EBC Emerging Contaminants Seminar

The Life Cycle of PFAS – The Forever Chemical
Welcome

Daniel K. Moon

President & Executive Director

Environmental Business Council of New England
Welcome to the Seminar

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Seminar Co-Chair

Chair, EBC TSCA & Emerging Contaminants Committee

Vice President, Weston & Sampson
Seminar Introduction – What You Will Learn

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PFAS in Massachusetts

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PFAS in Massachusetts

EBC Emerging Contaminants Seminar: The Life Cycle of PFAS
February 25, 2020

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PFAS in Massachusetts

Where are we seeing it?

How big a problem is it?
PFAS Testing of Drinking Water Supplies

Public

(2/12/20)
PFAS Testing of Drinking Water Supplies
Public & Private

Private Wells Affected in the Area

(2/12/20)
Inertia & Acceleration & PFAS
Inertia & Acceleration & PFAS

Dictionary

Search for a word

inertia
/iˈnər-tēə/

noun

1. a tendency to do nothing or to remain unchanged. "the bureaucratic inertia of government"

   Similar: inactivity, inaction, inactiveness, inertness, passivity

2. PHYSICS
   a property of matter by which it continues in its existing state of rest or uniform motion in a straight line, unless that state is changed by an external force.

Translations, word origin, and more definitions
Inertia & Acceleration & PFAS

**Definition of Inertia**

1. A tendency to do nothing or to remain unchanged.
   "the bureaucratic inertia of government"
   
   Similar: inactivity, inaction, inactiveness, inertness, passivity

2. PHYSICS
   A property of matter by which it continues in its existing state of rest or uniform motion in a straight line, unless that state is changed by an external force.
In physics or physical science, acceleration (symbol: a) is defined as the rate of change (or derivative with respect to time) of velocity. ... To accelerate an object is to change its velocity, which is accomplished by altering either its speed or direction (like in case of uniform circular motion) in relation to time.
Inertia & Acceleration & PFAS

Initial State:
• Follow USEPA’s lead

External Forces Acting on MassDEP:
• Significant Sites in Adjacent States
• UCMR3 Results -> Significant Sites here
• Subsequent Testing: If you look for PFAS, you find it
• New (daily?) Toxicity Studies
• Informed Stakeholders
• Need for Answers/Closure: What does it mean?
Inertia & Acceleration & PFAS

External Forces Acting on MassDEP:
Inertia & Acceleration & PFAS

New State:

- Different Path & Faster Speed
  - Expand PFAS of Concern (to 6)
  - Implement AFFF Takeback
  - Establish drinking water guideline
  - Review & Update Toxicity Information
  - Develop & promulgate cleanup standards and notification criteria
  - Propose Drinking Water MCL*
  - Plan Public/Private Well Sampling Program
  - Expand Focus... biosolids, landfills, surface water...
Comments on the Proposed MCL
Due February 28, 2020

https://www.mass.gov/regulations/310-CMR-22-the-massachusetts-drinking-water-regulations#proposed-amendments-public-comment

• Submit comments on the draft regulations, along with your name and contact information, to:
  – Email: program.director-dwp@mass.gov with PFAS MCL Comments in the subject line,
  or
  – Mail: MassDEP Drinking Water Program, 1 Winter Street, 5th Floor, Boston, MA 02108 Attn: PFAS MCL Comments
Per- and Polyfluoroalkyl Substances (PFAS)

Learn about a group of contaminants in the environment, Per- and polyfluoroalkyl substances (PFAS). Find out where they have been found and what Massachusetts is doing to address them.

TABLE OF CONTENTS

- What are PFAS and why are they a problem?
- PFAS detected in drinking water supplies in Massachusetts
- Health advisories and downloadable fact sheets
- Development of a PFAS Drinking Water Standard (MCL)
- Laboratories, testing and sample collection
- Bottled water and home water filters
- PFAS and Waste Sites
- Take-back program for legacy firefighting foam
- PFAS in Wastewater Residuals
- Links to additional information

https://www.mass.gov/info-details/per-and-polyfluoroalkyl-substances-pfas
for more information about MassDEP’s PFAS efforts
Identifying and Addressing Industrial Sources and Occurrence of PFAS in New Hampshire’s Environment and Drinking Water

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Manager, Hydrology and Conservation Section
Drinking Water and Groundwater Bureau
New Hampshire Department of Environmental Services
Identifying and Addressing Industrial Sources and Occurrence of PFAS in New Hampshire’s Environment and Drinking Water

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February 25, 2020
Recent News from USEPA

• February 20, 2020 USEPA issued a preliminary regulatory determination to develop regulatory limits for PFOS and PFOA.

• Once this is published in the Federal Register, there will be a 60 day public comment period.

• It will take years for USEPA to regulate PFAS in drinking water, if it does at all.

• USEPA has not established an MCL for a manmade contaminant since 1995 (PAHs)

• USEPA issued a preliminary regulatory determination for perchlorate in October 2008 – still no MCL
Contaminant Candidate List (CCL) – Every five years, the Administrator shall publish a list of contaminants which, at the time of publication, are not subject to any proposed or promulgated national primary drinking water regulation (NPDWR), which are known or anticipated to occur in public water systems, and which may require regulation.

Regulatory Determination – Every five years, the Administrator shall, after notice of the preliminary determination and opportunity for public comment, for not fewer than five contaminants included on the CCL, make determinations on whether or not to regulate such contaminants. A determination to regulate a contaminant shall be based on specified criteria.

Regulation Development – The Administrator shall propose the Maximum Contaminant Level Goal (MCLG) and NPDWR not later than 24 months after determination and promulgate within 18** months after proposal.

Unregulated Contaminant Monitoring – Process to monitor up to 30 different unregulated contaminants every 5 years.

Six Year Review – Every 6 years, review and (if appropriate) revise the standard. Any revision must maintain or improve public health protection.
General Flow of SDWA Regulatory Processes

At each stage, need increased specificity and confidence in the type of supporting data used (e.g. health, occurrence, treatment).
Three Regulatory Determination Criteria Specified by the 1996 SDWA Amendments

A. requires EPA to publish a MCLG and promulgate an NPDWR for a contaminant if the Administrator determines that:

1) The contaminant may have an adverse effect on the health of persons;

2) The contaminant is known to occur or there is substantial likelihood that the contaminant will occur in public water systems with a frequency and at levels of public health concern; and

3) In the sole judgment of the Administrator, regulation of such contaminant presents a meaningful opportunity for health risk reduction for persons served by public water systems.

*SDWA Section 1412(b)(1)
NH MCLs - Based on Non-Cancer Endpoints

- Adopted July 18, 2019 & Effective September 30, 2019
- Community and non-transient water systems are sampling – 1800 sources
- NHDES intends to sample transient public water systems one time
- NH MCLs are also the Ambient Groundwater Quality Standards (AGQS)

<table>
<thead>
<tr>
<th>Specific PFAS</th>
<th>NHDES Revised MCLs</th>
<th>Animal Health Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFOA</td>
<td>12 ng/L</td>
<td>Liver toxicity &amp; altered lipid metabolism</td>
</tr>
<tr>
<td>PFOS</td>
<td>15 ng/L</td>
<td>Suppressed immune response to vaccines</td>
</tr>
<tr>
<td>PFHxS</td>
<td>18 ng/L</td>
<td>Reduced female fertility</td>
</tr>
<tr>
<td>PFNA</td>
<td>11 ng/L</td>
<td>Liver toxicity &amp; altered lipid metabolism</td>
</tr>
</tbody>
</table>
Select drinking water standards and guidance values in the U.S.

<table>
<thead>
<tr>
<th>Specific PFAS</th>
<th>NH DES (MCLs)</th>
<th>NJ DWQI (MCLs)</th>
<th>NY DOH (MCLs)</th>
<th>MN DOH (HBGV)</th>
<th>MI DHHS (SL)</th>
<th>CA OFHHA (DWLC)</th>
<th>US EPA (LHA)</th>
<th>VT DEP (advisory)</th>
<th>CT DPH (advisory)</th>
<th>MA DEP (proposed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFOA</td>
<td>12 ng/L</td>
<td>13 ng/L</td>
<td>10 ng/L</td>
<td>38 ng/L</td>
<td>9 ng/L</td>
<td>0.1 ng/L</td>
<td>70 ng/L combined*</td>
<td>20 ng/L combined*</td>
<td>70 ng/L combined*</td>
<td>20 ng/L combined*</td>
</tr>
<tr>
<td>PFOS</td>
<td>15 ng/L</td>
<td>14 ng/L†</td>
<td>10 ng/L†</td>
<td>15 ng/L</td>
<td>8 ng/L</td>
<td>0.4 ng/L</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>PFHxS</td>
<td>18 ng/L</td>
<td>-</td>
<td>-</td>
<td>47 ng/L</td>
<td>84 ng/L</td>
<td>-</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>PFNA</td>
<td>11 ng/L</td>
<td>13 ng/L†</td>
<td>-</td>
<td>-</td>
<td>9 ng/L</td>
<td>-</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>PFHpA</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>*</td>
<td>*</td>
<td>*</td>
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</tr>
<tr>
<td>PFDA</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>*</td>
</tr>
</tbody>
</table>

MCL = maximum contaminant level  
HBGV = health-based guidance value  
SL = screening level  
LHA = lifetime health advisory  
† Proposed value(s)  
DWLC = Drinking Water Limit for Cancer

PFBS established in MN (2,000 ppt), MA (2,000 ppt), and MI (420 ppt), and PFBA in MN (7,000 ppt)

Data obtained from ITRC 2019
PFAS are manmade chemicals used in products that resist heat, oils, grease, stains and water.

