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  - Pesticides
  - Natural Disasters
  - BPA
  - Mold
  - Lead
  - Mercury
Perfluoroalkyl Substances (PFAS): Potential Exposure Sources, Potential Health Impacts, and Guidance for Clinicians

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Objectives

1. Define the chemical family of perfluoroalkyl substances (PFAS) and where they can be found.

2. Identify the scope of potential exposure across the United States.

3. Describe potential health impacts in children.

4. Discuss implications for clinicians.
What are PFAS?

PFAS Family Tree
Properties of PFAS

- PFOA - perfluorooctanoate
- PFOS – perfluorooctane sulfonate
- PFHx – perfluorohexanoate
- Stain-resistant
- POPs – long half-lives, lipophilic
- PFOS ceased production 2002
- PFOA out of production in 2015
Perfluoralkyl Substances (PFAS)

- PFAS are widely used to make everyday consumer products
- Resistant to stains, heat, oil, grease, and water, and also act as lubricants
- Extremely persistent in the environment and resistant to typical degradation processes
- The half-life, or the amount of time it takes for 50% of the chemical to leave the human body is measured in years.
- This slow elimination time makes it difficult to determine how changes in lifestyle, diet, or other exposure-related factors influence blood levels (NIEHS, 2012).
PFAS Basics

**Uses**
- Non-stick cookware
- Carpet and clothing treatments
- Paper and cardboard packaging
- AFFF fire-fighting foam

**Sources**
- Waste from manufacturing facilities
- Fire-fighting foam run-off
- PFC-containing sludge used as soil amendment

**Exposure Pathways**
- Drinking water
  - Private residential wells, municipal systems
- Air and dust
- Fish (in contaminated areas)
- Consumer products
  - Food containers/wrapping
  - Clothing
  - Cookware
- Produce
What other potential exposure points and pathways exist for PFAS?
### Wisconsin House Dust

Perfluorinated chemicals found in vacuum dust samples from 39 Wisconsin homes.

<table>
<thead>
<tr>
<th>Congener</th>
<th>Detection Freq(^a) (%)</th>
<th>Median (range) ng/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perfluorooctane sulfonate (PFOS)</td>
<td>100</td>
<td>47 (8.7–1100)</td>
</tr>
<tr>
<td>Perfluorooctanoic acid (PFOA)</td>
<td>100</td>
<td>44 (6.5–420)</td>
</tr>
<tr>
<td>Perfluoroheptanoic acid (PFHpA)</td>
<td>100</td>
<td>17 (2.4–140)</td>
</tr>
<tr>
<td>Perfluorohexane sulfonate (PFHxS)</td>
<td>100</td>
<td>16 (2.1–1000)</td>
</tr>
<tr>
<td>Perfluorononanoic Acid (PFNA)</td>
<td>100</td>
<td>12 (1.3–280)</td>
</tr>
<tr>
<td>Perfluoroheptane sulfonate (PFHpS)</td>
<td>97</td>
<td>9.9 (ND-37)</td>
</tr>
<tr>
<td>Perfluorodecanoic acid (PFDA)</td>
<td>72</td>
<td>5.7 (ND-60)</td>
</tr>
<tr>
<td>Perfluorodecane sulfonate (PFDS)</td>
<td>95</td>
<td>5.4 (ND-120)</td>
</tr>
<tr>
<td>Perfluoropentanoic acid (PFPA)</td>
<td>97</td>
<td>5.4 (ND-32)</td>
</tr>
<tr>
<td>Perfluorododecanoic acid (PFDoA)</td>
<td>95</td>
<td>5.0 (ND-41)</td>
</tr>
<tr>
<td>Perfluorotetradecanoic acid (PFTeA)</td>
<td>97</td>
<td>3.7 (ND-24)</td>
</tr>
<tr>
<td>Perfluorobutanoic acid (PFBA)</td>
<td>97</td>
<td>3.5 (ND-64)</td>
</tr>
<tr>
<td>Perfluoroundodecanoic acid (PFUA)</td>
<td>87</td>
<td>3.1 (ND-48)</td>
</tr>
<tr>
<td>Perfluorotridecanoic acid (PFTrA)</td>
<td>92</td>
<td>2.1 (ND-11)</td>
</tr>
<tr>
<td>Perfluorobutane sulfonate (PFBS)</td>
<td>59</td>
<td>1.8 (ND-31)</td>
</tr>
<tr>
<td>Perfluorohexanoic acid (PFHxA)</td>
<td>20</td>
<td>0 (ND-180)</td>
</tr>
<tr>
<td>Total perfluorinated chemicals</td>
<td>100</td>
<td>280 (70–2513)</td>
</tr>
</tbody>
</table>

