The Comparative Toxicogenomics Database (CTD): A public resource to understand the health effects of PFAS

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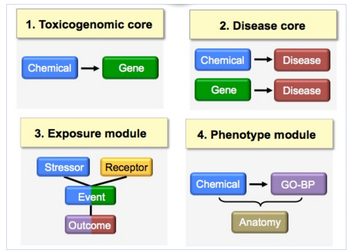
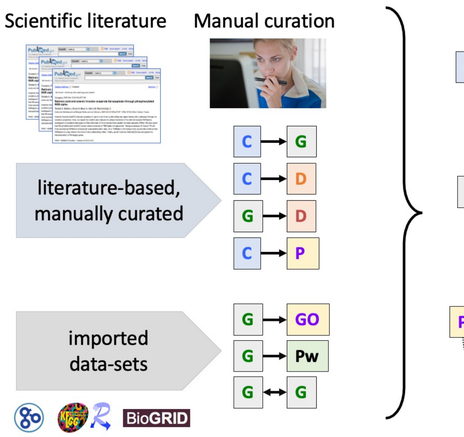
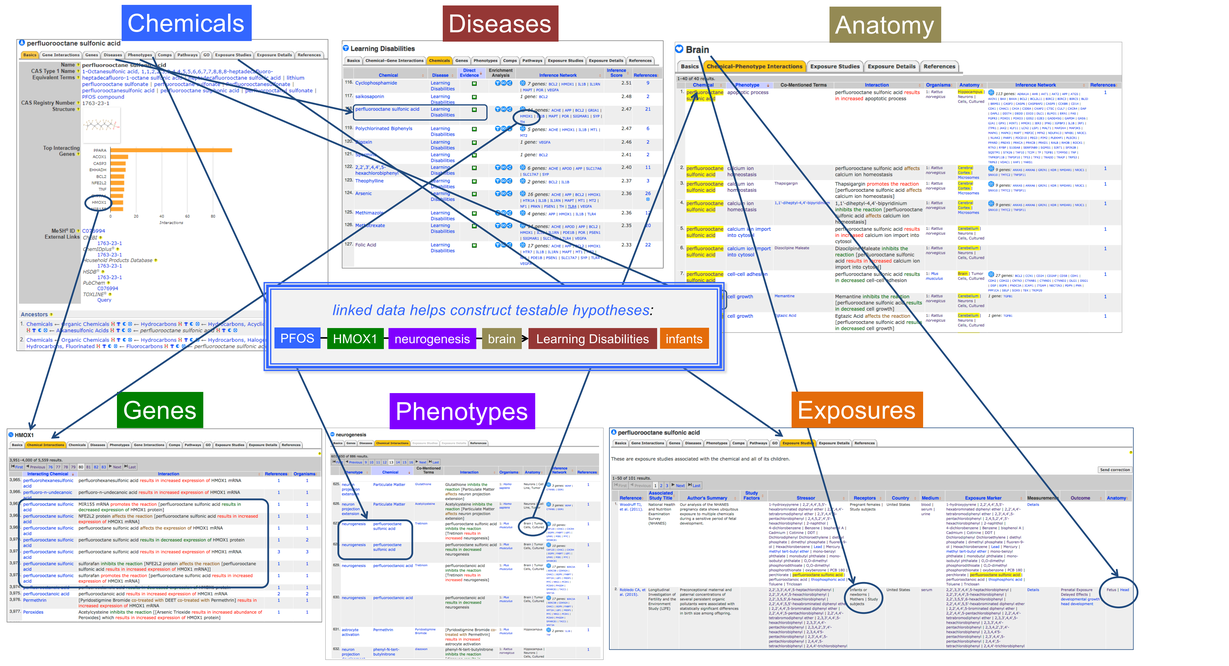
CTD data – what it is and where it comes from

- ctdbase.org
- public resource (free to non-commercial users)
- read and manually curate the scientific literature
- relate chemical-gene-phenotype-disease-exposure information
- use FAIR controlled vocabularies & ontologies
- curate 5 types of interactions from the literature:

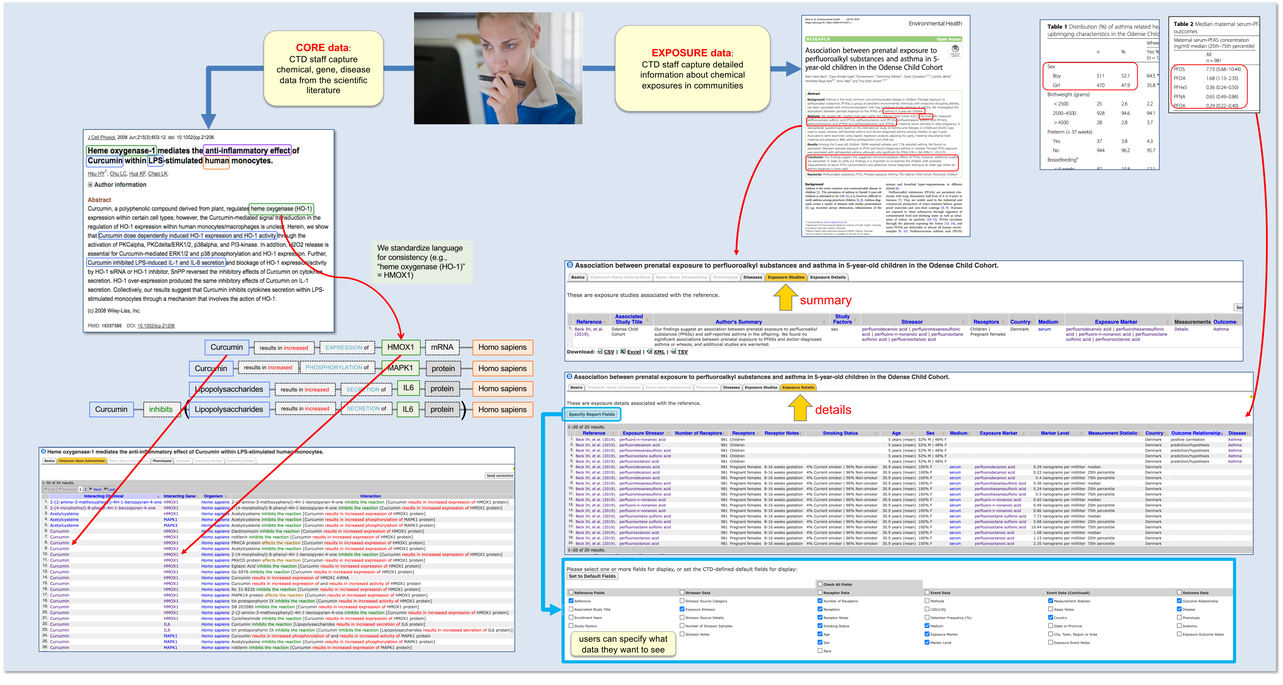




Make connections between chemicals, genes, diseases and more



Search for information about chemical exposures and health outcomes



Abundant PFAS data and tools to understand health connections

CTD Data Type	Count
Unique chemicals	18,000
• # PFAS with curated data	62
Chemical-gene interactions	2.9M
Gene-disease associations	32M
Chemical-disease associations	3.5M
Chemicals with exposure data	1,500
Diseases with exposure data	503

Acknowledgements
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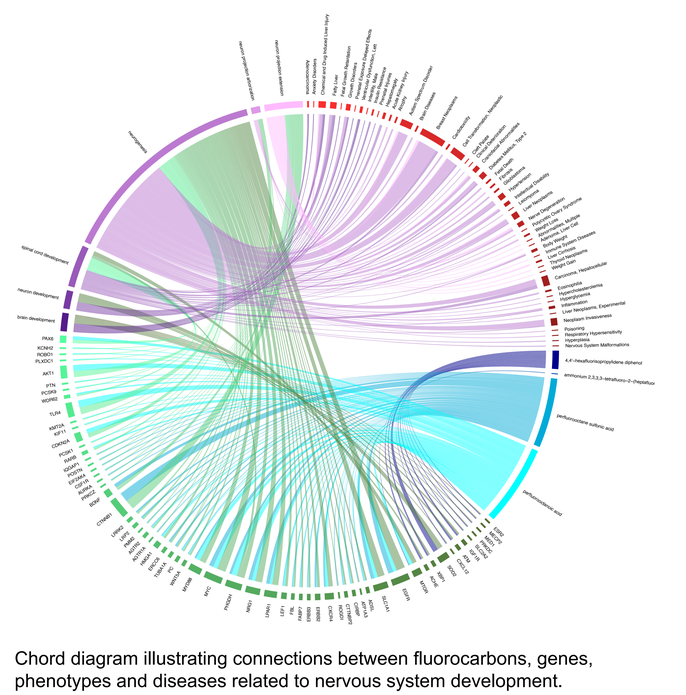
Contact Information
Contact us with feedback, questions, or collaborative ideas: ctdbase.org



Chord diagram illustrating connections between fluorocarbons, genes, phenotypes and diseases related to nervous system development.

Exposure Assessment in Japan Environment and Children's Study (JECS)

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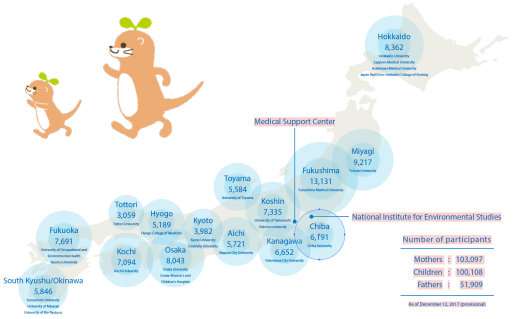
What are being studied in JECS?

