Agenda

1. What are PFAS?
2. Fate and transport in the environment
3. Health effects
4. Regulatory limits / exposure thresholds
5. Treatment
6. What’s next?
What are PFAS?
What are PFAS?

• PFAS: Per- and polyfluoroalkyl substances
• Resistant to heat; water- and oil-repelling properties; friction-reducing properties; non-biodegradable
• Used as surfactants and coatings for the past 60 years
• Thousands of compounds
• Two in particular are more prevalent in environment / studied more extensively
  – PFOA: Perfluorooctane carboxylate (perfluorooctanoic acid)
  – PFOS: Perfluorooctane sulfonate (perfluorooctanesulfonic acid)
PFAS chemical families

PFAS
- Non-polymer
  - Perfluorinated
    - PFAAs
    - PFCAs
    - PFASs
    - FASAs
  - Polyfluorinated
    - PFOA
    - PFOS
- Polymer
  - Potential Precursors
  - Coatings
    - Precursors / intermediates
      - Surfactants
PFAS chemical families

<table>
<thead>
<tr>
<th>Compound class</th>
<th>Features of chemical structure</th>
<th>Classification</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perfluoroalkylsulfonates (PFSA)</td>
<td>$\text{F}_3\text{C}-\left[\text{F} \cdot \text{F} \cdot \text{F} \cdot \text{S} \cdot \text{O} \cdot \text{O}\right]_n$</td>
<td>Perfluorinated</td>
<td>PFOS ($n = 7$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PFHxS ($n = 5$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PFBS ($n = 3$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PFNA ($n = 7$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PFOA ($n = 6$)</td>
</tr>
<tr>
<td>Perfluoroalkylcarboxylates (PFCA)</td>
<td>$\text{F}_3\text{C}-\left[\text{F} \cdot \text{F} \cdot \text{F} \cdot \text{C} \cdot \text{C} \cdot \text{O} \cdot \text{O}\right]_n$</td>
<td>Perfluorinated</td>
<td>PFHpA ($n = 5$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PFHxA ($n = 4$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PFBA ($n = 2$)</td>
</tr>
<tr>
<td>Fluorotelomer sulfonates (FTSA)</td>
<td>$\text{F}_3\text{C}-\left[\text{F} \cdot \text{F} \cdot \text{F} \cdot \text{C} \cdot \text{C} \cdot \text{C} \cdot \text{S} \cdot \text{O} \cdot \text{O}\right]_n$</td>
<td>Polyfluorinated</td>
<td>6:2 FtS ($n = 5$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8:2 FtS ($n = 7$)</td>
</tr>
</tbody>
</table>

Additional PFAS compounds gaining attention

- Perfluorobutanonic acid (PFBA)
- Perfluoropentanoic acid (PFPeA)
- Perfluorohexanoic acid (PFHxA)
- Perfluoroheptanonic acid (PFHpA)
- Perfluorononanoic acid (PFNA)
- Perfluorodecanoic acid (PFDA)
- Perfluoroundecanoic acid (PFUnA)
- Perfluorododecanoic acid (PFDoA)

- Perfluorobutane sulfonic acid (PFBS)
- Perfluoropentane sulfonic acid (PFPeS)
- Perfluorohexane sulfonic acid (PFHxS)
- Perfluoroheptane sulfonic acid (PFHpS)
- Perfluorononane sulfonic acid (PFNS)
- Perfluorodecane sulfonic acid (PFDS)
- Perfluoroundecane sulfonic acid (PFUnS)
- Perfluorododecane sulfonic acid (PFDoS)