\(^a\) Reporting limit = 1 ng/g.

Chemosphere, 2012
Other Potential Exposure Sources

- Cord Blood
- Breast Milk
- Occupational Settings
Why is this important?

- Widespread human exposure
- May affect developing fetus and child
- "contaminant of emerging concern" – EPA
- May bioaccumulate in people
- May increase cancer risk
- Long half-lives in humans
- PFAS levels exceed EPA’s LTHA in drinking water in several states
PFOA Geometric Mean Serum Concentration (µg/L) in Various Study Populations (Environmentally Exposed Communities, & General U.S. Population)

- Ohio River Valley (2005-2006)
- Decatur, Alabama (2009)
- Red Cross Donors in 6 cities (2006)
- NHANES (2005-2006)
- NHANES (2011-2012)
- Pease Tradeport NH, age ≥12 (2015)
- Pease Tradeport NH, age <12 (2015)
PFOS Geometric Mean Serum Concentration (μg/L) in Various Study Populations (Environmentally Exposed Communities, & General U.S. Population)

- Ohio River Valley (2005-2006)
- Decatur, Alabama (2009)
- Red Cross Donors in 6 cities (2006)
- NHANES (2005-2006)
- NHANES (2011-2012)
- Pease Tradeport NH, age ≥12 (2015)
- Pease Tradeport NH, age <12 (2015)
PFHxS Geometric Mean Serum Concentration (μg/L) in Various Study Populations (Environmentally Exposed Communities, & General U.S. Population)

- Ohio River Valley (2005-2006)
- Decatur, Alabama (2009)
- Red Cross Donors in 6 cities (2006)
- NHANES (2005-2006)
- NHANES (2011-2012)
- Pease Tradeport NH, age ≥12 (2015)
- Pease Tradeport NH, age <12 (2015)
PFOS and PFOA primarily accumulate in:
- Serum
- Kidney
- Liver

(ATSDR, 2016).

- Animal research indicates that PFAS are absorbed in the GI tract with no quantitatively significant metabolism of PFOA and PFOS following oral exposure.
- Research suggests that PFAS are not metabolized or undergo chemical reactions in the body.

(ATSDR, 2015).
Potential Health Effects – Further Research Needed

**Animals**
- Increased liver weight (critical effect)
- Spleen, thymus, and developmental
- Cancer – liver, testis, pancreas

**Humans**
- Possible changes in growth, learning and behavior
- Decreased fertility
- Increased cholesterol
- Immune effects
- Cancer – kidney, bladder, testicular, prostate
Possible PFAS Human Effects

- Thyroid?
- PFAS in Breast Milk
- Liver Enzymes?
  - Immunotoxic, Ulcerative Colitis?
  - Cholesterol, Lipids, Uric Acid (Obesity?)
- Kidney Cancer?
- Testosterone (Prostate, Testicular Cancer?)
Possible PFAS Human Effects

