Breaking Down PFAS Workshop

10:00 AM to 2:00 PM

January 22, 2020

Co-hosted by:

Breaking Down PFAS Program Agenda

First Session: 10 AM –11:30 AM

- Introductions – Michael Markus, General Manager, OCWD
- California PFAS Regulatory Update – Sean McCarthy, South Coast Section Chief, State Water Resources Control Board
- PFAS Exposure Impacts – Dr. Lisa Corey, Senior Toxicologist, Intertox Inc.
- PFAS Risk Communication and Engagement – Dr. Melissa Harclerode, Technical Specialist, CDM Smith
- Panel Discussion – Moderator Jason Dadakis, Executive Director of Water Quality and Technical Resources, OCWD

PFAS Litigation (Lunch Session) 11:30 AM – 12:30 PM

- Richard Head, SL Environmental

Second Session: 12:30 PM –2:00 PM

- OCWD Update: PFAS Pilot Study – Dr. Megan Plumlee, Director of Research, OCWD
- OCWD Update: Planning Study – Chris Olsen, Director of Engineering, OCWD
- PFAS Treatment; Scaling Up to Full Scale Case Studies – Alan LeBlanc, Senior Project Manager, CDM Smith
- PFAS State of Research and Emerging Technologies – Jennifer Hooper, Senior Research Engineer, CDM Smith
- Panel Discussion – Moderator Michael Zafer, Water Technology Leader, CDM Smith

Introductions

First Session: 10:00 AM – 11:30 AM

California PFAS Regulatory Update

Sean McCarthy – South Coast Section Chief, State Water Resources Control Board, Division of Drinking Water

PFAS Exposure Impacts

Dr. Lisa Corey – Senior Toxicologist, Intertox, Inc.

PFAS Risk Communication and Engagement

Dr. Melissa Harclerode – Technical Specialist, CDM Smith

Panel Discussion

Moderator – Jason Dadakis, Executive Director of Water Quality and Technical Resources, OCWD

PFAS Drinking Water Treatment and Permit Considerations

Sean McCarthy, State Water Resources Control Board

Presentation Outline

- PFAS Regulatory Update
- Why is a permit needed?
- How to apply for a permit? What documents are needed?
- What can I expect when operating a permitted treatment plant?

PFAS Regulatory Update

Notification Levels:

Established by State Board at the level which does not pose a significant health risk but warrants notification. If exceeded, provide notice to governing body of the local agency where consumers reside.

- PFOA 5.1 ppt
- PFOS 6.5 ppt

Response Levels:

Recommend additional action by PWS to reduce public exposure to the contaminant

- 70 ppt (individual or combined PFOA and PFOS)

PFAS Regulatory Update

- Phased investigation: DDW, DWQ, RWQCB
- Monitoring orders issued March 2019 (HSC section 116400)
  - Wells nearby high-risk facilities or previous findings
  - 2 miles of airports
  - 1 mile of landfills
  - 1 mile of wells with previous UCMR3 detections
  - Quarterly monitoring concluding 1Q 2020
- Additional monitoring is under consideration
  - Metal plating facilities, military bases

PFAS Regulatory Update

- Impacts of AB 756 (HSC section 116378), effective Jan 1, 2020
  - Specific authority to order monitoring for PFAS
  - Confirmed detections reported in Consumer Confidence Report
  - Response Level exceedances, provide public notice within 30 days or remove well from service
- Revision to Response Levels expected
- OEHHA beginning development of Public Health Goals for PFOA, PFOS
- MCL development will follow final PHGs

Health and Safety Code Section 116550

“No person operating a public water system shall modify, add to or change his or her source of supply or method of treatment of, …unless the person first submits an application to the department and receives an amended permit …authorizing the modification, addition, or change in his or her source of supply or method of treatment.”

Drinking Water Treatment Plant Permits

- Establish appropriate treatment and operating conditions for contaminant removal from drinking water
- Technical evaluation of permit application including design, operations and monitoring plan, and compliance with all drinking water regulations
- Permit review process considers treatment applied and impacts to water system quality
- Permits are not construction permits

Permit Application Package

- CEQA documents
- Engineering Plans and Specifications
  - Representative of as-built plant
- Operations and Monitoring Plan
  - Sample locations, analytes and frequency
  - Flow parameters (Well sequencing, EBCT)
  - Media type and volume
  - Criteria and procedure for media replacement
- Operator Certification: T1 or T2, depending on flow

Permit Timeline

Time needed to issue permit is dependent on multiple factors

- CEQA completion
- Submittal and quality of all documents requested

Suggestions for streamlining our review process

- Meet with DDW District Office early and regularly
- Obtain comments on design and specifications before construction begins
- Results of modeling, bench-scale, or pilot testing
- Plan early how treatment plant operations will integrate with all water system operations
    - Will multiple well operations be limited by treatment plant capacity?

Possible Permit Conditions

- Monitoring locations and frequency
  - Combined effluent, lead vessel effluent, 50/75% port sampling
- Criteria for media change-out
- Lead-lag vs. single vessel
- Detections of compounds without NLs in treated effluent
- Continuous disinfection of treated water

Possible Permit Conditions

- Monthly report
  - Volume treated, track media exhaustion
  - Process monitoring results
  - Media change-outs
  - Incident reports and corrective actions
- Future operations, removal of additional PFAS compounds

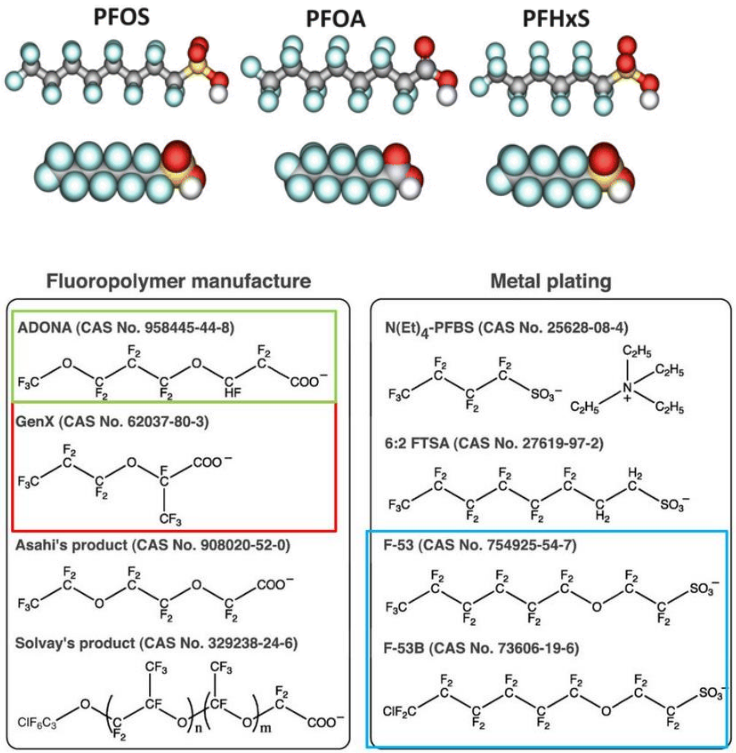
PFAS Exposure Impacts

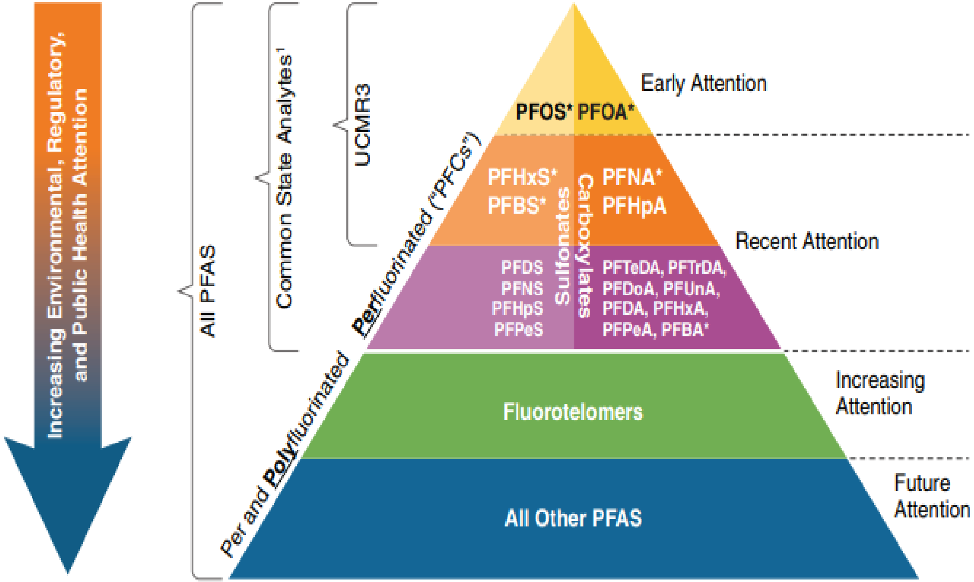
Dr. Lisa Corey, Intertox, Inc.

Topics

- What are PFAS?
- How do I get exposed?
- What happens in my body?
- What are the health effects?

What are PFAS?



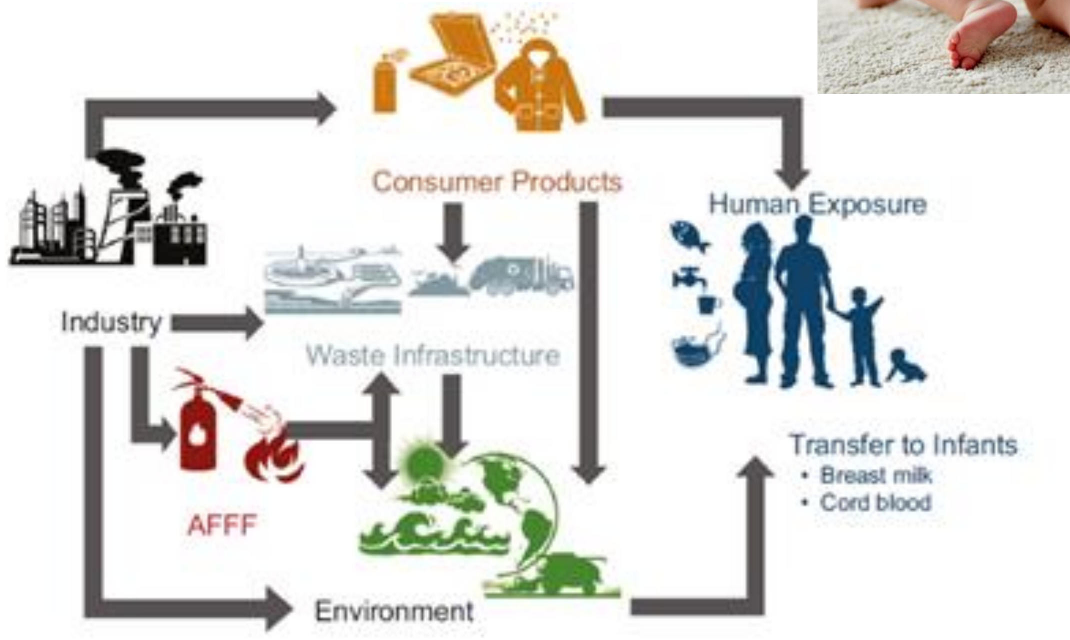


*Common regulatory criteria or health advisories
¹Sum of informal poll (NJ, NH, MN)

Thematic and not proportional.
Bottom of triangle indicates additional number of compounds; not a greater quantity by mass, concentration, or frequency of detection.

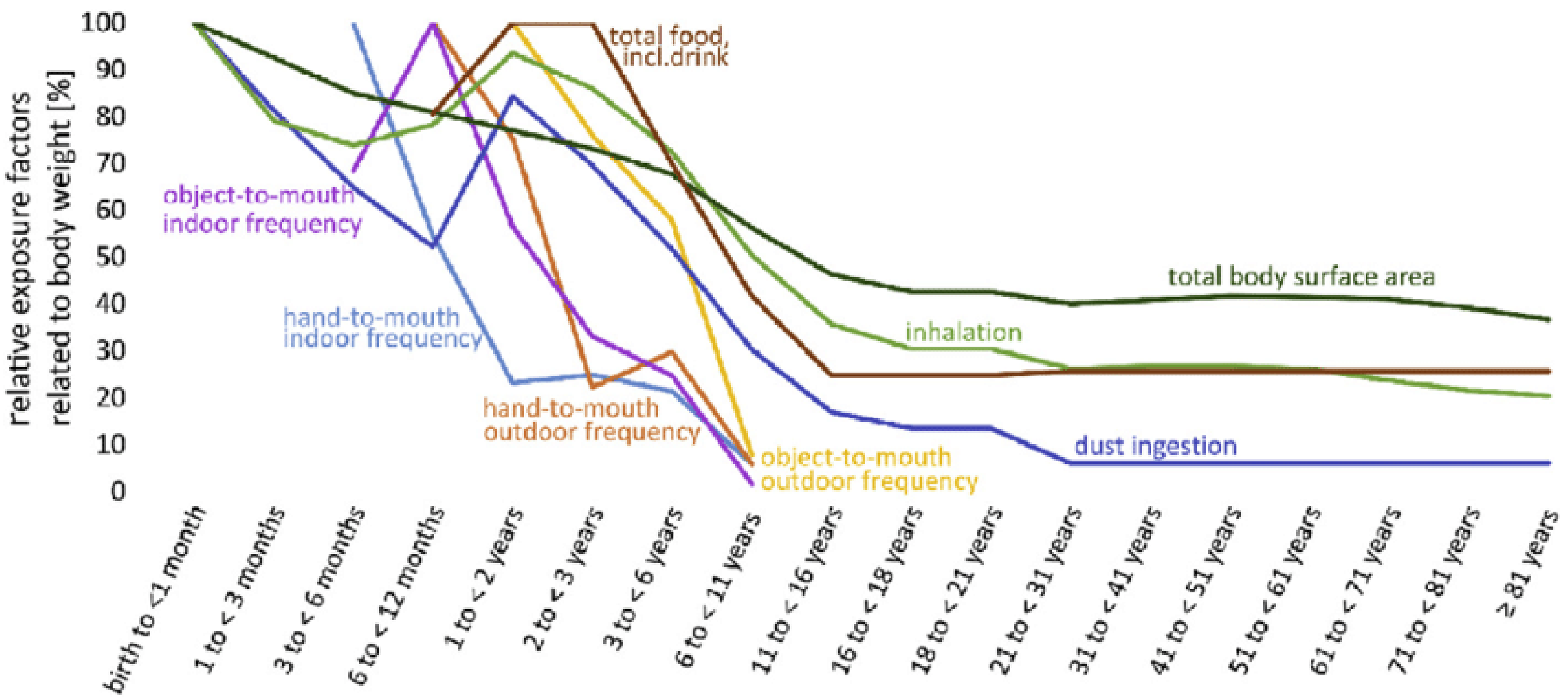
Figure 3-1. Emerging awareness and emphasis on PFAS occurrence in the environment
(Source: J. Hale, Kleinfelder, used with permission)

Exposure Routes

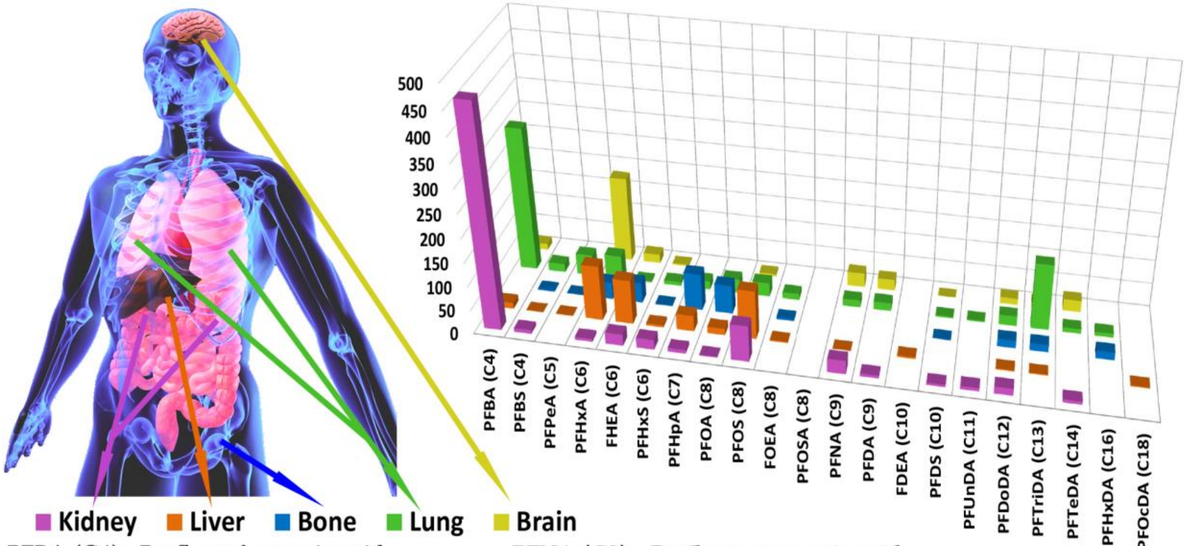


Potential major exposure pathways of PFAS to humans.
Figure from Sunderland et. al. (2019)

Exposure by Lifestage



Distribution and Elimination



PFBA (C4) - Perfluorobutanoic acid
PFBS (C4) - Perfluorobutanesulphonate
PFPeA (C5)- Perfluoropentanoic acid
PFHxA (C6)- Perfluorohexanoic acid
FHEA (C6) - Perfluorohexyl ethanoic acid
PFHxS (C6) - Perfluorohexanesulphonate
PFHpA (C7) - Perfluoroheptanoic acid
PFOA (C8) - Perfluorooctanoic acid
PFOS (C8) - Perfluorooctanesulphonate
FOEA (C8) - Perfluorooctyl ethanoic acid
PFOSA (C8) - Perfluorooctane sulfonamide
PFNA (C9) - Perfluorononanoic acid
PFDA (C9) - Perfluorodecanoic acid
FDEA (C10) - Perfluorodecyl ethanoic acid
PFDS (C10)- Perflurodecanesulphonate
PFUnDA (C11) - Pverfluoroundecanoic acid
PFDoDA (C12) - Perfluorododecanoic acid
PFTriDA (C13) - Perfluorotridecanoic acid
PFTeDA (C14) - Perfluorotetradecanoic acid
PFHxDA (C16) - Perfluorohexadecanoic acid
PFOcDA (C18) - Perfluorooctadecanoic acid

Mean concentrations of PFASs (ng/g) in 5 human tissues (Perez et al., 2013)

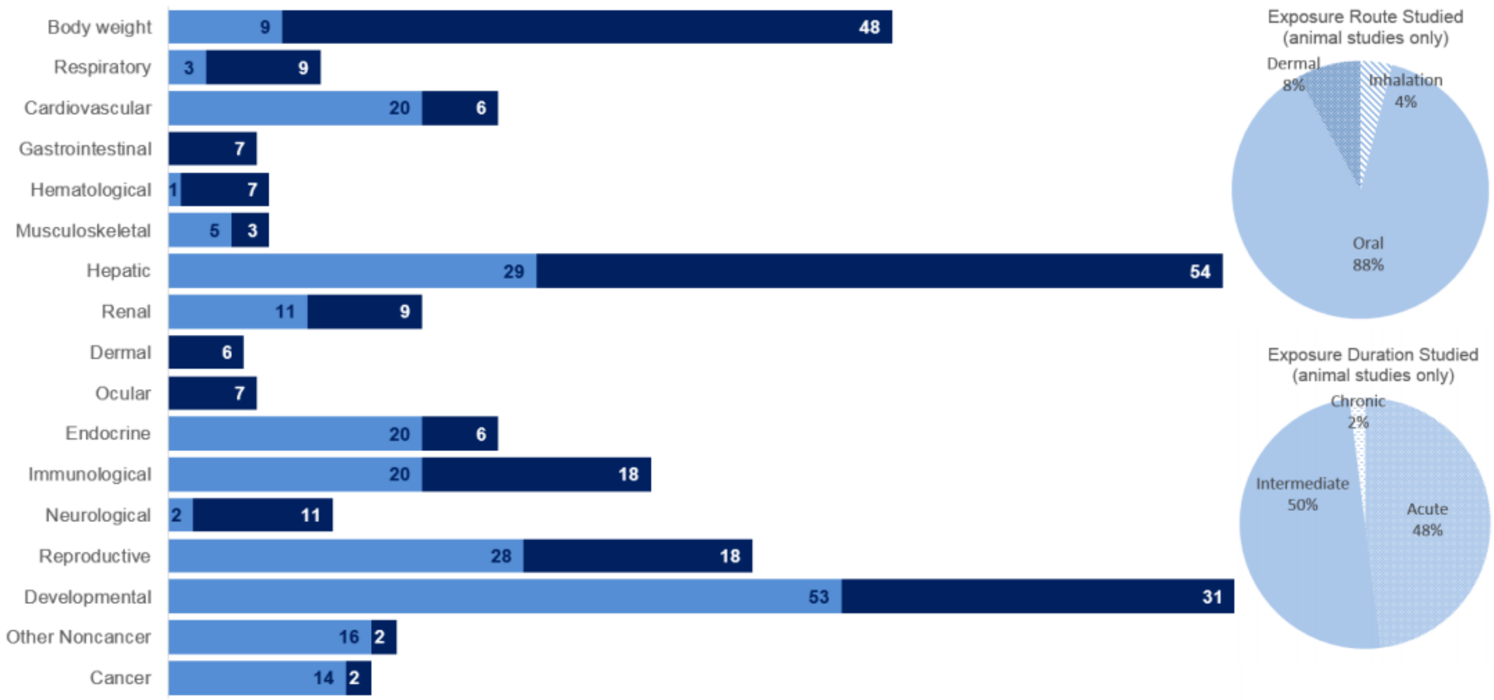
Serum Half Lives

PFAS	Mouse	Human
PFOA	20 days	3-4 years
PFOS	40 days	4-5 years
PFHxS	30 days	8.5 years
PFHxA	2 hours	32 days
PFNA	60 days	Unknown
PFBS	5 hrs	28 days
PFBA	12 hrs	3 days

