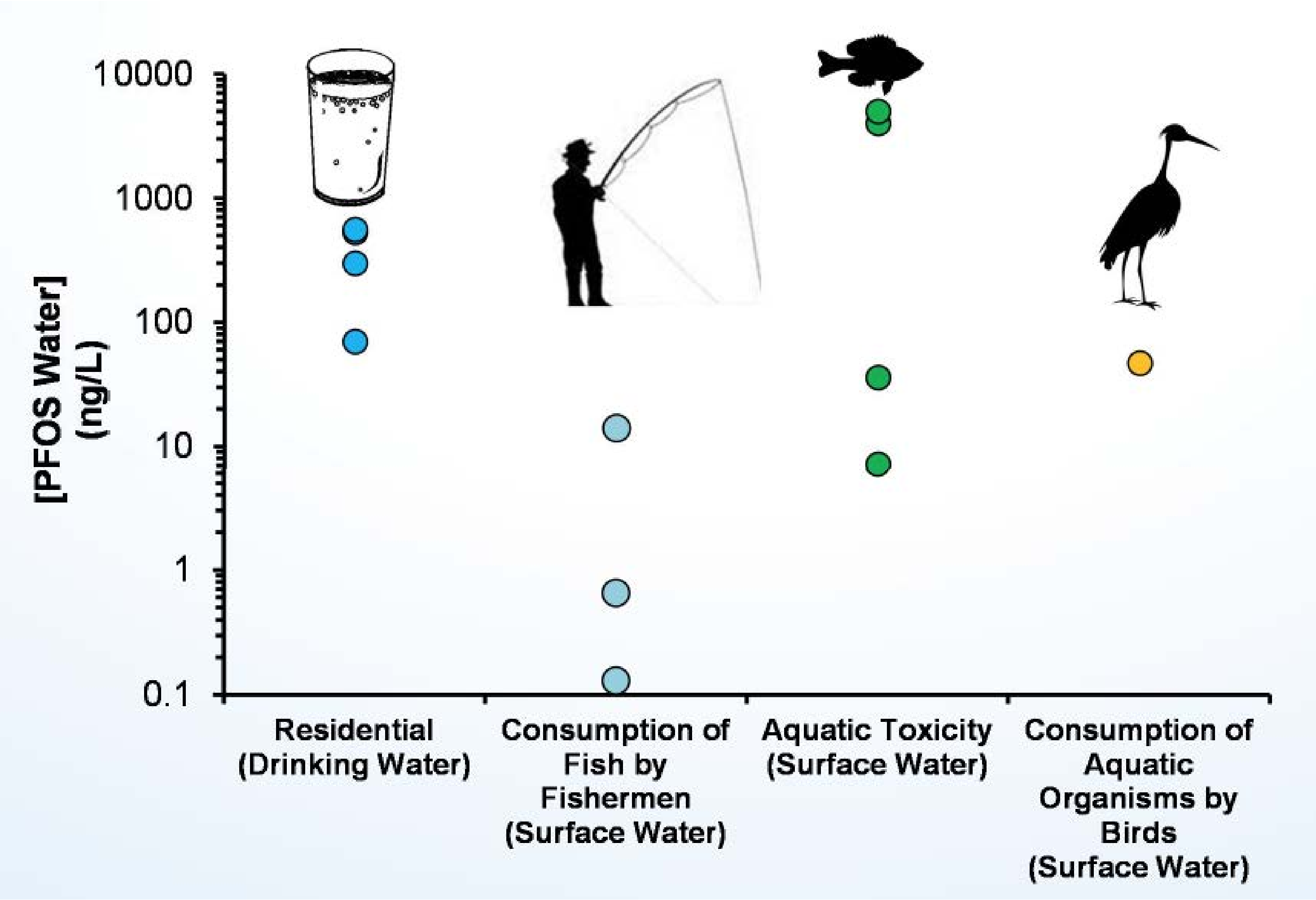
Values to Protect Humans from PFOA/PFOS in Drinking Water Span an Order of Magnitude





Example PFOS Risk-Based Screening Criteria



Source: Used with permission from Jason Conder, Geosyntec

Current New England Soil Screening Values

Location	Agency / Dept	Year	Standard / Guidance	Type	GW Protection	Human Health	Concentration (mg/kg)		
							PFOA	PFOS	PFBS
USEPA	Regions	2017	RSL	Soil	X		1.7E-04	3.8E-04	0.13
	Regions	2017	RSL	Soil		X	1.26	1.26	1,260
New Hamsphire	DES/EHP	2017	DCRB	Soil		X	0.5	0.5	
Vermont	DOH	2016	SSV	Soil		X	0.5		

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Vermont Hazardous Waste Disposal

VERMONT HAZARDOUS WASTE MANAGEMENT REGULATIONS
PROPOSED RULE

Note: A waste that exhibits a hazardous waste characteristic or that is federally listed must be identified by its EPA hazardous waste code (refer to **§ 7-202(g)**).