**Industrial Uses**
- AFFF
- Chemical production
- Metal plating
- Textiles, upholstery, apparel, carpets
- Medical devices
- Paper and packaging
- Rubber and plastics
- Semiconductor manufacturing
- Photo imaging

**Commercial Products**
- Non-stick cookware
- Fast food containers
- Candy wrappers
- Microwave popcorn bags
- Personal care and cosmetic products
- Paints and varnishes
- Stain-resistant carpet and chemicals
- Water-resistant apparel
- Cleaning products
- Electronics
- Ski wax
- Insect baits
Data collected since 2016 shows PFAS impacts to a range of environmental media

<table>
<thead>
<tr>
<th>Statewide and Site-Specific Water Quality Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Public water supplies</td>
</tr>
<tr>
<td>• Private drinking water</td>
</tr>
<tr>
<td>• Groundwater</td>
</tr>
<tr>
<td>• Surface water</td>
</tr>
<tr>
<td>• Bottled water</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Statewide Waste Quality Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Wastewater</td>
</tr>
<tr>
<td>• Wastewater sludge and biosolids</td>
</tr>
<tr>
<td>• Landfill leachate</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Additional Site-Specific Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Soil</td>
</tr>
<tr>
<td>• Sediment</td>
</tr>
<tr>
<td>• Fish</td>
</tr>
<tr>
<td>• Loon eggs</td>
</tr>
<tr>
<td>• Air</td>
</tr>
<tr>
<td>• Stack residue</td>
</tr>
</tbody>
</table>
Public Water Systems

<table>
<thead>
<tr>
<th>SOURCES SAMPLED</th>
<th>SOURCES WITH PFAS DETECTIONS</th>
<th>SOURCES EXCEEDING NH MCL</th>
</tr>
</thead>
<tbody>
<tr>
<td>982</td>
<td>314</td>
<td>69</td>
</tr>
<tr>
<td></td>
<td>32%</td>
<td>7%</td>
</tr>
</tbody>
</table>

Impacts approx. 192,000 people or 26% of NH residents that obtain drinking water from a public water system.
Private Wells

- 46% of NH on private wells (approx. 250,000 wells)
- 3000 sampled
- 1000 exceed an NH MCL
- Sampling locations are biased near 3 air emission sites
- Unexplained elevated levels in several communities
- 1000+ wells need to be sampled still near air emission sites
- Data accurate as of 12/19
  - NHDES’ database down due to security upgrades
  - Recent lab data not yet uploaded
Davis et al., 2007, *Chemosphere*
Waste Sites

• 297 sites exceed a PFAS MCL

• Almost all sites were pre-PFAS – open waste sites due to other contaminants

• Sites include landfills, industrial sites, salvage yards, fire training areas and other miscellaneous waste sites.

Updated 2/2020
## Waste Site Data Summary

### Waste Site Sources

<table>
<thead>
<tr>
<th>Source</th>
<th>Sites Sampled</th>
<th>% Sites &gt; AGQS</th>
<th>Max. PFOA (12 ppt)</th>
<th>Max. PFNA (11 ppt)</th>
<th>Max. PFHxS (18 ppt)</th>
<th>Max. PFOS (15 ppt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class B Foam / AFFF</td>
<td>20</td>
<td>100%</td>
<td>130,000</td>
<td>4,500</td>
<td>31,000</td>
<td>490,000</td>
</tr>
<tr>
<td>Manufacturing – textiles</td>
<td>3</td>
<td>100%</td>
<td>69,500</td>
<td>2,960</td>
<td>200</td>
<td>2,560</td>
</tr>
<tr>
<td>Manufacturing – paper</td>
<td>6</td>
<td>75%</td>
<td>21,000</td>
<td>320</td>
<td>2,400</td>
<td>7,600</td>
</tr>
<tr>
<td>Metal Working/Plating</td>
<td>22</td>
<td>65%</td>
<td>1,070</td>
<td>22</td>
<td>806</td>
<td>7,080</td>
</tr>
<tr>
<td>Other Waste Disposal</td>
<td>15</td>
<td>67%</td>
<td>3,200</td>
<td>31</td>
<td>89</td>
<td>4,750</td>
</tr>
<tr>
<td>Unlined Landfill</td>
<td>161</td>
<td>74%</td>
<td>3,700</td>
<td>774</td>
<td>663</td>
<td>1,600</td>
</tr>
<tr>
<td>Other Manufacturing</td>
<td>14</td>
<td>36%</td>
<td>2,510</td>
<td>110</td>
<td>75</td>
<td>162</td>
</tr>
<tr>
<td>Metal Recycling</td>
<td>14</td>
<td>80%</td>
<td>1,700</td>
<td>100</td>
<td>674</td>
<td>1,440</td>
</tr>
<tr>
<td>Tannery</td>
<td>3</td>
<td>100%</td>
<td>1,230</td>
<td>4</td>
<td>769</td>
<td>2,410</td>
</tr>
<tr>
<td>Lined Landfill</td>
<td>13</td>
<td>69%</td>
<td>2,200</td>
<td>30</td>
<td>107</td>
<td>632</td>
</tr>
<tr>
<td>Mixed/Other/Unknown</td>
<td>93</td>
<td>58%</td>
<td>2,090</td>
<td>960</td>
<td>745</td>
<td>1,700</td>
</tr>
<tr>
<td>Dry Cleaner</td>
<td>21</td>
<td>75%</td>
<td>160</td>
<td>29</td>
<td>88</td>
<td>1,800</td>
</tr>
<tr>
<td>Semiconductor/Circuit Board</td>
<td>9</td>
<td>67%</td>
<td>170</td>
<td>13</td>
<td>150</td>
<td>850</td>
</tr>
<tr>
<td>Commercial Products</td>
<td>4</td>
<td>100%</td>
<td>242</td>
<td>102</td>
<td>69</td>
<td>405</td>
</tr>
<tr>
<td>Wastewater/Residuals</td>
<td>6</td>
<td>83%</td>
<td>560</td>
<td>13</td>
<td>81</td>
<td>204</td>
</tr>
<tr>
<td>Lined Lagoon</td>
<td>12</td>
<td>8%</td>
<td>18</td>
<td>0</td>
<td>14</td>
<td>7</td>
</tr>
</tbody>
</table>

Approximate data through 07/31/2019
Waste Sites – Maximum Groundwater Concentrations

Approximate data through 07/31/2019

Max. PFOA (12 ppt)
Max. PFNA (11 ppt)
Max. PFHxS (18 ppt)
Max. PFOS (15 ppt)
Waste Sites – Maximum Groundwater Concentrations – excluding AFFF

- Textiles
- Paper
- Metal Working/Plating
- Solid Waste Management and Disposal

Approximate data through 07/31/2019
AFFF Sites, continued

Sites Sampled | % Sites > AGQS
---|---
20 | 100%

- Local Fire Dept.
- Bulk Oil Storage Facility
- Manufacturing Fire
- Training - Local
- Training - DoD
- Tanker Rollover
- Airport

Approximate data through 07/31/2019
Open HWRB Sites
Approx. 215 of 530 sites (state, CERCLA, Brownfields, landfills) have screened for PFAS

HWRB PFAS Data
- 59% of the waste sites that tested exceed NH’s new AGQS/MCL
- 20% >70 ppt AGQS
- 10% >New AGQS and <70 ppt AGQS
- 9% <New AGQS
- 2% Non-Detect
- 2% Not Sampled

Updated 10/2019

Approximate data through 07/31/2019
Fire Station Water Supply Well Sampling Initiative

Private Wells Serve 171 (of 237) Stations
- 2016: Foam use survey
- 2017: Recommendation to test
- 2019: Screening effort

- 65 Stations Have Screened for PFAS
- **17% of Fire Stations Tested Exceed NH’s AGQS/MCL**

Updated 10/2019

Approximate data through 07/31/2019
HWRB/DWGB PFAS Data

Maximum Wastewater-Related Impacts in Groundwater Monitoring Wells
(Not compliance boundary violations)

- **Groundwater Discharge Permit Sites**
  - Wastewater Disposal to Groundwater (~ 96)
  - 43% total
  - 10% >70 ppt AGQS
  - 16% >New AGQS and <70 ppt AGQS
  - 24% <New AGQS
  - 7% Non-Detect
  - 2% Not Sampled
  - **46% of Groundwater Discharge Sites that Sampled Exceed NH’s New MCL/AGQS**

- **Groundwater Release Detection (RD) Permit Sites**
  - Lined Lagoons (~ 18)
  - 33% total
  - 6% >70 ppt AGQS
  - 22% >New AGQS and <70 ppt AGQS
  - 39% <New AGQS
  - 14% Non-Detect
  - **10% of Release Detection Sites that Sampled Exceed NH’s New MCL/AGQS**

Updated 10/2019
HWRB PFAS Data

MSW Landfills
(Lined and Unlined)
172 of 187 Screened for PFAS

**73% of Landfills Sampled Exceed NH’s New MCL/AGQS**

Updated 10/2019

Approximate data through 07/31/2019
Source Water Protection Initiatives

- Legacy firefighting foam collection & disposal initiatives
- PFAS reduction initiatives for wastewater plants
  - Municipal & industrial WWTF being sampled in 2020
  - NHDES will coordinate with WWTFs to identify sources of PFAS & 1.4-dioxane & to work with industry
  - Septage/biosolids
- Statewide source identification initiatives
  - Air permits
  - Industry codes/classifications
- Industry awareness of new PFAS standards
- “Registered Groundwater Discharges”
  - Non-domestic wastewater discharges to septic systems
  - Thousands of discharge registrations being re-assessed
PFAS Background References

NHDES Website

https://www4.des.state.nh.us/nh-pfas-investigation/

ITRC

• Fact Sheets
  https://pfas-1.itrcweb.org/

• Technical Guidance Document (2020)

• Education and training
Fate & Transport and Recycling of PFAS in the Environment

Steven LaRosa
Senior Project Manager
Weston & Sampson
ENVIRONMENTAL BUSINESS COUNCIL

LIFE CYCLE OF PFAS

PFAS FATE & TRANSPORT

February 25, 2020
Important Concepts for PFAS Fate and Transport

- Release Mechanisms
- Source Material Makeup
- PFAS structural make up impacts reactivity and transport (Heads and Tails)
- Persistence in Environment
- Partitioning of PFAS is complicated
  - Hydrophobic effects
  - Lipophobic effects
  - Interface interactions
  - Multiple ionic species present
How PFAS Cycle Through the Environment

PFAS, which are unregulated in industrial discharges, enter the environment through air, surface water and groundwater.