Health Effects Studies: PFOA

Figure 2-1. Overview of the Number of Studies Examining PFOA Health Effects*

Developmental, hepatic, and body weight effects of PFOA were the most widely examined potential toxicity outcomes
More studies evaluated health effects in humans than animals (counts represent studies examining endpoint)

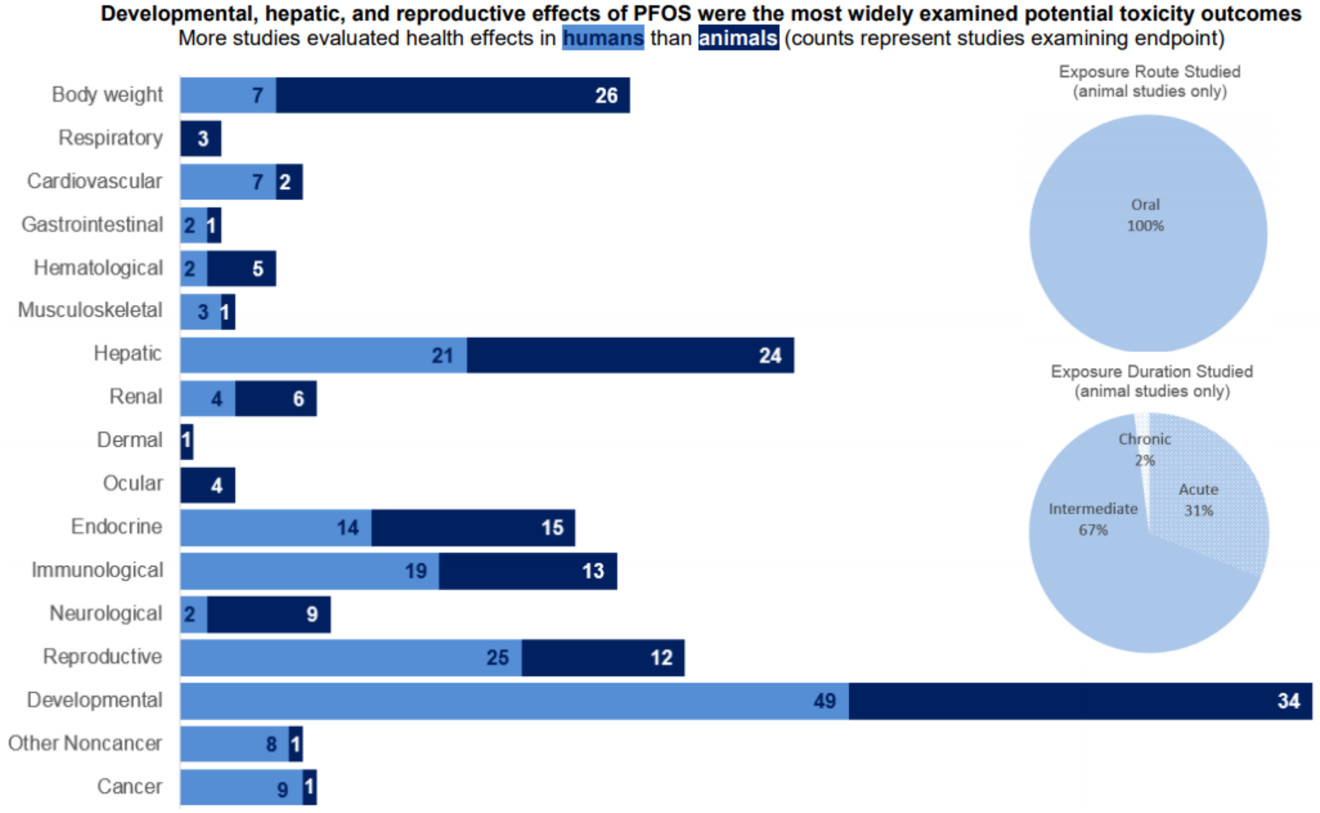


*Includes studies discussed in Chapter 2. A total of 271 studies (including those finding no effect) have examined toxicity; most animal studies examined multiple endpoints. In this figure, the number of human studies is referring to the number of publications.

ATSDR, 2018

Health Effects Studies: PFOS

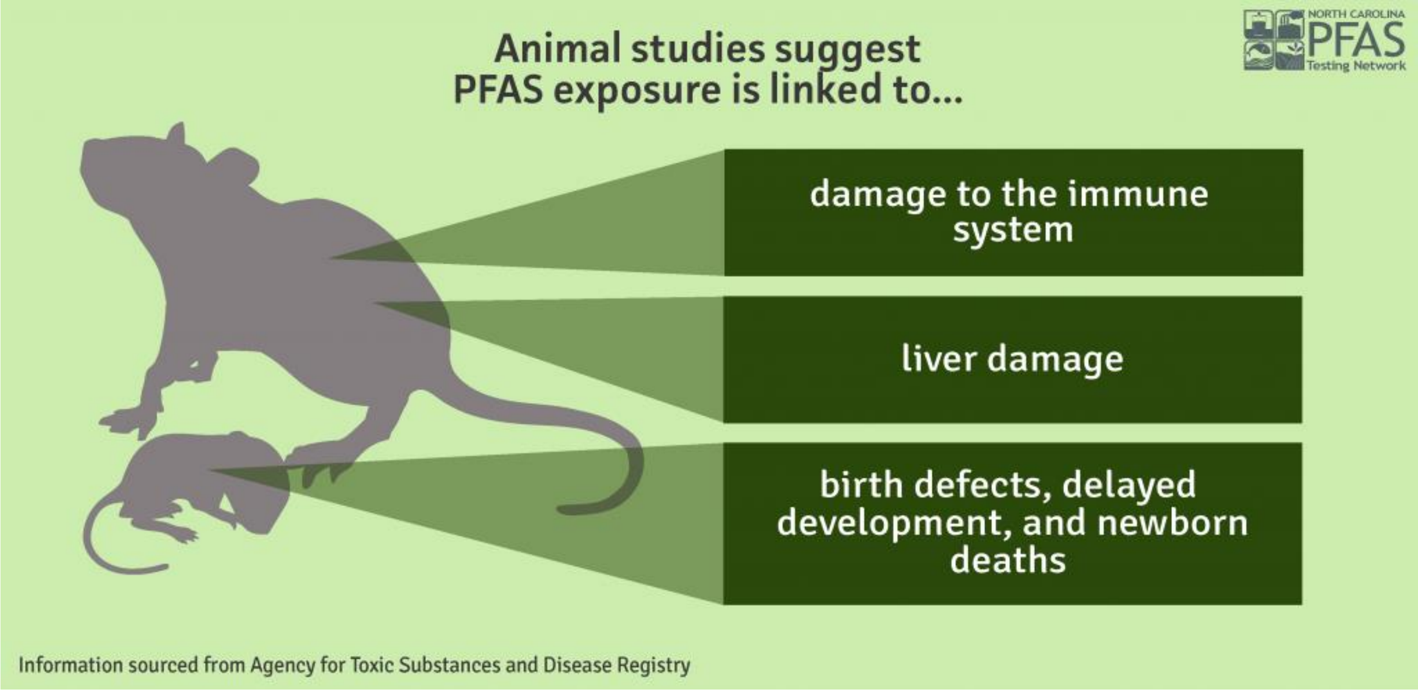
Figure 2-2. Overview of the Number of Studies Examining PFOS Health Effects*



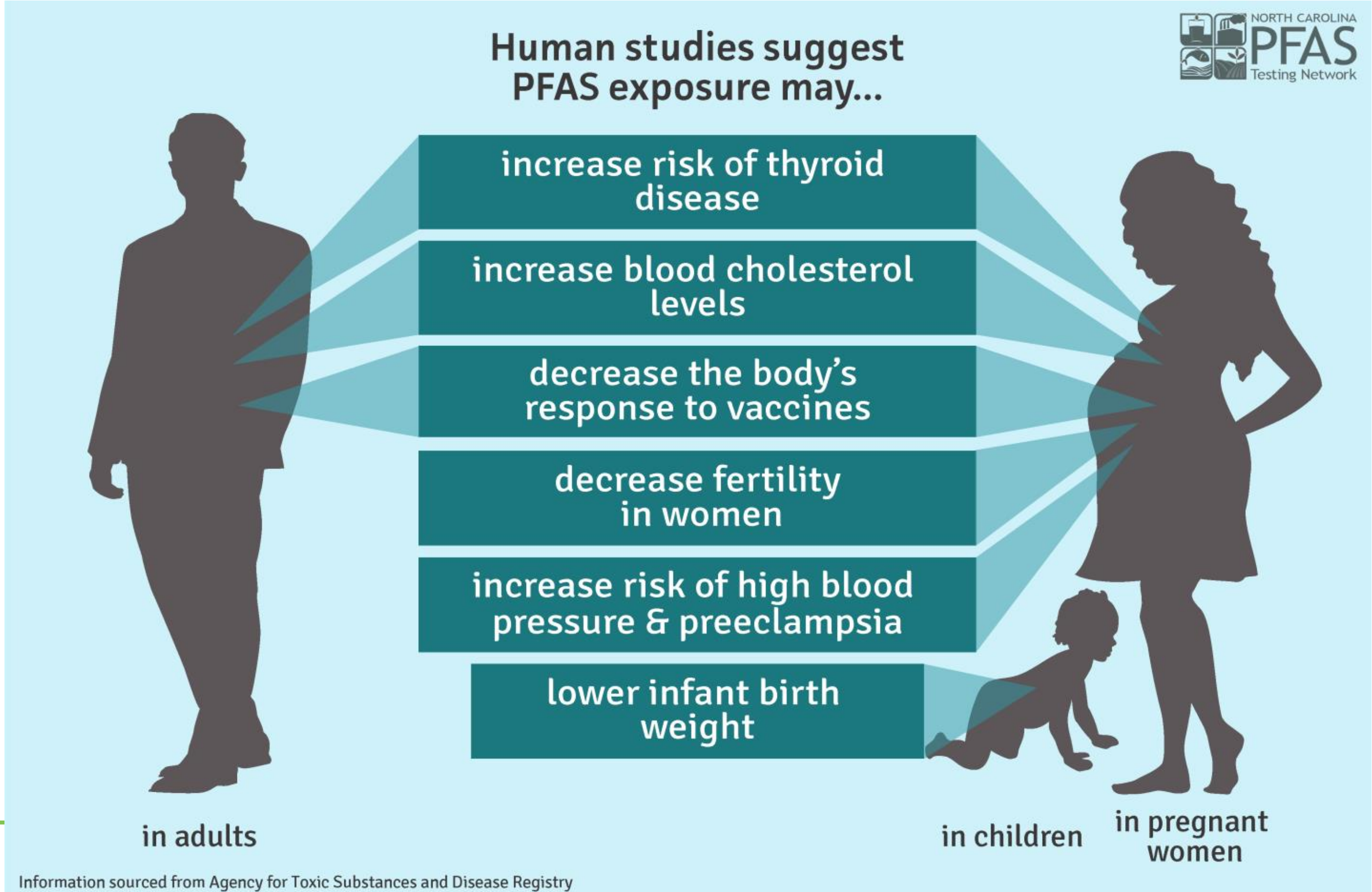
*Includes studies discussed in Chapter 2. A total of 218 studies (including those finding no effect) have examined toxicity; most animal studies examined multiple endpoints. In this figure, the number of human studies is referring to the number of publications.

ATSDR, 2018

Health Effects: Animal Studies



Health Effects: Human Studies



Cancer

- The International Agency for Research on Cancer (IARC 2017) concluded that PFOA is possibly carcinogenic to humans (Group 2B)
- EPA (2016) concluded that there was suggestive evidence of the carcinogenic potential of PFOA and PFOS in humans
- C8 Study
  - Increases in testicular and kidney cancer have been observed in highly exposed humans.
  - "There were no suggestions of positive findings for other cancers of interest, including liver, pancreas, or breast."
- In its exhaustive review, ATSDR also reported the same conclusion:
  - "The occupational exposure studies have consistently found no increases in the risk of pancreatic, liver, or respiratory tract cancers or deaths from these cancers; a general population case: control study also found no associations between serum PFOA and pancreas or liver cancer."

Most Sensitive Endpoints

Figure 1-4. Summary of Sensitive Targets of PFOA – Oral

Developmental endpoints are the most sensitive target of PFOA.
Numbers in circles are the lowest LOAELs for all health effects in animals.

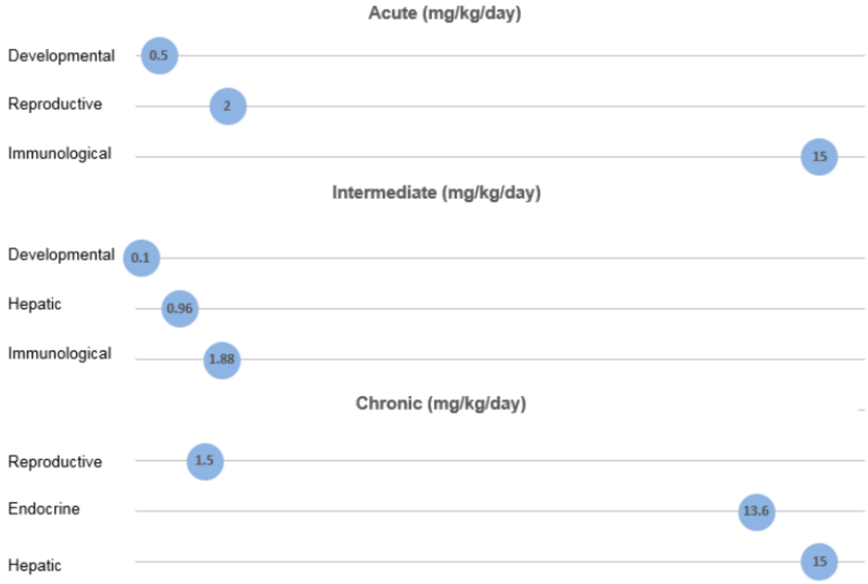
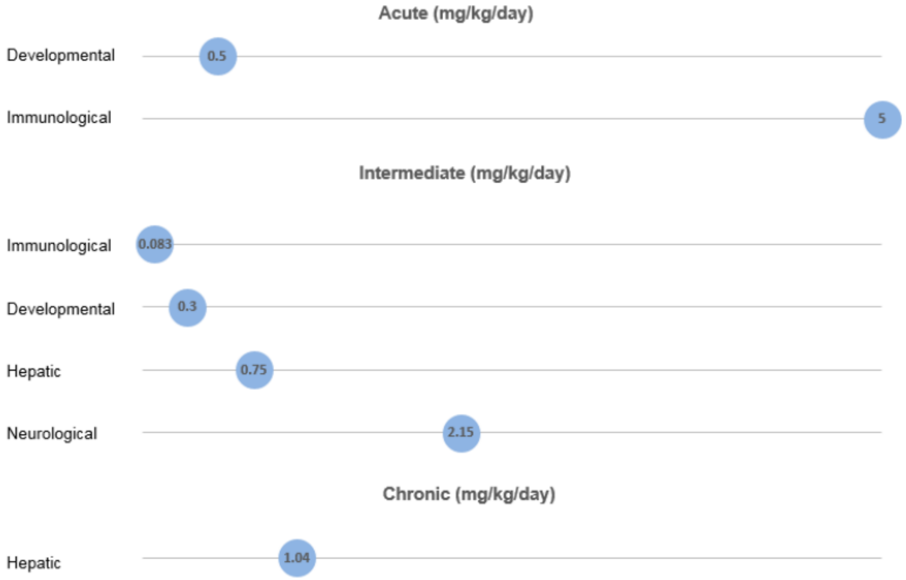


Figure 1-5. Summary of Sensitive Targets of PFOS – Oral

The immune system and developing organism are the most sensitive targets of PFOS.
Numbers in circles are the lowest LOAELs for all health effects in animals.



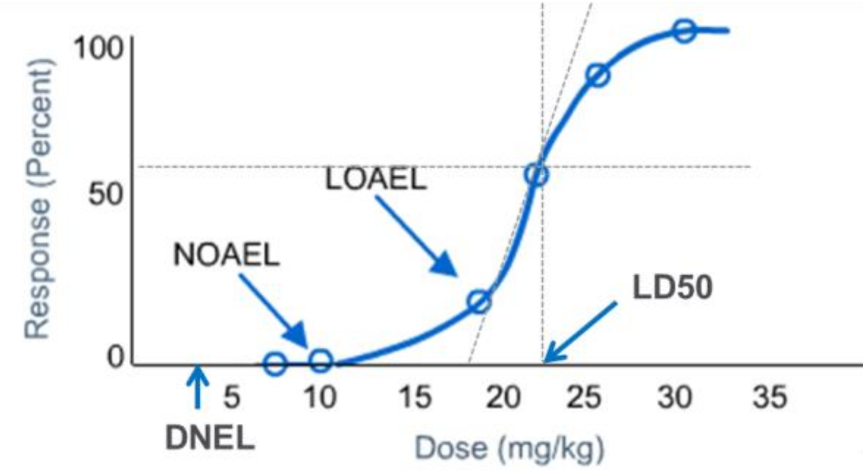
ATSDR, 2018

Dose-Response

- Paracelsus (1493-1541)
- Philippus Theophrastus Aureolus Bombastus von Hohenheim

Sola dosis facit venenum

"Only the dose makes the poison"



Controlling Risk

Risk = Exposure * Toxicity

↓Exposure → ↓Risk

↓Toxicity → ↓Risk

Summary

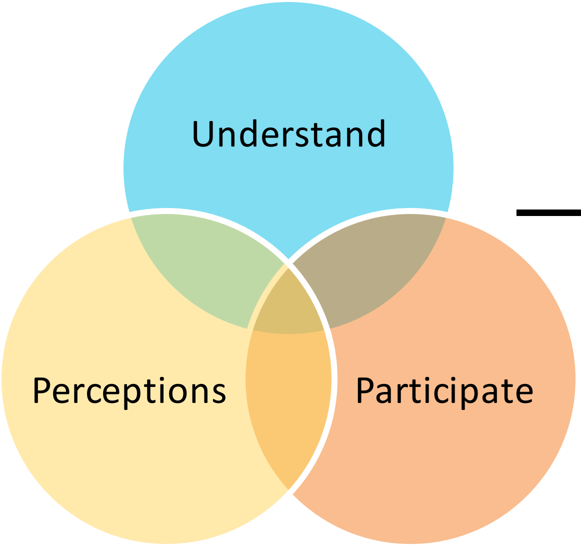
- We are all exposed through various routes
- Most research is in PFOA and PFOS (more needed)
- Short chain have similar effects but at higher doses (reflects shorter half-life)
- Most consistent effects are immune and repro/developmental

PFAS Risk Communication and Engagement

Dr. Melissa Harclerode, CDM Smith

Risk Communication: Short & Long-Term Goals

Three components of risk communication



Short Term Goal = Public Outreach

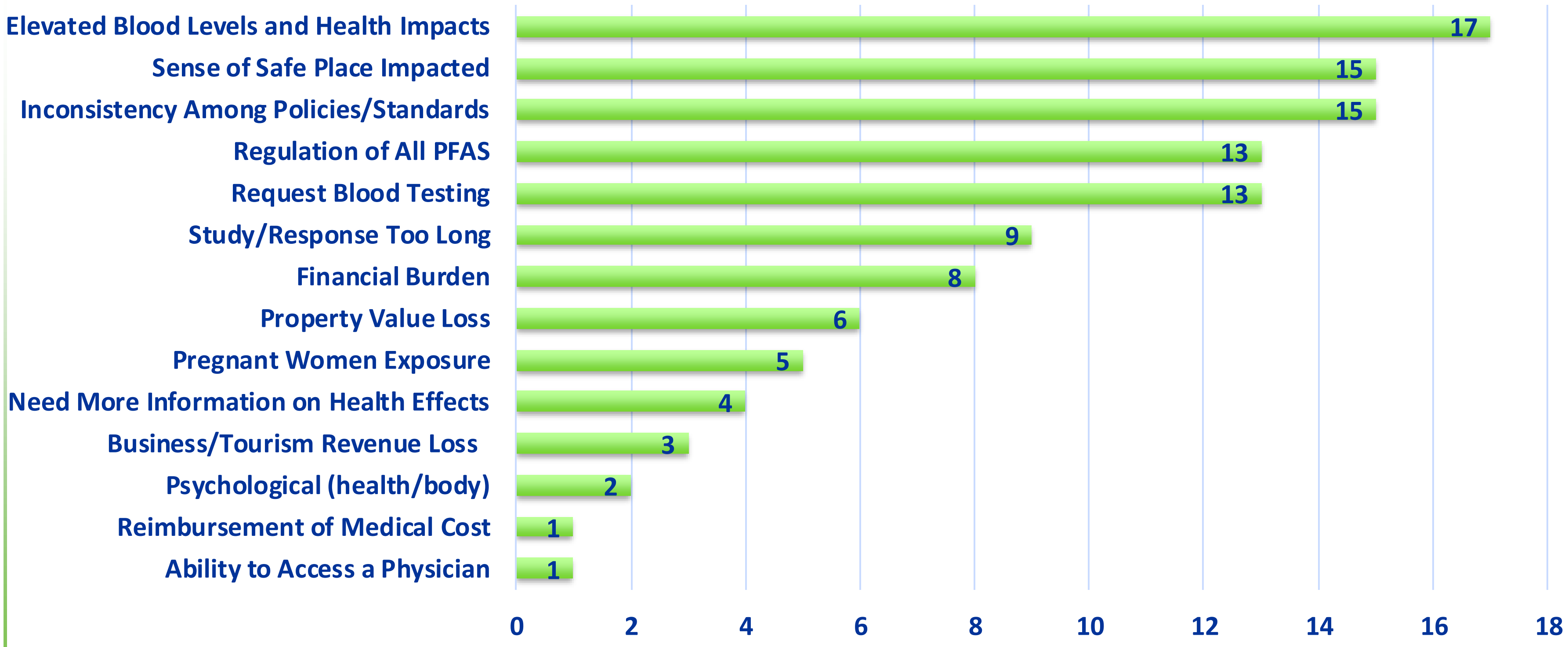
Long Term Goal = Address Risk Communication Challenges