Hazardous Waste Code	Vermont Listed Hazardous Waste	Hazard
VT 21	Liquid wastes containing perfluorooctanoic acid (PFOA) in concentrations equal to or greater than 20 parts per trillion (ppt). For PFOA and PFOS, the standard of 20 ppt applies to the sum of the two substances (e.g. if the PFOA concentration is 15 ppt and the PFOS concentration is 6 ppt then there is an exceedance of the standard).	(T)
VT 22	Liquid wastes containing perfluorooctanesulfonic acid (PFOS) in concentrations equal to or greater than 20 parts per trillion (ppt). For PFOA and PFOS, the standard of 20 ppt applies to the sum of the two substances (e.g. if the PFOA concentration is 15 ppt and the PFOS concentration is 6 ppt then there is an exceedance of the standard).	(T)

Source: Vermont Hazardous Waste Management Regulations, Proposed Rule. Available at: http://dec.vermont.gov/sites/dec/files/co/pfoa/documents/2016_07_12%20Vermont%20Hazardous%20Waste%20Management%20Rule%20Proposed%20Rulemaking%20clean.pdf

Vermont Hazardous Waste Disposal

§ 7-203 CONDITIONAL EXEMPTIONS

The following wastes are exempted from the provisions of these regulations:

(aa) Consumer products that are available to the general public in the marketplace which were treated with perfluorooctanoic acid, perfluorooctanesulfonic acid or a material containing perfluorooctanoic acid or perfluorooctanesulfonic acid.

(bb) Remediation wastes from an environmental response action that contain perfluorooctanoic acid, perfluorooctanesulfonic acid or a material containing perfluorooctanoic acid or perfluorooctanesulfonic acid and when those remediation wastes disposed in accordance with an corrective action plan or disposal plan approved by the Secretary.

(cc) Sludges and other residuals from a wastewater treatment or drinking water system that contain perfluorooctanoic acid, perfluorooctanesulfonic acid or a material containing perfluorooctanoic acid or perfluorooctanesulfonic acid and when those remediation wastes disposed in accordance with an corrective action plan or disposal plan approved by the Secretary.

Source: Vermont Hazardous Waste Management Regulations, Proposed Rule. Available at: http://dec.vermont.gov/sites/dec/files/co/pfoa/documents/2016_07_12%20Vermont%20Hazardous%20Waste%20Management%20Rule%20Proposed%20Rulemaking%20clean.pdf

Treatment Challenges

Many Compounds

- Diverse range
- Varying toxicity and persistence
- Varying response to treatment

Properties

- Stable
- Highly water soluble
- Mostly non-volatile
- Resistant to degradation

Precursors

- Persistent
- May degrade to PFOS/PFOA/other PFAS
- Can serve as ongoing source

Ongoing Development of Treatment Technologies

- Research flooding environmental journals
  - What are the current commercially available technologies?
  - What technologies should we continue to track?

- Technology summaries available from:

American Water Works Association

Water Research Foundation

INTERSTATE TECHNOLOGY REGULATORY COUNCIL ITRC

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AWWA Treatment Technologies Fact Sheet

Treatment Method	Treatment Process	Documented PFC Removal Percentages	Relative Treatment Cost	Application
Activated Carbon	Granulated activated carbon (GAC) or powdered activated carbon (PAC)	PFOA ≥ 90% PFOS ≥ 90% PFNA ≥ 90%	$$	Surface Water, Groundwater, PWSs, Households

AWWA 2016, Available at:
https://www.awwa.org/Portals/0/files/resources/water%20knowledge/rc%20healtheffects/AWWAPFCFactSheetTreatmentandRemoval.pdf