Increasing # carbon
Short-chain and long-chain PFAS

<table>
<thead>
<tr>
<th>Short-chain PFCAs</th>
<th>Long-chain PFCAs</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFBA</td>
<td>PFOA</td>
</tr>
<tr>
<td>PFPeA</td>
<td>PFNA</td>
</tr>
<tr>
<td>PFHxA</td>
<td>PFDA</td>
</tr>
<tr>
<td>PFHpA</td>
<td>PFUnA</td>
</tr>
<tr>
<td>PFBS</td>
<td>PFOS</td>
</tr>
<tr>
<td>PFPeS</td>
<td>PFNS</td>
</tr>
<tr>
<td>PFHxS</td>
<td>PFDS</td>
</tr>
<tr>
<td>PFHpS</td>
<td>PFUnS</td>
</tr>
<tr>
<td>Short-chain PFSAs</td>
<td>Long-chain PFSAs</td>
</tr>
<tr>
<td>PFBA</td>
<td>PFOA</td>
</tr>
<tr>
<td>PFPeS</td>
<td>PFNA</td>
</tr>
<tr>
<td>PFHxS</td>
<td>PFDA</td>
</tr>
<tr>
<td>PFHpS</td>
<td>PFUnA</td>
</tr>
</tbody>
</table>

• Short-chain
  – PFCAs with 7 or fewer carbons
  – PFSAs with 5 or fewer carbons
  – Lower potential to persist and bioaccumulate
  – Continue to be produced

• Long-chain
  – PFCAs with 8 or more carbons
  – PFSAs with 6 or more carbons
  – Generally, higher persistence and bioaccumulation potential
  – Voluntarily phased out – no longer produced or imported to US
PFOS and PFOA are sources and transformation products

Data source: ITRC Fact Sheet “Naming Conventions and Chemical and Physical Properties of per- and polyfluoroalkyl substances”
## PFAS fate and transport and comparison to “legacy” pollutants

<table>
<thead>
<tr>
<th>Behavior</th>
<th>PFAS</th>
<th>Dioxin/PCBs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bind to soil/sediment</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Water soluble</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Groundwater/surface water is primary receiving medium</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Volatile</td>
<td>No, but can be released in stack emissions</td>
<td>No, but can be released in stack emissions</td>
</tr>
<tr>
<td>Bioaccumulates in fish</td>
<td>No (short-chain) / Yes (long-chain)</td>
<td>Yes</td>
</tr>
<tr>
<td>Partitions to lipids (fats)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Binds to protein</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

**PFOS**

```
F F F F F F F SO_3H
```

**PFOA**

```
F F F F F F F
```

“Tail” is Insoluble in Water and Lipid

“Head” is Water Soluble
Why do we care about PFAS?

• Not limited to DuPont, 3M, and Department of Defense
  – PFAS was widely used in industry for over 60 years in industrial processes and to manufacture consumer products

• Evolving understanding of health risks, increased public awareness, and Flint effect
  – Pressure on agencies to take action

• Health-based standards are very low, and may go lower
  – Analytical procedures, lower detection limit, more compounds detectable

• PFAS is persistent and treatment options are limited
## Historical manufacturing of PFAS compounds

<table>
<thead>
<tr>
<th>PFAS</th>
<th>Development Time Period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1930s</td>
</tr>
<tr>
<td>PTFE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Invented</td>
</tr>
<tr>
<td>PFOS</td>
<td></td>
</tr>
<tr>
<td>PFOA</td>
<td></td>
</tr>
<tr>
<td>PFNA</td>
<td></td>
</tr>
<tr>
<td>Fluoro-</td>
<td></td>
</tr>
<tr>
<td>telomers</td>
<td></td>
</tr>
<tr>
<td>Dominant Process</td>
<td></td>
</tr>
</tbody>
</table>

Data source: ITRC Fact Sheet “History and Use of per- and polyfluoroalkyl substances”
Major uses of PFAS compounds

- **Firefighting** - aqueous film forming foam (AFFF)
  - Required by federal law for use at airports
- **Textiles and paper products** - coating to repel water, oil, and stains
  - Outerwear (e.g. Gore-Tex), umbrellas, tents, carpets, upholstery (e.g., Scotchgard)
  - Food and non-food paper and cardboard packaging
- **Metal plating**
  - Corrosion and mechanical wear prevention, fume suppressant
- **Wire manufacturing**
  - Coating and insulation
- **Industrial surfactants, resins, molds**
  - Mold-release compounds, rubber, plastic manufacturing
- **Architectural resins**
  - Shower panels
- **Semiconductor**
  - Surfactants, anti-reflective coatings
PFAS in consumer products