Risk Communication Challenges

Regulatory	▪ Federal and state standards, guidance, and policies for PFAS are not uniform ▪ Only available for a handful of compounds
Fate and Transport	▪ Complicated due to the potential of multiple sources ▪ Persistence and migration in the environment
Toxicological/ Epidemiological	▪ Risks are not fully known or characterized ▪ No medical procedure to remove PFAS (such as lead)
Technical	▪ Difficulty in distinguishing between low levels of PFAS from use of consumer products and PFAS industrial use contamination
Analytical Ability	▪ Numerous PFAS compounds in existence, yet not all can be measured
Quality of Life	▪ Community outrage due to involuntary risk ▪ Misinformation and misperception of risk

Snapshot of Stakeholder PFAS Concerns

USEPA 2018 Community Meeting Concerns

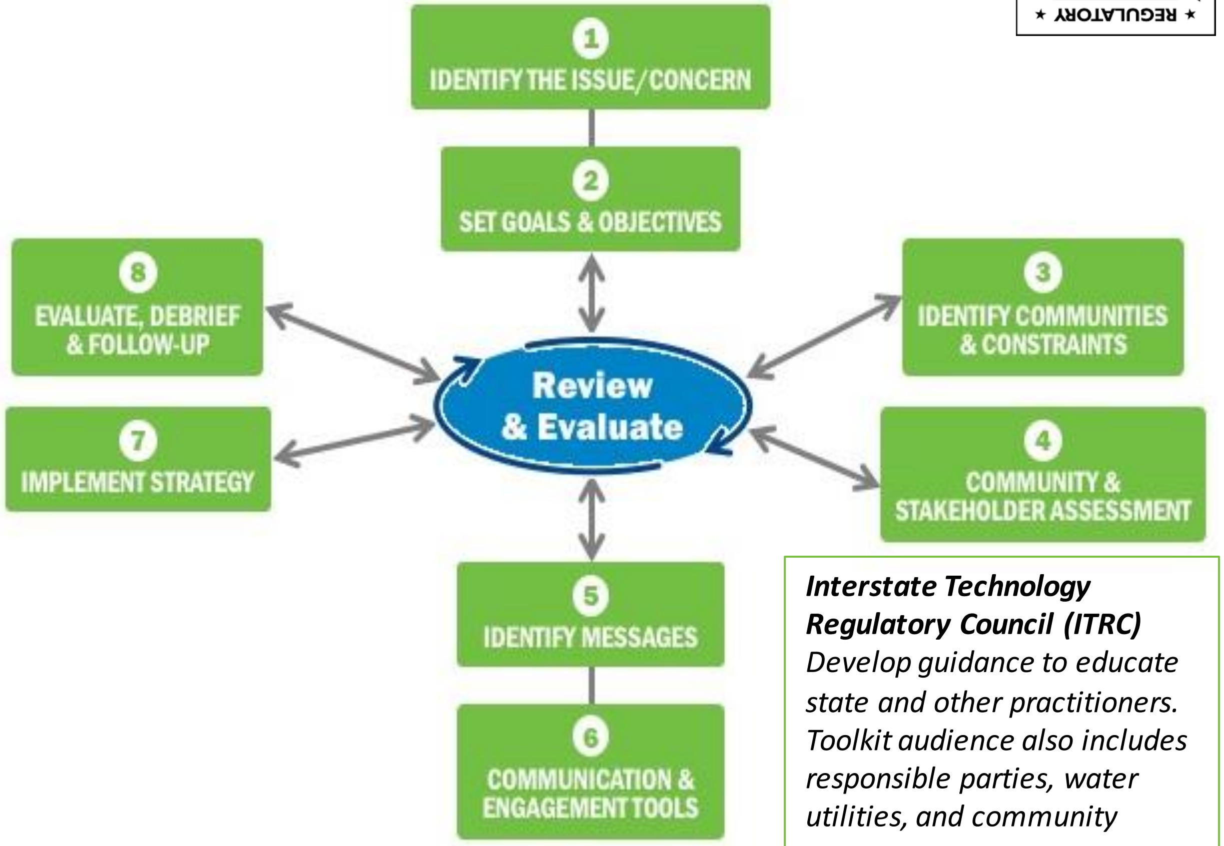


Represents number of stakeholders, data from 4 USEPA 2018 community meetings, ITRC PFAS Risk Communication Subgroup

How to Engage Public Stakeholders

- Water Utility Outreach and Communication Team
- PFAS Technical & Subject Matter Experts
- Water quality outreach lessons learned, materials and tools

ITRC Risk Communication Toolkit



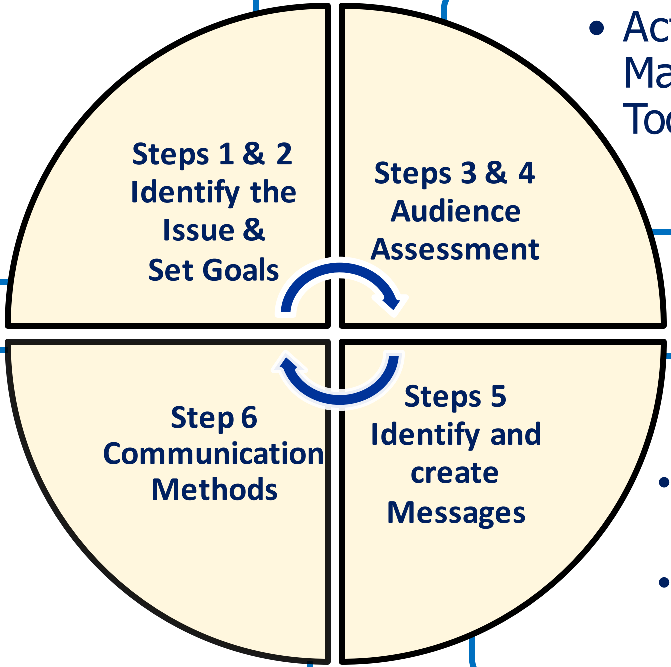
Interstate Technology Regulatory Council (ITRC) *Develop guidance to educate state and other practitioners. Toolkit audience also includes responsible parties, water utilities, and community groups.*

NJDEP 2014. Establishing Dialogue: Planning for Successful Environmental Management, K. Kirk Pflugh, J. Auer Shaw, B. B. Johnson; New Jersey Dept. of Environmental Protection (Updated from 1992)

How to Engage Public Stakeholders

USEPA PFAS Action Plan *developing risk communication toolbox that includes multi-media materials and messaging for federal, state, tribal and local partners to use with the public (December 2019)*

- Agenda for First Internal Communication Team Planning Meeting
- PFAS-specific SMART Goals



- Actor Mapping Tools

- Guidance for Writing Analytical Results Summary Letters
- Guidance for Writing Press Releases
- Social Factors Vision Board

- Message Mapping Guide
- PFAS-specific Key Messages

Develop and Communicate Performance Metrics & Milestones

Develop SMART Goals

- **S**pecific
- **M**easurable
- **A**chievable
- **R**ealistic
- **T**imely

Example: By (date), the community is informed via the municipal website, flyers, and newsletter of PFAS testing results. After (months), a public meeting will be held to present risk management recommendations and obtain community input.

Message Mapping Process

A mapped message starts with a question or statement, responds with three key ideas, is no more than twenty-seven words, and takes no longer than nine seconds to deliver.

Example: Should we be concerned about PFAS in the future?

Water quality monitoring includes quarterly PFAS testing. Consumers are notified if PFAS are confirmed at concentrations above standards. Recommendations will be provided to manage potential risks.

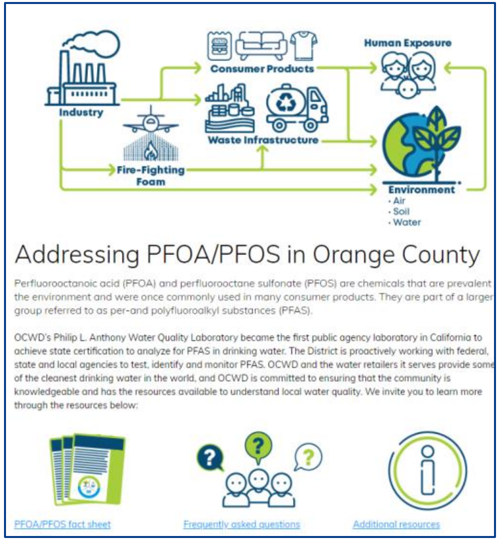
ITRC Risk Communication Toolkit for Environmental Issues and Concerns, PFAS Examples in Toolkit Appendices

Risk Communication: Public Outreach Resources

OCWD Website:

- Fact Sheets
- FAQs
- Additional Resources

Source: https://www.ocwd.com/what-we-do/water-quality/pfoapfos/



CA SWRCB Website:

- Active Centralized Information Repository for site investigation and action
- Various California agencies including, but not limited to, the State & Regional Water Resources Control Boards, the Department of Toxic Substances Control, and the Office of Environmental Health Hazard Assessment

Source: https://www.waterboards.ca.gov/pfas/

Risk Communication: Public Education

- Inform on risk assessment factors, including differences among federal and state criteria, *select factors shown below*

State	New Jersey	Texas	USEPA	Vermont
PFOA Threshold Level (ug/L)	0.014	0.290	0.07	0.02
Critical Effect Key Study Reference	Increased liver wt.	Mammary gland developmental effects	Developmental (reduced ossification, accelerated puberty)	Based on EPA Health Advisories
Toxicity Value - RfD (mg/kg-day)	0.000002 (2×10^{-6})	0.000012 (1.2×10^{-5})	0.00002 (2×10^{-5})	
Receptor	Adult	Child (0-6 years) residential, non-cancer	Lactating women	Infant (0-1 year)

ITRC PFAS Fact Sheets: Table 5.1 Basis of Different North American Standards and Guidance Values for Water – PFOA (Updated January 2019)

Risk Communication Tools: Public Education

- Collaborate with academia and community liaisons
  - Example: Understanding PFOA Class at Bennington College, Vermont

Fact sheets, Bennington College example
http://www.bennington.edu/center-advancement-of-public-action/environment-and-public-action/understanding-pfoa

Risk Communication Tools: Community Assessment

- Identify populations that require **targeted outreach**
- Develop baseline to evaluate outreach activities
- Town surveys may have helpful demographic data on water quality

2019 Castle Rock Water
Community Perception Indicators and Target Outreach Groups

Community Perception Indicator	Primary Districts	Primary Demographic
Level of Concern for the Town's Plan to Address Water Issues		
Serious concerns / Town does not have a solid plan	3, 4, and 6	• Age: 55 and up • Residency: >20 years; between 5 to 10 years • Household Income: >$50,000
Somewhat concerned / not confident in the Town's plan	1 and 5	• Age: 35 to 64 • Residency: >5 years • Household Income: >$100,000
I do not know enough about the issue to make an informed decision	1 thru 6, with focus on 1, 2, 3 and 5	• Age: 18 and up • Residency: <5 to >20 years • Household income: <$50,000 to >$150,000

Risk Communication Tools: Social Vision Board

Rate the level of impact to the following quality of life factors	Not At All	Somewhat	Moderate	High Extent
Business Revenue (tourism, agriculture, livestock)	XXX	X	XXX	XXXXX
Property Value	XXXX	XXX	XX	
Neighborhood as a Safe Place	XXX	X		
Financial Burden			XXXX	XXXXX
Physical Wellbeing		XXX	XXX	

- Objective to gain deeper insight into stakeholder concerns, values, and preferred communication mode to facilitate knowledge transfer and capacity building towards a successful risk management strategy.
- Social factors identified via a review of USEPA public meeting notes collected by ITRC PFAS team members

ITRC Risk Communication Toolkit for Environmental Issues and Concerns, PFAS Examples in Toolkit Appendices

Risk Communication Tools: OCWD Bottled Water Campaign

- Be creative! Promote good water quality

Advanced purified bottled water sourced from wastewater

Source: https://www.ocwd.com/news-events/newsletter/2017/december-2017/gwrs-bottled-water-efforts-garner-one-planet-award/

Forty years of water reuse technology and experience is now available in a bottle!

- May include education on bottled water
  - NHDES performed statewide sampling of bottled water

PFAS Stakeholder Outreach Best Practices

- Don't be complacent, develop a risk communication plan
- Understand stakeholder concerns
- Have empathy and care for those under stress
- Reach out to experts and local champions
- Use multiple modes of communication
- Identify risk management metrics that meet stakeholder needs
- Maintain transparency in uncertainties and limitations
- Evaluate, debrief, and follow-up

Panel Discussion – First Session

Lunch Session – PFAS Litigation: 11:30 PM – 12:30 PM

Richard Head
SL Environmental

PFAS Litigation

Examples Of Water System PFAS Damages

- Design, construction and operation of new wells and treatment facilities
- Extension of service to impacted private wells
- Replacement water
- Property damage

PFAS Timeline

Table 2-1. Discovery and manufacturing history of select PFAS

PFAS[1]	Development Time Period							
	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s
PTFE	Invented	Non-Stick Coatings			Waterproof Fabrics			
PFOS		Initial Production	Stain & Water Resistant Products	Firefighting foam				U.S. Reduction of PFOS, PFOA, PFNA (and other select PFAS[2])
PFOA		Initial Production	Protective Coatings					
PFNA					Initial Production	Architectural Resins		
Fluoro-telomers					Initial Production	Firefighting Foams		Predominant form of firefighting foam
Dominant Process[3]		Electrochemical Fluorination (ECF)						Fluoro-telomerization (shorter chain ECF)
Pre-Invention of Chemistry /			Initial Chemical Synthesis / Production			Commercial Products Introduced and Used		

Notes:

1. This table includes fluoropolymers, PFAAs, and fluorotelomers. PTFE (polytetrafluoroethylene) is a fluoropolymer. PFOS, PFOA, and PFNA (perfluorononanoic acid) are PFAAs.
2. Refer to Section 3.4.
3. The dominant manufacturing process is shown in the table; note, however, that ECF and fluorotelomerization have both been, and continue to be, used for the production of select PFAS.

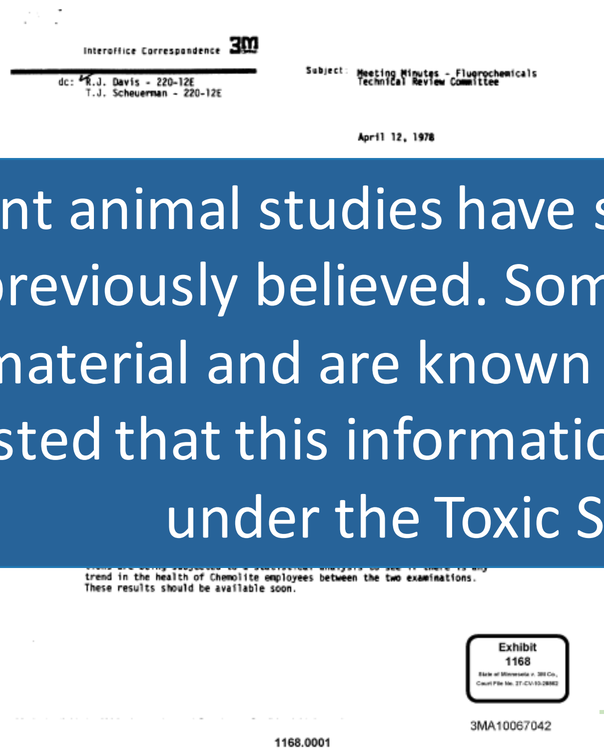
Sources: Prevedouros et al. 2006; Concawe 2016; Chemours 2017; Gore-Tex 2017; US Naval Research Academy 2017

Toxic Substances Control Act (TSCA)

Its main objective is to regulate chemicals that pose an "unreasonable risk to health or to the environment."

3M Had Knowledge of the Risks

Fluorochemicals Technical Review Committee Letter 1979



Interoffice Correspondence 3M

dc: R.J. Davis - 220-12E
T.J. Scheuerman - 220-12E

Subject: Meeting Minutes - Fluorochemicals Technical Review Committee

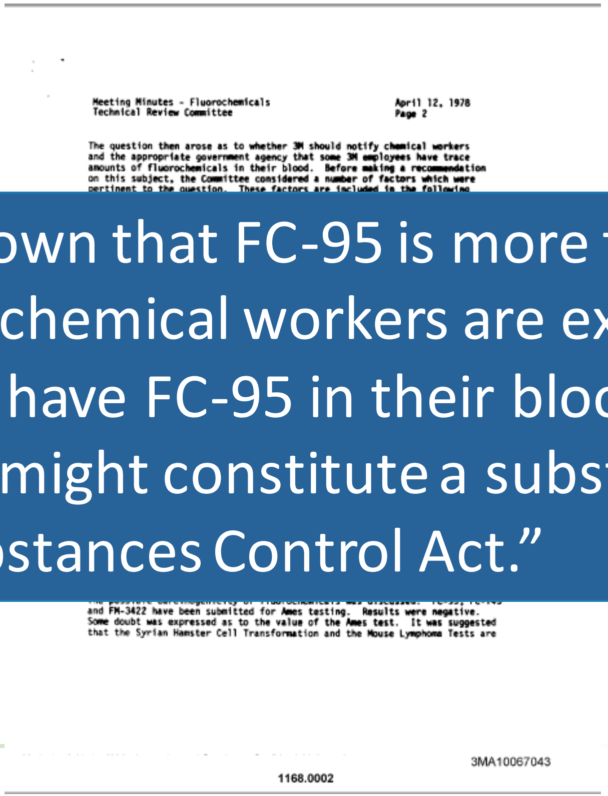
April 12, 1978

trend in the health of Chemolite employees between the two examinations. These results should be available soon.

Exhibit 1168
State of Minnesota v. 3M Co., Court File No. 27-CV-10-28862

3MA10067042

1168.0001



Meeting Minutes - Fluorochemicals Technical Review Committee — April 12, 1978, Page 2

The question then arose as to whether 3M should notify chemical workers and the appropriate government agency that some 3M employees have trace amounts of fluorochemicals in their blood. Before making a recommendation on this subject, the Committee considered a number of factors which were pertinent to the question. These factors are included in the following

and FM-3422 have been submitted for Ames testing. Results were negative. Some doubt was expressed as to the value of the Ames test. It was suggested that the Syrian Hamster Cell Transformation and the Mouse Lymphoma Tests are

3MA10067043

1168.0002

"Recent animal studies have shown that FC-95 is more toxic than was previously believed. Some chemical workers are exposed to this material and are known to have FC-95 in their blood. It was suggested that this information might constitute a substantial risk under the Toxic Substances Control Act."

3M Had Knowledge of the Risks

Internal Memo 1979

International Research and Development Corporation

Aborted Study

T-3351

SPONSOR: 3M Company

COMPOUND: Fluorad® Fluorochemical Surfactant FC-95

SUBJECT: 90-Day Subacute Rhesus Monkey Toxicity Study.

"[PFOS] was administered to rhesus monkeys….The study was terminated after 20 days because of the early deaths of the monkeys in all treatment groups."