Nutrient-rich materials that remain after wastewater treatment and testing are used on farms as low-cost fertilizers. Significant contributions to wastewater from nearby industrial sites can lead to elevated PFAS levels in the residual materials that can seep into groundwater if not removed during treatment.

Firefighting foams containing PFAS were previously used at airports, military bases and training sites. In some sites, the runoff migrated through soil into surface and groundwater.

At older landfill sites, wastewater containing dissolved and suspended materials from contaminated waste may have leached into groundwater or entered surface water.

New technologies have enabled recent detection of PFAS in drinking water supplies. Water treatment facilities that hadn’t previously known of PFAS in their water supplies are determining the most effective treatments for removal.

PFAS were used in common household products such as non-stick cookware, shampoo, food containers and paint. Because they don’t easily break down, PFAS can accumulate in the human body and end up in source water and drinking water.

Liquid waste that seeps from landfills and wastewater are treated at wastewater plants, but PFAS may remain in the water after treatment and contaminate groundwater.

Note: This illustration does not capture every source of PFAS exposure or the varying levels per exposure source.

More AWWA resources available at awwa.org/PFAS
Release Mechanisms

• Use/Release of PFAS can result in impacts to:
  – Air—atmospheric transport can result in large impacted areas,
  – Surface Soils—air deposition, AFFF use, infiltration of runoff water
  – Surface Water—via direct discharge, infiltration from soils, runoff from soils, WWTF discharges
  – Groundwater—via infiltration, wastewater disposal and soil
  – Sediment—storm water infiltration, runoff of soils, groundwater discharge
  – Biota—via ingestion of impacted water, plants?, other biota
Source Type

- **AFFF Sources**
  - AFFF is a mixture of compounds - <5% PFAS
  - There can be many PFAS (short and long) and precursors
  - Hydrocarbons from fire source
  - “Complex Mixture” in source area may effect advection, adsorption, precursor breakdown

- **Manufacturing Sources**
  - Can have single PFAS source or complex PFAS mixture
  - Additional compounds may be present

- **Landfill Leachate**
  - “Complex Mixture” in source area may effect advection, adsorption, precursor breakdown

- **Wastewater Treatment Facilities**
  - Multiple inputs may be present (industries, humans, surface water)
  - Treatment may cause oxidation of precursors
  - Concentration of PFAS in biosolids due to high TOC
  - Biosolids drying, composting, spreading
Structural Makeup

- Anionic Perfluorinated Alkyl Acids
  - Negatively charged
  - Low vapor pressure
  - Water soluble

PFAAs generally act as surfactants with tail in the air and head in water.
Structural Makeup

- Anionic Perfluorinated Alkyl Acids
  - PFSAs more strongly sorbed than PFCAs
  - Sorption generally increases with C
  - Short chains can have greater sorption than expected.
  - Retardation factors for anions can be predicted as with other contaminants (generally)

\[ R_f = 1 + K_{d} \times \frac{\text{Bulk density}}{\text{Porosity}} \]

<table>
<thead>
<tr>
<th>Analyte</th>
<th># Carbon</th>
<th>(K_{oc})</th>
<th>(R_f)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFBA</td>
<td>4</td>
<td>76</td>
<td>5</td>
</tr>
<tr>
<td>PFPeA</td>
<td>5</td>
<td>23</td>
<td>1.4</td>
</tr>
<tr>
<td>PFHxA</td>
<td>6</td>
<td>20</td>
<td>1.1</td>
</tr>
<tr>
<td>PFHpA</td>
<td>7</td>
<td>43</td>
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</tr>
<tr>
<td>PFOA</td>
<td>8</td>
<td>78</td>
<td>5</td>
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<tr>
<td>PFNA</td>
<td>9</td>
<td>229</td>
<td>14</td>
</tr>
<tr>
<td>PFDA</td>
<td>10</td>
<td>912</td>
<td>57</td>
</tr>
<tr>
<td>PFUnA</td>
<td>11</td>
<td>3,600</td>
<td>225</td>
</tr>
<tr>
<td>PFBS</td>
<td>4</td>
<td>62</td>
<td>4</td>
</tr>
<tr>
<td>PFHxS</td>
<td>6</td>
<td>112</td>
<td>7</td>
</tr>
<tr>
<td>PFOS</td>
<td>8</td>
<td>631</td>
<td>39</td>
</tr>
</tbody>
</table>

Structural Makeup

- Polyfluorinated Substance transport
  - State of charge may dominate retardation
    - Anions > Cations > Zwitterions
  - Short Chains generally migrate faster
  - Cation exchange onto soils may be significant….on par with organic carbon
  - Transformation into Perfluorinated end products may occur with distance from source.
Precursor Transformation

- Branched and linear isomers
- Complex mixture
- Cationic & zwitterionic
- PFSAs (and some PFCAs) as end products

Figure 2-5. ECF degradation pathway overview (Example for perfluorooctane sulfonyle homologue).

Source: ITRC PFAS Fact Sheet – Fate and Transport 3/16/18
Precursor Transformation

- Built by 2’s
- Fairly “clean” process yielding predictable mixtures
- PFCAs only as end products

Figure 2-4. Fluorotelomer degradation pathway overview (Example for 8:2 fluorotelomer homologue)

Source: ITRC PFAS Fact Sheet – Fate and Transport 3/16/18
What is Expected Where?

PFAS plumes have varying complexity related to source type, time since release and location relative to the source.

➢ Source Zone
  - complex chemistry
  - multiple “families” of contaminants
  - competing transport mechanisms
  - “minimal” precursor breakdown (unless remediation has occurred)

➢ Transition Zone
  - separation of “families” via sorption/retardation/biodegradation
  - precursor transformation seen (more PFAAs with distance?)
  - separation of PFCAs/PFSAs and short chain/long chain via sorption/retardation

➢ Distal Zone
  - “simpler” chemistry
  - terminal end products dominate
Transport in Air

• PFAS can be volatized by drying activities (precursor alcohols)

• “Carried” in water vapor

• “Carried” on or as particulate

• Deposition via wet and dry methods

• Transported in all wind directions, potentially miles
Transport in Vadose Zone

- Chain length and organic content of soil dependent transport dominant

- However, individual PFAS Koc, ionic state and the presence of other contaminants may have significant impact

- Soil types will define advective transport via infiltration

- Adsorbed PFAS may act as “source” to groundwater for decades

- Air/Water Interface interactions likely results in retardation of migration

- Formation of micelles and interactions with NAPL
Transport in Groundwater

- Chain length and organic content of soil dependent transport dominant

- However, individual PFAS Koc, ionic state and the presence of other contaminants may have significant impact

- Soil types will define advective transport via infiltration

- Air/Water Interface interactions likely results in retardation of migration

- Formation of micelles and interactions with NAPL
“RECYCLING”

- Terminal…”FOREVER”….no degradation of perfluorinated PFAS
- Soluble, “Mildly” bound to organic carbon, “Mildly” bound ionic soils.
- Nearly Ubiquitous in Environmental Media

Conceptual Site Models for Release, Fate and Transport Complicated
How PFAS Cycle Through the Environment

PFAS, which are unregulated in industrial discharges, enter the environment through air, surface water and groundwater.

Nutrient-rich materials that remain after wastewater treatment and testing are used on farms as low-cost fertilizers. Significant contributions to wastewater from nearby industrial sites can lead to elevated PFAS levels in the residual materials that can seep into groundwater if not removed during treatment.

Firefighting foams containing PFAS were previously used at airports, military bases and training sites. In some cases, the runoff migrated through soil into surface and groundwater.

At older landfill sites, wastewater containing dissolved and suspended materials from contaminated waste may have leaked into groundwater or entered surface water.

New technologies have enabled recent detection of PFAS in drinking water supplies. Water treatment facilities that hadn’t previously known of PFAS in their water supplies are determining the most effective treatments for removal.

PFAS were used in common household products such as non-stick cookware, shampoo, food containers and paint. Because they don’t easily break down, PFAS can accumulate in the human body and end up in source water and drinking water.

Liquid waste that seeps from landfills and wastewater are treated at wastewater plants, but PFAS may remain in the water after treatment and contaminate groundwater.

More AWWA resources available at awwa.org/PFAS

Note: This illustration does not capture every source of PFAS exposure or the varying levels per exposure source.
Your House

Industry
- Air
- Wastes
- NPDES
- Products

WWTF
- Discharge
- Sludge
- Biosolids

Landfill
- Leachate

Water Supply

Soil

Groundwater

Surface Water
Important Concepts for PFAS Fate and Transport

• Source zones may be complex: long-term discharge potential
  – Non PFAS related contaminants can confound understanding of source area
  – Investigation areas may be larger than you’re used to

• Perfluorinated PFAS:
  – TERMINAL
  – Mobility is chain-length dependent, affected by OC, pH, inorganic cations, etc.