National Institute for Environmental Studies (NIES) has been conducting the study called "Japan Environment and Children's Study (JECS)". JECS is a large-scale cohort study involving over 100,000 mother-child dyads living throughout Japan. JECS has been investigating children from foetus until they become 13 years old, examining how chemical substances in the environment and their lifestyles are related to the development and diseases of children. We evaluate the effect of environmental factors on children's health, which will lead to the prevention of diseases and preparation of an environment where children grow up in good health so that children of the next generation can spend their lives in the healthy environment.

Ongoing in 15 regions throughout Japan

As the Programme Office, NIES has been conducting the study in cooperation with 15 Regional Centres throughout Japan. At each centres, JECS has been conducted with the cooperation of local governments and medical institutions. The Medical Support Centre situated in the National Center for Child Health and Development provides medical expertise. Each Regional Centre holds seminars and events related to child rearing so that the participants enjoy taking part in the study.



Disclaimer: The authors declare no conflict of interest, employment and personal financial interest associated with this presentation. The findings and conclusions of this presentation are solely the responsibility of the authors and do not represent the official views of the Japanese government

PFAS exposure and some outcomes

Using about 25,000 analytical data, relationship between maternal plasma PFAS and Kawasaki disease by age 4 years was investigated. No association was found between 7 PFAS concentrations and the onset of Kawasaki disease in children. We measured PFAS concentrations in the mother's blood during pregnancy, and did not measure PFAS in the children blood with Kawasaki disease.

Table 3
Univariable and multivariable regression results between Kawasaki disease incidence and individual PFAS substances.

Univariable regression Substance	Odds ratio	Standard Error	Lower95%CI	Upper95%CI	P-value	q-value[a,b]
Perfluorooctanoic acid (PFOA)[a]	0.894	0.060	0.784	1.018	0.092	0.238
Perfluorononanoic acid (PFNA)[a]	0.904	0.080	0.760	1.076	0.256	0.358
Perfluorododecanoic acid (PFDA)[a]	0.917	0.080	0.773	1.087	0.319	0.372
Perfluoroundecanoic acid (PFUnA)[a]	0.936	0.087	0.781	1.123	0.478	0.478
Perfluorotridecanoic acid (PFTrDA)[a]	0.888	0.080	0.745	1.058	0.184	0.322
Perfluorohexane sulfonic acid (PFHxS)[a]	0.878	0.070	0.752	1.026	0.102	0.238
Perfluorooctanesulfonic acid (PFOS)[a]	0.839	0.072	0.710	0.993	0.041	0.238
Multivariable regression†						
Substance	Odds ratio	Standard Error	Lower95%CI	Upper95%CI	P-value	q-value[a,b]
Perfluorooctanoic acid (PFOA)[a]	0.890	0.061	0.778	1.019	0.091	0.266
Perfluorononanoic acid (PFNA)[a]	0.889	0.082	0.742	1.066	0.205	0.287
Perfluorododecanoic acid (PFDA)[a]	0.901	0.082	0.753	1.077	0.251	0.292
Perfluoroundecanoic acid (PFUnA)[a]	0.913	0.089	0.755	1.104	0.345	0.345
Perfluorotridecanoic acid (PFTrDA)[a]	0.866	0.081	0.722	1.040	0.123	0.266
Perfluorohexane sulfonic acid (PFHxS)[a]	0.889	0.073	0.758	1.044	0.152	0.266
Perfluorooctanesulfonic acid (PFOS)[a]	0.835	0.074	0.701	0.994	0.043	0.266

[a]Substance values were $\log_2$ transformed. Because PFAS were $\log_2$ transformed, regression coefficients represent the expected change in dependent variables as a result of a 2 fold change in PFAS levels.
[a,b]The False discovery Rate correction (FDR) was implemented.
†Adjusted for maternal age, folic acid level, and family income.
Each model odds ratio is expressed as a per log unit increase in PFAS substances.

Iwata et al. (2024) Environment International 183:108321

Relationship between 18,000 plasma PFAS concentrations during pregnancy and wheezing and asthma symptoms up to age 4. No clear association was found between maternal PFAS and wheezing or asthma symptoms in children. The exposure-response curves were linear and nearly flat. No differences were observed based on child sex or maternal asthma status.

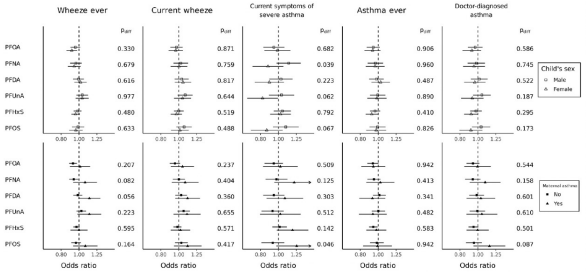


Fig. 4. Adjusted odds ratios per doubling increases in PFAS concentrations for wheeze and asthma stratified by sex of the child or the maternal history of asthma. P_{diff} indicates p-values for the difference between estimates. The corresponding numerical values are presented in Supplementary Table S3.