Collaborators:

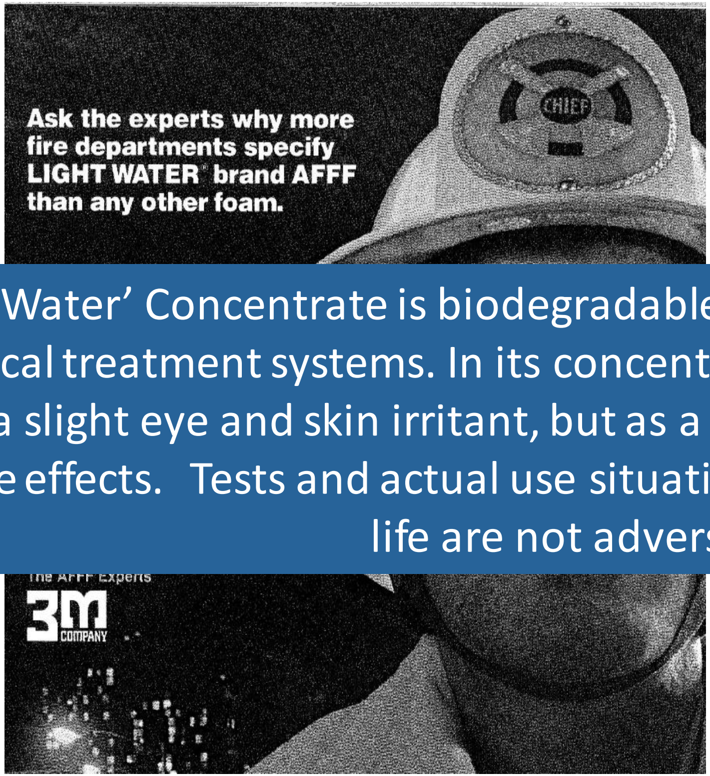
D. C. Jessup, Ph.D., Associate Director of Research
R. G. Geil, D.V.M., Vice President and Director of Pathology
J. S. Mehring, Ph.D., Director of Large Animal Toxicology

Date: January 2, 1979

137-087

1978 3M AFFF Brochure

"… biodegradable, low in toxicity, and it can be treated in biological treatment systems"



Typical Properties of "Light Water" Concentrates

	6%	3% (Freeze Protected)
SPECIFIC GRAVITY		
77°F (25°C)	1.012	1.055
40°F (4.4°C)	1.025	1.066
10°F (– 23.3°C)	—	1.084
VISCOSITY, CENTISTOKES		
77°F (25°C)	2.4	7.5
40°F (4.4°C)	4.8	16.3
– 10°F (– 23.3°C)	—	90
MINIMUM USE TEMPERATURE	35°F (1.7°C)	0°F (– 18°C)
FREEZE POINT	25°F (– 4°C)	– 15°F (– 26°C)
pH at 77°F	7.5	7.5

Excellent Long Term Storage

"LIGHT WATER" Concentrate may be stored in its shipping container without change in its original physical or chemical characteristics. It does not show significant sedimentation or precipitation in storage or after tempera-

Premix solutions in fresh water may be stored long term for ready use at temperatures above freezing.

Environmentally Neutral

Standardized tests are conducted as an ongoing program to evaluate and assess the impact of "Light Water" Concentrate on humans and the natural environment. Based on these test results, "Light Water" Concentrate is biodegradable, low in toxicity, and it can be treated in biological treatment systems. In its concentrate form, "Light Water" AFFF was found to be a slight eye and skin irritant, but as a foam solution, there are no noticeable negative effects. Tests and actual use situations have shown that animal and aquatic life are not adversely affected.

"Light Water" AFFF Alcohol Type Concentrate

This special concentrate is available for hazards involving alcohol and other polar solvents. Underwriters' Laboratories lists "LIGHT WATER" ATC as an AFFF for flammable

"'Light Water' Concentrate is biodegradable, low in toxicity, and it can be treated in biological treatment systems. In its concentrate form, 'Light Water' AFFF was found to be a slight eye and skin irritant, but as a foam solution, there are no noticeable negative effects. Tests and actual use situations have shown that animal and aquatic life are not adversely affected."

3M Environmental Laboratory

Encompasses all work performed during the period 1975-1978

TECHNICAL COMMUNICATIONS CENTER – 201-2CN

(If report is printed on both sides of paper, send two copies to TCC.)

Lnvironmental Laboratory (EE & PC)

Dept. Number 0535

Fluorochemicals, per se, are unique materials manufactured by the Commercial Chemicals Division. There has been a general lack of knowledge relative to the environmental impact of these chemicals;

13

SECURITY ▶ ☐ Open (Company Confidential) ☒ Closed (Special Authorization) 3M CHEMICAL REGISTRY ▶ New Chemicals Reported

FM 3422 was found to be "completely resistant" to biodegradation under the test conditions employed

Fluorochemical
(Analytical)
(Aquatic)
(Degradation)
Joil)
zoxicity
(Bioconcentration)

REPORT ABSTRACT: (200-250 words) This abstract information is distributed by the Technical Communications Center to alert 3M'ers to Company R&D. It is Company confidential material.

3M Did Not Warn of

Internal Memo 1988

27-CV-10-28862

Filed in Fourth Judicial District Court
11/17/2017 7:27 PM
Hennepin County, MN

3M Internal Correspondence

Surfactant Correspondence File

Date: 30-Dec-1988 06:31pm CST
From: US053491@USSP01
RICKER, DON@PROFS@SSWMB@GRETEL
Dept:
Tel No:

TO: CHASMAN, JON N @PROFS @SSWMB @QUIGLY
TO: KILLIAN, MICHAEL E @PROFS @SSWMB @QUIGLY
TO: PIKE, MIKE T @PROFS @SSWMB @QUIGLY

Subject: FC-129 Biodegradability

To: US009762--USSP01 MIKE T PIKE US082710--USSP01 MICHAEL E KILLIAN
US105996--USSP01 Jon N Chasman

FROM: Don Ricker - US053491 - USSP01
Specialty Chemical Division QA - 236-1B-10 (733-2488)
Subject: FC-129 Biodegradability
IF YOU DECIDE TO PROCEED WITH THIS TESTING, PLEASE HAVE THE SAMPLES SUBMITTED THROUGH ME. BY MEANS OF THIS MEMO I AM NOTIFYING E. REINER THAT MIKE KILLIAN, JON CHASMAN ARE THE RESPONSIBLE PARTIES FOR THE

> "I don't think it is in 3M's long-term interest to perpetuate the myth that these fluorochemical surfactants are biodegradable."

I don't think it is in 3M's long-term interest to perpetuate the myth that these fluorochemical surfactants are biodegradable. It is probable that this misconception will eventually be discovered, and when that happens, 3M will likely be embarrassed, and we and our customers may be fined and forced to immediately withdraw products from the market.

If 3M wants to continue to sell and use fluorochemical surfactants as low level specialty components in cleaning products, I believe that 3M has to accurately describe the environmental properties of these chemicals and then lobby in each EEC nation for the adoption of regulations that exempt low level specialty uses. The already adopted German surfactant biodegradation regulation quite clearly does not exempt specialty uses of nonbiodegradable surfactants.

3MA10035965

Lessons Learned from PFAS Litigation

- 3M and DuPont Knowledge
- Health impacts
- Air emissions
- Water discharges
- Landfill leachate

Litigation

Wilbur Tenant

- Confidential settlement

West Virginia/Ohio PFOA Drinking Water Contamination

- 2001 a class action of approx. 70,000 people in West Virginia and Ohio
- 2004 settlement valued in excess of $300 Million, including water filtration systems for impacted private and public water supplies, funding of independent scientific health studies for PFOA
- 2013 MDL in Ohio - approximately 3500 claims of class members
- Four bellwether 2015-2017: compensatory awards as high as $5.1 Million and additional punitive damage awards as high as $10.5 Million. During the fourth trial, on Feb. 13, 2017, a settlement was reached for approx. $670.7 million

New Jersey PFOA Drinking Water Contamination

- Class action arising out of public and private drinking water contamination originating from DuPont's Chambers Works facility
- 2011settlement of approximately $8.2 million

Minnesota Attorney General

- Lawsuit against 3M for contamination of southeast Twin Cities' metro area. Settlement of $850 million

Current Litigation Status

<u>AFFF Cases</u>

- Multi-District Litigation (MDL) – District of South Carolina
- Approximately 30 public water systems

<u>Non- AFFF Cases</u>

- Remain in the courts where filed

Legal Liability of Manufacturers

Liability theories

- Product Liability
- Negligence
- Nuisance/Trespass
- Statutory Claims

Product Liability – Why Is It Fair?

The burden … from dangerous products … should be placed upon those who profit from their production . . . That burden should not be imposed exclusively on the innocent victim.

Brooks v. Beech Aircraft Corp., 902 P.2d 54, 58 (3d. Cir. 1995)

Product Not Performing as Intended

Product Liability – Why is it Fair?

A manufacturer is liable if a defect in the manufacture or design of its product causes injury while the product is being used in a reasonably foreseeable way.

Aubin v. Union Carbide Corp., 177 So. 3d 489, 513 (Fla. 2015)

Defect Means

A product did not perform the way consumers expected.

Or

The risks of the design outweigh the benefits of the design.

What Does Failure to Warn Mean?

The foreseeable risks could have been reduced or avoided by providing reasonable instructions or warnings,

and

the failure to provide those instructions or warnings makes the product unreasonably dangerous.

How Does Product Liability Apply to PFAS?

Why the Manufacturers?

Criteria	Products with PFAS
Product causes harm when used as intended	
Harm is caused by the defect	
The risk of the harm does not outweigh the benefits	
The risks could have been reduced or avoided by providing reasonable warnings	

Why the Manufacturers?

Criteria	Products with PFAS
Product causes harm when used as intended	✔
Harm is caused by the defect	
The risk of the harm does not outweigh the benefits	
The risks could have been reduced or avoided by providing reasonable warnings	

Why the Manufacturers?

Criteria	Products with PFAS
Product causes harm when used as intended	✓
Harm is caused by the defect	✓
The risk of the harm does not outweigh the benefits	
The risks could have been reduced or avoided by providing reasonable warnings	

Why the Manufacturers?

Criteria	Products with PFAS
Product causes harm when used as intended	✔
Harm is caused by the defect	✔
The risk of the harm does not outweigh the benefits	✔
The risks could have been reduced or avoided by providing reasonable warnings	

Why the Manufacturers?

Criteria	Products with PFAS
Product causes harm when used as intended	✓
Harm is caused by the defect	✓
The risk of the harm does not outweigh the benefits	✓
The risks could have been reduced or avoided by providing reasonable warnings	✓

Emergent Contaminant Litigation

TCP

MTBE

Second Session: 12:30 PM – 2:00 PM

OCWD PFAS Pilot Study

Dr. Megan Plumlee – Director of Research, OCWD

OCWD PFAS Planning Study

Chris Olsen – Director of Engineering, OCWD

PFAS Treatment

Alan LeBlanc – Senior Project Manager, CDM Smith

PFAS State of Research and Emerging Technologies

Jennifer Hooper – Senior Research Engineer, CDM Smith

Panel Discussion

- Speakers plus Dr. Dora Chiang, CDM Smith
- Moderator – Michael Zafer, Water Technology Leader, CDM Smith

OCWD Update: PFAS Pilot Study

Dr. Megan Plumlee, OCWD

Extent of PFAS Impact in OCWD Service Area

Current DDW NL/RLs:

<u>Notification Levels:</u>

PFOA = 5.1 ng/L;

PFOS = 6.5 ng/L

<u>Response Level:</u>

PFOA + PFOS = 70 ng/L

***RL to be lowered in early 2020**

*PHG process has begun

- **11 water retailers** (i.e., groundwater "Producers") in the OCWD service area (71 wells) projected to be impacted by potential 10 ppt PFOA Response Level
- **~ 1/3 of groundwater basin** production (100,000 afy) could be unable to be served
- Producers would pay ~ $50 million/year additional water supply cost by switching to imported water
- Very preliminary estimate of ~$850 million (capital + 30-y O&M) to treat these wells – consultant-led **Planning Study** to provide more precise estimate

Two OCWD Projects Underway

TREATMENT STUDY

Objectives:

- Bench and pilot scale testing to demonstrate performance of various products (GAC, IX, novel adsorbents)
- Use performance with unit cost to identify best value for different Producer water qualities

PLANNING STUDY

Objectives:

- Planning study for 10 Producers (pre-design):
  - Assess number of wells impacted, area needed, how treatment is integrated with Producer operations, assess blending
- Develop capital and O&M costs for each Producer

PFAS Treatment Technologies

Carbon Adsorption:
granular activated carbon (GAC)

Ion Exchange
(IX) resin

Reverse Osmosis or Nanofiltration
(RO or NF)

Conventional treatment approach

Higher capital cost, concentrate disposal

OCWD Pilot Testing

Installed pre-fab building to house pilot

OCWD Pilot Testing

- Pilot adjacent to OCWD-owned well in Anaheim that supplies the water
- PFAS in well:
  - 14 to 23 ng/L PFOA
  - 19 to 27 ng/L PFOS

OCWD Pilot Testing

- Pilot commissioned December 2019

- Pilot test system (Evoqua):
  - 8 GAC (10-min EBCT)
  - 4 IX (2-min EBCT)
  - 2 novel adsorbents (5-min EBCT)

Loading IX resins

OCWD Pilot Testing – Products

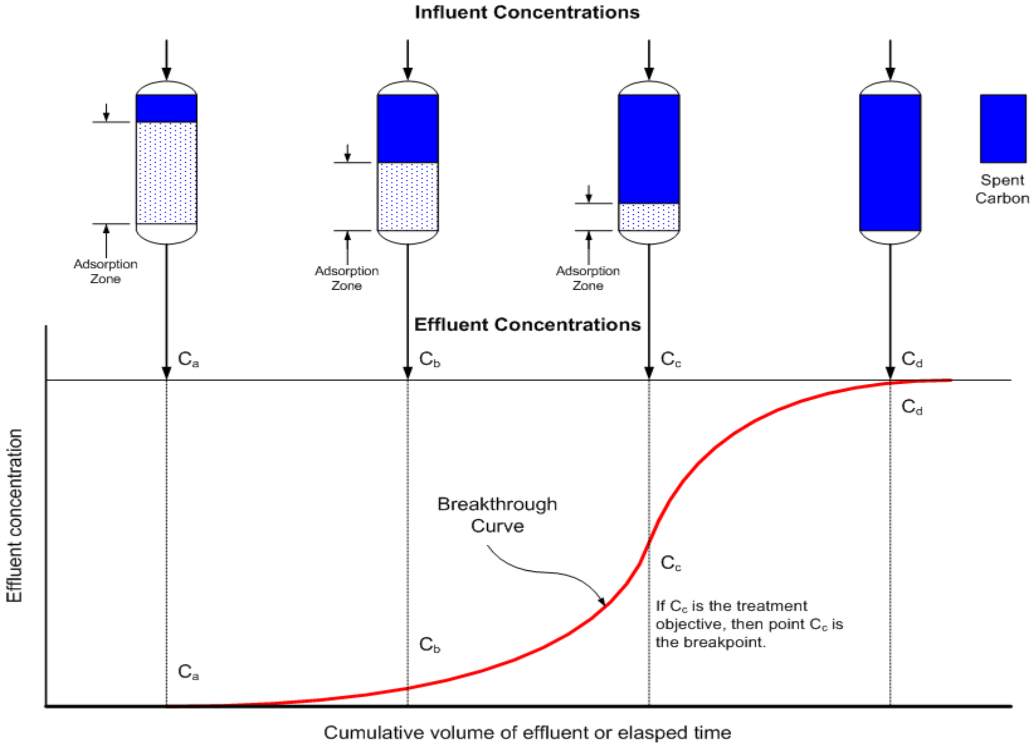
Vendor	Product	Media Material / Type
GRANULAR ACTIVATED CARBONS:		
Calgon	FILTRASORB 400 (F400)	Bituminous GAC (Virgin)
Calgon	FILTRASORB 400 (F400)	Bituminous GAC (Reactivated)
Calgon	F600	Bituminous GAC
Cabot	Norit GAC400	Bituminous GAC
Cabot	HYDRODARCO 4000	Lignite-Based GAC
Evoqua	UltraCarb® 1240LD	Bituminous GAC (low density)
Evoqua	AquaCarb® 1230CX	Enhanced Coconut Shell GAC
Jacobi	AquaSorb F23	Enhanced GAC

Vendor	Product	Media Material / Type
NOVEL ADSORBENT MEDIA:		
Cetco	FLUORO-SORB®	Modified Zeolite
CycloPure	DEXSORB®	Modified Zeolite
ION EXCHANGE:		
Purolite	Purofine PFA694E	Single Use Resin
Calgon	CalRes 2301	Single Use Resin
Evoqua	PSR2+	Single Use Resin
ECT2	Sorbix LC4	Single Use Resin

GAC Pilot – Two 4-Column Skids

IX Pilot – One 6-column Skid, for 4 IX Products and 2 Novel Adsorbents

Breakthrough Curve – Definition



https://www.thewastewaterblog.com/activated-carbon

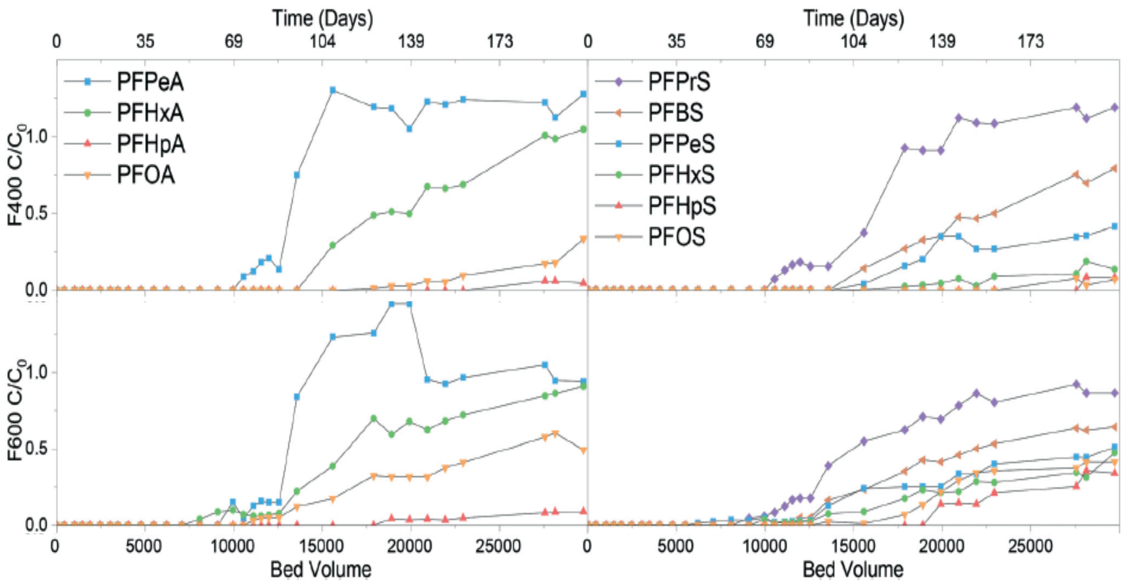
Rapid Small Scale Column Testing (RSSCT) in Lab

- RSSCT can be performed at bench (lab) scale with activated carbon and crushable adsorbents
  - We are using RSSCT to evaluate GAC and novel adsorbents
- Objective: Screen products quickly to determine the best performing products
- Advantage of RSSCT (over pilot) is the ability to **quickly** screen **multiple** waters – we will test water from 9 different Producers
- Scope was expanded to 8 GAC/adsorbents tested in parallel (typical project ≤ 4 products/columns)
- Began ~January (Battelle)

RSSCT COLUMN

Example Outcomes (Pilot Data)

- Bed volume = water volume treated (can be plotted as time)
- 7 months comparing Calgon F400 and F600
- Shorter chain PFAS break through first
- F400 performed ~50% better than F600 for long chain PFAS



Liu, Werner, Bellona 2019

Using Lab and Pilot Data Together

- RSSCT – compare various GAC/novel products, and repeat this for range of different water qualities
- Model analysis of RSSCT data (GAC/novel) to predict full-scale product performance (Jacobs model)
  - Characterize breakthrough curves and relationship to water quality (e.g., TOC)

RSSCT COLUMN

Using Lab and Pilot Data Together

- Coupled with RSSCT, use pilot GAC results to update ("calibrate") the predicted full-scale performance
- Importantly, pilot also enables predicting full-scale IX performance (IX not included in RSSCT/ lab testing)
- Make GAC/IX product recommendations for each water retailer (Groundwater Producers)
  - Consider target PFAS compounds; and best value products (life cycle costs)
- Project time sensitivity may necessitate design flexibility

Any questions?

PFAS PILOT PROGRAM

Commissioned December 2019

ORANGE COUNTY WATER DISTRICT
SINCE 1933

JACOBS
evoqua WATER TECHNOLOGIES
carollo
CABOT
CalgonCarbon A Kuraray Company
cyclopure
ect2
CETCO
Jacobi CARBONS
Purolite

OCWD Update: Planning Study

Chris Olsen, OCWD

Purpose of Study

If RL is reduced for PFOA/PFOS, there is a potential that 11 Producers totaling 71 wells would be impacted.

	Units	PFOA	PFOS
2019 California Response Level	ng/L	70 (combined)	
2019 California Notification Level (NL)	ng/L	5.1	6.5
"Potential" California Response Level (RL)	ng/L	10	40

In August when awarding the pilot study work, we asked ourselves: what more can we do early on to provide a benefit to our Producers who may be shutting down wells and needing PFAS treatment systems to resume serving groundwater?

End of August 2019, we issued a Request for Proposals to include:

Producer Well Assessment:

- Meet with individual Producers, gather information on their groundwater conveyance systems, impacted wells, reservoirs, imported water connections.
- Conduct site visits for each Producer’s well(s)/reservoir(s) to determine available area of land for treatment system(s).
- Determine how the treatment system(s) would be integrated into the Producer’s existing operations.
- Provide a conceptual layout for each location. Meet with individual Producers to discuss treatment options and to review the Planning Study draft reports and final report.

- Provide cost estimates for any necessary land acquisition to accommodate a treatment system(s), plumbing connections, transmission alignments and system integration.

- Include capital and operation and maintenance cost estimates for both GAC and IX treatment systems, include membrane filtration as an alternative.