Water Research Foundation Treatment Technologies Assessment

Removal <10%	Removal 10-90%	Removal > 90%

Compound		M.W. (g/mol)	AER	COAG/DAF	COAG/ FLOC/SED/ G- or M-FIL	AIX	GAC	NF	RO	MnO_4, O_3 ClO_2, Cl_2, CLM, UV, UV-AOP
Compound	PFBA	214	assumed	assumed						
	PFPeA	264								
	PFHxA	314								
	PFHpA	364								
	PFOA	414								
	PFNA	464		unknown		assumed	assumed			
	PFDA	514		unknown		assumed	assumed			
	PFBS	300								
	PFHxS	400								
	PFOS	500								
	FOSA	499	unknown	unknown		unknown	assumed	unknown	assumed	unknown
	N-MeFOSAA	571	assumed	unknown		assumed	assumed	assumed		unknown
	N-EtFOSAA	585		unknown		assumed	assumed	assumed		unknown[a]

a - <10% removal by Cl_2 and $KMnO_4$; "assumed": treatment performance is assumed based on the PFAA size/charge and/or known removal data of shorter or longer chain homologues
AER: Aeration, AIX: Anion Exchange, CLM: Chloramination, Cl_2: Hypocholorous/Hypocholorite, ClO_2: Chlorine Dioxide, COAG: Coagulation, DAF: Dissolved Air Flotation, O_3: Ozone, FLOC: Flocculation, GAC: Granular Activated Carbon Filtration, G-FIL: Granular Filtration, M-FIL: Microfiltration, MnO_4: Permanganate, RO: Reverse Osmosis, SED: Sedimentation, UV: UV Photolysis, UV-AOP: UV Photolysis with Advanced Oxidation (Hydrogen Peroxide)

Water Research Foundation 2016, Available at: http://www.waterrf.org/PublicReportLibrary/4322.pdf

ITRC PFAS Resources

PFAS – Per- and Polyfluoroalkyl Substances HOME

Search this website ...

- Navigating this Website
- Fact Sheets
- References
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- Document Feedback

PFAS Fact Sheets

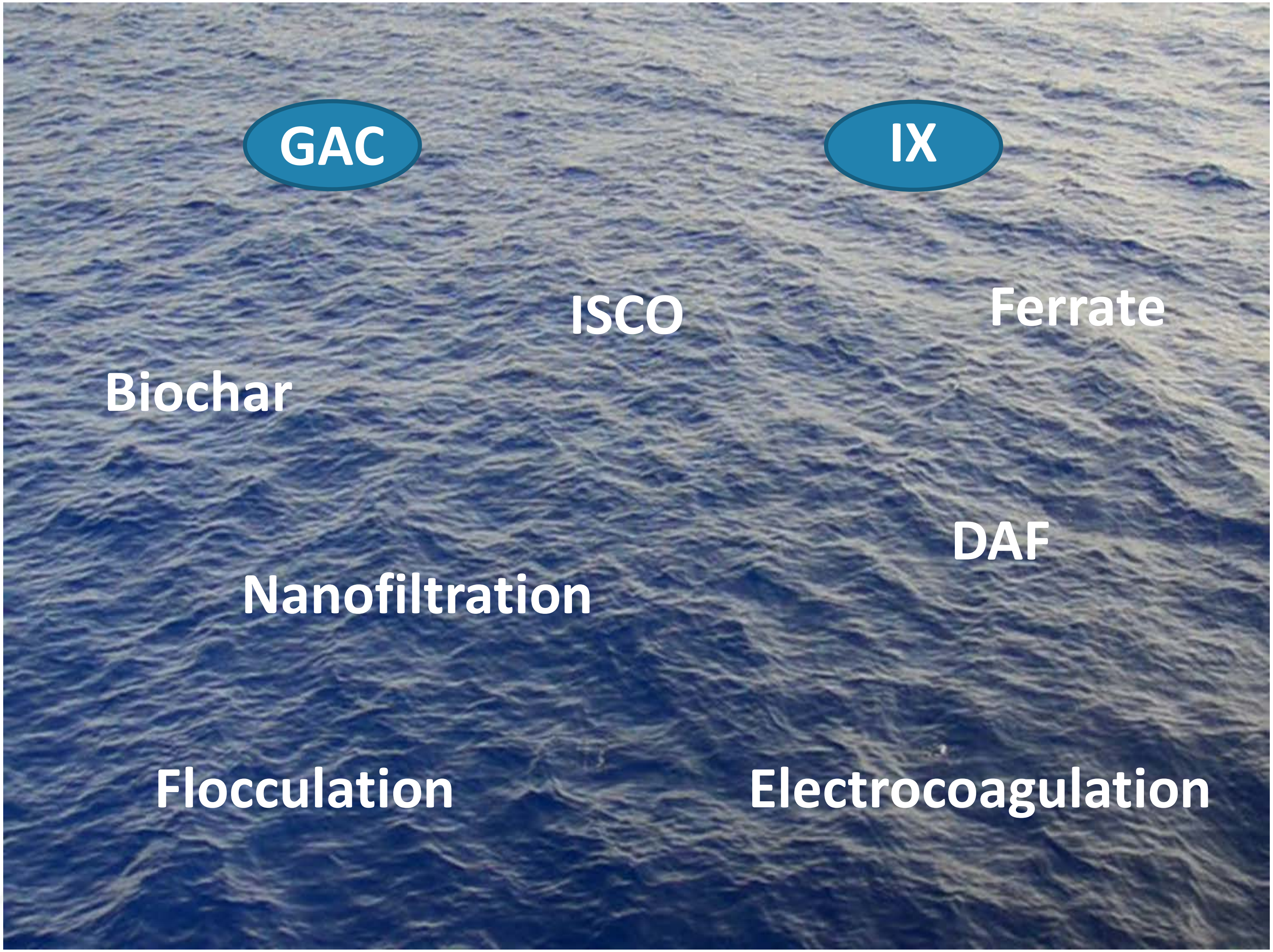
This page includes in the links for the ITRC PFAS fact sheets. The fact sheets are available as PDF files. Several tables of supporting information are published separately so that they can be updated periodically by ITRC. The fact sheet user should visit this page to access the current versions of the tables.

