PFAS: A REVIEW

"From PFOS to GenX"

OUTLINE

- PFAS as contaminants of environmental concern
  - *A bit of history*
- What have we learned:
  - *Exposure and Toxicity*
  - *Sampling and Analysis*
  - *Treatment and Remediation*
- The future of PFAS in the environmental marketplace:
  - *Regulations*
  - *Analytical Needs*
  - *Market Considerations*

WHEN YOU THINK PFAS, THINK…

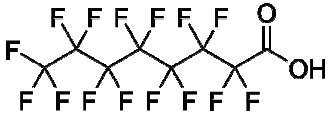
WHEN YOU THINK PFAS, THINK…

SCOTCHGARD™ PROTECTOR 3M

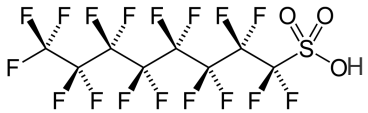
BUREAU VERITAS

ENVIRONMENTAL INTEREST IN PFAS

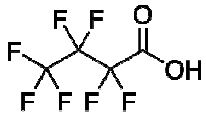
Where it began…



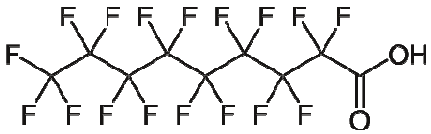
Perfluorooctanoic Acid
(PFOA)
≈ "Teflon®"



Perfluorooctanesulfonic Acid
(PFOS)
≈ "Scotchguard®"

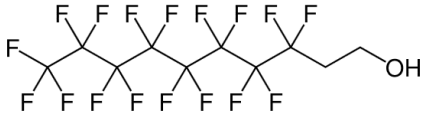


Perfluorobutanoic Acid
(PFBA)

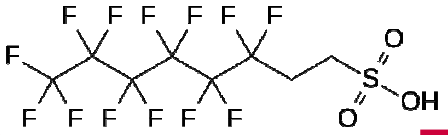


Perfluorononanoic Acid
(PFNA)

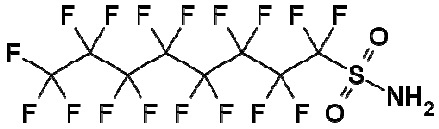
Precursors



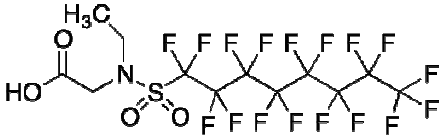
8:2 Fluorotelomer Alcohol
(8:2 FTOH)



6:2 Fluorotelomersulfonic Acid
(6:2 FTS)

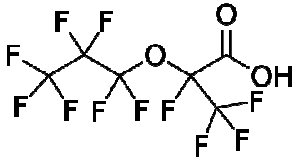


Perfluorooctanesulfonamide
(PFOSA)

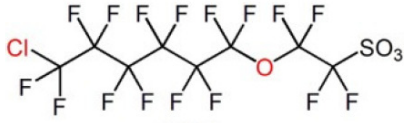


N-Ethylperfluorooctanesulfonamidoacetic Acid
(EtFOSAA)

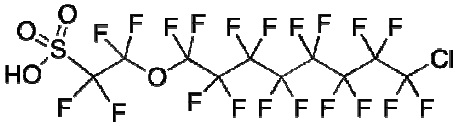
Replacements



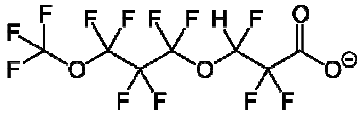
2,3,3,3-Tetrafluoro-2-
(heptafluoropropoxy)propanoic acid
(GenX)



9-Chlorohexadecafluoro-3-oxanonane-1-sulfonate
(F53B major)



11-Chlororeicosafluoro-3-oxaundecane-1-sulfonic Acid
(F53B minor)



Dodecafluoro-3H-4,8-dioxanoate
(ADONA)

3000+
Compounds

MAJOR SOURCES OF PFAS IMPACT

- Fire training/response sites
  - *AFFF inventories*
  - *AFFF releases*
- Industry
  - *Dupont ↔ Chemours*
  - *3M*
  - *3rd party manufacturers*
- Wastewater treatment plants
  - *Biosolids*
- Landfills
  - *Historic impacts*