Atagi et al. (2024) Environmental Research 240:117499

PFAS Compounds Flow to Farms and Gardens via Wastewater Systems (+ Trucks)

Limited Control by Most States or US EPA

by Amy D Kyle, PhD MPH – with the Sierra Club PFAS Team Grassroots Network

Dangerous PFAS Compounds Go Down the Drain to Wastewater Systems - from homes, businesses, industries

PFAS from domestic, industrial, commercial, government sources and facilities go down the drain ----- >>> **wastewater systems**

* drains * toilets * dishwashers * storm water in some areas * factories * stores * chemical plants * public facilities * laundry * garbage disposals * warehouses * firefighting sites * airports * *semiconductor manufacturing * spills at sites * metal plating fume suppressants * papermaking plants * coatings and paints * landfills *

PFAS are NOT DECREASED or DESTROYED -- During Wastewater Treatment

- PFAS end up in the liquid and sludge residues.
- These sludges are dried out then often mixed with other material to create **"biosolids."**
- **Biosolids are then trucked to farms to be spread on the land, as a fertilizer.**
  - Other land application uses can include mine restoration, forest lands, recreation areas, ecological restoration.
- **Biosolids are also mixed into garden products marketed as turf builders, fertilizers, top soil, compost, and such.**
  - These products are often used in home gardens
- **From 40 to 60% of the sludge from wastewater plants is applied to lands, moving substantial quantities of PFAS.**
- Almost the same percentage is sent to solid waste facilities, which often fail to contain the PFAS and allow it to escape in leachate.

Wastewater treatment has several stages and requires large facilities

The stages of wastewater treatment are known as "primary," "secondary," and in many cases, "tertiary.?

Acknowledgements and Disclaimer

This analysis was conducted with the volunteer PFAS Team of the National Toxics Team of the Sierra Club Grassroots Network and is a work in progress. Thanks to team members and colleagues contributed to this discussion.

The views presented in this poster are those of the author and do not represent any institution. Contact: Amy D Kyle at amyk50005@gmail.com

More information including references is at our web site: https://www.sierraclub.org/grassroots-network/pfas

PFAS in Biosolids Threaten Farm Products and Farmers

Farmers apply sludge/biosolids as a source of nutrients

They are not notified of PFAS.

PFAS from biosolids are persistent

PFAS may accumulate in soil or water on farms and in farm products

Farms have closed due to PFAS contamination -- milk, meat, or plant products -- in Maine, Texas, Michigan.

Very limited compensation to farmers for their losses.

No protection for consumers.

PFAS Biosolids are in Products Marketed to Gardeners

Biosolids from wastewater treatment plants are mixed into gardening products --

Fertilizers, compost, turf builders, soil amendments

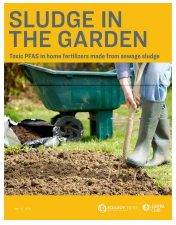
Testing by the Sierra Club and Ecology Center in 2021 found PFAS in all tested garden products.

See report at http://sc-org/pfas-sludge

They recommended that gardeners avoid garden products with sludge, residuals, or wastewater products in it, and this remains good advice.

There are no standards or limits from US EPA for PFAS in garden products.

Products may be marked as "highest quality" even if contaminated. Quality labeling is about microbes not PFAS.



Biosolids await application to farmlands. Photo credit: Virginia Extension.

Actions Now

Acknowledge that wastewater provides a pathway for dispersal of PFAS to farms and gardens, in addition to direct emissions or discharges

Learn more

Expand monitoring of PFAS in wastewater and make data public.

Improve methods to capture all PFAS in wastewater not just a few.

Pretreatment

Take decisive actions to keep PFAS out of wastewater so it never gets to treatment plants – through permitting and other means

States can add conditions to wastewater permits to preclude release of PFAS into wastewater systems, and some have done so. This should be expanded.

EPA can develop and enforce permit conditions nationally.

Ban use of sludge biosolids in garden products.

Control use of sludge biosolids on farmlands

Regulate any uses of sludge biosolids on lands to control releases.

What You Can Do Today:

Ask your state what they are doing to control PFAS in biosolids from wastewater treatment plans and keep it from farms and gardens.

We Invite You to Join Us

In the PFAS SubTeam of the Sierra Club Grassroots Network –

We are working to better understand PFAS in biosolids -- science, policy actions, impacts on farms, farmers, farmworkers, as well as gardens and gardeners, monitoring and testing results, and improving methods.

We are building tools and resources for local and state Sierra Club chapters and groups, and volunteers interested in these issues.

Web site with key information, news, eye on EPA, action opportunities.