An Introductory document has been prepared that briefly describes the contents of each of the fact sheets.

- Naming Conventions and Physical and Chemical Properties
- Regulations, Guidance, and Advisories
  - Section 4 Tables Excel file – current date November 2017
    - Table 4-1 presents the available PFAS water values established by the USEPA, each pertinent state, or country (Australia, Canada and Western European countries)
    - Table 4-2 presents the available PFAS soil values established by the USEPA, each pertinent state, or country (Australia, Canada and Western European countries)
  - Section 5 Tables Excel file – current date November 2017
    - Table 5-1 summarizes the differences in the PFOA values for drinking water in the United States.
    - Table 5-2 summarizes the differences in the PFOS values for drinking water in the United States.
- History and Use (Spanish Version)
- Environmental Fate and Transport (to be published February 2018)
- Site Characterization Tools, Sampling Techniques, and Laboratory Analytical Methods (to be published February 2018)
- Remediation Technologies and Methods. (to be published February 2018)

ITRC 2018, Available at: http://pfas-1.itrcweb.org/fact-sheets/

Current Water Treatment Options



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GAC Considerations

- GAC source: coal versus coconut
- EBCT drives efficacy and cost
  - Typical range is 7–15 min
  - Influent factors:
    - PFAS types and concentrations
    - VOCs, other compounds
    - NOM

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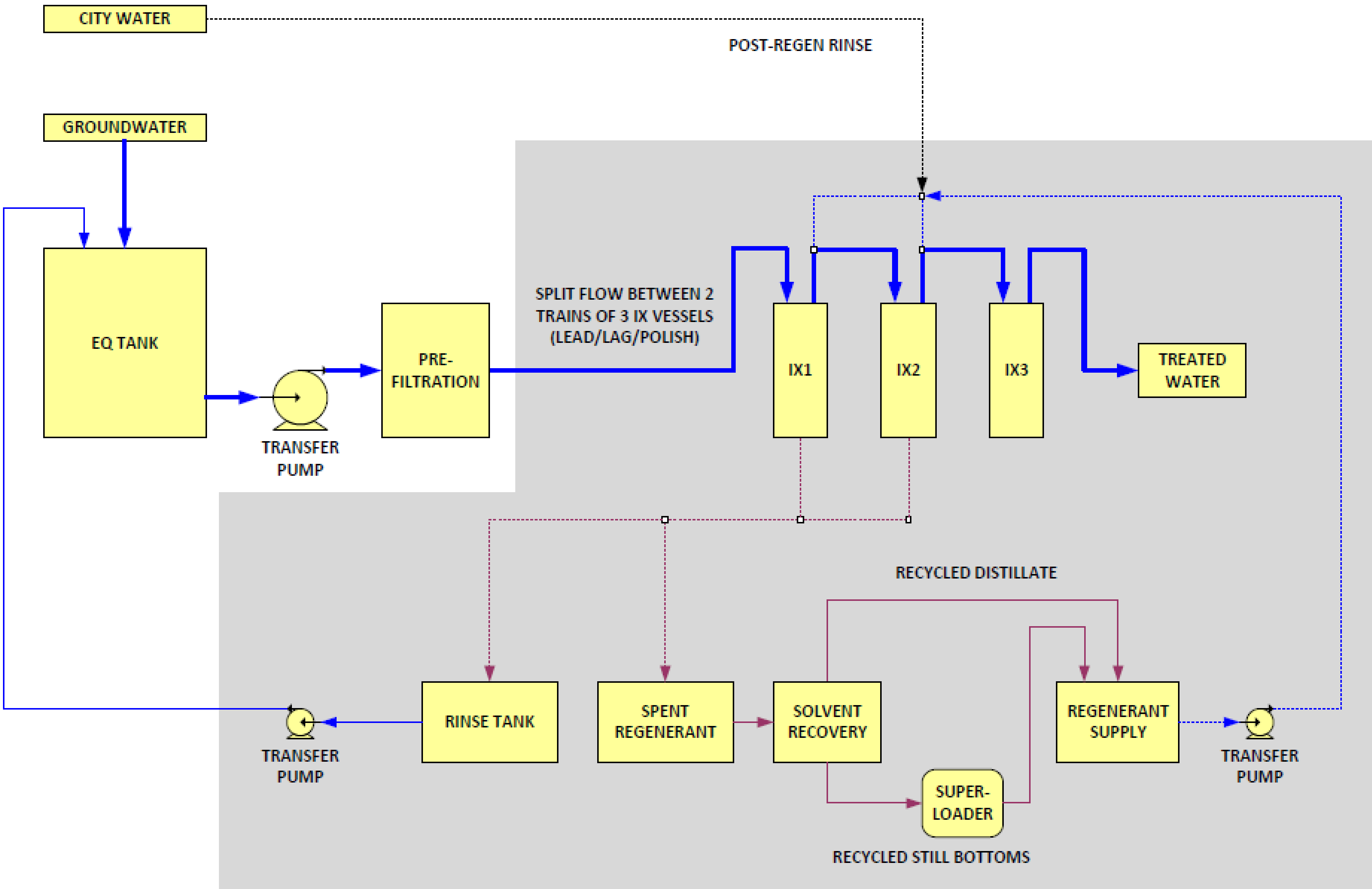
Ion Exchange Resin Considerations