• Polyfluorinated PFAS (precursors) are varying in their stability
  – Much more variable in terms of transport
  – Oxidizing remedial techniques (ISCO, air sparge, aerobic bioremediation) can transform precursors to TERMINAL PFAAs

• Surfactant properties may lead to increased concentrations at air/water interface or at water/NAPL interface
Questions?
PFAS Cycling Between Landfills and WWTPs?

Steve Zemba, Ph.D.

Project Director
Sanborn, Head & Associates, Inc.
PFAS Cycling Between Landfills and WWTPs?

The Life Cycle of PFAS
EBC Emerging Contaminants Seminar
Environmental Business Council of New England
Framingham, Massachusetts
February 25, 2020

Steve Zemba, PhD, PE
Sanborn, Head and Associates, Inc.
Presentation Overview

- PFAS Surface Water Standards
- PFAS Sources in Municipal Solid Waste
- Cycling of PFAS Between Landfills and Wastewater Treatment Plants
- Preliminary Data from PFAS Waste Investigation
## Surface Water Screening Levels for PFOS

<table>
<thead>
<tr>
<th>State</th>
<th>Drinking Water Std/Guideline (ng/l)</th>
<th>Surface Water Screening Level (ng/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MI</td>
<td>16</td>
<td>11</td>
</tr>
<tr>
<td>MN</td>
<td>15</td>
<td>6 (lakes) 14 (rivers)</td>
</tr>
<tr>
<td>FL</td>
<td>70</td>
<td>4 (proposed)</td>
</tr>
<tr>
<td>NH</td>
<td>15</td>
<td>6 ? (speculation)</td>
</tr>
</tbody>
</table>
Leachate characteristics
- 37,800 gal/day
- 1,550 ng/L PFOS

Merrimack River
- 4,800,000,000 gal/day
- PFOS from leachate: 0.012 ng/L

Clean Water Act allows dilution

Lowell WWTP NPDES Permit
- Chlorine
  - Effluent Limit 196 µg/L
  - EPA AWQC 11 µg/L
- Phosphorus (phosphate)
  - Effluent Limit 1,080 µg/L
  - EPA Gold Book guideline 50 µg/L
VT 2017 Assessment of Leachate

<table>
<thead>
<tr>
<th>WWTF</th>
<th>Daily Max. Leachate (GPD)</th>
<th>Receiving Water</th>
<th>LMM</th>
<th>Calculated RWC from leachate meeting the 'no restrictions' guideline concentrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Montpelier</td>
<td>23,000</td>
<td>Winooski R.</td>
<td>190</td>
<td>PFOA 24 ng/L, PFOS 0.2 ng/L</td>
</tr>
<tr>
<td>Burlington North</td>
<td>23,000</td>
<td>Winooski R.</td>
<td>494</td>
<td>PFOA 9.6 ng/L, PFOS 0.08 ng/L</td>
</tr>
<tr>
<td>Essex Junction</td>
<td>30,000</td>
<td>Winooski R.</td>
<td>470</td>
<td>PFOA 12 ng/L, PFOS 0.1 ng/L</td>
</tr>
<tr>
<td>Barre</td>
<td>7,000</td>
<td>Stevens Branch</td>
<td>37</td>
<td>PFOA 24 ng/L, PFOS 0.2 ng/L</td>
</tr>
<tr>
<td>Newport City</td>
<td>15,000</td>
<td>Clyde River</td>
<td>101</td>
<td>PFOA 22.8 ng/L, PFOS 0.19 ng/L</td>
</tr>
<tr>
<td>Guideline</td>
<td></td>
<td></td>
<td></td>
<td>PFOA 720 ng/L, PFOS 6 ng/L</td>
</tr>
</tbody>
</table>

Dilution is a necessary part of the equation!

Source =>

Memo
To: Emily Boedecker, Commissioner, DEC
Thru: Matt Chapman, General Counsel, DEC
From: Pete LaFlamme, Director, Watershed Management Division
      Chuck Schwer, Director, Waste Management & Prevention Division
Date: October 15, 2017
RE: Recommendations for Landfill Leachate Discharge Guideline Levels for PFOA and PFOS
PFAS Relationship Between Landfills and Wastewater Treatment Plants (WWTPs)

Do PFAS cycle between landfills and WWTPs?
PFAS in Landfill Leachate

  - 70 PFAS / 95 samples / 18 landfills
  - Estimate 563 – 638 kg of PFAS in leachate per year in the U.S.
Ballpark Estimate of PFAS in Sewage Sludge

Assume
- 7.7 million tons of sewage sludge (estimate for 1998 in U.S)
- PFAS content 100 ppb (µg/kg) in sludge

Find
- 700 kg/year of PFAS in sewage sludge
- Order of magnitude comparable to leachate

Note
- ~10 million gals AFFF in 2004 $^1$ – 1% F implies 380,000 kg of PFAS
- Production of APFO: 230,000 to 450,000 kg in 2002 alone $^2$

---


Preliminary Mass Flux Estimates for a Specific Landfill
(Some) Sources of PFAS at Landfills (?)

- Consumer products
- Sewage sludge
- Industrial wastes
- Auto shredder residue
- Debris from fire cleanup
- Discarded AFFF

- Paper and packaging
- Clothing and carpets
- Outdoor textiles and sporting equipment
- Ski and snowboard waxes
- Non-stick cookware
- Cleaning agents and fabric softeners
- Polishes and waxes, and latex paints
- Pesticides and herbicides
- Hydraulic fluids
- Windshield wipers
- Paints, varnishes, dyes, and inks
- Adhesives
- Medical products

Icons courtesy of Microsoft Word
PFAS Waste Study

- Broad goal: Characterize PFAS sources
- Required by VT DEC
- Wastes included:
  - Sludge materials
  - Contaminated soils
  - Bulky items / coated fabrics
  - C&D materials (e.g., carpeting)
  - Specific suspected industries

PFAS Mass Flux Estimates by Compound

Leachate PFAS Data from January 2018 VT-DEC Sampling Combined with Landfill Leachate Generation
- Leachate-1 Modified Method 537
- Leachate-2 MLA 110

Mass InFlux Estimates Based on Measured PFAS Concentrations and Measured or Estimated Waste Acceptance Rates

PFAS In = 23 g/day (total)
PFAS Out = 0.7 – 2.6 g/day
Ratio of PFAS InFlux to PFAS OutFlux

PFAS OutFlux Based on Average PFAS Concentration in Leachate

Ratios >1 Indicate the PFAS InFlux Exceeds the PFAS OutFlux – PFAS Likely Sequester in Landfill

Ratios < 1 Indicate a PFAS Influx Smaller than the PFAS Outflux – Not All Sources Identified
PFAS in Sludge Materials (Part 1)

Sample Designation Key
Mun = Municipal
Ind = Industrial
Pap = Paper
Grt = Sewer Grit
D = Field duplicate
PFAS in Sludge Materials (Part 2)

Sample Designation Key

Mun = Municipal
Ind = Industrial
Pap = Paper
Grt = Sewer Grit
D = Field duplicate
PFAS in Contaminated Soil

Sample Designation Key (x axis)

PAH = Polycyclic Aromatics
PET = Petroleum Hydrocarbons
PCB = Polychlorinated Biphenyls
TFR = Tire Fire Residue

D (at end) = Field duplicate
PFAS Background Levels in VT Soils

- 66 locations from parks and forests across VT
- PFAS depicted found in >50% of samples
- Median concentrations:
  - PFOS: 700 ppt = 0.7 ppb
  - PFOA: 300 ppt = 0.3 ppb
- Triangles: reporting limits
- Circles: 95% percentiles

PFAS in Bulky Waste Coverings and Textiles

Sample Designation Key (x-axis)

A = Artificial Tree
B = Fabric Swatches
C = Clothing
F = Furniture
G = Gel Ice Pak
H = Hot Tub Cover
L = Luggage
M = Mattress / Box Springs
P = Pool
R = Carpeting
T = Tarp/Tent
U = Umbrella
Y = Inflatable Toy

D (at end) = Field duplicate
PFAS in Construction and Demolition Waste (C&D)

Sample Designation Key (x axis)

CP = Carpeting
SH = Shingles (Roof)
VS = Vinyl Siding
WF = Wood Flooring
WC = Wall & Ceiling Material
LT = Linoleum Tile
PS = Plastic Straps
FS = Fiberboard Siding

D (at end) = Field duplicate
PFAS in Commercial Wastes

Sample Designation Key

WP = Waterproof Coatings
SC = Surface Coatings
CM = Cosmetics Manufacturing
FP = Food Packaging
W = Wire Manufacturing
CT = Clothing & Textiles
PM = Plastics Manufacturing
CW = Carwash
CP = Coated Paper
E = Electroplating
P = Packaging
IP = Ink Printing

A, B, C (end) = Related Samples
D (end) = Field duplicate
Paired Comparison: PFAS Content and SPLP

Sample Designation Key

Concentration in waste in ng/g (ppb)
(left bar, right axis)
Leachate extract concentration in ng/l (ppt)
(right bar, left axis)

C&D = Construction/Demolition
Mun = Municipal Sludge
Ind = Industrial Sludge
PET = Petroleum Hydrocarbons
CP = Carpeting
WF = Wood Floors
Comm = Commercial

Sample names and numbers correspond to previous slides

Leached % values below axis indicate leached fraction of PFAS sample mass
Michigan Leachate Study: PFOA Loadings to WWTPs

Leachate influent vs. overall WWTP influent

Based on:
- Single sample
- Permitted WWTF discharge
- Average leachate discharge
Conclusions

- Multiple PFAS loadings to both landfills and WWTPs
- Mass flux comparisons/balances are important
- Landfills may sequester most of the PFAS that enters
- Decisions to accept or refuse wastes should be made carefully and more data collected to evaluate PFAS fate
Contact Information