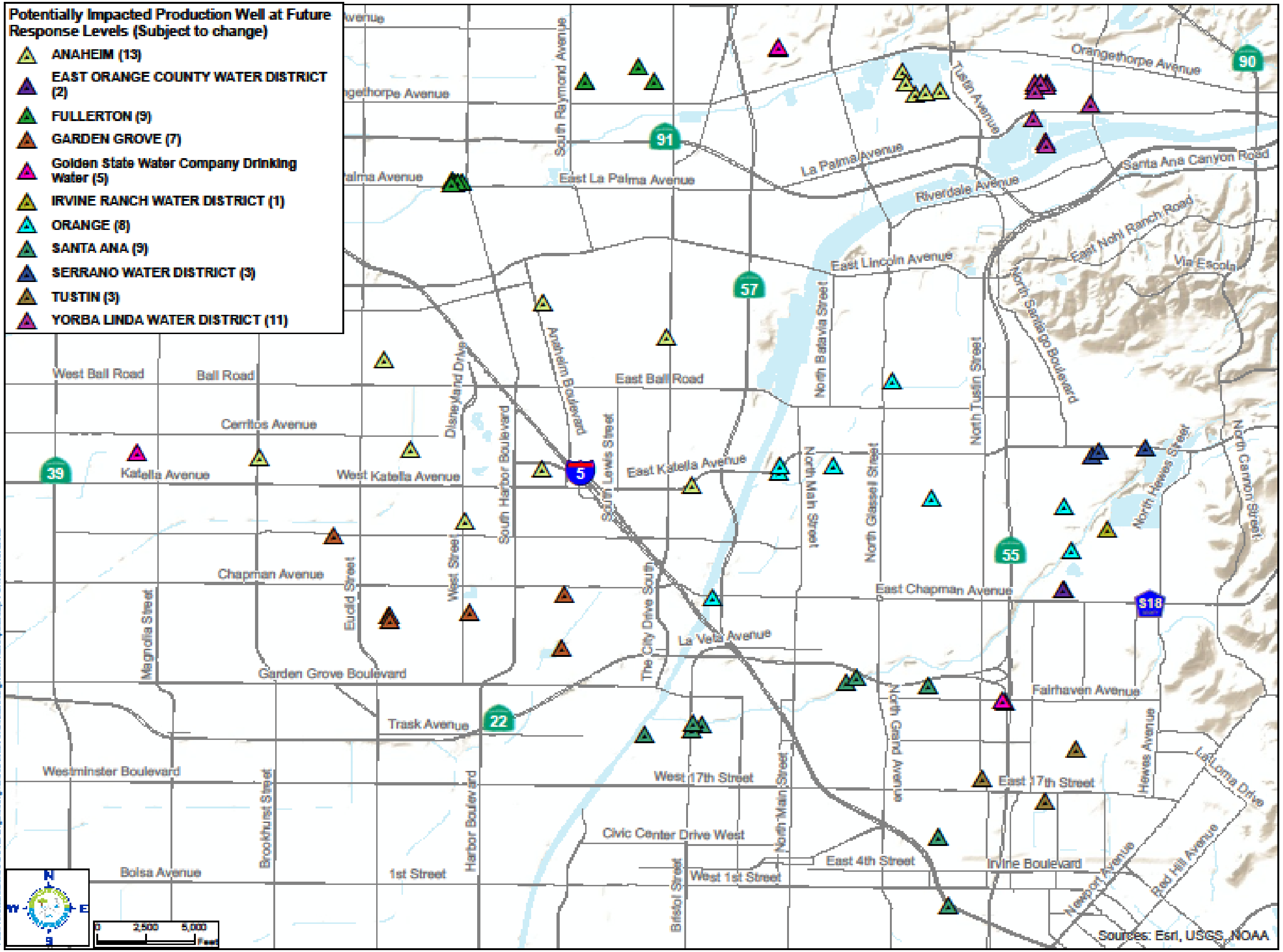
- Perform initial individual Producer permitting assessment/requirements, develop list of required permits (including permit description, issuing regulatory agency, summary of permit requirements, permit acquisition timeline) for each Producer.

Additionally, for each Producer:

- Estimate anticipated duration of construction for treatment systems.
- Determine any necessary utility extensions required for a treatment system.
- Develop a preliminary phasing schedule for construction.
- Assuming OCWD is going to pay for some or all the treatment system(s) capital costs and construction will be staggered based on individual Producer needs and constraints, develop a plan for the construction schedules. The plan is intended to provide OCWD a schedule and projected annual outlays for separate financial planning.
- The final report shall be separated into individual, standalone Producer reports and include discussion of all items listed in the Project Description and Scope of Work.

The participating Producers include:

- Anaheim – 13 production wells
- East Orange County Water District – 2 production wells
- Fullerton – 9 production wells
- Garden Grove – 7 production wells
- Golden State Water Company – 5 production wells
- Irvine Ranch Water District – 1 production well
- Orange – 8 production wells
- Santa Ana – 9 production wells
- Serrano Water District – 3 production wells
- Tustin – 3 production wells
- Yorba Linda Water District – 11 production wells



Potentially Impacted Production Well at Future Response Levels (Subject to change)
ANAHEIM (13)
EAST ORANGE COUNTY WATER DISTRICT (2)
FULLERTON (9)
GARDEN GROVE (7)
Golden State Water Company Drinking Water (5)
IRVINE RANCH WATER DISTRICT (1)
ORANGE (8)
SANTA ANA (9)
SERRANO WATER DISTRICT (3)
TUSTIN (3)
YORBA LINDA WATER DISTRICT (11)
Orangethorpe Avenue
South Raymond Avenue
East La Palma Avenue
La Palma Avenue
Santa Ana Canyon Road
Riverdale Avenue
East Nohl Ranch Road
Via Escola
East Lincoln Avenue
Tustin Avenue
North Batavia Street
North Tustin Street
North Santiago Boulevard
Anaheim Boulevard
Disneyland Drive
West Ball Road
Ball Road
East Ball Road
Cerritos Avenue
Katella Avenue
West Katella Avenue
East Katella Avenue
South Harbor Boulevard
South Lewis Street
North Main Street
North Glassell Street
North Hewes Street
North Cannon Street
Chapman Avenue
East Chapman Avenue
Euclid Street
West Street
Magnolia Street
The City Drive South
La Veta Avenue
Garden Grove Boulevard
Fairhaven Avenue
Trask Avenue
North Grand Avenue
Westminster Boulevard
Brookhurst Street
Harbor Boulevard
West 17th Street
East 17th Street
Hewes Avenue
La Loma Drive
Civic Center Drive West
North Main Street
East 4th Street
Irvine Boulevard
Newport Avenue
Red Hill Avenue
Bolsa Avenue
1st Street
Bristol Street
West 1st Street
90
91
57
39
5
55
22
S18
N
W
E
S
0
2,500
5,000
Feet
Sources: Esri, USGS, NOAA

Options

- Shutting down the well (replace with MWD water)
- Blending with imported water
- Blending with other groundwater
- Packing part of a well (avoid zones with PFAS)
- Engineered treatment (GAC, IX, or NF/RO)

Membranes
(RO or NF)

Ion Exchange (IX)

Carbon Adsorption (GAC)

- Planning Study awarded to Carollo on October 9, 2019
- fast paced study, 6 months total
- initial meeting between OCWD and Carollo, verified scope, individual Producer meeting agendas, provided all lab data
- hit the ground running... site visits

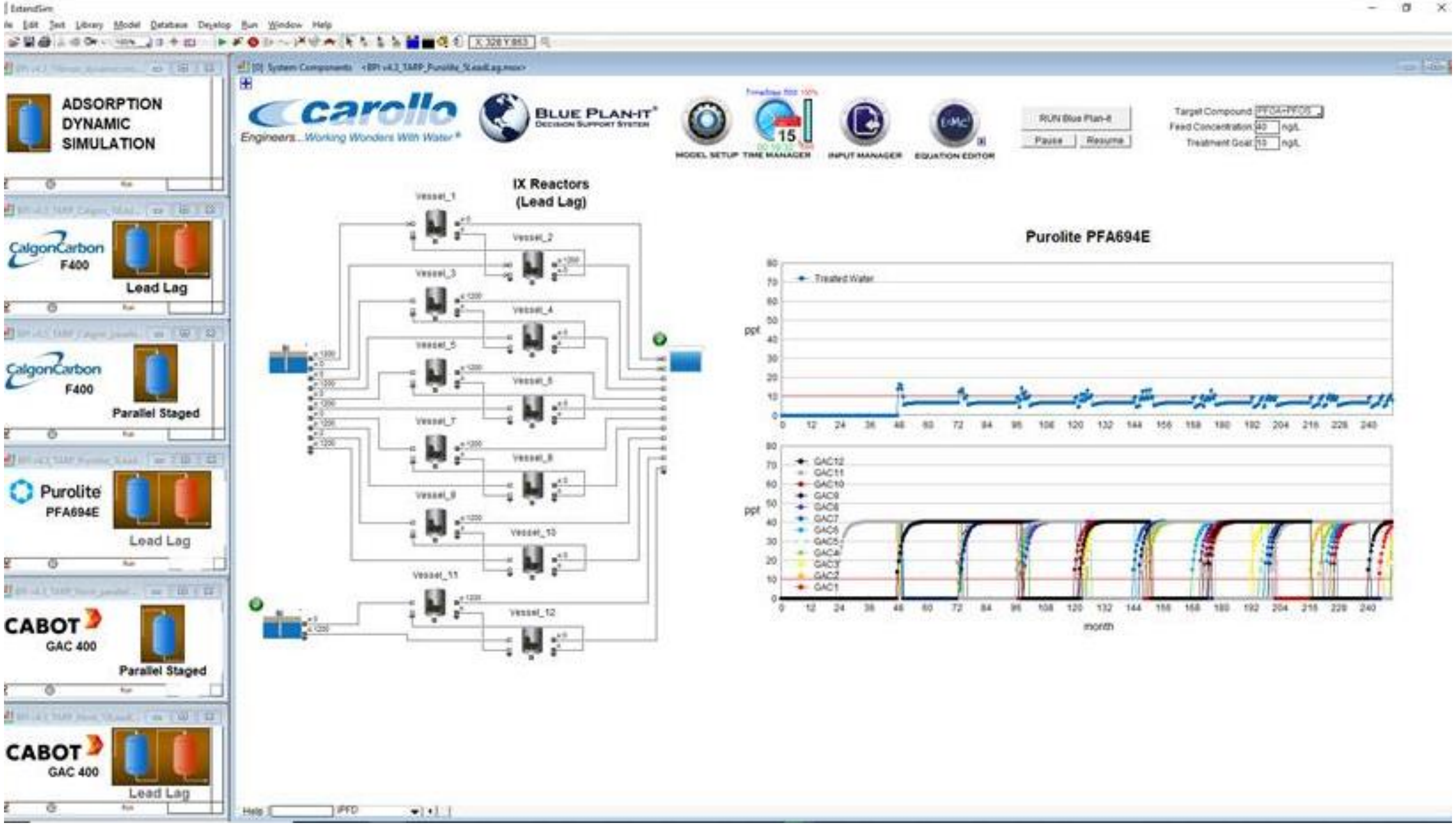
PFAS TREATMENT SYSTEMS PLANNING STUDY

Orange County Water District

Item No.	Priority	Item	Preferred Format	Responsible Party	Date Received
1	High	Documentation on hydraulic model development and/or update	any	City	
2	High	GIS Data - Pressure zone boundaries	GIS	City	
3	Received	GIS Data - Service area boundary	GIS	OCWD	11/4/2019
4	Received	GIS Data - Vacant land/parcels	GIS	OCWD	11/4/2019
5	High	GIS Data - Water distribution system (pipelines, pumps, tanks, treatment plants, supply sources, etc.)	GIS	City	
6	High	Hydraulic model	any	City	
7	High	Hydraulic profile	.pdf	City	
8	High	List of all existing well capacities	any	City	
9	High	Monthly imported water use (MGD) (2013-present)	any	City	
10	Received	2015 Urban Water Management Plan	.pdf	Carollo	11/4/2019
11	Medium	Existing evaluation criteria (minimum size for new pipes, minimum pressure, maximum velocity)	any	City	
12	Medium	Recent bid tabs for pipeline projects	any	City	
13	Low	Description of existing treatment systems at all wells (if available)	any	City	
14	Low	Treatment cost per acre-foot for all wells	any	City	
15	Low	Well as-built drawings (site and well) for all wells	.pdf	City	
16	Low	Well daily production rate (MGD) for all wells (2013-present)	xls	City	
17	Low	Well pump curves for all wells	any	City	

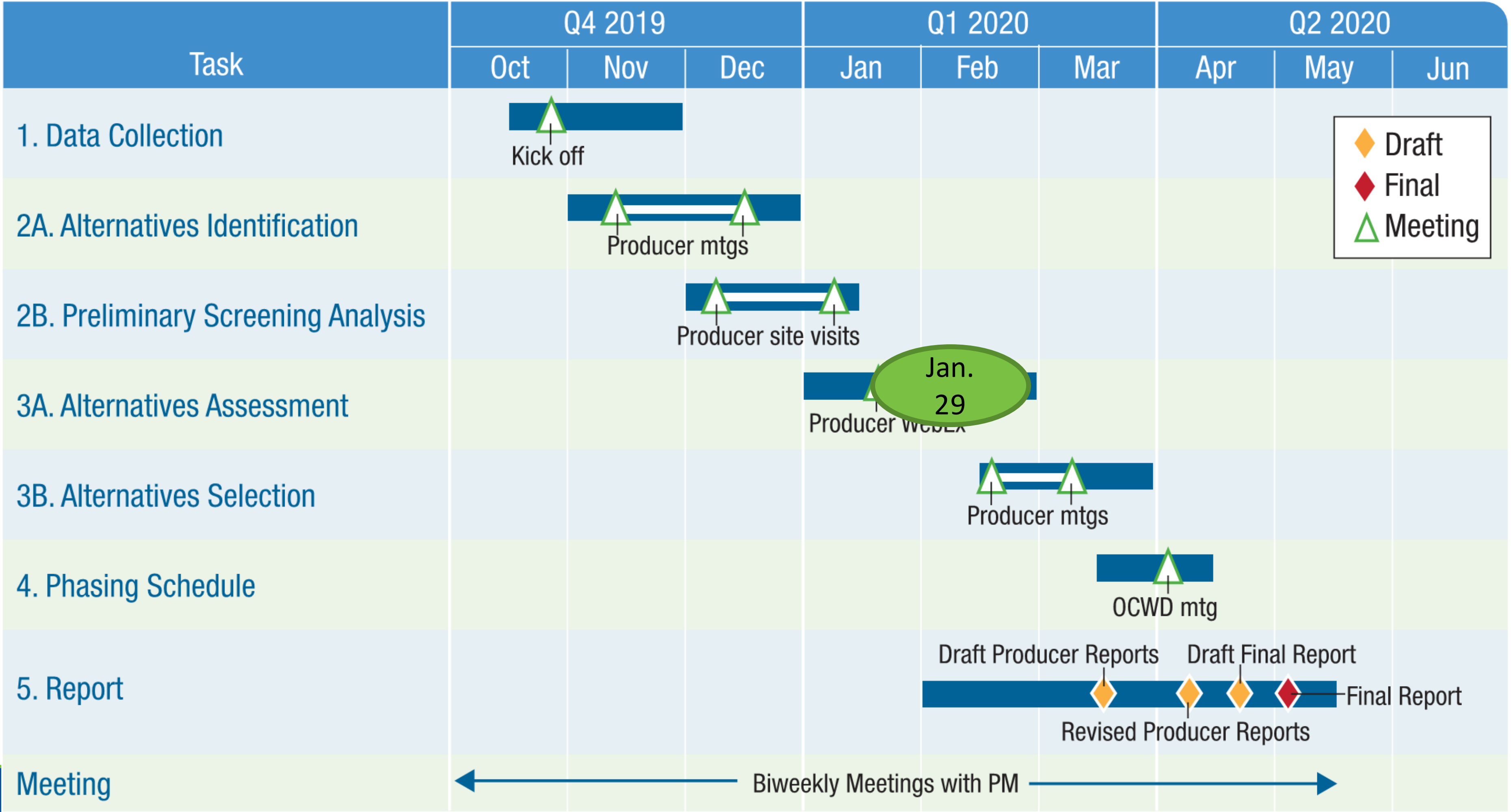
Legend		
	Low	Low Priority Data Need
	Medium	Medium Priority Data Need
	High	High Priority Data Need
	Received	Data Received

Blue Plan-it®

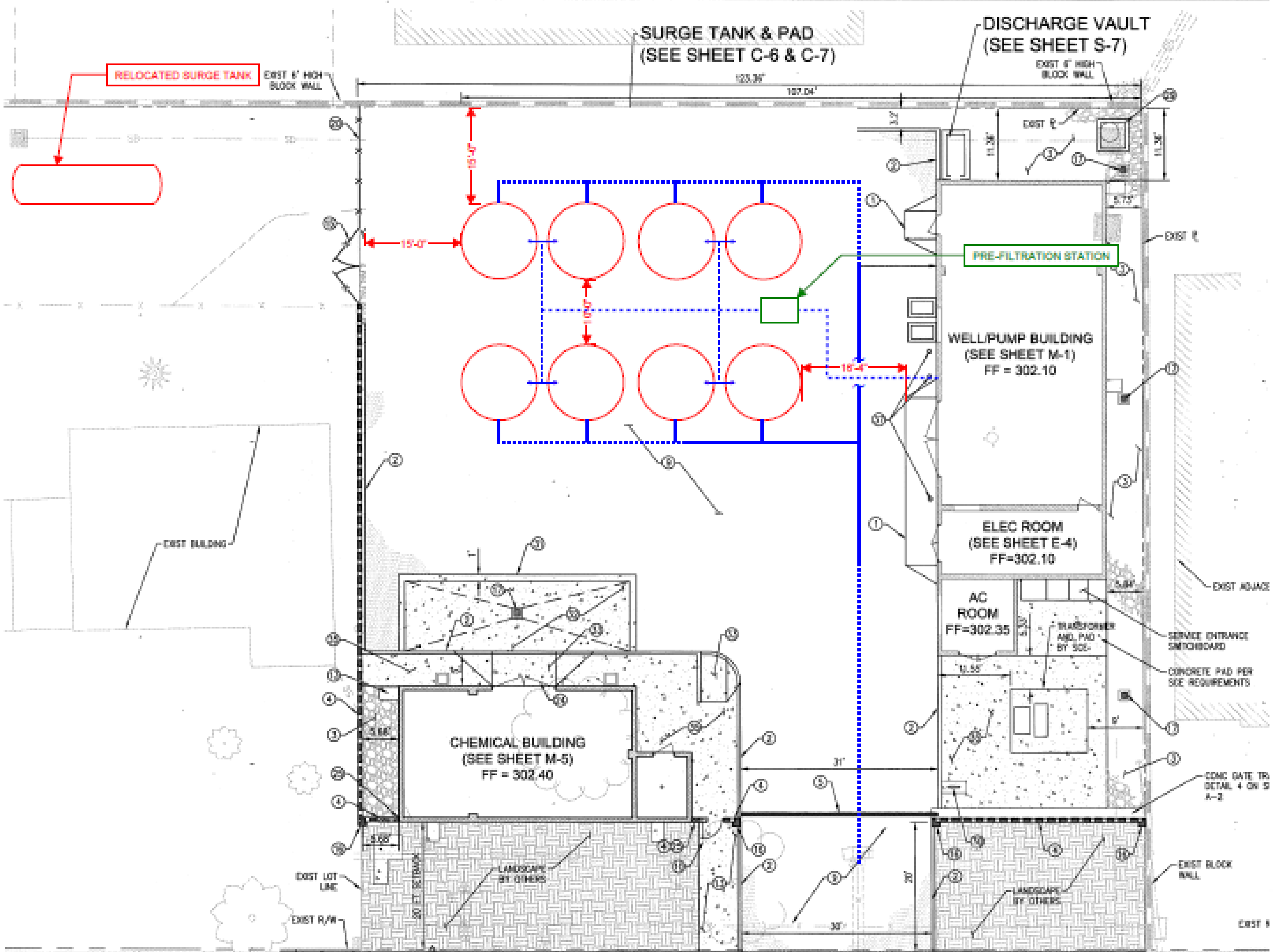


ADSORPTION DYNAMIC SIMULATION
CalgonCarbon F400
Lead Lag
CalgonCarbon F400
Parallel Staged
Purolite PFA694E
Lead Lag
CABOT GAC 400
Parallel Staged
CABOT GAC 400
Lead Lag
carollo
Engineers...Working Wonders With Water®
BLUE PLAN-IT®
MODEL SETUP
TIME MANAGER
INPUT MANAGER
EQUATION EDITOR
RUN Blue Plan-it
Pause
Resume
Target Compound
Feed Concentration
Treatment Goal
IX Reactors (Lead Lag)
Purolite PFA694E
Treated Water
ppt
month

Schedule



Task
Q4 2019
Q1 2020
Q2 2020
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
1. Data Collection
Kick off
2A. Alternatives Identification
Producer mtgs
2B. Preliminary Screening Analysis
Producer site visits
3A. Alternatives Assessment
Producer
Jan. 29
3B. Alternatives Selection
Producer mtgs
4. Phasing Schedule
OCWD mtg
5. Report
Draft Producer Reports
Draft Final Report
Final Report
Revised Producer Reports
Meeting
Biweekly Meetings with PM
Draft
Final
Meeting



SURGE TANK & PAD
(SEE SHEET C-6 & C-7)
DISCHARGE VAULT
(SEE SHEET S-7)
RELOCATED SURGE TANK
EXIST 6' HIGH BLOCK WALL
123.36'
107.04'
15'-0"
15'-0"
10'-0"
18'-4"
PRE-FILTRATION STATION
WELL/PUMP BUILDING
(SEE SHEET M-1)
FF = 302.10
ELEC ROOM
(SEE SHEET E-4)
FF=302.10
AC ROOM
FF=302.35
CHEMICAL BUILDING
(SEE SHEET M-5)
FF = 302.40
EXIST BUILDING
EXIST ADJACE
SERVICE ENTRANCE SWITCHBOARD
CONCRETE PAD PER SCE REQUIREMENTS
TRANSFORMER AND PAD BY SCE
LANDSCAPE BY OTHERS
EXIST LOT LINE
EXIST R/W
20' FT SETBACK
EXIST BLOCK WALL
31'
30'