- key points in plain, supported by explainers and citations to authoritative scientific, other sources.
- factsheets and communications tools

Monthly Newsletter -- short and succinct – coming soon

Will you join us? Sign up for the newsletter. Check out the web site. Send us your feedback. Tell us what you need.

https://www.sierraclub.org/grassroots-network/pfas

Meanwhile, Limited Actions So Far by EPA

1993: EPA adopted rules to limit certain ten metals and microbes in biosolids (503 rule)

- Metals to be removed before entering wastewater stream to treatment plant: "pretreatment"
- Nothing since -- no limits on PFAS in biosolids nor wastewater

Pretreatment: EPA has advised states that they can require removal of PFAS from industrial wastewater using permitting authorities

Some states have done this. Few restrictions in federal wastewater permits

2022 EPA PFAS roadmap:

- promises risk assessment in 2024 for two legacy PFAS (PFOS and PFOA) in biosolids

Project to prioritize all contaminants in biosolids reviewed by Science Advisory Board in 2023

- Using diverse, poorly documented, old models that may not work as promised
- No analysis at the scale of the landscape (rather than person)
- EPA has had "dialogues" with organizations for states and agriculture – general approaches
- Prospects for any action entirely uncertain.

Lessons learned by community-driven PFAS monitoring: major gaps in federal and state responses to the PFAS crisis

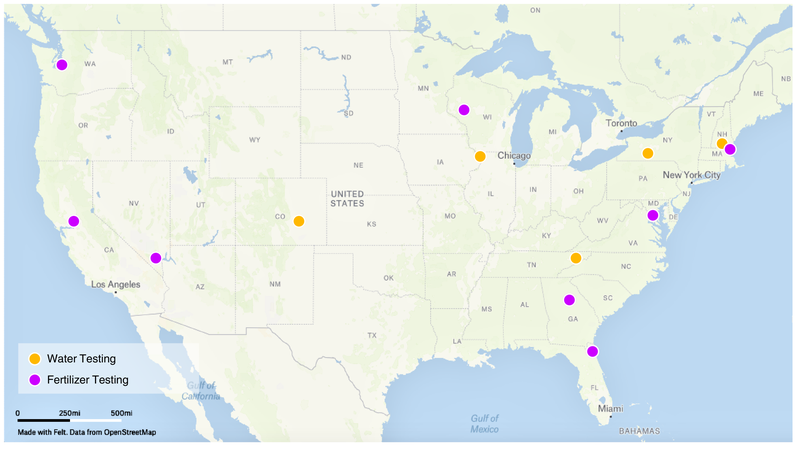
SIERRA CLUB

Background

Scientists, regulators, and the general public know very little about the locations of historic and ongoing PFAS production and use. There is also a critical lack of environmental monitoring. When data exists, it may not be available to the public or may obscure key details like specific location of the sample.

What we do

Sierra Club's Grassroots PFAS team and supporters have strategically employed community-based monitoring to daylight the impacts of PFAS in a variety of locations and industries. Team members review available information about PFAS sources in a region to develop targetted testing plans. We use this information to boost place-based advocacy and reveal broad gaps in policies to protect people and the environment from harm.



Action Needed

We encourage more community-based monitoring to bring visibility to local pollution hotspots and prompt more rigorous assessment of contamination. Monitoring studies should use modern methods with low detection limits. All data must be made available to the public.

The pollution "lessons" identified by Sierra Club's community monitoring are not unique to the places we sampled. Rather they suggest that similar dynamics exist across the country. Stronger rules are needed to force industries to disclose its use and emissions of PFAS. Government agencies must control emissions from industrial sources and ensure secure disposal of PFAS wastes.

Thanks to all of our contributors

Sierra Club Grassroots PFAS team: Stephen Colby Brown, Doris Cellarius, Dan Firth, Tracy Frisch, Amy Kyle, Sonya Lunder, and Denise Trabbic-Pointer

Field samplers: Emily Gant, Sagarika Maitra, Summya Katoon, & Wendy Heiger-Bernays (NH), Liz Rosenbaum (CO), Dan Firth (TN), Steven Hall (IL), Elizabeth Donderewicz & Bill Mattingly (NY)

Collaborating organizations: Laurene Allen - Merrimack Citizens for Clean Water, Jeff Gearheart & Gillian Miller - Ecology Center Michigan, Liz Rosenbaum - Fountain Valley Clean Water Coalition

For more information and references visit:
https://www.sierraclub.org/grassroots-network/pfas

Merrimack, NH

Surface water (N=10)

7 PFAS detected

Pipe = 86 & 92 ppt

Foam = 97 ppt

Industrial point sources discharge PFAS to rivers

The community of Merrimack has been a national hotspot of PFAS contamination due to emissions Saint Gobain Performance Plastics. Elevated measurements of PFAS have previously been reported in the Merrimack River, which is a drinking water source for downriver communities. Our sampling also identified elevated concentrations of PFOA in two wastewater pipes of unknown origin downriver from Saint Gobain, as well as PFOS in foam collecting on the river surface near the drain sites.

Implications: Many industries continue to directly discharge PFAS-contaminated water into sewers and surface water.