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Project Director
szemba@sanbornhead.com
T 802.391.8508

Thanks for your attention!
Vermont's PFAS Quest Continues: from Village Greens to Land Application Sites

Vermont Department of Environmental Conservation
Waste Management & Prevention Division
Residual Management & Emerging Contaminants Program
Vermont's PFAS Quest Continues: from Village Greens to Land Application Sites

Acknowledgements

- Joshua Burns, John Schmeltzer, Kasey Kathan, VTDEC
  - Steven LaRosa, Weston & Sampson
- Johanna Palmer, Laura Woodard, Joe Hayes, ATC
- Vermont WWTF operators, municipal managers
  - septage haulers
  - myriad of environmental consultants
Teflon Town: ChemFab's toxic legacy

Once The Pride Of North Bennington, Chemfab Made Fabrics Used Worldwide, And In Space
• 700 samples collected from private wells
• >60% wells with PFOA detected
• ~ 50% wells with > 20 ppt PFOA
• POET systems installed
• New municipal water supply lines extended to ~400 homes
Per- and Polyfluoroalkyl Substances (PFAS) in Vermont Shallow Soils

Wenyu Zhu, Ph.D.
Department of Civil and Environmental Engineering
University of Vermont

Harrison Roakes, P.E.
Sanborn, Head & Associates

- Summer 2018
- 66 samples collected
- Analyzed for 17 PFAS
<table>
<thead>
<tr>
<th>VT Regulated PFAS</th>
<th>Health Advisory/ MCL (ng/L)</th>
<th>Groundwater Enforcement Std (ng/L)</th>
<th>Residential Soil (mg/kg)</th>
<th>Recommended Limit for Landfill Leachate to WWTP (ng/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFHxS (C6)</td>
<td></td>
<td>20 ppt (*)</td>
<td>1.22 ppm (sum)</td>
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<tr>
<td>PFHpA (C7)</td>
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<tr>
<td>PFOA (C8)</td>
<td></td>
<td></td>
<td></td>
<td>120,000</td>
</tr>
<tr>
<td>PFOS (C8)</td>
<td></td>
<td></td>
<td></td>
<td>1000</td>
</tr>
<tr>
<td>PFNA (C9)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(*) = any combination of the 5 compounds
Statewide evaluation of PFAS in:
- ~400 samples. Analyzed for 24 PFAS. Modified 537.
- Landfill leachates (4)
- WWTF influent, effluent (19), sludges/biosolids (22)
- Industrial discharges (2)
Average of $\sum$ VT-5 PFAS (ppt) in Samples of WWTF Influent and Effluent
PFAS (ppt) Signature, LF Leachate and WWTF Receiving

- Influent
- Effluent
- Leachate
<table>
<thead>
<tr>
<th>Type</th>
<th>Pathogen Reduction</th>
<th>Vector Attraction Reduction</th>
<th>Pollutant limits</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A</td>
<td>Further Reduced (PFRP)</td>
<td>Required</td>
<td>Metals, PCBs</td>
<td>Distributed under Permit</td>
</tr>
<tr>
<td>Class B</td>
<td>Significantly Reduced (PSRP)</td>
<td>Required</td>
<td>Metals, PCBs</td>
<td>Land Applied at Permitted Sites</td>
</tr>
<tr>
<td>Septage</td>
<td>PSRP – Lime Stabilization</td>
<td>Required</td>
<td>Metals, PCBs</td>
<td>Land Applied or WWTP</td>
</tr>
<tr>
<td>Sludge</td>
<td>None</td>
<td>None</td>
<td>Metals, PCBs, TCLP</td>
<td>Landfill, Transfer to Facility</td>
</tr>
</tbody>
</table>
Vermont Sludge/Biosolids Management Trends

Recycled as Biosolids


0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Vermont Organics

Septage Management

Land App 16%

WWTP 84%
Average PFAS (ug/kg) in Samples of Solids Collected at WWTFs

VT-5 PFAS  Total PFAS


PFAS (ug/kg; ppb)
Average PFAS (ppb) in Samples of Residual Materials

VT-5 PFAS  Total PFAS

Sludge  Class B  Class A  SPF
Average of $\sum$VT-5 PFAS in Samples of Influent, Effluent and Solids

- Influent
- Effluent
- Solids

<table>
<thead>
<tr>
<th>Location</th>
<th>Influent</th>
<th>Effluent</th>
<th>Solids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barre</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bartonville</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bennington</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burlington North</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Essex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milton</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Montpelier</td>
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<td>S.B. Bartlett Bay</td>
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<td></td>
</tr>
<tr>
<td>Springfield</td>
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<td></td>
</tr>
<tr>
<td>Swanton</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Westrock</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Comparing PFAS Signatures in Biosolids Analyzed as Liquid (ng/L) vs Solid (ng/g)
August – October 2019

- 4 Land App Sites (Class B biosolids, stabilized septage)
- Soil Sampling Cores at 0-6” and 24-30”
- Samples of Groundwater from Onsite Monitoring Wells (low flow)
- Drinking water supply wells within an approximate 0.25-mile radius
Site 1: Class B Biosolids, lime-stabilized/dewatered, broadcast applied biennially

1 nearby well w/ 3.86 PFHxA, 4.04 PFBS, not attributed to land application site
Site 2: Class B Biosolids, Anaerobically Digested/dewatered, broadcast applied annually, Windsor soils
Site 3: Class B Biosolids, anaerobically digested, liquid, injected, annually
Site 4:  Field A - stabilized septage, broadcast, routinely during growing season  
Field B - stabilized septage, occasional class B biosolids (lime stabilized), biannually  
Field C - stabilized septage/class B biosolids (lime stabilized), broadcast, biannually

4 residential water supplies w/in .25 miles of site = all ND
Results from Permittee Sampling “Directive”: PFAS (ppb) in Shallow Soil Samples
ΣPFAS (n=66)
- 8 locations >5,000 ng/kg
- 23 locations 2,000-5,000 ng/kg
- 25 locations 1,000-2,000 ng/kg
- 10 locations <1,000 ng/kg

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Max</th>
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<tbody>
<tr>
<td>PFBA</td>
<td>N/A</td>
</tr>
<tr>
<td>PFPeA</td>
<td>1,300</td>
</tr>
<tr>
<td>PFHxA</td>
<td>4,400</td>
</tr>
<tr>
<td>PFHpA</td>
<td>900</td>
</tr>
<tr>
<td>PFOA</td>
<td>4,900</td>
</tr>
<tr>
<td>PFNA</td>
<td>5,000</td>
</tr>
<tr>
<td>PFDA</td>
<td>7,600</td>
</tr>
<tr>
<td>PFUnDA</td>
<td>2,600</td>
</tr>
<tr>
<td>PFDoDA</td>
<td>690</td>
</tr>
<tr>
<td>PFTrDA</td>
<td>130</td>
</tr>
<tr>
<td>PFTeDA</td>
<td>N/A</td>
</tr>
<tr>
<td>PFHxDA</td>
<td>N/A</td>
</tr>
<tr>
<td>PFODA</td>
<td>N/A</td>
</tr>
<tr>
<td>PFBS</td>
<td>1,600</td>
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<tr>
<td>PFHxS</td>
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<tr>
<td>PFOS</td>
<td>9,700</td>
</tr>
<tr>
<td>PFDS</td>
<td>920</td>
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</tbody>
</table>
Perfluoroalkyl Substances (PFAS) Statewide Sampling Plan

June 2019

https://dec.vermont.gov/pfas/pfoa

Eamon Twohig
Eamon.Twohig@vermont.gov
802-490-6189
Utilizing Current Tools for Treating Proprietary Chemistry

AnnieLu Dewitt

PFAS Water Treatment Lead
Clean Harbors
PFAS and Proprietary Chemistry

- PFAS Chemistry originated from a failed refrigerant coolant experiment
- Discovered by accident in 1938 and described as the “slipperiest material in existence”
- Commercial possibilities were and are endless
- This chemistry is complicated and not well understood outside of the companies that produce these chemicals
- Small and large changes in chemical structure can be made and patented
- Companies protect their proprietary property and do not have to disclose information about these chemicals
- Currently we are playing catch up to identify and treat the changing chemistry
Current Analytical Tools for Identification of PFAS

- LC/MS/MS - including 537 series of methods, 8327 these methods are targeted analysis methods
- Very low detection limits capable of seeing concentrations below 1ppt
- The trade off is that these methods are very selective in what they are looking for and sort out other compounds
- A small change in the chemical structure would make the compound invisible because the current methods being employed commercially are so targeted and selective.
- Of the over 6,000 compounds that fit the current definition of PFAS there are approximately 35 compounds with commercially available standards
Developing Less Targeted Analytical Options

- TOP Assay (TOPA)- Method that gently heats and oxidizes constituents in a sample down to their base structures that can be identified by current methods. Method is not meant for quantitation or even qualification of other analytes but gives a better picture of other PFAS compounds present.

- EPA Method 5050 followed by Method 9056 for fluorine analysis - reporting limits are high (ppm range) and identification is very broad. This method is good for highly concentrated waste streams to get an understanding of total fluorine content.

- Total Fluorine by IR- reporting limits in the ppm range but gives you information on all the C-F bonds present. Similar to the old TPH by IR method.