• Paper and packaging (including pizza boxes, microwave popcorn bags)
• Clothing, sporting equipment
• Ski and snowboard waxes
• Non-stick cookware
• Polishes and waxes
• Pesticides and herbicides

• Hydraulic fluids
• Windshield wipers
• Latex paints and varnishes
• Adhesives
• Shampoo, hair conditioners, sunscreen, cosmetics, toothpaste, dental floss
Fate and transport in the environment
Fate & transport: Major sources - AFFF

AFFF releases: Airports, DoD sites, petroleum refineries
- Soil → Leaching → Groundwater → Surface Water
- Transport via advection/displacement (LONG plumes, no degradation)
- Exposure via drinking of groundwater; food chain (crop irrigation); fish consumption (surface water)

Figure source: ITRC Fact Sheet “Environmental Fate and Transport of per- and polyfluoroalkyl substances”
Fate & transport: Major sources – industrial sites

Industrial Sites: Textiles, paper, metal plating, surfactants
- Direct use of PFAS; use of PFAS-containing mixtures
- Air $\rightarrow$ Deposition $\rightarrow$ Leaching $\rightarrow$ Groundwater
- Transport via advection/dispersion
- Exposure via groundwater pathways

Figure source: ITRC Fact Sheet “Environmental Fate and Transport of per- and polyfluoroalkyl substances”
Fate & transport: Major sources – municipal waste

Landfills, WWTPs, land application
- Personal care and consumer products, legacy industrial waste disposal
- Landfills → Leaching to groundwater
- WWTP → directly to surface water → biosolids land application → crop uptake → food chain
- Exposure via groundwater or food-chain pathways

Figure source: ITRC Fact Sheet “Environmental Fate and Transport of per- and polyfluoroalkyl substances”
PFAS prevalence in public water supply: Recent survey in New Hampshire

- Voluntary public water system PFAS sampling (2016 – 2018)
- 402 of 1,883 water systems sampled
- 4 systems with NH MCL exceedances
- NH DES estimates that 1.25% of unsampled PWS (18 additional systems) may require treatment

<table>
<thead>
<tr>
<th>Concentration</th>
<th>PFHxS</th>
<th>PFNA</th>
<th>PFOS</th>
<th>PFOA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not detected</td>
<td>357</td>
<td>390</td>
<td>336</td>
<td>253</td>
</tr>
<tr>
<td>&lt;10 ppt</td>
<td>35</td>
<td>6</td>
<td>47</td>
<td>125</td>
</tr>
<tr>
<td>10 – 20 ppt</td>
<td>2</td>
<td>3</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>20 – 40 ppt</td>
<td>7</td>
<td>3</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>40 – 60 ppt</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>&gt;60 ppt</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

NH MCL (ppt)* 85 23 70 38

* Proposed January 2019
PFAS prevalence in groundwater monitoring: Recent survey in New Hampshire

Mandatory and voluntary PFAS sampling (2016 – 2018)

<table>
<thead>
<tr>
<th>Facility type</th>
<th>Number in NH</th>
<th>Sampled to date</th>
<th>Projected number with MCL exceedance</th>
<th>Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipal solid waste</td>
<td>200</td>
<td>58%</td>
<td>44% (88 facilities)</td>
<td>Expanded monitoring well networks, additional investigations (nature and extent), possible treatment of private and PWS</td>
</tr>
<tr>
<td>Hazardous waste site</td>
<td>515</td>
<td>27%</td>
<td>53% (273 sites)</td>
<td></td>
</tr>
<tr>
<td>Wastewater disposal (permitted)</td>
<td>96</td>
<td>44%</td>
<td>29% (28 facilities)</td>
<td></td>
</tr>
<tr>
<td>Oil remediation site</td>
<td>1500</td>
<td>1%</td>
<td>Data too limited, but some facilities show evidence of PFAS greater than MCLs</td>
<td></td>
</tr>
<tr>
<td>AFFF sites</td>
<td>293</td>
<td>5.5%</td>
<td>31% (91 facilities)</td>
<td>120 PWS and 4,600 private wells estimated to be within 1,000 feet of the 293 fire stations in the state</td>
</tr>
<tr>
<td>Biosolids recycling</td>
<td>No data, but in consideration for testing of biosolids and development of leaching-based screening levels</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
PFOA and PFOS in soil and sediment