TOXICITY

- Consistent toxicity information is still somewhat elusive
- PFAS may pose potential for adverse human health effects given their potential toxicity, mobility and bioaccumulation potential
- Longer chain PFAS have half-lives in the body ranging from 2-9 years
- Potential human toxic effects:
  - *Toxicity studies (human and animal) are inconsistent and inconclusive, but suggestive PFAS toxicity*
  - *Bioaccumulate in the protein rich organs*
  - *IARC has classified PFOA as "possibly carcinogenic"*
  - *EPA has concluded that both PFOA and PFOS are possibly carcinogenic*
- Toxicologists agree that harmonize study protocols are required and that significant additional reseach is required to conclusively link PFAS to carcinogenicity

BUREAU VERITAS

WHAT HAVE WE LEARNED: SAMPLING

- Strict/rigorous sampling protocols
- Have a solid and defensible field QA program
- Sample containers must be PFAS-free
- Water for QC purposes must be PFAS-free
- Adsorption of PFAS onto surfaces can be rapid and must be accounted for

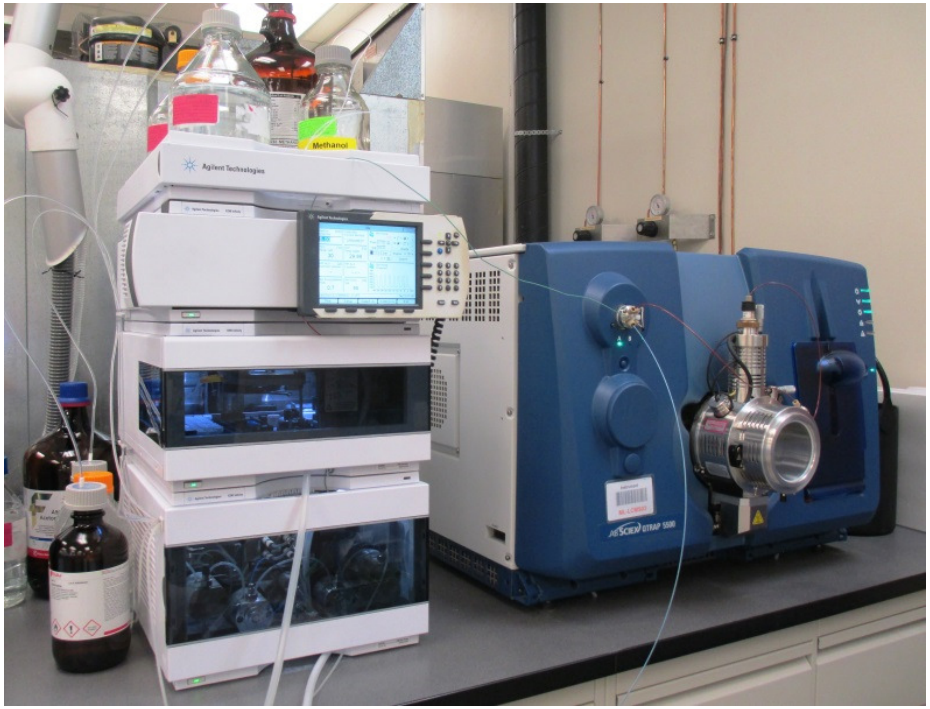
WHAT HAVE WE LEARNED: SAMPLING

- Through experience, many environmental stakeholders are adopting a common sense, yet still precautionary approach to the collection of samples for PFAS
- Three main categories of materials associated with sample collection:
  - *Prohibited materials*
  - *Acceptable materials*
  - *Materials requiring screening*

Prohibited	Acceptable	Screen/Verify
• Waterproof field books	• Aluminum clipboards; Loose paper	• Post-it Notes®
• Water and dirt resistant leather gloves	• Powderless nitrile gloves	• Any special gloves required as specific personal protective equipment (PPE)
• Decon 90	• Alconox®, Liquinox® or Citrinox®	• Off-brand markers
• Chemical or “Blue” ice	• Regular ice (sealed polyethylene bags)	