Steuben County, NY

Well and Surface Water (N=83)

Total PFAS = 1 to 82.1 ppt

Land application of sewage sludge threatens local water quality

Residents of Bath, Cameron, Thurston and Painted Post, New York are concerned that the application of processed sewage sludge to local agricultural fields pose a threat to community wells and waterways. Community tests show that PFAS are markedly higher in wells near land-application sites (average >15 ppt) compared to sites with no sludge application (<2 ppt).

Implications: Nationally more than half of all treated sewage waste is applied to agricultural fields as a fertilizer. This practice can recycle PFAS from wastewater into food crops and contaminate local water sources.

Northeastern TN

Surface water (N=20)

Sum 8 PFAS = 5.6 to 14.4 ppt

PFAS enter surface water through dispersed sources

Community tests document widespread contamination of streams and reservoirs in the Northeastern portion of Tennessee. While there were no detectable PFAS in the upper reaches of the watersheds studied, total PFAS measurements of 5 to 14 ppt are found in inhabited regions. PFOS levels in 4 surface water samples exceed EPA's proposed drinking water limit.

Implications: PFAS are ubiquitous in American surface water. This will pose a challenge for drinking water providers who will soon be required to meet stringent new legal limits for 6 PFAS chemicals. Source water protection is vital.

The ongoing use of PFAS use in firefighting threatens surface water

Firefighters used 3200 gallons of PFAS-based AFFF to extinguish a major industrial fire in Rockton IL. Sierra Club monitoring measured 78 to 87 ppt PFAS in the Rock River near the site, and another 75-100 ppt of unidentifiable PFAS "precursor" chemicals. Illinois EPA's samples of effluent from the Rockton sewage treatment plant contained nearly 6000 ppt PFAS, indicating PFAS passed via wastewater drains back into Rock River.

Implications: 15 states have banned sales of PFAS-based foams, and 16 states have initiated a Take Back programs. In most of the country, remaining stockpiles pose a risk to water quality.

Rock Creek IL

Surface water (N=5)

Sum PFAS = 78 to 87 ppt

TOP Assay = 153 to 191 ppt

Sewage-sludge based home fertilizers contain PFAS

Sierra Club and Ecology Center analyzed 20 brand name home fertilizers made from processed sewage sludge. Concentrations of 2 specific PFAS exceeded screening levels in the state of Maine for biosolids used on agricultural lands. The samples also contained 2- to 8-times more PFAS precursor chemicals, and concentrations of Total Organic Fluorine were ~1000 times greater than identifiable PFAS.

Implications: The PFAS found in sludge-based fertilizers pose a risk to home gardens and nearby water supplies. The products do not clearly disclose their origin nor the potential presence of PFAS and other contaminants.

National sampling of commercial sludge fertilizers (N=20)

Method - LC-MS/MS, TOP Assay, Total Organic Fluorine

Sum 25 PFAS = 38 to 233 ppb

TOP Assay = 193 to 374 ppb

Total Organic Fluorine = 13,000 to 321,000 ppb

Military contamination extends beyond presently identified sites

In 2018 Liz Rosenbaum moved from Fountain to Wigwam CO to escape the PFAS contamination plume from Fort Peterson Air Force Base. However water sampling by NRDC and Sierra Club in 2021 and 2022 confirmed PFAS was also found in Wigwam drinking water. While three nearby water systems have been treating water since 2016, Wigwam managers hadn't alerted their customers to the problem. The state of Colorado is paying for pitcher filters and a consultant to help Wigwam address the contamination.

Implications: Military contamination could extend beyond presently identified locations.

Wigwam, CO

Drinking water (N=4)

Sum 12 PFAS = 74 to 81 ppt

Measuring PFAS Atmospheric Transport with Environmental Matrices

Kai Muran[1], Andrew A. May[1,2]

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THE OHIO STATE UNIVERSITY
COLLEGE OF ENGINEERING

Introduction and Motivation

- PFAS are ubiquitous in the atmosphere and are emitted by a variety of sources.
- Atmospheric deposition can occur into a variety of environmental media.
- Previous studies have demonstrated the use of tree bark as an atmospheric sampler due to its porosity and ease of collection, but few studies have exploited this in studying PFAS.
- Tree bark represents a potentially valuable source of time-integrated PFAS loading information for Ohio environments.
- Direct environmental measurements of PFAS can help quantify environmental loading and improve understanding of PFAS fugacity.

Objectives

- Quantify atmospheric PFAS composition and loading in Ohio using SIP/PUF disks, tree bark, and soil.
- Explore differences in PFAS concentration and composition in the downwind vicinity of waste handling facilities (e.g., landfills, hazardous waste incinerator), manufacturing facilities (e.g., food packaging, fluoroproducts), and other industrial sources.
- Develop a high-throughput sample preparation method capable of analyzing neutral and ionic PFAS in these media.