Range of direct-contact risk-based screening levels

Leaching-based screening level

Data source: ITRC Fact Sheet “Environmental Fate and Transport of per- and polyfluoroalkyl substances”
PFOA and PFOS in surface water and stormwater

Data source: ITRC Fact Sheet “Environmental Fate and Transport of per- and polyfluoroalkyl substances”
PFOS in fish tissue

Range of recreational fishing risk-based screening levels

Data source: ITRC Fact Sheet “Environmental Fate and Transport of per- and polyfluoroalkyl substances” and ATSDR “Toxicological Profile for Perfluoroalkyls”
Summary – significant pathways and media

• Where do we find PFAS?: Worldwide
  – Freshwater lake sediments in Antarctica

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Exposure Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaching to groundwater</td>
<td>Groundwater</td>
</tr>
<tr>
<td>Migration and discharge to surface water</td>
<td>Surface water and fish</td>
</tr>
<tr>
<td>Air dispersion, deposition, and subsequent leaching</td>
<td>Groundwater</td>
</tr>
<tr>
<td>Biosolids application / irrigation with contaminated groundwater</td>
<td>Food crops</td>
</tr>
<tr>
<td>Direct contact with soil</td>
<td>Soil</td>
</tr>
</tbody>
</table>

• Identified in these media because:
  – No degradation of PFOA/PFOS
  – Analytical detection limits are very low (less than 10 parts per trillion)
PFAS sampling and analysis

• Sampling requires avoiding use of PFAS-containing materials
  – No Teflon®, low-density polyethylene, or jars with lined lids
  – No personal care products (sunscreen, etc.) and food wrappers
  – No waterproofed clothing, self-sticking notes, waterproof paper, etc.

• Drilling make-up water - must be PFAS-free

• Analysis by EPA Method 537 version 1.1
  – Detection limits in water: 0.5 – 6.5 ng/L
  – Measures a subset of PFAS compounds

• Equipment blanks a must
Health effects
Health effects - humans

• Epidemiology studies:
  – Occupational studies
  – Residents living near a PFOA manufacturing facility with high PFAS in drinking water
  – General population/background exposures

• C8 Science Panel and ATSDR: Evidence suggestive of link between PFAS exposure and:
  – Pregnancy-induced hypertension/preeclampsia
  – Elevated liver enzymes
  – Elevated uric acid
  – High cholesterol
  – Thyroid disease
  – Ulcerative colitis
  – Carcinogenicity – increase in testicular and kidney cancers in highly exposed populations
Toxicological effects - animals

• Most studies on PFOA and PFOS
  – Only 18% of animal studies are on other PFAS compounds
  – No studies on short-chain PFAS

• Primary adverse effects:
  – Liver
  – Immune
  – Developmental
  – Carcinogenicity to liver, testes, and pancreas
Comparing toxicological effects in humans and animals

<table>
<thead>
<tr>
<th>Toxicological effect</th>
<th>Human</th>
<th>Animal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preëclampsia</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Liver</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Thyroid</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Uric acid</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Immune</td>
<td>(X)*</td>
<td>X</td>
</tr>
<tr>
<td>Developmental</td>
<td>(X)*</td>
<td>X</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Ulcerative colitis</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Carcinogenicity</td>
<td>X**</td>
<td>X</td>
</tr>
</tbody>
</table>

• Some states (N.J., Mich.) have determined that substantial evidence exists for these effects in humans
• Carcinogenicity: IARC: PFOA possibly carcinogenic in humans
  USEPA: suggestive evidence of PFOA and PFOS carcinogenicity in humans
Challenges in developing toxicity values

• Human epidemiology studies not sufficient to establish a statistically significant relationship between PFAS intake and adverse effect