- Engineered resins
- Ability to bind short-chain PFAS
- Less issues with fouling
- Initial costs are higher than GAC, but may prove more cost efficient over time

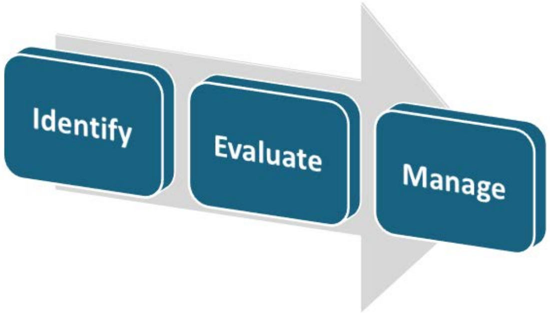
IX Resins: Regeneration vs. Disposal



Treatment Realities

- PPT and beyond? Determining use endpoints
- PFAS spectrum and profile
- Mixed sources
- Field proven and scalable
- Residuals management challenges
- Reliability/Stakeholder acceptance
- Integration with overall treatment strategies

Risk Management Framework



- Identify
  - PFAS sampling:
    Analyte list, precursor identification
  - Source identification
- Evaluate
  - In-place regulations and future requirements
- Manage
  - Source control
  - Treatment options
  - Communication and action plan

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Additional Information: Integral PFAS Newsletter

PFAS ALERTS | Vol 1. Issue 10 - October 2017 | INTEGRAL CONSULTING INC.

In This Issue of PFAS Alerts…

more than 30 citations with abbreviated abstracts on a broad range of topics are presented. See the *Special Highlights* section for the most notable citations.

Contents

Note: PFAS Alerts is a monthly subscription-based newsletter prepared by Integral Consulting Inc. It should not be forwarded to others outside of the subscriber's organization. Active hyperlinks are provided to the original source documents that can be accessed online. For more information on the subscription or for any questions on technical

Finally, in a study of PFAAs in zebrafish tissues, Wen et al. reported that long-chain PFAAs inhibited the bioconcentration of short-chains, suggesting a relevant mechanism influencing uptake and kinetics of PFAAs is the potential for competitive binding to proteins.

- **Source apportionment/forensics** methods were applied to PFAS mixtures in three studies. Lu, Ma, Zhang et al. used factor analysis applied to 11 PFAS to demonstrate 3 plausible sources contributing to PFAS in shallow groundwater: chemical source, paper mill source, and textile source. Zheng et al. used correlation analysis to support an observation that source contributions of PFAS to surface water of the Yangtze River Delta are relatively consistent. Lu, Jiao, Piao et al. determined that ∑PFAS detected in rain water indicates that the spatial footprint from an industrial park may extend 60 km.

Policy and Regulation

British Columbia released values for PFOA, PFOS and PFBS in soil and groundwater. Water values are based on adult exposure, but have a footnote that says they "may not adequately protect other age groups". Generic numerical water standards include PFOS = 0.3 µg/L;

Questions?

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