Fecundity

Hypertension
In Pregnancy

Pre-eclampsia

Birth Weight
C8 Study (PFOA, PFOS): 2004-6

No “Probable Link” N=41

- HTN
- Coronary Heart Disease
- Stroke
- Chronic kidney disease
- Liver disease
- Osteoarthritis
- Parkinson’s disease
- Other autoimmune diseases (not UC)
- “Common infections” (i.e. influenza)
- Neurodevelopmental disorders, including ADHD and learning disabilities
- Asthma or COPD
- DM type 2
- Birth defects, miscarriage or stillbirths
- Preterm birth or low birth weight

“Probable Link” N=6

- High cholesterol
- Thyroid disease
- Ulcerative colitis
- Testicular cancer
- Kidney cancer
- Pregnancy-induced hypertension

Study of 69,030 participants from West Virginia and Ohio (Ohio-River Valley) exposed to PFOA from a Chemical Plant

http://www.c8sciencepanel.org/prob_link.html
For six disease categories, the Science Panel concluded that there was a *Probable Link to C8 exposure* (although do not rise to a level of causation in a scientific study)

- **High cholesterol** (Nelson et al., 2010)
- **Ulcerative colitis** (Steenland, 2013),
- **Thyroid disease** (Melzer et al., 2010),
- **Testicular cancer** (Barry et al., 2013; Vieira et al., 2013),
- **Kidney cancer** (Barry et al., 2013; Vieira et al., 2013),
- **Pregnancy induced hypertension** (Stein et al., 2009; C8 Science Panel 2011)
No association – Prostate Cancer
- Eriksen, 2009
- Lundin, 2009
- Vieira, 2013
- Barry, 2013
- Raleigh, 2014
- Ducatman, 2015

No association – Testicular Cancer
- Gilliland, 1993
- Leonard, 2008
- Lundin, 2009
- Steenland, 2012
- Vieira, 2013
- Gilliland, 1993

No association – Kidney Cancer
- Leonard, 2008
- Lundin, 2009
- Raleigh, 2014
Emerging Concerns

- **Poor response to childhood vaccine**
  (Grandjean, 2012)
  (Only tetanus and diphtheria antibodies were studied in a single study confounded by presence of PCBs and methyl mercury.)

- **Low Birth Weight**
  (Fee et al., 2008)
  [Estimated 15-19 gram (~0.03-0.04 lb.) reduction in birth weight for each 1 μg/L increase in maternal PFOA blood level, and even smaller reductions for PFOS (Johnson et al. 2014; Verner et al. 2015).]
Pediatric Studies

No association – ADHD, Autism, Milestones, IQ
- Fei, 2008
- Stein & Savitz - 2011
- Bellinger, 2013
- Liew, 2015

No LBW, Miscarriage or Birth Defects
- C8 Study - 2011
Case Study
Case

- 4-year-old boy in good health
- Mother worked at Pease Tradeport in Portsmouth, New Hampshire for 10 years and through pregnancy
- The boy attends daycare at Tradeport
- The mother heard that the water at Pease was contaminated with PFOA + PFOS + PFHxS for more than a decade
- The mother wants her child’s blood tested for PFAS
- Should the health provider do it?
Challenges

- Uncertainty
- Toxicology is complicated
- Balancing accuracy v. simplicity
- Misunderstanding, confusion, distrust
- Identifying values, perceptions, information needs
- Competing viewpoints
What does this mean for my child’s health?

• PFAS are toxic in experimental animals
• Further study required in humans
• Studies of potential health impacts on children have not yet shown definitive results

What can I do to protect the health of my child?

• Since these chemicals are only measured experimentally, testing your child is not recommended
• Since there is no treatment to 'remove' PFAS from the body, efforts should focus on preventing further exposure
• Routine Well Child Care visits with your child’s MD are recommended
Your Child’s PFC Blood Test Results Compared with Children in the Schecter Study