• Mechanism of toxicity in humans not well understood
  – Toxicity in rodents likely modulated by activation of an enzyme that is much less active in humans
  – Difference in scientific opinions concerning relevance of other mechanisms

• Challenges correlating blood PFAS levels to intake
  – PFAS half-life in humans in years (3 to 5 years) versus days for primates and hours for rodents
  – Modeling used to translate serum levels in animals to serum levels in humans, and serum levels in humans to human intake
Quantifying toxicity

• Only current option - use toxicological studies in animals
  – For PFOA/PFOS, EPA identified “point-of-departure” (POD) dose as 1 mg/kg/day (developmental and immune toxicity)

• EPA applied biokinetic model that accounted for differences in animal (mouse) to human serum half-life (days to years)
  – Human equivalent dose (HED) 200 times lower than animal POD (0.0053 mg/kg/day) due to differences in half-life
  – EPA then applied 300-fold uncertainty factor to HED
  – Critical effect: Bone development (developmental effect)

• Toxicity value is 50,000 times lower than POD in animal study
  – Reflects methods to account for differences in half-life and uncertainty factors
EPA’s drinking water health advisory level

• Drinking water health advisory: 0.07 ug/L (70 parts per trillion)
  – RfD (toxicity value)
  – RSC (amount of daily exposure that can safely come from drinking water)
  – Water intake rate (amount of water ingested daily)
  – Applied to PFOA + PFOS

\[
\text{DW Advisory} = \frac{\text{RfD} \times \text{BW}}{\text{DWI}} \times \text{RSC}
\]

\[
\text{DWEL} = \frac{0.00002 \text{ mg/kg/day}}{0.054 \text{ L/kg-day}} \times 0.2 = 0.00007 \text{ mg/L (70 ng/L)}
\]

Drinking water intake (DWI)
Critical receptor: Lactating woman
(accounts for transfer to breast milk)

Relative Source Contribution (RSC)
Assumes 20% of allowable intake comes from drinking water
Regulatory limits / exposure thresholds
PFOA and PFOS groundwater and drinking water regulatory levels – United States

USEPA HA
0.07 ug/L
Why the differences among drinking water values?

States are:
- deriving their own toxicity values
- using atypical receptors (infant, infant + mother)
- deriving their own RSC values

<table>
<thead>
<tr>
<th>Regulatory Entity</th>
<th>PFAS Compound</th>
<th>Toxicity value (RfD)</th>
<th>Drinking Water Intake (DWI)</th>
<th>Relative Source Contribution (RSC)</th>
<th>Regulatory value (ug/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPA - office of water</td>
<td>PFOA/PFOS</td>
<td>2.0E-05</td>
<td>lactating woman</td>
<td>0.2</td>
<td>0.07</td>
</tr>
<tr>
<td>Alaska</td>
<td>PFOA/PFOS</td>
<td>2.0E-05</td>
<td>child</td>
<td>1</td>
<td>0.4</td>
</tr>
<tr>
<td>California</td>
<td>PFOA/PFOS</td>
<td>2.0E-06</td>
<td>adult</td>
<td>0.2</td>
<td>0.014</td>
</tr>
<tr>
<td>Maine</td>
<td>PFOA/PFOS</td>
<td>6.0E-06 8.0E-05</td>
<td>adult</td>
<td>0.6</td>
<td>0.13</td>
</tr>
<tr>
<td>Minnesota</td>
<td>PFOA/PFOS</td>
<td>1.8E-05 5.1E-06</td>
<td>infant and mother</td>
<td>0.5</td>
<td>0.035</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>PFOA/PFOS</td>
<td>5.2E-06 8.0E-06</td>
<td>lactating woman</td>
<td>0.4</td>
<td>0.038</td>
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<td>New Jersey</td>
<td>PFOA/PFOS</td>
<td>2.0E-06</td>
<td>adult</td>
<td>0.2</td>
<td>0.014</td>
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<tr>
<td>North Carolina</td>
<td>PFOA</td>
<td>1.5E-04</td>
<td>adult</td>
<td>0.2</td>
<td>1</td>
</tr>
<tr>
<td>Texas</td>
<td>PFOA/PFOS</td>
<td>1.2E-05 2.3E-05</td>
<td>child</td>
<td>1</td>
<td>0.29</td>
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<tr>
<td>Vermont</td>
<td>PFOA/PFOS</td>
<td>2.0E-05</td>
<td>infant</td>
<td>0.2</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Different values/assumptions than used by USEPA

\[ \text{DW Advisory} = \frac{\text{RfD} \times \text{BW}}{\text{DWI}} \times \text{RSC} \]
Summary – human exposures