BUREAU VERITAS

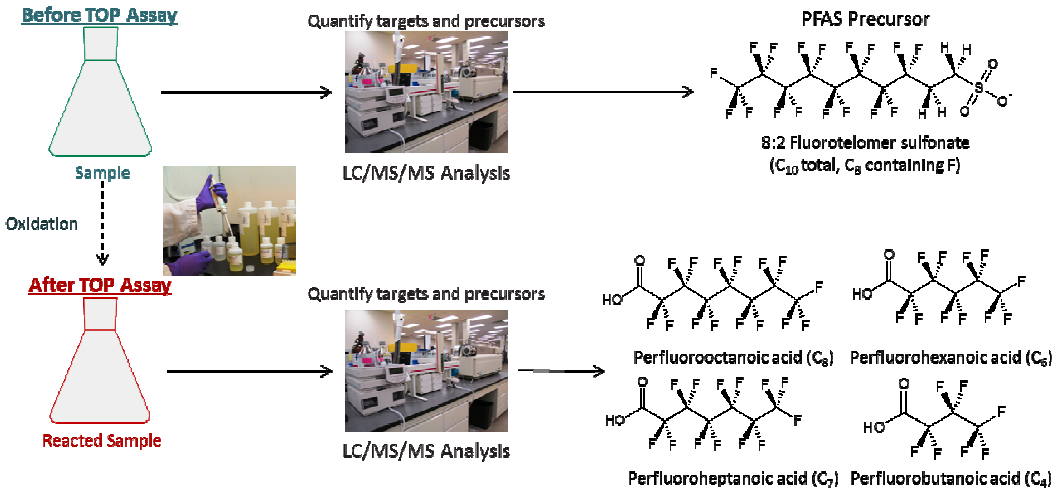
WHAT HAVE WE LEARNED: ANALYSIS



- Eliminate all sources of contamination
- Isotope Dilution techniques are a “must”
- SPE-LC/MS/MS
- Reporting Limits (water) = 2 - 4 ppt
  - *Detection Limits = 0.1 – 0.5 ppt*
- Reporting Limits (soil) = 1 – 2 ppb
  - *Detection Limits = 0.1 – 0.5 ppb*
- Reporting requirements:
  - Branched and linear isomers
  - Naming conventions (e.g. sulfonate vs. sulfonic acid)

BUREAU VERITAS

WHAT HAVE WE LEARNED: ANALYSIS (TOPs ASSAY)



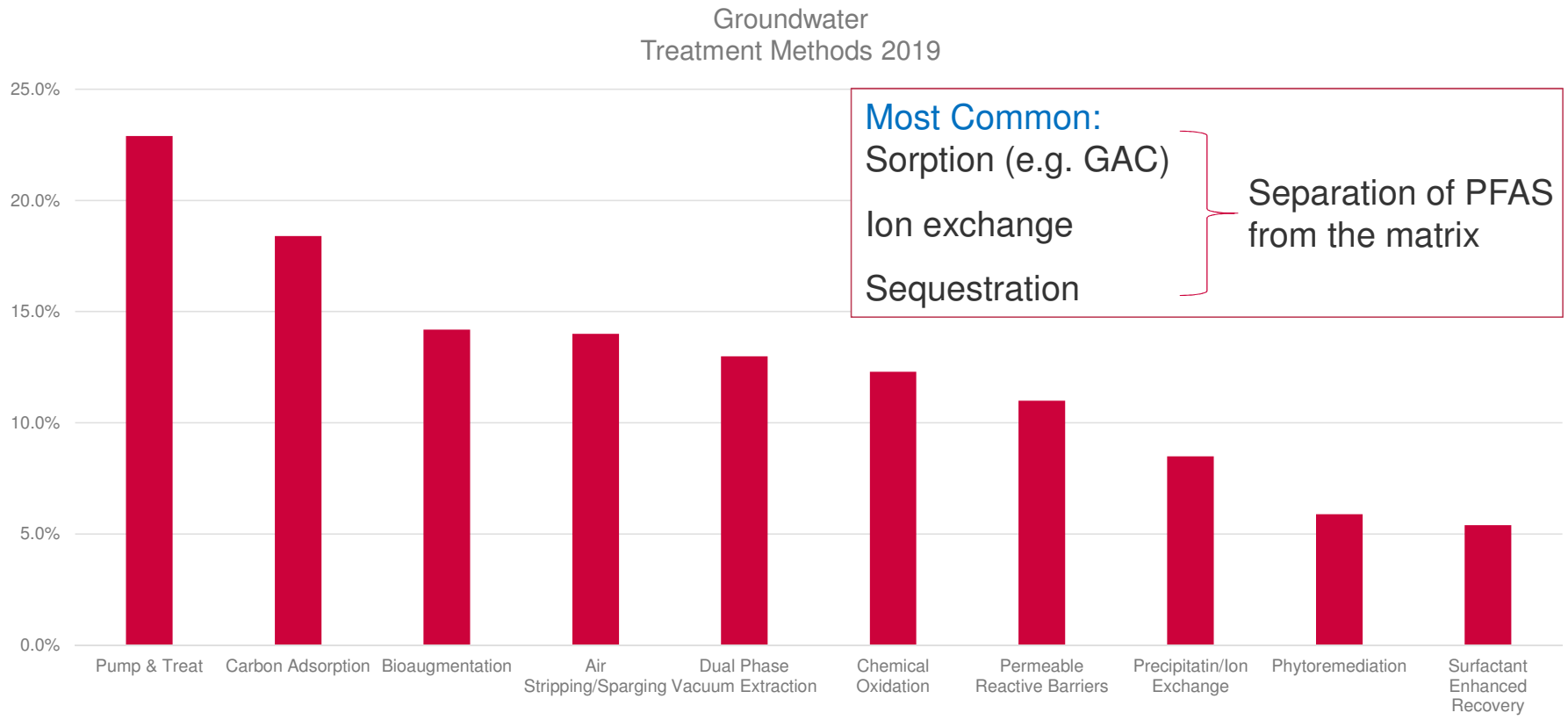
General:

- Chemical oxidation method
  (Houtz and Sedlak (2012). *Environ. Sci. Technol.*, 46, 9342-9349)
- Transforms PFAS precursors to perfluorocarboxylic acid (PFCA) end products without affecting target PFASs
- Accelerated approach to predicting *in situ* precursor behavior

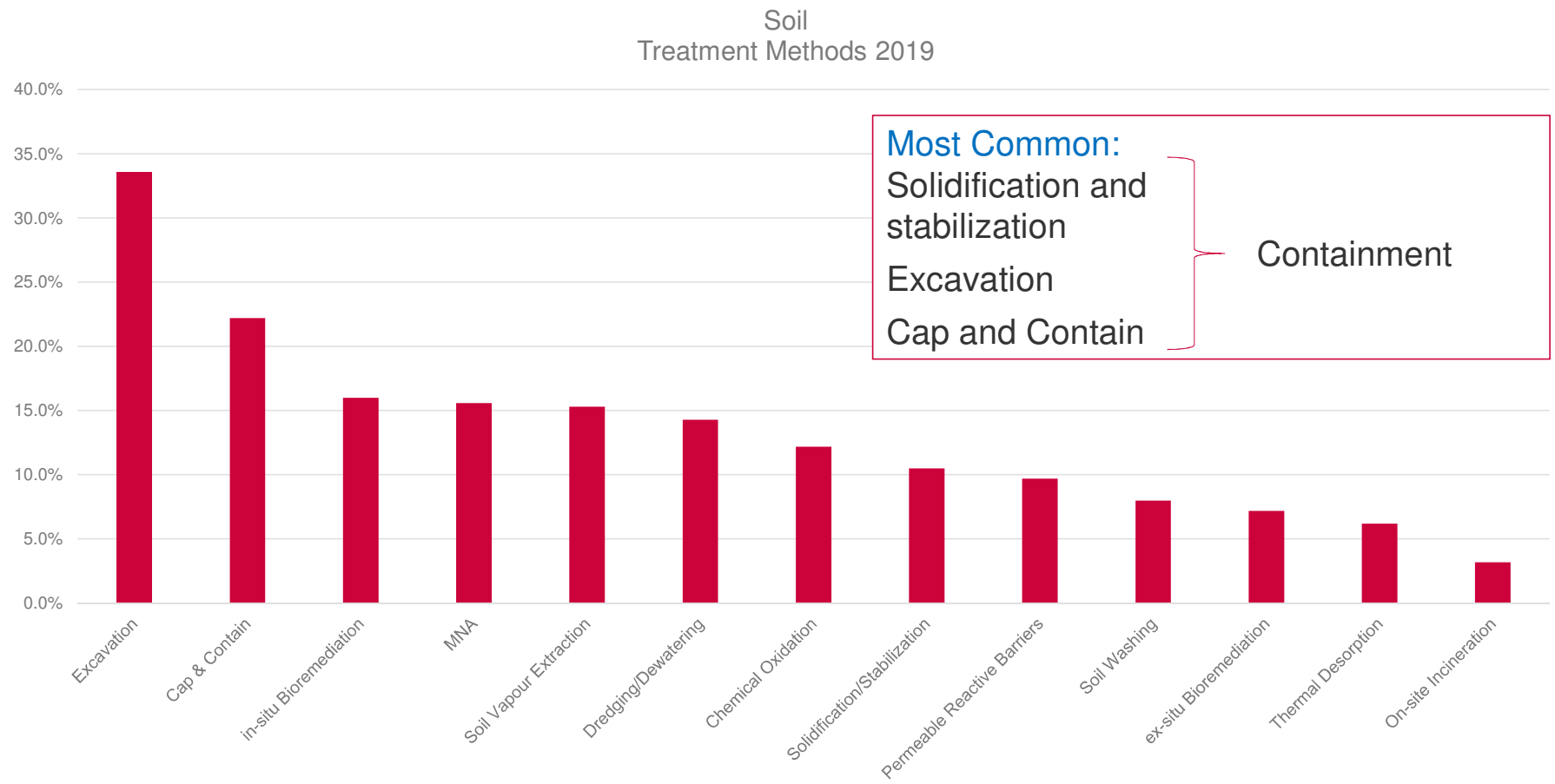
Limitations:

- Not necessarily a comprehensive indicator of total PFAS
- Expensive

REMEDIATION/TREATMENT (WATER)



REMEDIATION/TREATMENT (SOIL)



THE FUTURE: REGULATIONS

Jurisdiction		PFOA (µg/L)	PFOS (µg/L)	PFBA (µg/L)	PFBS (µg/L)	PFHxS (µg/L)	PFPeA (µg/L)	PFHxA (µg/L)	PFHpA (µg/L)	PFNA (µg/L)	GenX (µg/L)
Drinking Water											
Health Canada[2]	Screening Value	0.2	0.6	30	15	0.6	0.2	0.2	0.2	0.02	N/V
British Columbia	BC CSR	0.2	0.3	N/V	80	N/V	N/V	N/V	N/V	N/V	N/V
U.S.A - EPA	Health Advisory	0.07	0.07	N/V	N/V	N/V	N/V	N/V	N/V	N/V	N/V
U.S.A. – Minnesota	HBV	0.035	0.027	7	3	0.027	N/V	N/V	N/V	N/V	N/V
U.S.A. – New Jersey	MCL	0.014	0.013	N/V	N/V	N/V	N/V	N/V	N/V	0.013	N/V
U.S.A. – N. Carolina	IMAC	2	N/V	N/V	N/V	N/V	N/V	N/V	N/V	N/V	0.14
Europe – UK	HBV	10	0.3	N/V	N/V	N/V	N/V	N/V	N/V	N/V	N/V
Australia	HBV	0.56	0.07	N/V	N/V	0.07	N/V	N/V	N/V	N/V	N/V

(1) **Sources: ITRC PFAS Regulations, Guidance and Advisories Fact Sheet (June 2018)**
(2) **Protection of Human Health - $[PFOS]/SV_{PFOS} + [PFOA]/SV_{PFOA} \leq 1$**
(3) **Highlighted values have not yet been promulgated**

BUREAU VERITAS

THE FUTURE: NEEDS

New Matrices:

- *Air (Stack samples, Ambient Air, Industial Hygiene)*
- *Biosolids*
- *Tissue (Plant, Animal)*

New Methods:

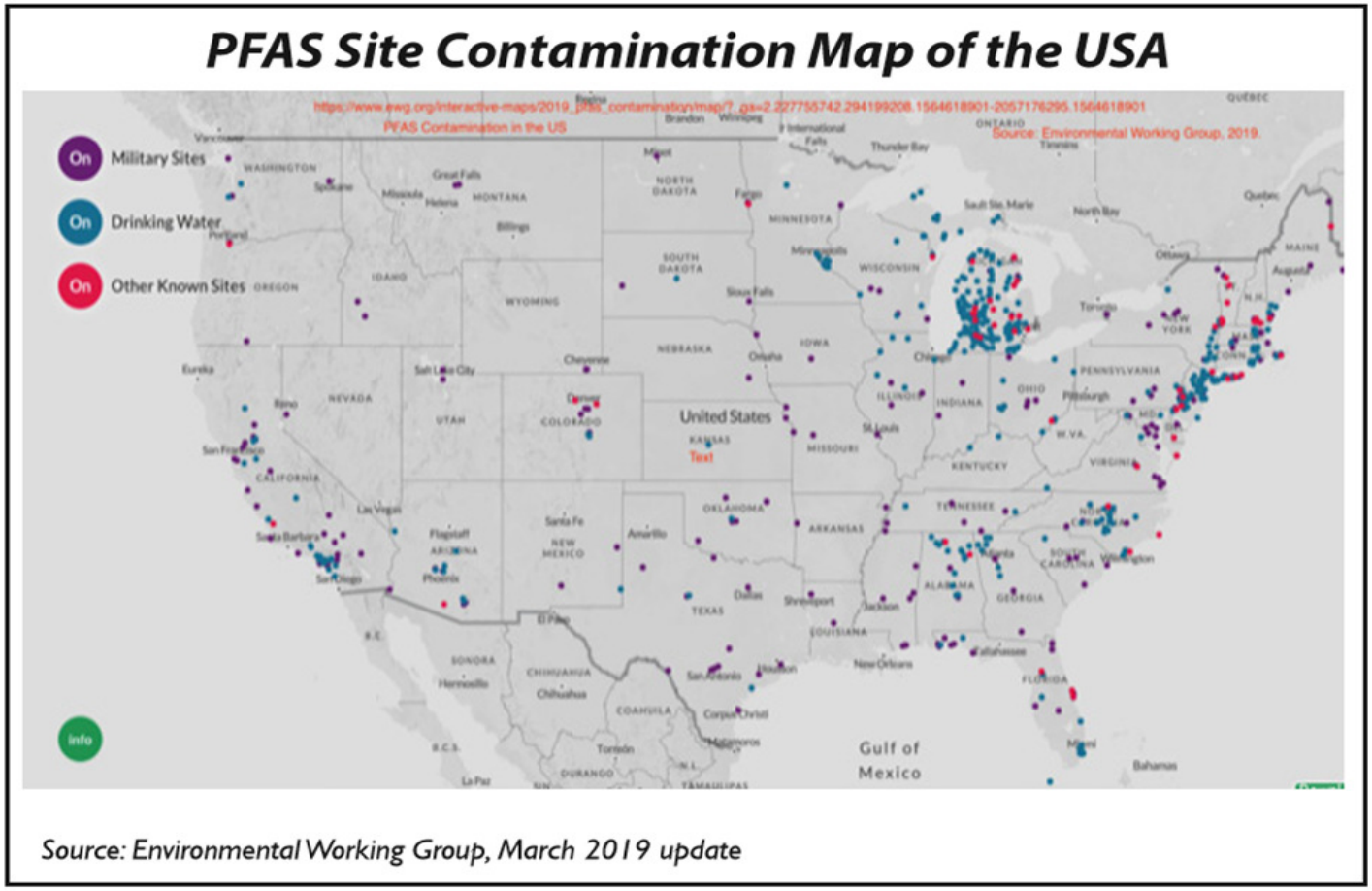
- *Total Organic Fluorine as a replacement for TOPs*
  - *Particle induced gamma emission (PIGE)*
  - *Combustion ion chromatography (CIC)*
  - *Neutron Activation Analysis (NAA)*

Remedial Technologies

- *Effective technologies for remediating PFAS contaminated sites*
- *Treatment technologies for all PFAS*
- *Economically Achievable*

BUREAU VERITAS

THE FUTURE: MARKET CONSIDERATIONS



1,398 Sites in 49 states…

…expect the number and density of sites to grow significantly

THE FUTURE: MARKET CONSIDERATIONS

EBJ Survey: Demand for Remediation by Type of Contaminant

Contaminant	Very Strong	Strong	Good	Flat	Decline
PFAS	32%	39%	25%	4%	0%
Other Emerging Contaminants	11%	29%	46%	14%	0%
1,4-Dioxane	7%	30%	41%	22%	0%
Hydrocarbons	10%	20%	37%	30%	3%
Heavy Metals	7%	17%	41%	34%	0%
PCBs	4%	4%	41%	48%	4%
Nuclear Waste	4%	0%	30%	67%	0%
Asbestos	0%	15%	11%	59%	15%
Medical Waste	0%	4%	15%	81%	0%

Source: 2019 EBJ Remediation Markets Survey. Question was: Please rate the demand for remediation work by type of contaminant in the next two to three years.

BUREAU VERITAS

THE FUTURE: MARKET CONSIDERATIONS

EBJ's Working Model on Number of Sites with PFAS Contamination and Remediation Costs