- Time of Flight LC/ MS- Very promising but currently very time consuming and labor intensive.
Non-Selective PFAS Removal from Water

- Adsorptive media such as GAC, organoclays and others will remove PFAS non-selectively
- Ion exchange media will also remove other contaminants besides PFAS but in a different way. They will target the polar end of analyte.
- The more we learn about replacement chemistry the easier it will be to adapt and adjust adsorptive and ion exchange medias if required.
- Currently ND for all identified* PFAS compounds is achievable. The issue is some analytes have a short breakthrough time. This can be managed with a good analytical and maintenance program.
What are the Implications of Selective Identification and Non-Selective Removal

• Understand that what is reported may not be the complete picture of PFAS in the water
• Non-selective removal of PFAS will be impacted by other constituents in the water and that is why comprehensive water chemistry is helpful in designing and maintaining a treatment system that best fits the characteristics of the incoming water.
• For very complicated influent water a treatment train of consecutive media has been found to be most effective.
• In many cases the most difficult part of treatment is getting the influent water prepared for efficient PFAS removal.
• Standard isotherms for carbon usage are rarely a good indicator of what to expect for the lifetime of a carbon system for PFAS because of competitive adsorption from TOC, VOCs etc.
A Conservative Approach to PFAS Water Treatment is the Best Defense Throughout the Lifecycle of a PFAS Project

- Identification- Obtain a comprehensive analysis of the incoming water to evaluate competitive analytes for adsorption and ion exchange
- Agreement on Project Objectives- Confirm with all parties what expectations are for discharged water. What constitutes ND, what analyte list and methods are to be used
- Pilot Study- If time allows this is the best means for determining breakthrough rates. If time does not allow for this an option is to start with a very robust treatment train that can be adjusted
- Selecting Approach and Equipment- Comparing costs and benefits to find the right fit for the application throughout the complete lifecycle of the project not just mobilization and initial equipment costs
- Final Deposition of Spent Media and Associated Solids- Landfill, incineration or reactivation
SCID* Approach to PFAS Water Treatment

• Separate- Separate contaminants from the water by mechanical filtration, adsorption and ion exchange

• Concentrate- The contaminants are concentrated from large volumes of water onto relatively small quantities of media

• Isolate- The contaminants are isolated onto the media

• Destroy- Adsorptive and ion exchange media is destroyed in MACT compliant hazardous incinerators. High temperature incineration in MACT compliant facilities is the current BDAT (best demonstrated available technology)

• Clean Harbors’ considers high temperature incineration the best available technology for PFAS waste streams when practical. Landfills with a closed loop process will be given consideration as a treatment option on a case by case basis
Incineration and Emission Control Steps
- Kiln 1800 F
- Secondary Combustion Chamber 2050 F (1121 C)
- Spray Dryer
- Baghouse 1
- Saturator
- Condensers
- Baghouse 2
- DeNox
- Stack
MACT Incineration Process

• Incineration and Emission Control Steps
• Kiln 1800 F
• Secondary Combustion Chamber 2050 F (1121 C)
• Spray Dryer
• Baghouse 1
• Saturator
• Condensers
• Baghouse 2
• DeNox
• Stack
Current Options for Treatment

• GAC- Widely accepted treatment option for PFOA and PFOS shorter chained PFAS compounds dictate very short exchange cycles

• Resin- Different resins are good options for longer chained compounds, PFOA, PFOS and for shorter chained PFAS that are poorly adsorbed by GAC. Shorter EBCT

• Other adsorptive medias very promising for non potable applications with high concentrations as a pretreatment and as a standalone media

• Oxidation and other destructive technologies- have shown effectiveness of breaking down longer chained compounds. Our hesitation is that with the complex influent water we see and rapid deployment we may not have time to do full studies to calculate required energy in a timely manner. A static system would be an ideal situation for this type of application

• Incineration of water

• Reverse Osmosis- Very effective with PFAS compounds but the reject stream can be substantial and skilled RO operators are in very high demand
Industrial wastewater system with PFAS Concentrations as high as 700,000 ppt total PFAS consistently brought down to ND. Clean Harbors has designed and installed a system to treat 120 gpm daily. This treatment system has allowed customer to meet discharge parameters since installation.
Case Study – Military Installation West Coast
High Concentration PFAS, VOC, TOC, SVOCs, O&G, TSS, TDS

• In collaboration with on-site engineering firm Clean Harbors designed, built, installed and trained staff to operate a mobile high concentration PFAS treatment system that addressed TOC, VOCs, SVOCs, O&G, TSS, TDS and other contaminants to meet strict discharge limits for a local POTW. The system has continued to successfully treat influent water with concentrations in excess of 8ppm to less than 2 ppt for PFOS, PFOA and short chained PFBS.

• **System Operation & Maintenance** - Clean Harbors initiated the startup of the system in order to properly balance the system and train the on-site staff of Wood. Clean Harbors continues to assist with ongoing treatment decisions, media change-outs and disposal services, including incineration of spent media.

• The Clean Harbors’ team consisted of the Project Manager, a Field Supervisor, and a two-man crew including a foreman and field technician. The PM and Supervisor worked with the onsite Engineering Consultant to carry out the installation and system operation. The project commenced in January 2019 and is expected to continue through the end of Dec 2019.
Case Study – Petroleum Processing Client, Upper Midwest

PFAS Capture – Post-fire Construction and Operation of Treatment System

• **System Design** – Clean Harbors recommended the proper combination of equipment, filters, activated carbon, and resin needed to process PFAS concentrations. System is capable of flow rates up to 400 gallons per minute (gpm).

• **System Construction** – The entire system was transported, then constructed on-site in less than 3 days. After one day of performance testing, the system successfully reduced PFAS concentrations to non-detectable levels. System operates at 250 gpm.
  
  ➢ PFAS concentrations in the discharge water are well below permit limits. A second, similar system was installed on a similar schedule six weeks later.

• **System Operation & Maintenance** – Clean Harbors was contracted to operate the system to properly balance the treatment system alongside the on-site wastewater treatment plant operations. Clean Harbors then trained client personnel. Client staff assumed responsibility for system operation several weeks later.
  
  ➢ Clean Harbors continues media change-out and disposal services, including incineration and hazardous landfilling.
Case Study – Industrial Plater, Michigan

PFAS Control – Emergency; Full Scale Treatment Design and Implementation

Clean Harbors was contracted by a Michigan plating and surface finishing firm after discovery of multiple PFAS compounds in its discharge to the local publically owned treatment works. The POTW set strict PFAS limits, and demanded compliance within a limited time or cessation of all discharges. Clean Harbors provided services that met its client’s discharge permit limits, allowing continued operations.

- **Operations analysis** – Fluctuations in product demand triggered irregular treatment, discharge, and renewal of individual baths, which yielded a waste stream of constantly changing chemical composition.

- **Media testing** – Clean Harbors tested a number of adsorbent media, individually and in series. Each was intended to adsorb PFAS compounds or inorganic and organic waste components that interfered with PFAS capture.

- **Full-scale system design** – Testing data and the extensive experience and expertise of Clean Harbors staff were used to develop a treatment system.

- **System installation and operation** – Clean Harbors constructed and started the treatment system, which met POTW permit limits before the deadline. Clean Harbors commenced support of client staff through media exchange and disposal services, as well as performance testing.
Thank You
Questions and Contact Information

- AnnieLu DeWitt- Dewitt.Annielu@cleanharbors.com 207-232-8378
- John Goodno- Goodno.John@cleanharbors.com 475-777-4004
Remediation of PFAS: An Overview of Current Options

Paul Dombrowski, P.E.
Senior Remediation Engineer
ISOTEC Remediation Technologies
Remediation of PFAS: An Overview of Current Options

Paul M. Dombrowski, P.E.
ISOTEC Remediation Technologies, Inc.
PFAS Properties and Challenges

• C-F bond is one of strongest bond in nature
  • High energy to break bonds
  • Stable in acids, bases, oxidants, heat
  • Microorganisms do not gain energy from breaking the bond

• Low Vapor Pressure: Not suitable for vapor extraction

• Low Henry’s Law Constant: Not suitable for stripping from groundwater

• High $K_{oc}$: Adsorption potential

• Charged head: Ion exchange potential

• May be co-mingled with other VOCs
Adsorption by Activated Carbon

- PFOA & PFOS $K_{oc}$: same order of magnitude as PCE & benzene
- GAC commonly used for water treatment of PFAS
- Activated Carbon Based Injectate for in-situ remediation

Treatment Considerations
- No treatment or removal of PFAS
- Less effective for short-chain PFAS
- Competition for sorptive sites/desorption
- Not all activated carbon is the same

5 grams of carbon has an internal surface area equivalent to the surface of a professional football field
Adsorption – Soil Treatment

- RemBind® is a powdered adsorbent
  - Blend of aluminum hydroxide, carbon & clays

- Used to treat PFAS-impacted soil at full scale in USA, Sweden & Australia
  - 1,000 metric tons of soil was treated in Australia
  - Disposed to landfill with regulatory approval & no further management requirements
Adsorption

- Permeable Reactive Barrier Concept

- AquaGate+RemBind
  - composite particle
  - aggregate core coated with the RemBind®
Chemical Oxidants

• Heated persulfate effective for treatment of PFCAs
  • Temperature as low as 30°C
• Little evidence of PFOS treatment
• 1 field test to date
  • $O_3$ and $H_2O_2$ activated persulfate (Eberle, et al., 2017)
• Chem Ox treatment of PFAS will require careful balance of free radicals, reaction kinetics, and radical scavengers

_Dombrowski, et al. (2018) Technology review and evaluation of different chemical oxidation conditions on treatability of PFAS_
Chemical Reduction

• Theoretical and experimental evidence: PFOS is amenable to reduction

• Literature studies
  • UV (254 nm)
  • Vitamin B12
  • ZVI
  • Mixed Metal Oxide Electrodes
  • Boron Doped Diamond Electrode
  • Electrochemical
Foam Fractionation Technology

- Enhanced Extraction Method
  - Application of gas bubbles to bottom of water column
  - PFAS transfers from water to bubbles
  - High concentration solution/foam accumulates at top of water column
  - Foam removed by vacuum