Sampling Campaign

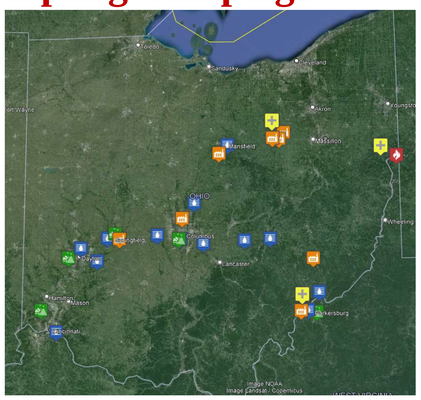


Figure 1. Sampling campaign map using Google Earth. Samples were/will be collected from areas near potential and/or known sources of atmospheric PFAS (re)emission for analysis. Preliminary samples will be analyzed using an untargeted screening technique. A ⛨ near the location icon indicates new locations to be added during final sampling campaign.

Sampling Site Determination

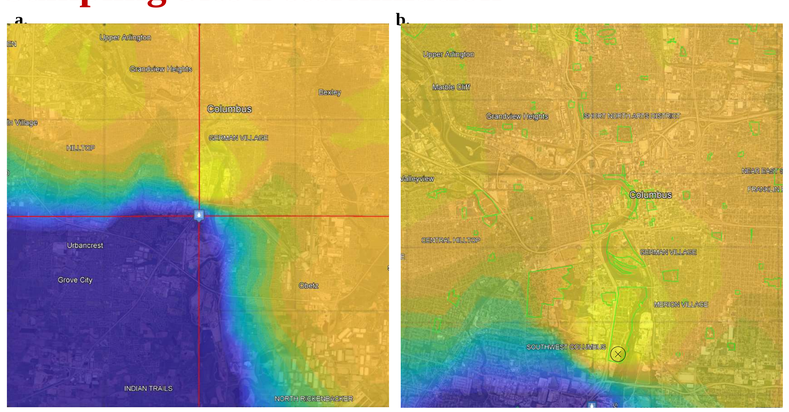
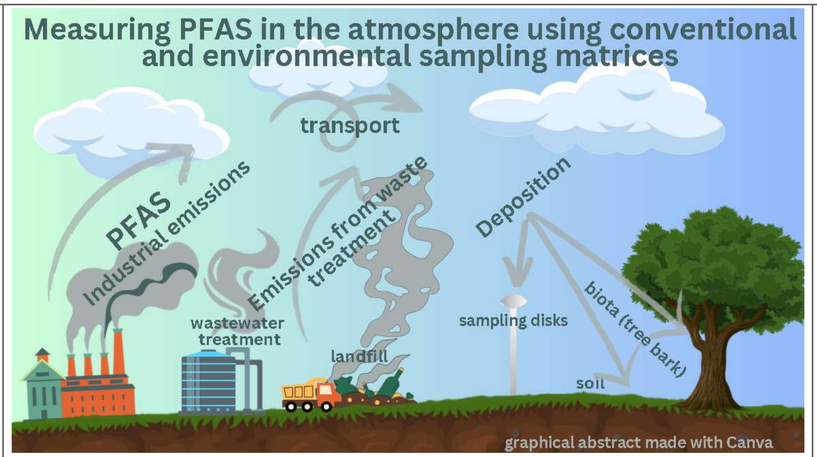


Figure 2. Gaussian plume model predictions overlaid on Google Earth. The brightest yellow areas represent areas of the highest predicted surface concentration at the site. **a.** 20km x 20km map centered the suspected emission source. **b.** Close up of area with parks/recreation areas highlighted. The ⊗ icon is the chosen sampling destination.



Sampling Methods

- Tree bark and soil collected during preliminary sampling campaign using a stainless-steel knife and trowel and placed into polypropylene bags.
- Bark collection 10-20 cm² area; ~1-5 mm depth; ~1.5-2 m above ground.
- Soil: Composite of several samples at each site at a depth of 1-3 cm.
- SIP/PUF disks will be used at a few sites in Columbus during final campaign.

Figure 3. Tree bark collection, December 2023. **Top right:** closeup of tree after sampling. Damage to the tree is minimal and will heal within weeks.

Sample Preparation – Preliminary Methods

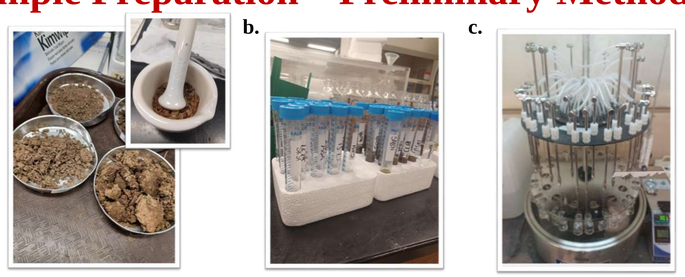


Figure 4. Soil and bark samples were **a.** dried, pulverized, and sieved through a stainless steel, 1.7 mm mesh sieve; **b.** extracted with 0.2 M NaOH in solvent, shaken, centrifuged, and reacidified with HCl in 18.2 MΩ water, and **c.** reconcentrated under nitrogen blowdown to about 1 mL final volume.