Site Category	Sites	% possible PFAS contamination	Est. Sites PFAS contamination*	Avg $mil remediation costs*	Total $mil remediation costs*	System Upgrade & Lifecycle Cost $mil*
NPL: Superfund	1,850	20-30%	460	5.00	2,310	
RCRA Corrective Action	4,000	20-30%	1,000	2.00	2,000	
RCRA UST	140,000	1-2%	700	0.50	350	
DOD	6,400	30-40%	2,240	6.50	14,560	
DOE	5,000	10-15%	600	5.00	3,000	
Civilian Agencies	3,000	25-30%	810	2.00	1,620	
State Sites	120,000	5-10%	8,400	0.50	4,200	
Manufacturing Sites Using PFAS	3,500	80-90%	875	30.00	26,250	
Other Manufacturing Sites	270,000	2-3%	6,750	0.50	3,375	
Landfills: Active	3,100	40-50%	1,395	2.00	2,790	
Landfills: Closed	10,000	30-40%	3,500	0.50	1,750	
Airports: Major	500	80-90%	425	20.00	8,500	
Airports: Regional	1,000	50-60%	550	5.00	2,750	
Airports: Commercial/Private	17,500	3-5%	700	6.00	4,200	
Wastewater: POTWs 10 MGD+	500	50-60%	275			37,130
Wastewater: POTWs <10 MGD	15,000	10-20%	2,250			22,500
Water Utilities: Urban	4,000	10-20%	600			12,000
Water Utilities: Rural	50,000	10-20%	7,500			9,000
Other	50,000	5-10%	3,500	0.50	1,750	
Total	**705,450**	**6%**	**42,560**	**1.91**	**80,160**	**80,630**

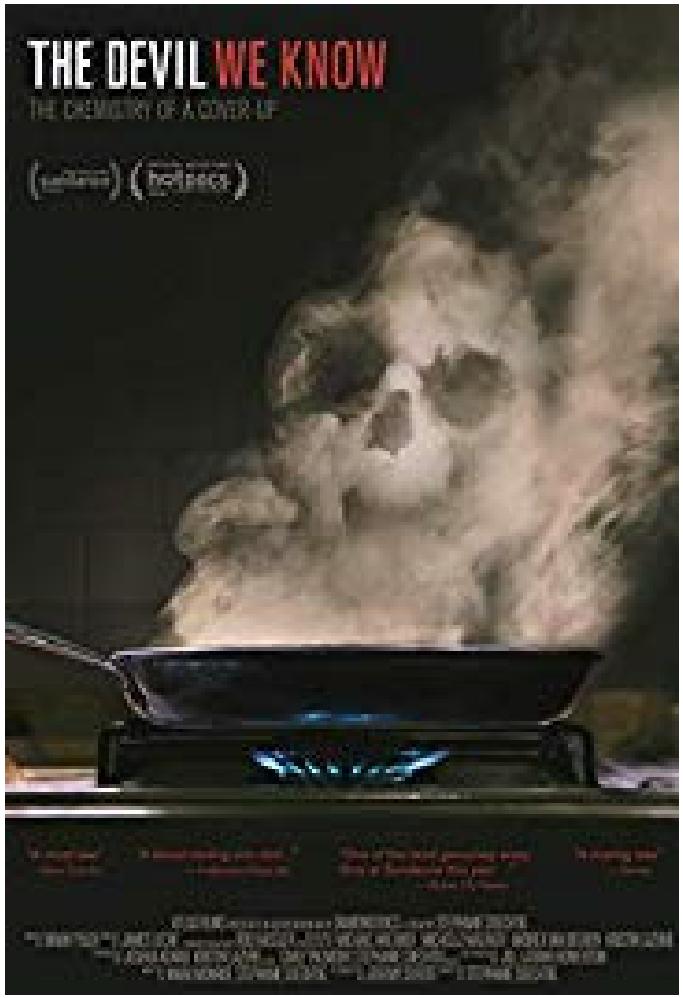
*Source: Environmental Business International, Inc. EBI estimates using site count estimates from EPA, ITRC, U.S. Census, US DOT FAA, water and solid waste industry associations, and a consensus of expert respondents to a '% possible PFAS contamination' surveys and interviews. *Figures calculated or using the midpoint of consensus ranges*

Anticipated US remediation costs…

$160 billion

BUREAU VERITAS

THE FUTURE: MARKET CONSIDERATIONS



RESOURCES

Printed from: Interstate Technology & Regulatory Council (ITRC). 2018. PFA
Washington, D.C.: Interstate Technology & Regulatory Council, PFAS Team.