- Source Area or Barrier Treatment

- Field Pilot Test in 2020 (ESTCP ER19-B3-5075)
  - Radius of Influence is a key design parameter
  - ISOTEC team member
Bioremediation

• Polyfluorinated forms of PFAS biotransform in the environment
  • Large number of polyfluorinated precursor compounds biotransform

• Fungi can biotransform PFOA

• Wetland bacteria reduced PFOA & PFOS laboratory at Princeton University
  • Autotroph that oxidizes ammonium to nitrite while reducing ferric iron
  • Removal of up to 60%
    • Huang and Jaffe, 2019
Thermal Treatment for PFAS
Thermal Desorption Treatment

- Heat excavated soil to 500 - 600°C to desorb PFAS into the gas stream
  - PFOS treatment in highly impacted soils is ineffective at 600°C (1-hr residence time)

- PFAS are destroyed at 900 - >1,000°C by thermal oxidation

- Potential emissions of hydrofluoric acid or other fluoro-organic compounds

- Alternative Heating Methods
  - Thermal Piles: heat, cover, keep under pressure
  - Smoldering combustion

Thermal Treatment for PFAS

PFAS Volatilization

- 350°C: 99.91% reduction
- 400°C: 99.998% reduction

Two Weeks of Heating
PFAS Remediation Summary
PFAS Remediation Resources

• SERDP-ESTCP PFAS FAQ and Reference Document
  • https://www.serdp-estcp.org/content/download/46353/431598/file/FAQ%20ER-201574%20September%202017.pdf

• CLU-IN PFAS Remediation Technologies
  • https://clu-in.org/contaminantfocus/default.focus/sec/Per-and_Polyfluoroalkyl_Substances_(PFASs)/cat/Remediation_Technologies/#3

• Remediation Journal – PFAS Issue (Vol 28, Issue 2, March 2018)
Paul M. Dombrowski, P.E. (MA, CT)
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O: 617-902-9383  M: 917-971-2956

Chemical Oxidation & Reduction/Fixation
Bioremediation
Thermal Remediation
Soil Mixing (Chemical Reagents & Stabilization)
Treatability Laboratory
Activated Carbon Injectates (BOS100® & BOS200®)
PFAS Sampling: Results of a Cross-Contamination Study

Jim Occhialini

Vice President
Alpha Analytical
PFAS Sampling: Results of a Cross Contamination Study

EBC Emerging Contaminants Seminar:
The Life Cycle of PFAS

2/25/2020
Framingham, MA

Jim Occhialini
Alpha Analytical
"What we find in the environment often depends on what we look for and how hard we look"  USGS website

Topics for Discussion

- Introduction
- Cross contamination study results
  - Acknowledgements
    - Elizabeth Denly, Michael Eberle, Nidal Rabah - TRC
    - Philip Bassignani, Alpha Analytical
**BACKGROUND CONTAMINATION?**

- **PFAS False Positives?**
- **Single digit ng/L RLs**
- **Ultra low detection limits not new to environmental data collection**
- **Widespread “mainstream” sampling at this level of sensitivity is new**
- **Ubiquitous nature of PFAS sources coupled with widespread sampling and ng/L RLs? Unprecedented**
### MassDEP Drinking Water Program February 2019

#### Do’s and Don’ts

MassDEP 12/27/2019 BWSC update "there is extensive guidance available online and it is not MassDEP's intent to require the use and avoidance of certain products, particularly as formulations may change over time"

<table>
<thead>
<tr>
<th>Category</th>
<th>Prohibited Items</th>
<th>Allowable Items</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pumps and Tubing</strong></td>
<td>Teflon® and other fluoropolymer containing materials</td>
<td>High-density polyethylene (HDPE), low density polyethylene (LDPE), or silicone tubing, peristaltic pump or stainless steel submersible pump</td>
</tr>
<tr>
<td><strong>Decontamination</strong></td>
<td>Decon 90</td>
<td>Alconox® or Liquinox®, potable water followed by deionized rinse.</td>
</tr>
<tr>
<td><strong>Sample Storage and Preservation</strong></td>
<td>LDPE or glass bottles, PTFE- or Teflon®-lined caps, chemical ice packs</td>
<td>Laboratory-provided sample container -preferred; or, HDPE or polypropylene bottles, regular ice</td>
</tr>
<tr>
<td><strong>Field Documentation</strong></td>
<td>Waterproof/treated paper or field books, plastic clipboards, Sharpie® and permanent markers, Post-It® and other adhesive paper products</td>
<td>Plain Paper, metal clipboard, pens</td>
</tr>
<tr>
<td><strong>Clothing</strong></td>
<td>Clothing or boots made of or with Gore-Tex™ or other synthetic water resistant and/or stain resistant materials, Tyvek® material</td>
<td>Synthetic or cotton material, previously laundered clothing (preferably previously washed greater than six times) without the use of fabric softeners</td>
</tr>
<tr>
<td><strong>Personal Care Products</strong></td>
<td>Cosmetics, moisturizers, hand cream and other related products</td>
<td>Sunscreens: Alba Organics Natural, Yes to Cucumbers, Aubrey Organics, Jason Natural Sun Block, Kiss My Face, Baby-safe sunscreens ('free' or 'natural')</td>
</tr>
<tr>
<td>(on day of sample collection)</td>
<td></td>
<td>Insect Repellents: Jason Natural Quit Bugging Me, Repel Lemon Eucalyptus, Herbal Armor, California Baby Natural Bug Spray, BabyGanics</td>
</tr>
<tr>
<td><strong>Food and Beverage</strong></td>
<td>Pre-packaged food, fast food wrappers or containers</td>
<td>Sunscreen and Insect Repellents: Avon Skin So Soft Bug Guard-SPF 30</td>
</tr>
</tbody>
</table>
Field sampling for PFAS...soils... non-potable GW ... water supply wells & fish tissue
lists:
acceptable sampling materials
no contact with acceptable equipment list

January 2020

Guidelines for Sampling and Analysis of Per- and Polyfluoroalkyl Substances (PFAS) Under NYSDEC’s Part 375 Remedial Programs

Objective

New York State Department of Environmental Conservation’s Division of Environmental Remediation (DER) performs or oversees sampling of environmental media and subsequent analysis of PFAS as part of remedial programs implemented under 6 NYCRR Part 375. To ensure consistency in sampling, analysis and reporting of PFAS, DER has developed this document to summarize procedures and update previous DER technical guidance pertaining to PFAS.

Applicability

Sampling for PFAS has already been initiated at numerous sites under DER-approved work plans, in accordance with specified procedures. All future work plans should include PFAS sampling and analysis procedures that conform to the guidelines provided herein.

As part of a site investigation or remedial action compliance program, whenever samples of potentially affected media are collected and analyzed for the standard Target Analyte List/Target Compound List (TAL/TCL), PFAS analysis should also be performed. Potentially affected media can include soil, groundwater, surface water, and sediment. Based upon the potential for biota to be affected, biota sampling and analysis for PFAS may also be warranted as determined pursuant to a Fish and Wildlife Impact Analysis. Soil vapor sampling for PFAS is not required.

Field Sampling Procedures

DER-10 specifies technical guidance applicable to DER’s remedial programs. Given the prevalence and use of PFAS, DER has developed “best management practices” specific to sampling for PFAS. As specified in DER-10 Chapter 2, quality assurance procedures are to be submitted with investigation work plans. Typically, these procedures are incorporated into a work plan, or submitted as a stand-alone document (e.g., a Quality Assurance Project Plan). Quality assurance guidelines for PFAS are listed in Appendix A - Quality Assurance Project Plan (QAPP) Guidelines for PFAS.

Field sampling for PFAS performed under DER remedial programs should follow the appropriate procedures outlined for soils, sediments or other solids (Appendix B), non-potable groundwater (Appendix C), surface water (Appendix D), public or private water supply wells (Appendix E), and fish tissue (Appendix F).

QA/QC samples (e.g., duplicates, MS/MSD) should be collected as specified in DER-10, Section 2.3(c). For sampling equipment coming in contact with aqueous samples only, rinsate or equipment blanks should be collected.
4. General PFAS Sampling

The following sections discuss technical issues such as the need to use PFAS-free water, information about PFAS-free clothing and PPE, and laboratory issues that should be considered when sampling for PFAS.

4.1 Sampling Objectives

Before conducting any PFAS sampling, it is recommended that a project-specific Quality Assurance Project Plan (QAPP) should be developed. The QAPP must meet MDEQ policy and should include the analyte list, method of analysis, environmental matrices, and reporting limits, which are based on the project objectives. All of these considerations will be discussed in more detail in this guidance document.

4.2 PFAS Cross-Contamination Potential Sources

Potential sources of PFAS cross-contamination in the typical sampling environment include water used during drilling or decontamination, materials used within the sampling environment, sampling equipment, field clothing, and personal protective equipment (PPE), sun and biological protection products, personal hygiene and personal care products (PCPs), food packaging, and the environment itself.

The materials associated with sampling that have the potential for PFAS cross-contamination have been divided into three major groups:

- **Prohibited (X)** identifies items and materials that should not be used when sampling. It is well documented that they contain PFAS or that PFAS are used in their manufacture.
- **Allowable (A)** identifies items and materials that have been proven not to be sources of PFAS cross contamination and are considered allowable for sampling.
- **Needs Screening (XS)** identifies items and materials that have the potential for PFAS cross-contamination due to lack of or scattered data or statements by manufacturers to prove otherwise. These items and materials are further sub-divided into two categories:
  - Category 1: Items and materials that will come in direct contact with the sample. These should not be used when sampling unless they are known to be PFAS-free, by collecting an equipment blank sample prior to use.
  - Category 2: Items and materials that will not come in direct contact with the sample. These should be avoided, if possible, unless they are known to be PFAS-free by collecting an equipment blank sample prior to use.