WELL NO.5
WELL NO.3
LEGEND
Ion Exchange (lead-lag)
GAC (lead-lag, 10 min EBCT/vessel)

Preliminary Producer Report TOC

1. Introduction
   - Background
   - Regulations
   - PFAS Treatment
   - Distribution System
   - Existing Site Layout
2. Water Quality and Process Design Criteria
   - Water Quality
   - Treatment Goals
   - Data from Pilot Testing
3. Alternative Identification and Screening
   - Screening Criteria
   - Individual Wellhead Treatment
   - Centralized Treatment
   - Blending
   - Feasible Alternatives

Preliminary Producer Report TOC (continued)

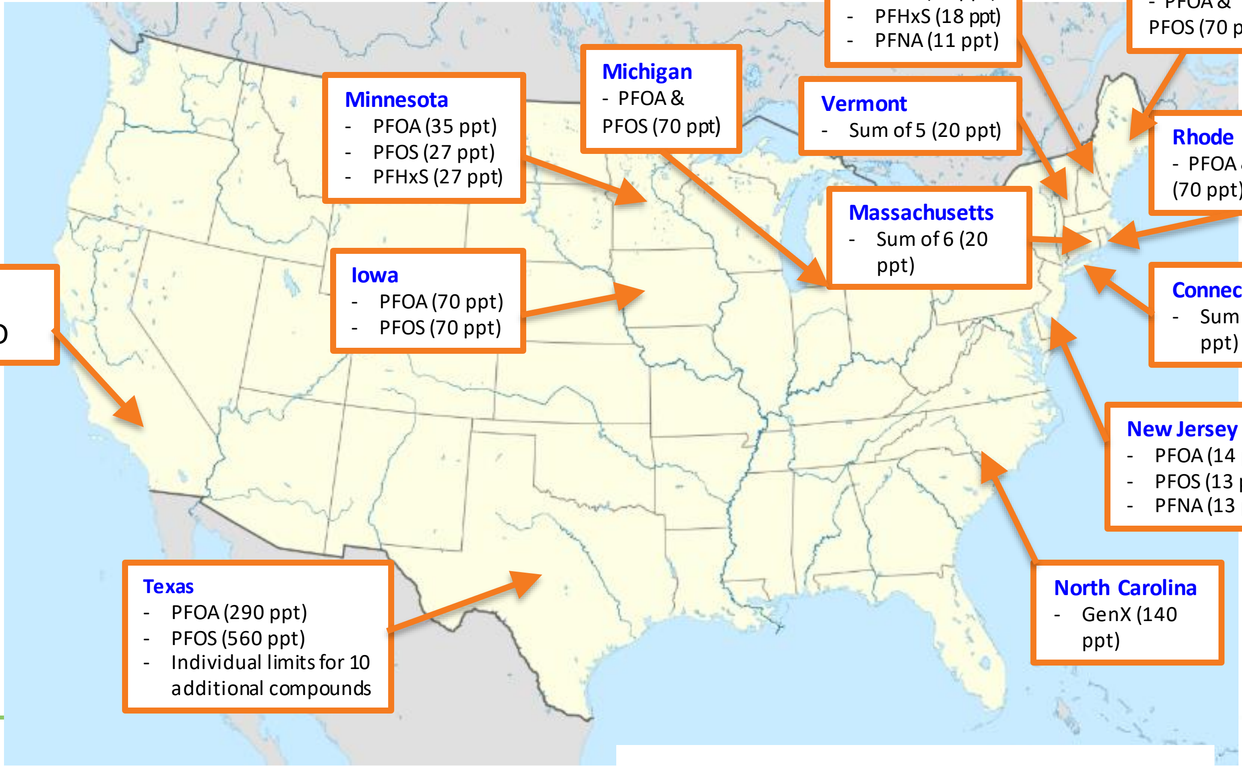
4. Alternative Assessment
   - Pretreatment Requirements
   - Design Criteria
   - Process Flow Diagrams
   - Site Layouts
   - Utilities (Electrical, sewer, storm drain, etc.)
   - Cost (Capital, O&M, and Life Cycle)
   - Construction Duration
   - O&M Activities
   - Permitting
   - Ranking and Selection

5. Conclusions and Recommendations

PFAS Treatment; Scaling Up to Full Scale Implementation Case Studies

Alan LeBlanc, CDM Smith

Regulatory Environment – States



California
- PFOA & PFOS TBD

Minnesota
- PFOA (35 ppt)
- PFOS (27 ppt)
- PFHxS (27 ppt)

Iowa
- PFOA (70 ppt)
- PFOS (70 ppt)

Michigan
- PFOA & PFOS (70 ppt)

Texas
- PFOA (290 ppt)
- PFOS (560 ppt)
- Individual limits for 10 additional compounds

New Hampshire
- PFOA (12 ppt)
- PFOS (15 ppt)
- PFHxS (18 ppt)
- PFNA (11 ppt)

Vermont
- Sum of 5 (20 ppt)

Massachusetts
- Sum of 6 (20 ppt)

Maine
- PFOA & PFOS (70 ppt)

Rhode Island
- PFOA & PFOS (70 ppt)

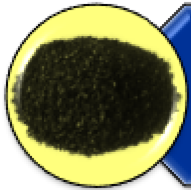
Connecticut
- Sum of 5 (70 ppt)

New Jersey
- PFOA (14 ppt)
- PFOS (13 ppt)
- PFNA (13 ppt)

North Carolina
- GenX (140 ppt)

PFAS Treatment

Available treatment technologies for PFAS removal:



Granular Activated Carbon (GAC)

Anion Exchange (AIX)

Membrane

PFAS Treatment Effectiveness

Table 2-1. Summary of PFAS removals for various treatment processes.

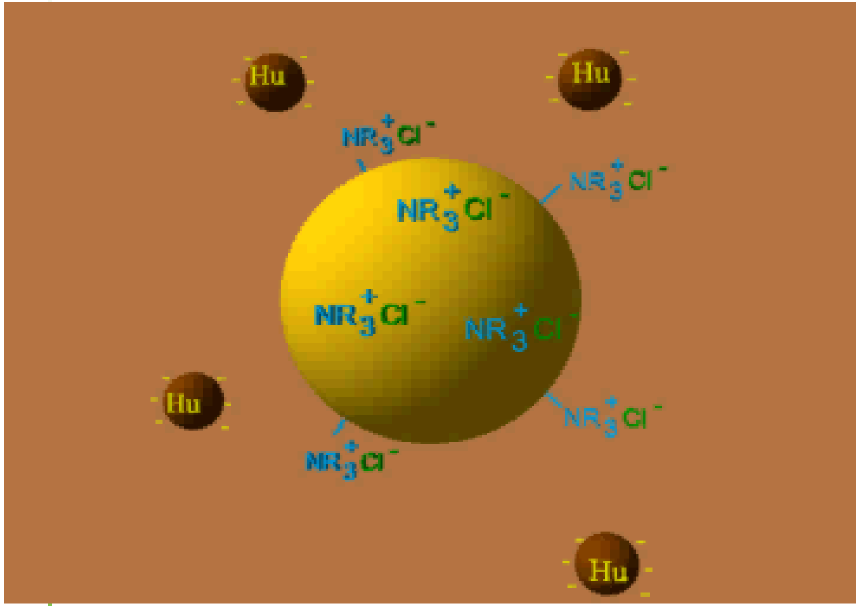
Compound	Molecular Weight (g/mol)	Aeration	Coagulation/Dissolved Air Flotation	Coagulation/Flocculation/Sedimentation/Granular Filtration or Microfiltration	Anion Exchange	Granular Activated Carbon Filtration	Nanofiltration	Reverse Osmosis	Permanganate/Ozone/Hypochlorous/Hypochlorite/Chloramination/UV photolysis
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)	■ (Assumed)	Unknown
N-EtFOSAA	585	●	Unknown	●	■ (Assumed)	■ (Assumed)	■ (Assumed)	■	Unknown

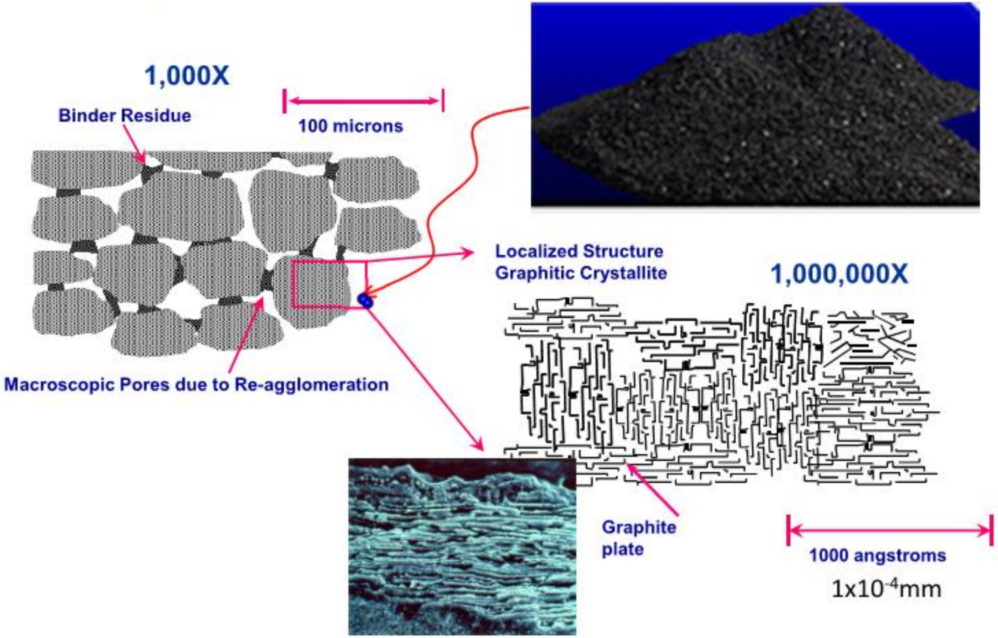
From Dickerson & Higgins, 2016 (WRF, #4322)

● Removal <10% ▼ Removal 10-90% ■ Removal >90% ☐ Unknown ☐ Assumed

Media for Removal of PFAS (GAC, IX)

- GAC – Adsorption process
- IX - Ion exchange process





Ion Exchange Resin

- Contained in columns 4 to 5 feet in depth
- 20 x 50 mesh area of bead-shaped particles – flow distribution
- Generally charged
  - Anionic
    - Exchange for negative ions
    - Charged with hydroxide (OH-) or chloride (Cl-) ions
  - Cationic
    - Exchange for positive ions
    - Charged with hydrogen (H+) or sodium (Na+) ions

GAC vs. AIX

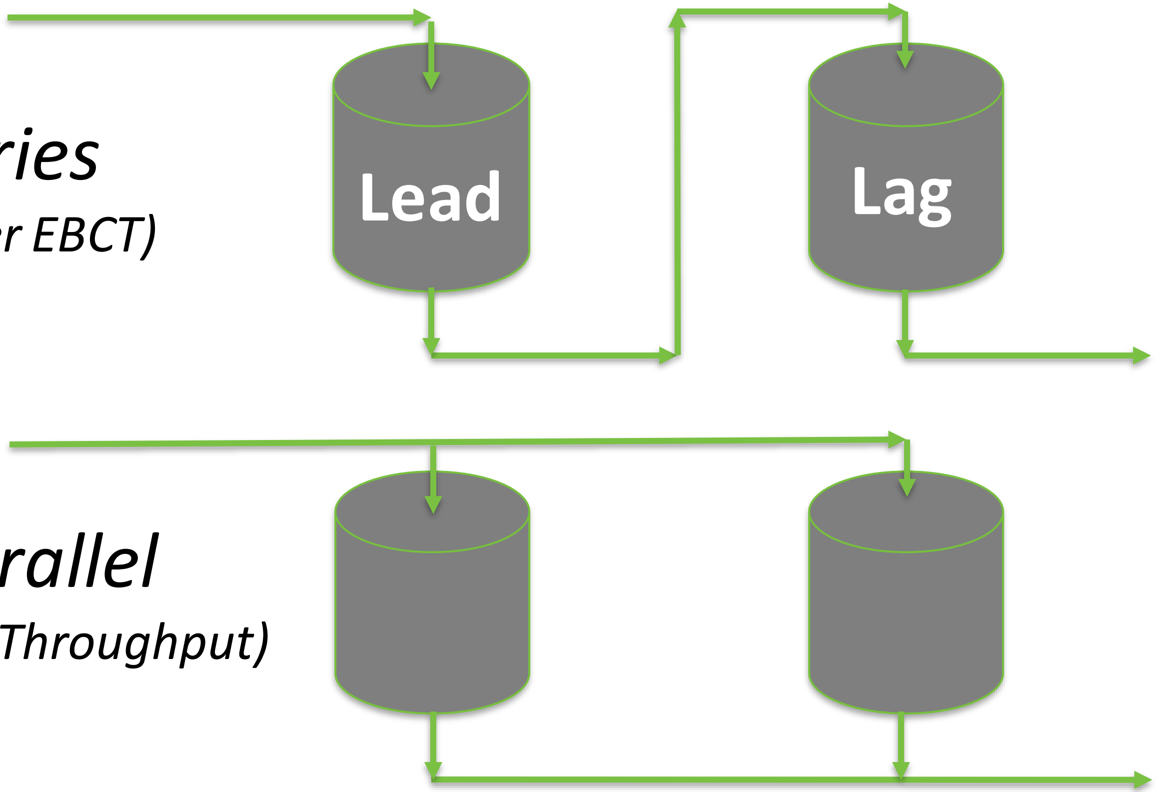
GAC	Single Use IX-R
7 to 20 minute EBCT	**2-3 minute EBCT**
Larger infrastructure footprint	Smaller infrastructure footprint
Typical bed life: 50,000-120,000 bed volumes	Typical bed life: 250,000-300,000 bed volumes
GAC media is less expensive	IX-R media is more expensive
Less effective for short chain PFAS	Effective for a wider range of PFAS, but less effective for PPCPs
Well established technology	Not as extensively practiced as GAC
Backwash is available	Backwash not recommended

- Life cycle costs for GAC and IX-R are often similar
- Neither is very effective for 1,4 Dioxane
- Both generate spent media requiring off-site reactivation (GAC) or incineration (IX-R)
- Pretreatment may be needed for both technologies to increase media life span

Series versus Parallel Operation

Series
(Longer EBCT)

Parallel
(Greater Throughput)



Pressure Vessel Sampling Ports

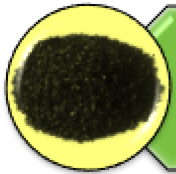
- Influent
- ¼ through bed
- ½ through bed
- ¾ through bed
- Effluent

Low Pressure Reverse Osmosis (RO) Membrane

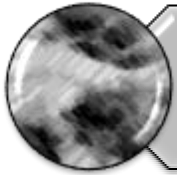
- Advantageous when removal of co-contaminants is needed
- Brunswick County, North Carolina
  - Surface Water, 35 mgd
  - PFAS, GenX, 1,4-dioxane, PPCPs, EDCs, pesticides/herbicides, NDMA, brominated DBPs, additional unidentified compounds
- Pilot-tested, designed, out to bid
- Residuals discharge
- Energy considerations

Bench-Scale Testing for PFAS Treatment

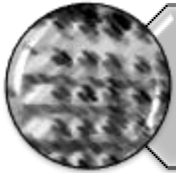
4 mgd plant (2016)



Granular Activated Carbon (GAC)



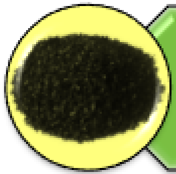
Anion Exchange (AIX)



Membranes

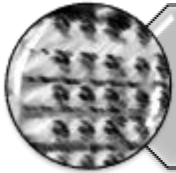
- ✓ Water quality (e.g., low organic)
- ✓ Familiarity with pressure vessels
- ✓ No liquid waste stream of concern
- ✓ Comparatively lower cost (vs. membrane)

2 mgd plant (2017)



Granular Activated Carbon (GAC)

Anion Exchange (AIX)



Membranes

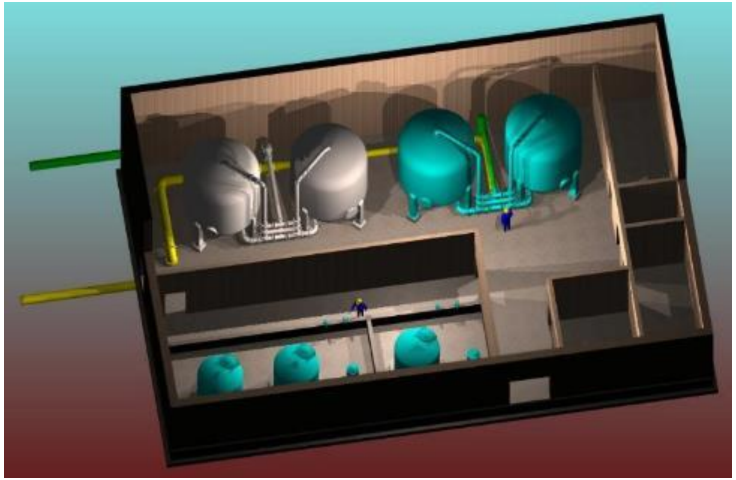
Bench-Scale Testing

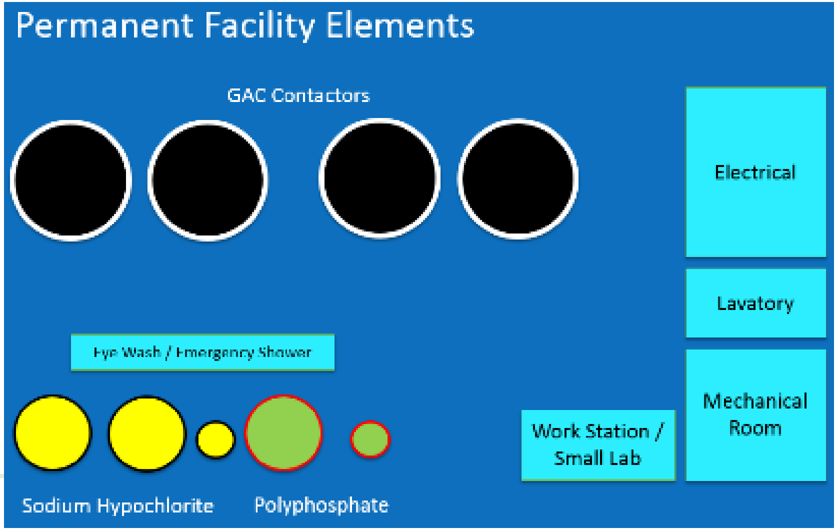
Bench-scale column tests performed at CDM Smith's Bellevue Research & Testing Laboratory to investigate two GAC products (coal-based vs. coconut-based)

- ✓ 9.8 minutes of empty bed contact time (EBCT)
- ✓ No measurable GAC breakthrough of any PFAS
- ✓ No change in anions levels
- ✓ No detection of arsenic
- ✓ No generation of long-chain PFAS from post-GAC treatment with sodium hypochlorite and phosphate
- ✓ Estimated longevity for GAC = 27,000 bed volumes

Conceptual Design

- PFAS treatment facility with a 2,700 gpm capacity
  - Sodium hypochlorite and phosphate chemical systems
  - Laboratory / office area
- Develop facility floor plan and site plan
- Cost estimate
- Permitting requirements





Final Design – It's More than Just PFAS Treatment

- Well pump hydraulics
- Remote location – fiber optic / radio communication upgrades & additional electrical supply needed
- Bulk truck media delivery in civil / mechanical design
- State and local permits

Current Status & Future Steps

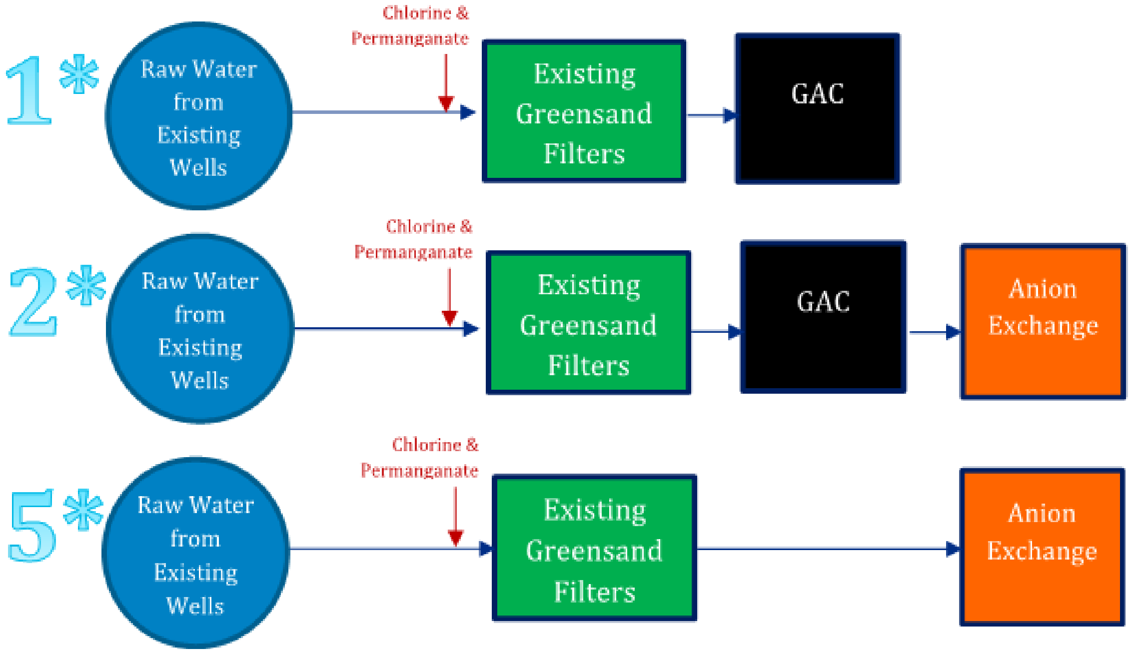
- $5.5 Million construction cost
- Plant on-line soon