<table>
<thead>
<tr>
<th>PFC Tested</th>
<th>Your Child’s Result (μg/L)</th>
<th>Schecter Study Results (μg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Median</td>
</tr>
<tr>
<td>PFOA perfluorooctanoic acid</td>
<td>4.97</td>
<td>2.85</td>
</tr>
<tr>
<td>PFOS perfluorooctane sulfonic acid</td>
<td>7.29</td>
<td>4.10</td>
</tr>
<tr>
<td>PFHxS perfluorohexyl sulfonate</td>
<td>2.15</td>
<td>1.2</td>
</tr>
<tr>
<td>PFUA perfluoroundecanoic acid</td>
<td>0.732</td>
<td>Not reported</td>
</tr>
<tr>
<td>PFOSA perfluorooctane sulfonamide</td>
<td>0.6</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>PFNA perfluorononanoic acid</td>
<td>1.74</td>
<td>1.2</td>
</tr>
<tr>
<td>PFDeA perfluorodecanoic acid</td>
<td>0.759</td>
<td>&lt;0.2</td>
</tr>
<tr>
<td>Me-PFOSA-AcOH$_2$ 2-(N-methyl-perfluoroctane sulfonamido) acetic acid</td>
<td>0.372</td>
<td>&lt;0.2</td>
</tr>
<tr>
<td>Et-PFOSA-AcOH 2-(N-ethyl-perfluoroctane sulfonamido) acetic acid</td>
<td>&lt;0.1</td>
<td>&lt;0.2</td>
</tr>
</tbody>
</table>

(μg/L) = micrograms per liter
Median = middle PFC value of all 300 children tested

Note: A value reported as <0.1 or < 0.2 indicates the result was less than the Limit of Detection (LOD) for that PFC by that testing method.
Samples were analyzed at the National Center for Environmental Health, US Centers for Disease Control and Prevention, Chamblee, GA.

A health level concern has not been established for perfluorochemicals in blood.
Citizen Inquiries

- Should my children be revaccinated?
- Should we be taking iodine?
- Should I breast feed my child?
- Will magnetic clay baths/detox patches help?
- Young mother: Will my baby require a liver transplant?
- Female adult: Will blood donation lower my PFAS levels faster?
- Male adult: Can herbs or cholestyramine lower the PFAS?
- 60 year old male: Did the water cause my erectile dysfunction?
Case

- Mother provides child’s blood tests with positive results for 9 different PFAS.
- She wants the child’s blood tested for everything else that could be wrong with her.
- The mother is concerned about the child’s thyroid, kidney, liver damage and overall immune system.
- Should the doctor order blood tests for these?
Case

- Hgb 12.2 gm%
- Hct 33%
- MCV 74
- WBC 8600
- Diff: P18L76M4E1B1
- Retic 1.2%
- Na 134
- K 4.9
- Cl 110
- BUN 16
- Cr 0.6
- Fe 86
- Ferr 20
- T4 8.6
- AST 56
- ALT 16
- ESR 4
Current Levels of Concern
Current Levels of Concern

PFAS in drinking water has been a growing issue in recent years.

January 2009
EPA’s Office of Water established provisional health advisories to assess potential risk from short-term exposure via drinking water:
- 0.2 µg/L for PFOS
- 0.4 µg/L for PFOA

May 2012
As part of the Third Unregulated Contaminant Monitoring Rule, EPA required all community water systems serving >10,000 customers to monitor for PFCs twice in a 12-month period during 2013-2015.

August 2015
ATSDR released draft Toxicological Profile for PFAS.

May 2016
EPA issues Lifetime Health Advisory for PFOA and PFOS
- 0.07 µg/L for PFOA
- 0.07 µg/L for PFOS or
- 0.07 µg/L for PFOA+PFOS

November 2016
NCEH and ATSDR continue to work together to investigate the relation between PFAS and human health and provide resources to communities.
National Scope

Status of CWS (n=65) with UCMR3 reported levels of PFOS + PFOA (sum) at or above 70 parts per trillion

Explanation

The 65 community water systems (CWS) were identified from sampling results reported in the USEPA UCMR 3 database. The limitations of these databases:

1. Samples were collected during January 2013 – December 2015 and may vary over time, and
2. The water samples collected by a CWS for UCMR reporting do not typically represent concentrations that people are exposed to in drinking water.