PFAS Fact Sheets

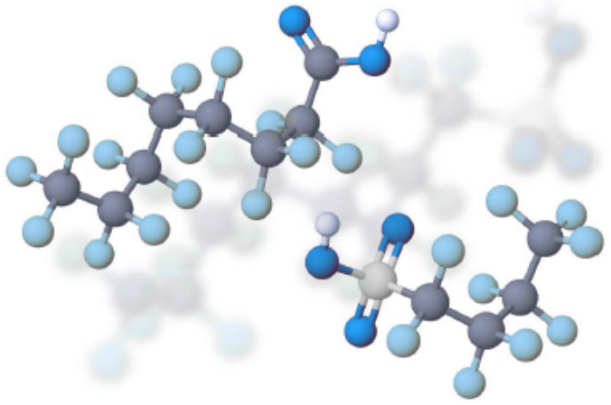
This page includes in the links for the ITRC PFAS fact sheets. The fact sheets are available a
supporting information are published separately so that they can be updated periodically by
visit this page to access the current versions of the files.

An Introductory document (Spanish Version) has been prepared that briefly describes the co
sheets. An Introductory document has been prepared that briefly describes the contents of
site also includes a combined references list and acronyms list.

- Naming Conventions and Physical and Chemical Properties (updated 3-16-18)
- Regulations, Guidance, and Advisories (updated 1-4-18)
  - Section 4 Tables Excel file – (updated 7-16-18)
    - Table 4-1 presents the available PFAS water values esta
      pertinent state, or country (Australia, Canada and Weste
    - Table 4-2 presents the available PFAS soil values establi
      pertinent state, or country (Australia, Canada and Weste
  - Section 5 Tables Excel file (published November 2017)
    - Table 5-1 summarizes the differences in the PFOA value
      States.
    - Table 5-2 summarizes the differences in the PFOS value
      States.
- Regulación, Orientación, y Asesoramiento para sustancias Per- y Polifluoroalquila
- History and Use (published 11-13-17)
- Historia y Uso (Spanish Version)
- Environmental Fate and Transport (published 3-16-18)
  - Table 3-1 Log Koc values for select PFAS Excel file (published April 2
- Site Characterization Considerations, Sampling Precautions, and Laboratory Ana
  3-15-18)
- Remediation Technologies and Methods (published 3-15-18)
  - Remediation Comparison Tables Excel file (published April 2018)
    - Table 1 – Solids Comparison
    - Table 2 – Liquids Comparison
- Aqueous Film Forming Foam (to be published August 2018)

EPA United States Environmental Protection Agency | EPA 823R18004 | February 2019 | www.epa.gov/pfas

EPA's Per- and Polyfluoroalkyl Substances (PFAS) Action Plan



U.S. Environmental Protection Agency

ENVIRONMENTAL BUSINESS JOURNAL®
Strategic Information for a Changing Industry

Vol. XXXII, Numbers 5/6, 2019 | *2019 Remediation & PFAS* | Environmental Business International Inc.

CONSULTANTS AND CONTRACTORS ENVISION THE DAWN OF THE PFAS ERA

Regulatory uncertainties hold back the sunrise, but experts seem convinced of a bright future

The remediation industry has hit a bit of a lull in the late 2010s. After all, the Superfund program is winding down, not many more CERCLA sites are being added to the list, RCRA corrective actions face a finite future, fuel storage tanks are much less likely to leak than they used to be, and we're certainly not making asbestos anymore. (Although the United States still imports asbestos for the chloralkali industry for membranes to make chlorine, and while the 750 metric tons imported in 2018 was not insignificant, it pales in comparison to the peak usage of 803,000 metric tons in 1973).

And that's just the private market. Government markets are in a lull as well as federal environmental budgets and programs continue to be de-emphasized during the Trump Administration—although the backlog of remediation work at DOE and DOD is still monumental. Meanwhile state & local government projects and markets keep plugging away, but are more often described by contractors as 'stable' or 'consistent' rather than 'high-growth' or 'revitalized'.

Keeping project work going on the private side is the relatively buoyant economy in an investor-friendly environment, some return of U.S. manufacturing and continued investment in real estate and infrastructure development. These factors contribute to pace recent growth in remediation at rates of 1-2%, or close to that of the modestly growing economy (see chart on page 3). The consensus of Environmental Business Journal's 2019 survey of remediation consultants and contractors

EBJ Survey: Demand for Remediation by Type of Contaminant

Contaminant	Very Strong	Strong	Good	Flat	Decline
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PCBs	4%	4%	41%	48%	4%
Nuclear Waste	4%	0%	30%	67%	0%
Asbestos	0%	15%	11%	59%	15%
Medical Waste	0%	4%	15%	81%	0%

Source: 2019 EBJ Remediation Markets Survey. Question was: Please rate the demand for remediation work by type of contaminant in the next two to three years.

Inside EBJ's 2019 Remediation & PFAS Edition

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