Case Study – 2 mgd plant

- Three groundwater wells
- Existing treatment plant:
  - Greensand filtration for iron and manganese removal
  - Chemical treatment (e.g. pre-oxidation, disinfection, pH adjustment)
- Test for PFAS in September 2016 due to proximity to military base

Bench Scale Testing: GAC versus Anion Exchange

PFAS treatment process to be placed downstream of the existing greensand filters (post iron & manganese removal)



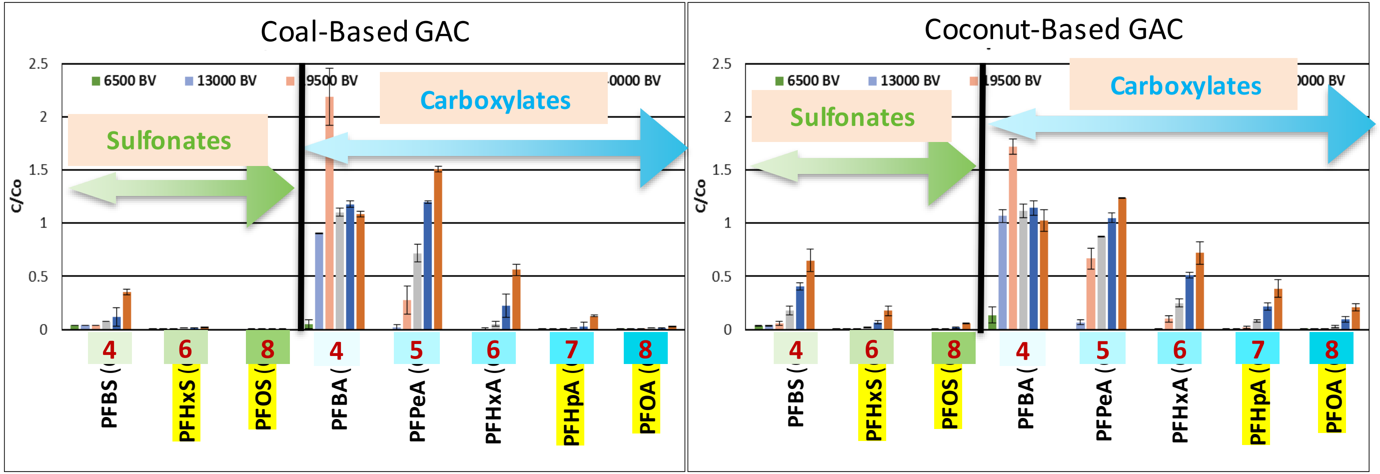
Bench Scale Testing: GAC versus Anion Exchange

Bench-scale testing to investigate:

- Two (2) GAC media
  - Coal-based vs. coconut-based
- Two (2) AIX resin media
  - Gel vs. macroporous
- GAC followed by AIX
- Impact of chlorine residual on PFAS removal

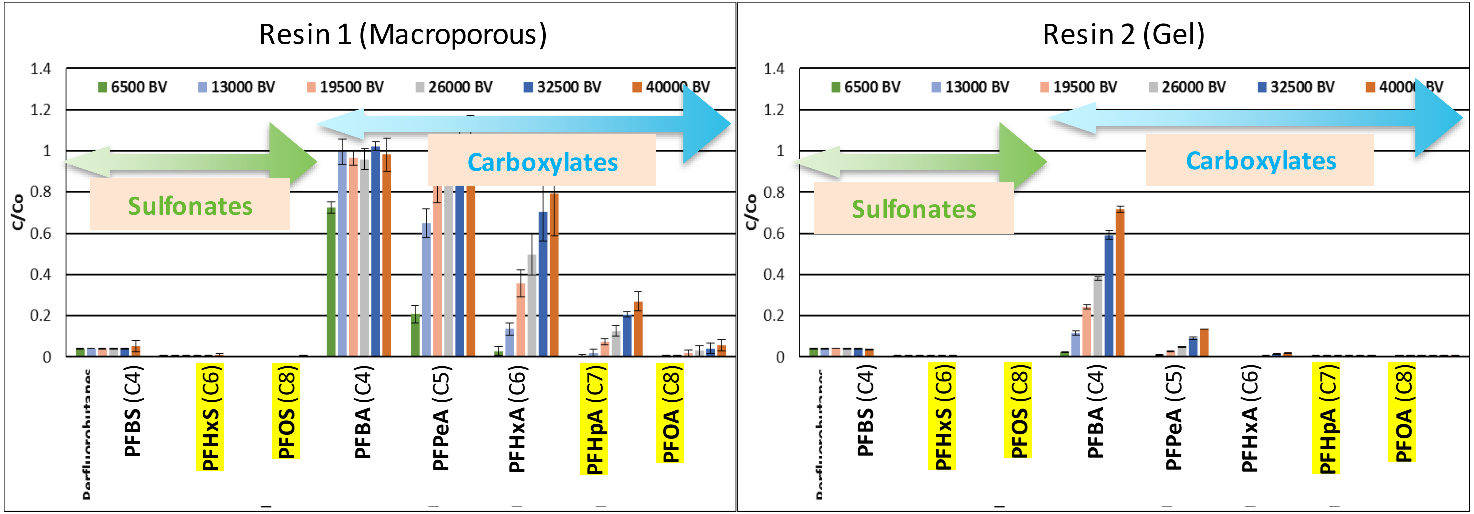
CDM Smith's Bellevue Laboratory, Washington

GAC



- Data in C/Co = final conc. / initial conc. = removal efficiency
- Lower C/Co = better PFAS removal
- The two GAC products behaved similarly
- Better removal efficiency with sulfonates than carboxylates
- Better removal efficiency with longer chain compounds

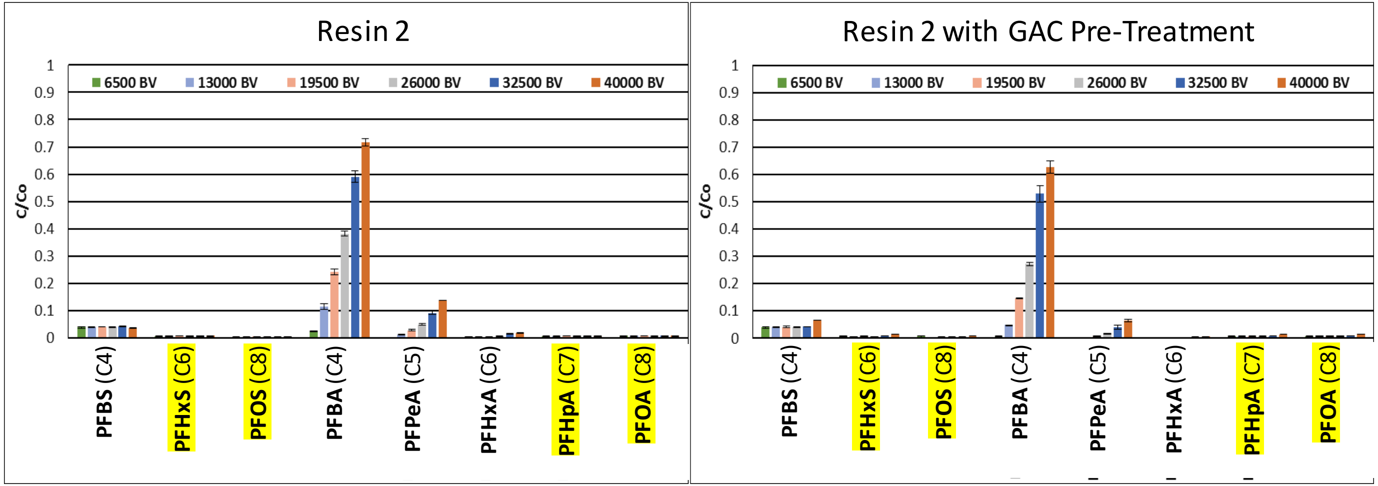
AIX



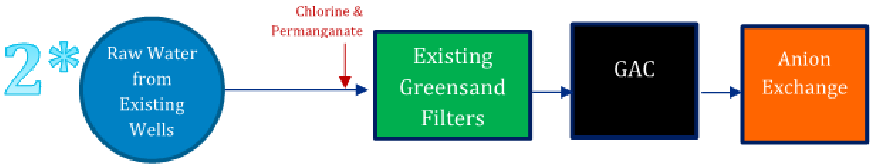
- Resin 2 is specific for PFAS removal
- Significant differences in PFAS removal efficiency between the two resins tested
- **Harder to remove shorter chain carboxylates**

Effects of Pre-GAC Treatment

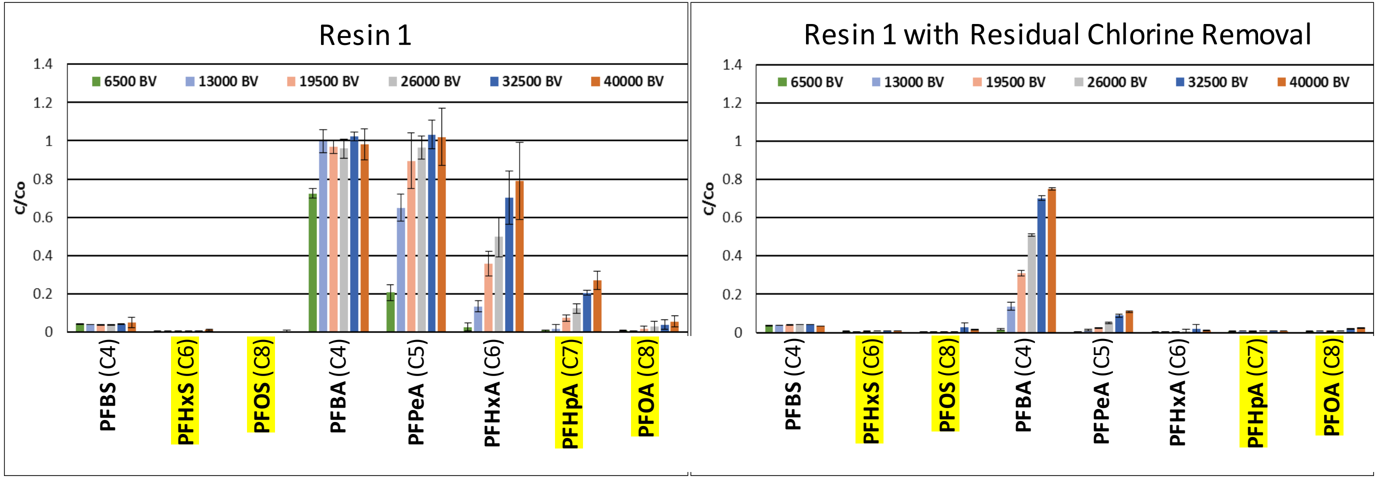
TOC = ~0.5 mg/L



Marginal improvement in treatment effectiveness by GAC pre-treatment upstream of AIX



Effects of Residual Chlorine Removal on AIX



- Chlorine residual in influent from the existing greensand filters
- Removal of residual chlorine (0.2-0.5 mg/L) with calcium thiosulfate resulted in enhanced PFAS removal efficiency
- Despite the dechlorination, PFBA still broke through quickly

Chloride to Sulfate Mass Ratio (CSMR)

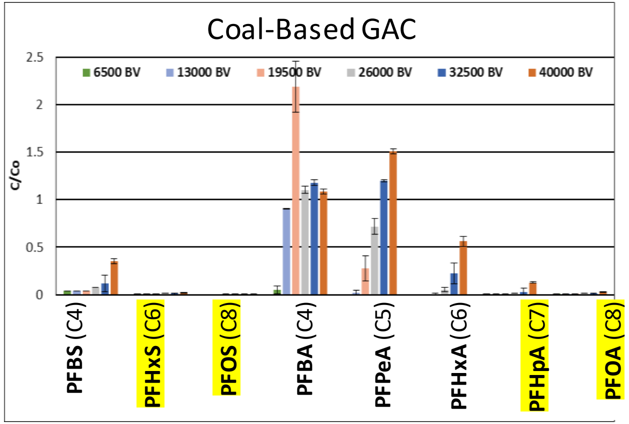
- Increased CSMR is associated with galvanic corrosion of lead solder connected to copper pipes
  - Raw water: **Average sulfate = 16.6 mg/L**
  - After 1,000 BVs:
    - Resin 1: sulfate = **6.4 mg/L**
    - Resin 2: sulfate = **16.6 mg/L**
  - After ~30,000 BVs:
    - Both Resin 1 and Resin 2 at the raw water sulfate level

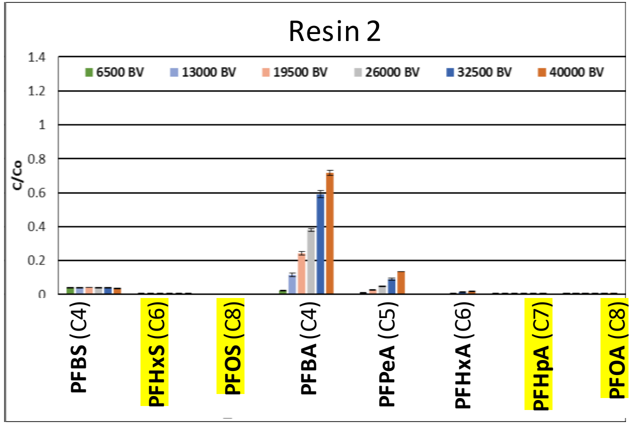
$$CSMR = \frac{\mathbf{Chloride}}{\mathbf{Sulfate}}$$

Scenario	CSMR
Current	7.7
After 1000 BVs – Resin 1	20
After 1000 BVs – Resin 2	7.7

Bench Scale Testing Conclusions

- Overall, both AIX and GAC treated the MassDEP PFAS effectively, but differences in performance among the media products were observed
- AIX outperformed GAC over 40,000 bed volumes and was chosen as the treatment technology for removing a wider range of PFAS including shorter chain compounds
- Resin 2 outperformed Resin 1 – no breakthrough in PFOA, PFOS, PFHpA & PFHxS
- Resin 2 impacted CSMR over a shorter duration than Resin 1
- De-chlorination improved AIX's PFAS removal effectiveness





Facility Design Concept

- New PFAS treatment facilities to be located aside existing WTP
- $3.1 Million construction bid received June 2019

Media Life Cycle Cost Comparison – Example

Parameters	GAC 1	AER 2
Vendor-recommended EBCT	10 mins	3 mins
Estimated unit cost	$2.00/lb	$6.46/lb
Amount of media per 12-ft diameter vessel	40,000 lbs	18,600 lbs
Media depth	11.8 ft	4.2 ft
Estimated changeout cost	$80,000/vessel	$120,000/vessel
Estimated changeout rate at 11.5 ppt of PFOA in lead vessel	Every 90,000 EBVs *(approx. 1.8-3.5 yrs*)*	Every 190,000 EBVs *(approx. 1.1-2.1 yrs*)*
Annual changeout cost for lead vessel	$228,000-$434,000*	$450,000-$881,000*

Real-Life PFAS Treatment Experiences

- Water customers' expectations ≠ Regulatory requirements
- Bituminous GAC can initially increase pH and release arsenic
- Marketplace for GAC (Calgon, Evoqua, Cabot/Norit) and anion exchange (Evoqua/Dowex, Purolite, Calgon) is competitive
- The companies and others offer the pressure vessels that house the media
- Oftentimes, the non-PFAS work becomes the project focal point

PFAS State of Research and Emerging Technologies

Jennifer Hooper, CDM Smith

State of Research on PFAS: *Fate and Transport, Occurrence, Treatment, Sampling and Analysis*

- WRF Research Priority Program Area: *Management, Analysis, Removal, Fate and Transport of PFAS in Water*
  - WRF 4322: Treatment Mitigation Strategies for PFCs
  - WRF 4913: Investigation of Treatment Alternatives for Short-Chain PFAS
  - WRF 5042: Assessing PFAS Release from Finished Biosolids
  - WRF 5031: Occurrence of PFAS in US WWTPs
- DoD (ESTCP/SERDP) has significant investments in research for treatment, analysis, ecotoxicity, fate and transport

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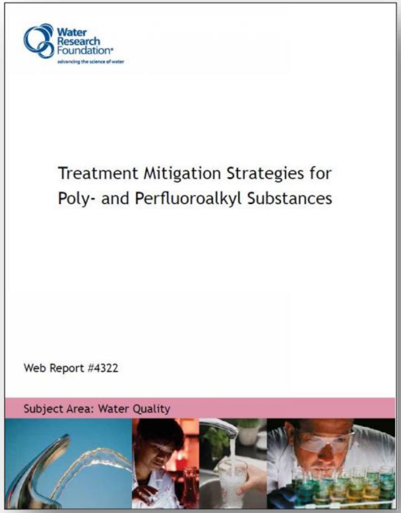
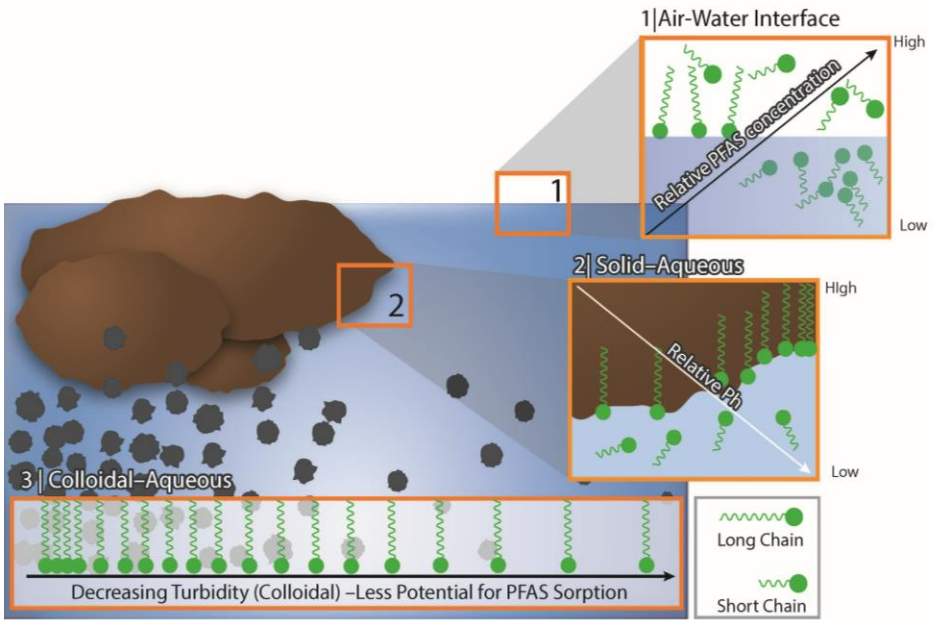


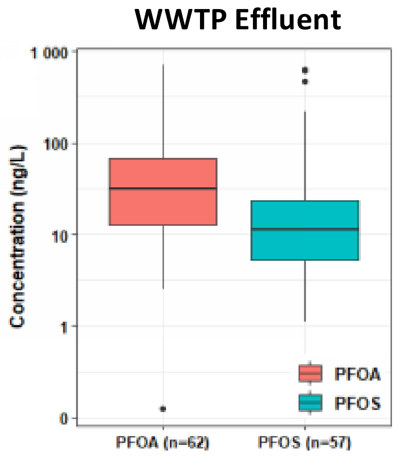
Fate and Transport During Water Treatment

- Precursor transformation
  - PFAS analysis via LC and GC
- Adsorption to solids
- Interfacial uptake (partitioning into air/water, water/surface, air/water/surface)
- Colloidal attachment
- Volatilization

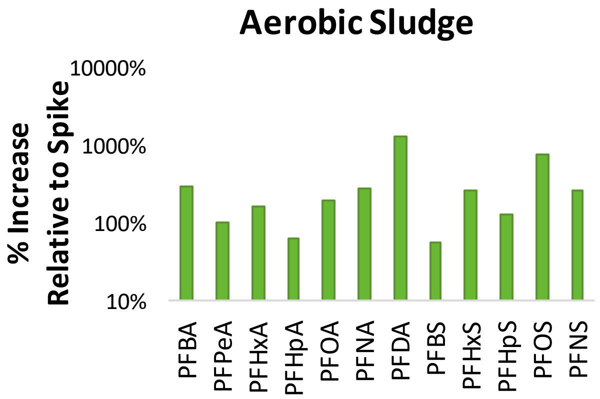


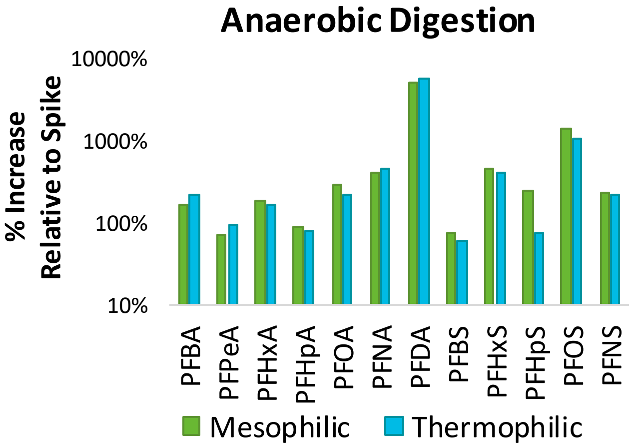
Occurrence of PFAS in US WWTPs (WRF 5031)