All of the materials or items discussed above in the MDEQ PFAS Sampling Guidance Documents will be divided into Prohibited, Allowable, or Needs Screening. Several examples of prohibited and allowable materials and materials that need screening are listed in the MDEQ PFAS Sampling Quick Reference Field Guide at the end of this document. Also, materials and items that are specific to a particular environmental media or sampling method will be thoroughly explained in that media's sampling guidance document (such as peristaltic pumps for groundwater sampling).
PFAS in Sampling Supplies: Fact or Fiction?

DOI: 10.1002/ren.21614

RESEARCH ARTICLE

Per- and polyfluoroalkyl substances in environmental sampling products: Fact or fiction?

Elizabeth Denly¹ | Jim Occhialini² | Phil Bassignani² | Michael Eberle³ | Nidal Rabah⁴

Passive Diffusion Bag
Nitrile Gloves
Bailer Line
Field Book (cover & pages)
Concept

- **Objective:**
  - Can PFAS be transferred from common field and other commercial products during sampling?

- **Disclaimer**
  - A first look at aqueous leachability
    - Worst case scenario
  - Snapshot
    - Not an in depth study
  - Products chosen at random
    - Generic product names are used as descriptions but not to endorse or invalidate any individual product for use
    - Nothing implied concerning a given product's results
      - Sources, manufacturers, product ID, lot #, etc.
<table>
<thead>
<tr>
<th>Batch 1</th>
<th>Batch 2</th>
<th>Batch 3</th>
<th>Batch 4</th>
<th>Batch 5</th>
<th>Batch 6</th>
<th>Batch 7</th>
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<tbody>
<tr>
<td>October 2017</td>
<td>October 2017</td>
<td>October 2017</td>
<td>February 2018</td>
<td>March 2018</td>
<td>March 2018</td>
<td>August 2018</td>
</tr>
<tr>
<td>Aluminum foil</td>
<td>HDPE tubing (clear, small diameter)</td>
<td>Field book cover</td>
<td>Bentonite plugs</td>
<td>Bentonite time-released pellets</td>
<td>LDPE tubing (0.17&quot; × 1/4&quot;)</td>
<td>Bubble wrap</td>
</tr>
<tr>
<td>PTFE tubing (3/16&quot; × ¼&quot;)</td>
<td>Silastic tubing</td>
<td>Field book pages</td>
<td>Bentonite granular</td>
<td>Silicone tubing (3/16&quot; × 3/8&quot;)</td>
<td>Laser marked water level tape with polyethylene jacket (Model #1)</td>
<td></td>
</tr>
<tr>
<td>Adhesive notes</td>
<td>HDPE tubing (clear, large diameter)</td>
<td>PTFE bladder</td>
<td>Bentonite 3/8&quot; chips</td>
<td>PTFE-lined tubing (1/4&quot; × 3/8&quot;)</td>
<td>Polytetrafluoroethylene (PVDF) laser marked flat water level tape (Model #2)</td>
<td></td>
</tr>
<tr>
<td>HDPE tubing (blue 1/8&quot; × 0.062&quot;)</td>
<td>LDPE tubing (2 manufacturers)</td>
<td>PTFE tubing</td>
<td>Bentonite medium chips</td>
<td>HDPE tubing (0.17&quot; × 1/4&quot;)</td>
<td>Silicone tubing</td>
<td></td>
</tr>
<tr>
<td>Resealable plastic storage bag</td>
<td>Polyethylene bladder</td>
<td>Sample labels</td>
<td>Bentonite time-released tablets</td>
<td>Pizza box</td>
<td>Water level tape with PVDF jacket (Model #3)</td>
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<tr>
<td>Level C chemical resistant clothing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Protein bar wrapper</td>
<td></td>
</tr>
<tr>
<td>Passive diffusion bag</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>LDPE tubing (3 types)</td>
<td></td>
</tr>
</tbody>
</table>
| Nitrile gloves | | | | | 3/8" × 1/2"
| Bailer line | | | | | 1/16" × 1/8"
| | | | | | 0.17" × 1/4"
| | | | | | PVC pipe |
| | | | | | PTFE-lined tubing (0.17" × 1/4") |
Experimental Design, Leaching Step

- **Leaching Step**
  - Shaker table, 24 hr. contact time then decant
    - 2 replicate extractions per product, batch leach & method blanks
  - PFAS-free water
    - 250 mL volume
      - neutral pH, moderate conductivity: 300 us/cm
  - 10 x 10 in product surface area (ideally)
    - Leaching containers
      - HDPE 250 ml bottles

- **Leaching blanks**
Leaching procedure

- 100 grams placed in metal pan, water added
  - Pelletized, coated bentonite was removed from the water once coating dissolved

- Otherwise, the bentonite was removed from water once it started to expand

- Standard preparation procedure from there
Quality Control:
- Method Blanks
- LCS
- Calibration Checks
- Extracted IS
- Matrix Spikes

**Experimental Design Analysis**

Solid phase extraction

LC/MS/MS, isotope dilution

24-compound target list
<table>
<thead>
<tr>
<th>Analyte</th>
<th>Acronym</th>
<th>CAS #</th>
</tr>
</thead>
<tbody>
<tr>
<td>4:2 Fluorotelomer sulfonic acid</td>
<td>4:2FTS</td>
<td>n/a</td>
</tr>
<tr>
<td>6:2 Fluorotelomer sulfonic acid</td>
<td>6:2FTS</td>
<td>27619-97-2</td>
</tr>
<tr>
<td>8:2 Fluorotelomer sulfonic acid</td>
<td>8:2FTS</td>
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<tr>
<td>N-methyl perfluorooctanesulfonamidoacetic acid</td>
<td>NEtFOSAA</td>
<td>2991-50-6</td>
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<tr>
<td>N-ethyl perfluorooctanesulfonamidoacetic acid</td>
<td>NMeFOSAA</td>
<td>2355-31-9</td>
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<tr>
<td>Perfluorooctane sulfonamide</td>
<td>FOSA</td>
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<td>Perfluorobutanoic acid</td>
<td>PFBA</td>
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<td>PFBS</td>
<td>375-73-5</td>
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<td>PFDA</td>
<td>335-76-2</td>
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<td>307-55-1</td>
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<td>PFDS</td>
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<td>PFHpA</td>
<td>375-85-9</td>
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<td>PFHpS</td>
<td>375-92-8</td>
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<td>307-24-4</td>
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<td>Perfluorohexanesulfonic acid</td>
<td>PFHxS</td>
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<td>Perfluorononanoic acid</td>
<td>PFNA</td>
<td>375-95-1</td>
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<td>PFNS</td>
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<td>Perfluorooctanoic acid</td>
<td>PFOA</td>
<td>335-67-1</td>
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<tr>
<td>Perfluorooctanesulfonic acid</td>
<td>PFOS</td>
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RL = 2 ng/L
PTFE Tubing

PTFE Tubing (ng/L)

C4 PFCA

No PFSAs

ng/L

PFBA  PFPeA  PFHxA  PFHpA  PFOA  PFNA  PFDA  PFUnA  PFDoA  PFTrDA  PFTeDA

PTFE TUBING A  PTFE TUBING B
LDPE Tubing

C4 & C5 PFCA

LDPE Tubing (ng/L)

No PFSAs

ng/L
### PTFE vs LDPE Tubing

#### PTFE Tubing (ng/L)

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#### C4 PFCA

- No PFSAs

#### C4 & C5 PFCA

- No PFSAs
PTFE Tubing & PTFE Bladder

C4 & C5 PFCA

No PFSAs
Water Level Tapes

Water Level Tapes
(ng/L)

No PFSAs

Water Level Tape Model 1
Water Level Tape Model 3

ng/L

PFBA  PFPeA  PFhxA  PFHpA  PFOA  PFNA  PFDA  PFUnA  PFDoA  PFTeDA  PFTeDA

0  5  10  15  20  25  30  35  40
**Field Book Pages vs Field Book Cover**

**Pages in Field Logbook (ng/L)**

- PFBS
- PFPeA
- PFHxA
- PFHpA
- PFOA
- PFNA
- PFDA
- PFUnA
- PFDa
- PFTeDA

**Cover of Field Logbook (ng/L)**

- PFBS
- PFBA
- PFPeA
- PFHxA
- PFHpA
- PFOA
- PFNA
- PFDA
- PFUnA
- PFDa
- PFTeDA

**Key**

- C7 PFCA
- C4 PFSA

**Legend**

- Book Pages A
- Book Pages B
- Book Cover A
- Book Cover B

**Notes**

- No PFSAs

**Graphs**

- NG/ML
- Y-axis: ng/L
- X-axis: PFASs
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# Miscellaneous, Fall 2018, 2ng/L RL

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Wrap Up

Start with -
Standard industry practice for site characterization & sampling…
And then make PFAS accommodations

Understand the potential for PFAS to be in the sampling materials you are using

Blanks?

Jim Occhialini
jocchialini@alphalab.com
Elizabeth Denly

Program Director
PFAS Group
TRC
Moderated Discussion

Moderator: Elizabeth Denly, TRC

Panelists:
- AnnieLu Dewitt, Clean Harbors
- Brandon Kernen, New Hampshire DES
- Steven LaRosa, Weston & Sampson
- Paul Locke, Massachusetts DEP
- Jim Occhialini, Alpha Analytical
- Eamon Twohig, Vermont DEC
- Steve Zemba, Sanborn, Head & Associates, Inc.
Closing Remarks

Frank Ricciardi

Seminar Co-Chair

Chair, EBC TSCA & Emerging Contaminants Committee

Vice President, Weston & Sampson