• Significant human exposure pathways for PFAS
  – Drinking water
  – Diet: food and migration from food packaging
  – Hand-mouth transfer from treated carpeting
  – Ingestion of household dust
  – Inhalation from treated clothing
  – Intake = 0.03 to 0.05 ug/kg/day

• Intake from drinking water w/ PFAS at health advisory concentration (70 PPT) about 1/10 normal intake from dietary & consumer product exposure

• Blood levels decreasing with phaseout of long-chain PFAS
Drinking water screening levels and standards – international
Treatment
Treatment technologies

• Two existing effective (full-scale) technologies - ex-situ and bind the PFAS; no destruction of PFAS

• Granular activated carbon (GAC)
  – Most effective with long-chain PFAS and PFAS <100 ug/L
  – Faster breakthrough with short-chain PFAS
  – Re-generate or dispose of GAC

• Ion exchange
  – Effective with both long- and short-chain PFAS
  – Breakthrough slower to occur than with GAC
  – Re-generate or dispose of resin

• Both technologies require PFAS waste (concentrate) to be thermally destroyed

• Many other ex-situ and in-situ technologies being researched
What’s next?
PFAS – where are we going?

Figure source: ITRC Fact Sheet “History and Use of per- and polyfluoroalkyl substances”
What’s next?
Development of toxicity values for other PFAS

• ATSDR:
  – PFNA (10-times lower than EPA’s value for PFOA)
  – PFHxS (same as EPA’s value for PFOA)

• EPA:
  – PPRTV for PFBS (1000-times higher than EPA’s value for PFOA)
  – Gen-X (4-times higher than EPA’s value for PFOA)

• ATSDR reviewed toxicological data for ten additional PFAS compounds and concluded that data were not sufficient to support derivation of toxicity values
What’s next?
Development of drinking water values for other PFAS

• Ten states have developed drinking water values for other PFAS

<table>
<thead>
<tr>
<th>PFAS compound</th>
<th>Range of drinking water values (ug/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFNA</td>
<td>0.013 – 0.29</td>
</tr>
<tr>
<td>PFBA*</td>
<td>7.0 – 7.1</td>
</tr>
<tr>
<td>PFBS</td>
<td>2.0 – 667</td>
</tr>
<tr>
<td>PFHxS</td>
<td>0.027 – 0.093</td>
</tr>
<tr>
<td>PFHpA*</td>
<td>0.01 – 0.56</td>
</tr>
</tbody>
</table>

* ATSDR concluded data not sufficient to derive toxicity values for PFBA and PFHpA
What’s next?
Development of soil values for PFAS

• Ten states have developed direct contact values for PFOA and PFOS
• Seven states have developed direct contact values for FPBA and/or PFBS
• Five states have developed leaching-based values for PFOA and PFOS

<table>
<thead>
<tr>
<th>PFAS compound</th>
<th>Range of soil values (mg/Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFOA – direct contact</td>
<td>0.5 – 16</td>
</tr>
<tr>
<td>PFOS – direct contact</td>
<td>0.5 – 6.0</td>
</tr>
<tr>
<td>PFOA - leaching</td>
<td>0.0017 – 0.35</td>
</tr>
<tr>
<td>PFOS - leaching</td>
<td>0.00022 – 0.05</td>
</tr>
</tbody>
</table>
What’s next?
More pressure from agencies to test for PFAS

- States want to avoid repeat of Flint, Mich.
- Mich., N.H., N.Y. among states pushing programs
  - Haz waste sites, landfills, POTWs, AFFF sources
- EPA Superfund
  - Requests for testing on sites not yet closed