- Evaluate occurrence and phase partitioning at 40 facilities
- PFAA mass loading may increase in WWTPs
- Transformation of precursors through various treatment steps



**Data prepared by SNWA*





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TEXAS TECH UNIVERSITY

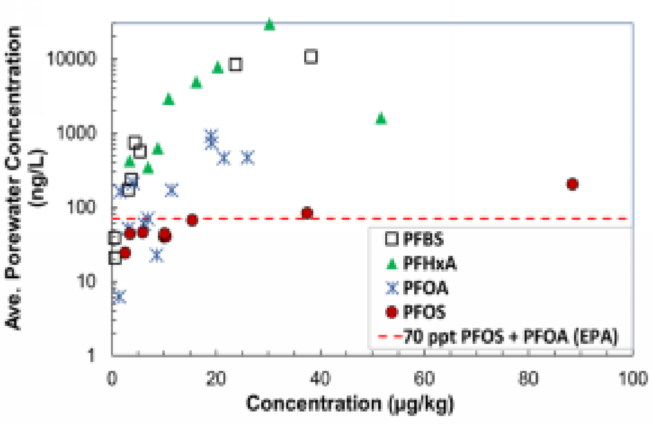
Southern Nevada Water Authority

Gwinnett

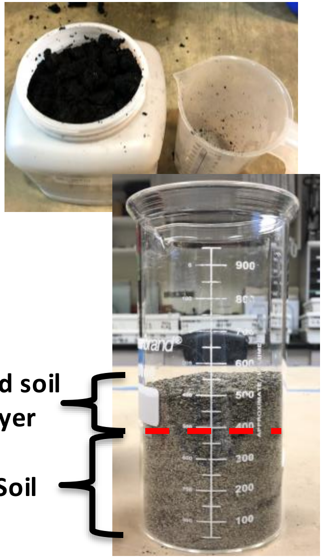
NC STATE UNIVERSITY

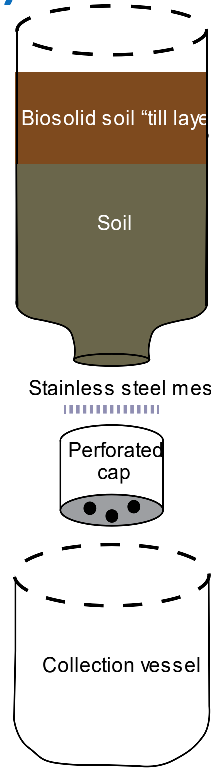
Release of PFAS From Biosolids (WRF 5042)

- Leaching of PFAS from biosolids from 7 facilities
  - Desorption equilibrium
  - PFAS leaching from biosolids in outdoor mesocolumns over 6 months



**Data generated by Dr. Linda Lee at Purdue*





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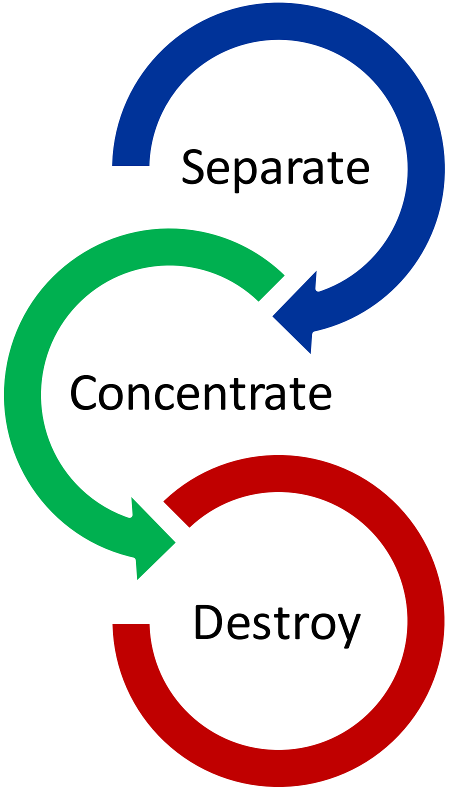
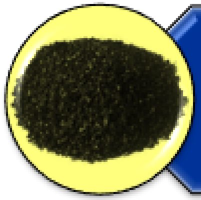
R&D Need for Comprehensive PFAS Treatment Solutions



Treatment Goals	Example Technologies
• Protect human health and the environment • Meet safe drinking water and discharge requirements	• GAC, AIX, RO (demonstrated) • NF • Regenerable sorbents • Foam fractionation
• Reduce waste stream volume	• Regenerable media → regenerant waste • Surfactant or coagulant separation → PFAS laden flocs • Foam fractionation → foam concentrate
• Zero PFAS waste discharge	• High temp thermal, electrochemical, plasma, sonolysis, others

Demonstrated Water Treatment Technologies



Granular Activated Carbon (GAC)

Anion Exchange (IX) Resin

Membrane Filtration

GAC and IX Resin: Rapid Small Scale Column Testing (RSSCT)

- Examine breakthroughs of short chain and long chain PFAS
- Compare PFAS removal effectiveness between GAC and ion exchange resin
- Evaluate performance of different commercial products
- Evaluate impact of site-specific parameters such as co-contaminants (VOCs), geochemical water quality (e.g., TOC, iron, pH), water treatment additives (e.g., chlorination, corrosion inhibitors) on PFAS removal effectiveness
- Evaluate need for pre-treatment

I&EC research
Industrial & Engineering Chemistry Research
Research Note
Cite This: *Ind. Eng. Chem. Res.* XXXX, XXX, XXX−XXX
pubs.acs.org/IECR

Assessing Rapid Small-Scale Column Tests for Treatment of Perfluoroalkyl Acids by Anion Exchange Resin

Charles E. Schaefer,[*,†] Dung Nguyen,[‡] Paul Ho,[‡] Jihyon Im,[§] and Alan LeBlanc[§]

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[‡]CDM Smith, 14432 SE Eastgate Way, #100, Bellevue, Washington 98007, United States
[§]CDM Smith, 670 North Commercial Street, #208, Manchester, New Hampshire 03101, United States

GAC Performance

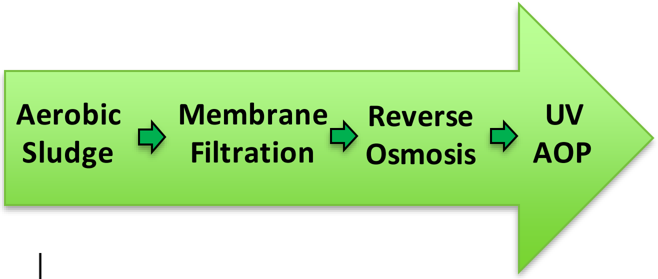
- Short-chain PFAAs break through faster than long-chain
- PFCAs break through faster than PFSAs
- Elevated TOC and/or chlorinated solvents at low (ppb) levels
- Coconut-based and bituminous coal-based carbons can be used
- Bituminous carbons are a reliable choice for PFAS treatment
  - Possible arsenic leaching
- May initially increase pH

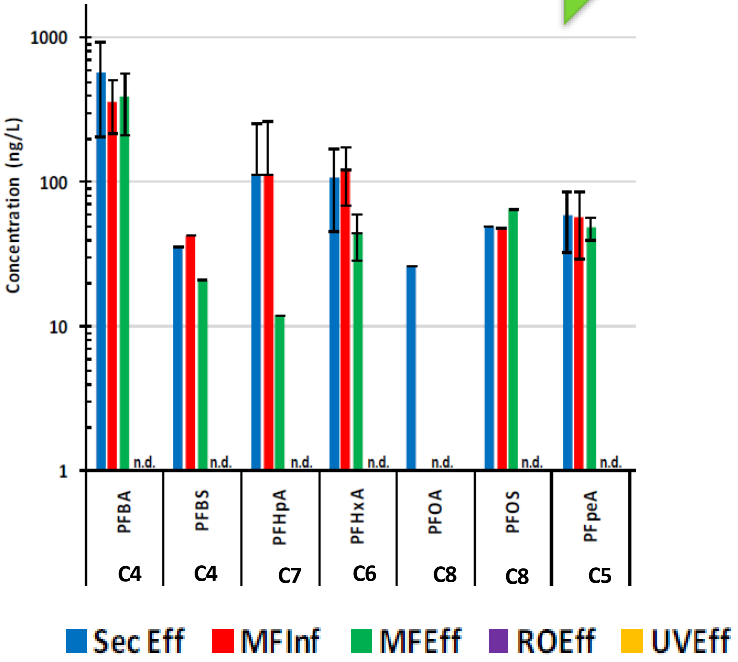
IX Resin Performance

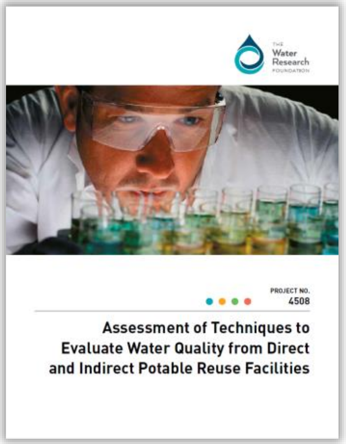
- Short-chain PFAAs break through faster than long-chain
- PFCAs break through faster than PFSAs
- Elevated TOC, iron and manganese adversely impacts performance
- Residual chlorine (0.3 mg/L) and/or polyphosphate (0.5 mg-P/L) negatively impacted removal
- Potential precipitate formation depending on geochemistry

RO Performance

- Multi-log removal efficacy across RO
- RO is a high energy process
- Generates a concentrated waste stream







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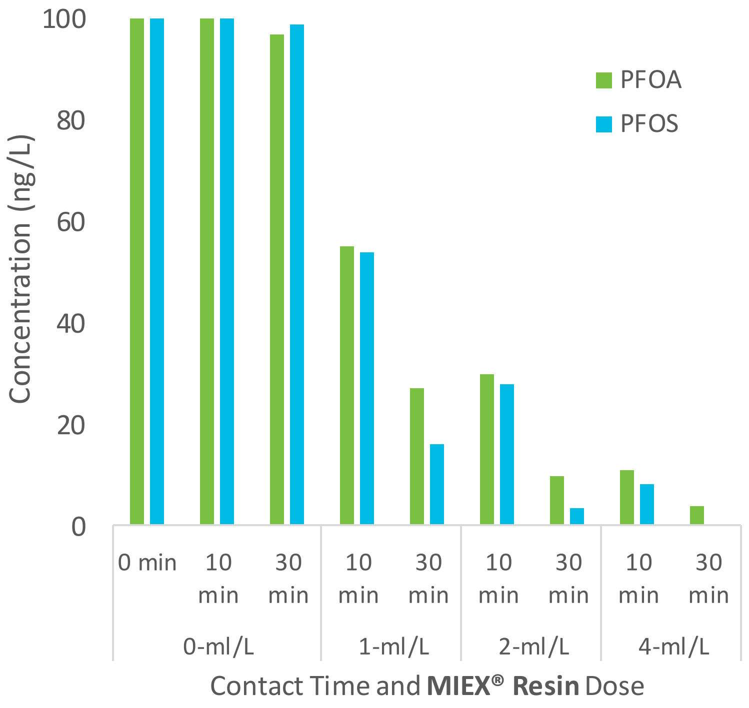
Emerging Technologies: Sorptive Removal

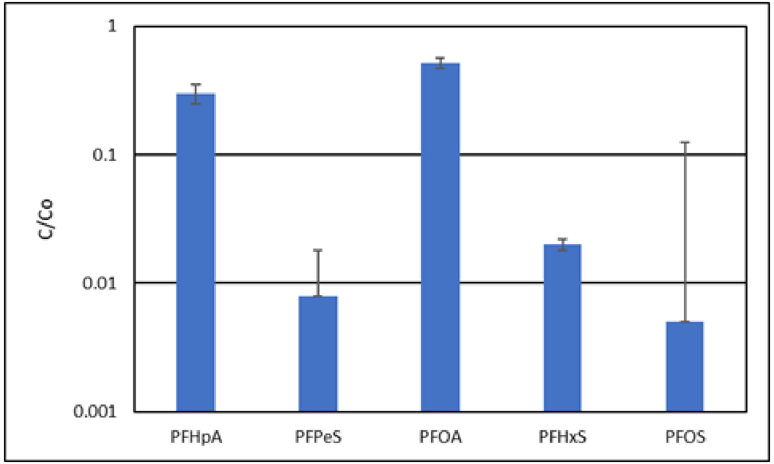
- MIEX
  - Strong base resin
  - Used for NOM, DBP precursors and DBPs
  - PFAS removal affected by
    - pH
    - NOM
    - Better removal for sulfonic than carboxylic PFAS
- PAC *(NC State University)*
- Other sorbents: aerogel, silver-doped IX, organically modified silica, fluorographene, cyclodextrin polymer *(SNWA)*



Emerging Technologies: Surfactant and Coagulant Removal

- **Surfactant and coagulant-enhanced removal**
  - 10 commercially available and proprietary petroleum-based surfactants
  - Alum, $FeCl_3$, Poly DADMAC
- **PerfluorAd**
  - Derived from plant-based fatty acids
  - Low volume of micro flocs generated
  - Large scale pilot tested in Europe and commercially available in the US
  - Low cost

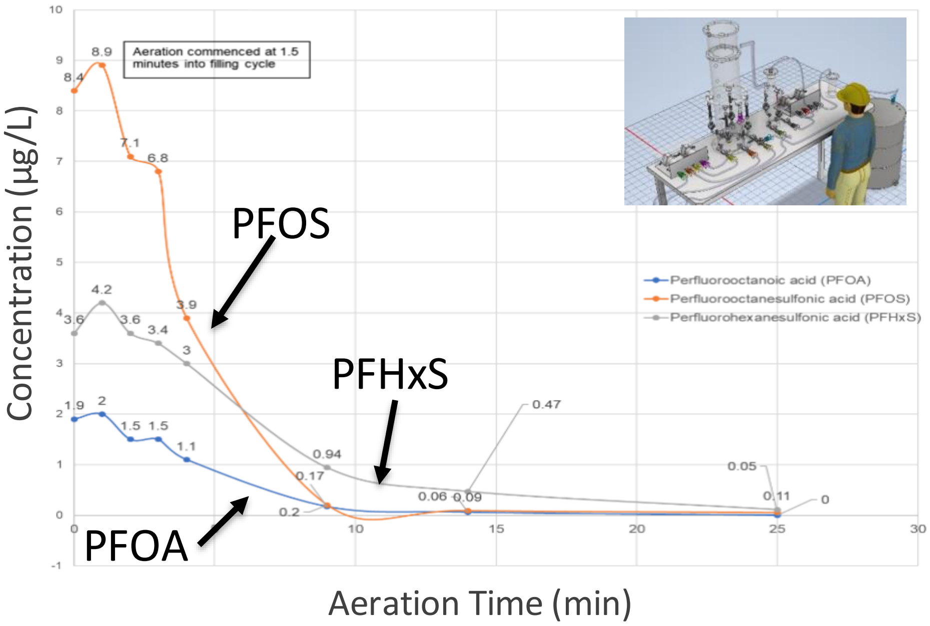
PerfluorAD Optimal dose
PerfluorAd (100 mg/L) + ferric chloride (150 mg/L)



*Developed by Cornelson and TRS

Emerging Technologies: Foam Fractionation

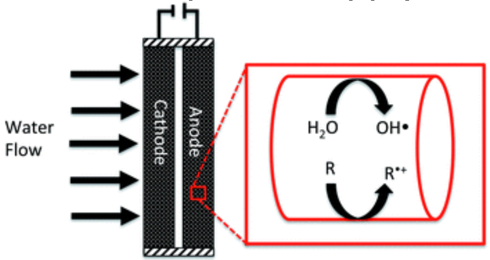
- **Foam fractionation**
  1. air bubble injection accumulates PFAS into air/water interface (foam)
  2. foam is removed and disposed or liquified via sonication and treated
- May 2019: 70,000 gpd system commenced in Australia
- 400 gal concentrate from 4M gal water treated (10,000 enrichment)
- No chemicals or spent media generated



https://www.youtube.com/watch?v=U25h5sLkf_s

Emerging Technologies: Destructive Te

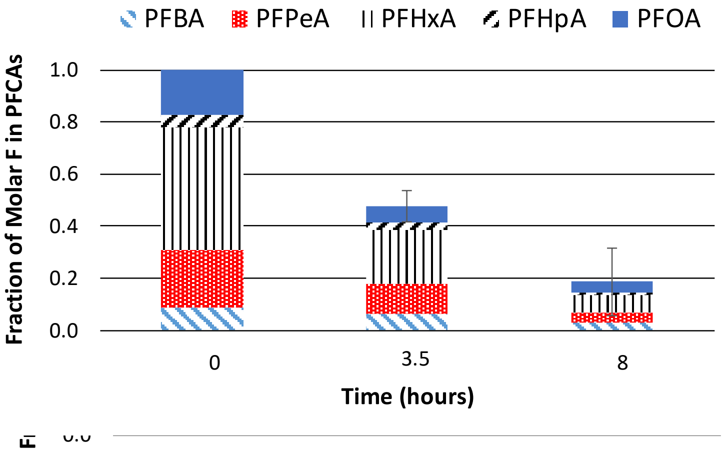
- PFAS destruction requires high energy to break C-F bond
- PFAS are mineralized to F^- and CO_2
- Stainless steel anode and boron-doped diamond cathode
- 80% reduction of PFCAs and PFSAs after 8-hr treatment
- No transient increases in PFCAs or PFSAs
- 200 W power supply; 25 – 200 mA/cm^2

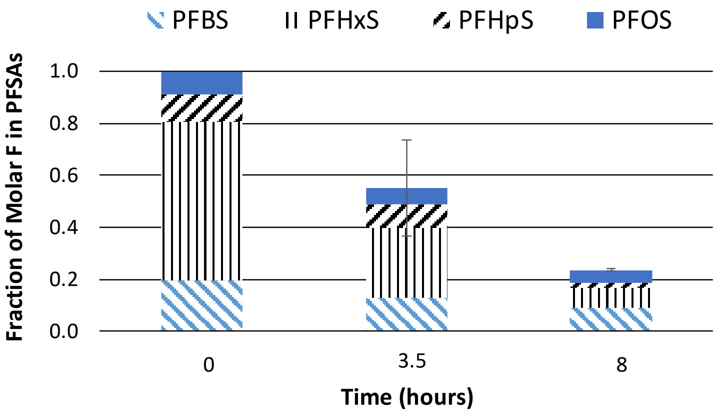


Environmental Science & Technology
Article
Cite This: Environ. Sci. Technol. 2018, 52, 10689–10697
pubs.acs.org/est

Electrochemical Transformations of Perfluoroalkyl Acid (PFAA) Precursors and PFAAs in Groundwater Impacted with Aqueous Film Forming Foams

Charles E. Schaefer,[*,†] Sarah Choyke,[‡] P. Lee Ferguson,[‡] Christina Andaya,[§] Aniela Burant,[∥] Andrew Maizel,[∥] Timothy J. Strathmann,[∥] and Christopher P. Higgins[∥]

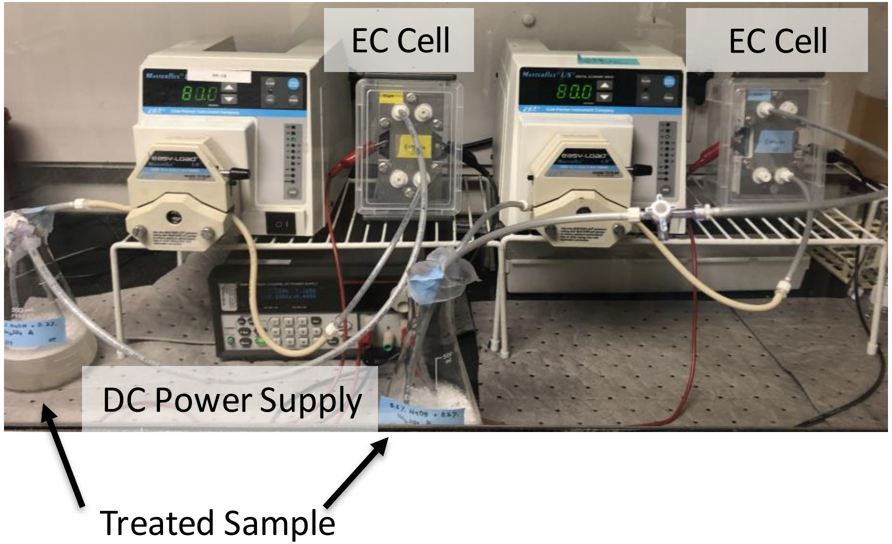




Emerging Technologies: Destructive Technologies

- WRF 4913: Investigation of Treatment Alternatives for Short-Chain Poly and Perfluoroalkyl Substances

- SERDP ER18-1063: Regenerable Resin Sorbent Technologies with Regenerate Solution Recycling for Sustainable Treatment of PFAS



Emerging Technologies: Destructive Technologies

- **UV/Reduction:** UV/indolacetic acid (IAA) with modified montmorillonite clay and UV/sulfite

- **Comprehensive treatment**
  - Separate concentrate and destroy!
  - NF or RO → reject concentrate → electrochemical or plasma
  - Foam fractionation → foam concentrate → electrochemical

UV batch reactor

Panel Discussion – Second Session

Adjourn