ATSDR is gathering additional information to clarify the status of finished drinking water delivered for public consumption at most of these CWS. The results to date are rated as follows:

- Current and past levels less than 700 ppt (9% all CWS)
- Current levels less than 70, may have been past exceedances (53)
- Current levels at or above 70; CWS is taking actions to reduce (5)
- Current levels at or above 70; no CWS actions identified (0)
- Collecting information (62)

Legend:

- Community water system (CWS) in Guam
- CWS in Saipan, Northern Marianas Islands

PFOS, perfluorooctane sulfonate; PFOA, perfluorooctanoic acid
CWS, Community water systems
UCMB, Unregulated Contaminant Monitoring Rule
ppt, parts per trillion
Recommendations

- Perform routine diagnostic/screening tests based on a thorough history, physical exam, and assessment
- No specific testing or screening is recommended based on PFAS levels
- Cannot connect specific health problems to PFAS
- Repeat PFAS testing not medically indicated
- No specific therapies: not iodine, not vitamin C, not cholestyramine, not revaccination, not phlebotomy
- ATSDR recommends: reduce future PFAS exposure
Reducing Exposures
Advice for Patients: Exposure Reduction

Drinking water: filters

- Point of use, point of entry

https://www.pbs.org/newshour/science/pfas-toxic-chemical-millions-peoples-drinking-water
Fish Advisories

territories and tribes to also issue safe eating guidelines to let people know what fish they can eat safely and to encourage consumption of fish and shellfish as part of a healthy diet.

Advisories: What Not to Eat?

A consumption advisory is a recommendation to limit or avoid eating certain species of fish or shellfish caught from specific water bodies or types of water bodies (e.g., lakes, rivers or coastal waters) due to chemical contamination.

Advisories may be issued for the general public or for specific groups of people at risk, such as:

- High consumers of fish
- The elderly
- Pregnant women
- Nursing mothers
- Children

An advisory about fish from a specific waterbody or type of waterbody may address more than one affected fish species or chemical contaminant.

National Listing of Fish Advisories

EPA maintains a national database of fish and shellfish advisories issued by states.

- General Fact Sheet
- Technical Fact Sheet
- Questions and Answers
- National Maps and Graphics
- Search for Advisories Where You Live

Advice for Patients: Exposure Reduction

- Reduce use of consumer products containing PFAS
- Frequent dusting with damp mop, damp wipe
Responding to Patient Concerns

- Listen to patient’s concerns
- Perform thorough medical history and physical exam including history of exposure
- Routine cholesterol screening, including children
- Blood testing for PFAS:
  - “There is currently no established PFAS blood level at which a health effect is known to occur.”
  - “PFAS blood levels can only show how you compare to the rest of the population.”

Responding to Patient Concerns

- Reassure that any unusual symptoms will be addressed.

- “The benefits of breastfeeding your baby outweigh those of not breastfeeding.”

- “There are no recommendations for repeating vaccinations.”

Resources on PFAS chemicals

Visit the following websites:

- » Environmental Protection Agency website: https://www.epa.gov/chemical-research/research-and-polyfluoroalkyl-substances-pfas
Visuals Acknowledgements and Sources

Slide #6, #13, #35, #36 : CDC, Permission P. Breysse
Slide #9
- Img.1: Northwestpaddlingassociationfestival.com (fabric with water);
- Img.2: Wikipedia (Teflon frying pan);
- Img.3: mountainviewcarpetcare.com (wine on carpet);
- Img.4: Firefightingprotection.com;
- Img.5: Starwarfare.wikia.com (French fries)
Slide #10: Img. Source: Purchased iStock
Slide #11: Source:
Slide #14, #15, #16: NH Department of Human & Health Services
Slide #20: Img. Source: Free Google images
Slide #21: Img. Source: Free Google images
Slide #23: Img. Source: AAP.org
Slide #34: Img. Source: iStock purchase
Thank you!