Laboratory Method Development

- In prior literature, SIP/PUF disks and tree bark samples are frequently Soxhlet extracted
- This experiment aims to develop an extraction method based on acid-base extraction and separation by centrifugation followed by cleanup and reconcentration before analysis.
- Ionic PFAS are typically analyzed with methanol as solvent; neutral PFAS in these media commonly utilize ethyl acetate as solvent, but this comes with challenges as ethyl acetate is incompatible with many plastics

Figure 5 (right). Polypropylene centrifuge tube disintegration after shaking with soil, 0.1M NaOH, and ethyl acetate within. Most severe degradation at the bottom of the tube, where some solvent has completely melted through.

Chemical Analysis

- Preliminary samples will undergo untargeted analysis by LC-ToF-MS.
- Final samples will be undergo qualitative analysis by QQQ-LC-MS/MS

Figure 6. (right) LC-ToF-MS at the College of Wooster used for preliminary sample analysis.

Data Analysis Plan

- End goals: determine PFAS air concentration (pg m^{-3}), soil concentrations (ng g^{-1}), and bark concentrations (ng g^{-1}); discern spatial patterns in PFAS concentrations.
- Theoretical air volume uptaken by SIP/PUFs (Shoeib et al. 2008)

$$V_{PSM}\left(\frac{dC_{PSM}}{dt}\right) = k_A A_{PSM}(C_A - C_{PSM}/K_{PSM-A}) \qquad (1)$$

- Tree bark-sampler comparability equations (Zhao et al. 2008)

$$K_{BA} = \{(LipCont)^{1.67} K_{OA}^{0.542} \cdot \exp[(-0.964\Delta H_{vap} + 3.130)\left(\frac{1}{T} - \frac{1}{302.05}\right) \cdot \frac{10^3}{R}] \cdot 10^{-9} + 210B\,(SSA)^{0.706}\left(\frac{P_{ptn}}{154}\right)^{-0.766}(TSP)K_{OA}\}/(1 + B(TSP)K_{OA}) \quad (2)$$

- Air-soil fugacity fractions (Xu et al. 2024)

$$f - \frac{f_s}{f_s + f_a} \qquad f_s - \frac{C_s RT}{0.411\varphi_{om}} K_{OA} \qquad f_a - C_a RT \qquad (3)$$

Anticipated Results and Practical Implications

- Neutral and ionic PFAS concentrations and spatial distributions will be determined in passive samplers, tree barks, soils, and air near likely air emission sources throughout Ohio.
- In the final sampling campaign, passive samplers will be used in and near Columbus, OH, and Wooster, OH, to determine whether these cities represent "area sources" of PFAS.
- The efficacy of tree bark as passive sampler will be compared to conventional passive sampling matrices. Tree bark allows for faster sampling and easier sample preparation compared to foam disk-based techniques.
- Final data will be used to evaluate the Community Multiscale Air Quality Modeling System for PFAS (CMAQ-PFAS).

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Detection of Perfluoroalkyl and Polyfluoroalkyl Substances in Surface Water via EPA Method 1633 using LC/MS/MS; A Solution to Challenging Matrices

Autumn Payne, Jesse Leonard, Cole Strattman, Sheng-Suan (Victor) Cai, Erasmus Cudjoe and Jacob Jalali

1 Introduction

Growing environmental and health concerns centered around Per- and Polyfluoroalkyl Substances (PFAS) have led to more substantive regulations of these substances in waters, soil, food and other matrices over the past decade. PFAS are man-made chemicals used in a wide variety of commercial products like nonstick cookware, food packaging, paints, clothing, fire retardants and surfactants since the 1940's. Due to their inert nature, PFAS are persistent and have been found to accumulate throughout the environment. Originally considered biologically inactive, recent research has suggested toxicity to humans and wildlife leading to global regulations restricting their levels in multiple matrices. As of January 2024, a finalized EPA method, EPA Method 1633, has been released with the analysis guidelines for multiple environmental matrices.

Having a robust and reliable testing solution for these potentially challenging matrices will be crucial for analytical success. This poses a challenge for regulatory and testing laboratories due to expanding PFAS screening lists, varied matrices and lower detection limits. To address this, laboratories rely on the analysis technique of LC/MS/MS (Liquid Chromatography with Tandem Mass Spectroscopy) to qualify and quantify these compounds. Here we present a solution to these analysis with the PerkinElmer LX-50 UHPLC/QSight triple-quadrupole Mass Spectrometer combination.

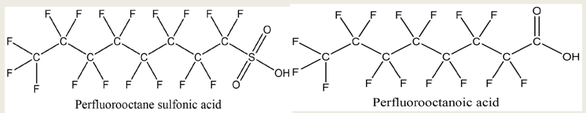


Figure 1: Chemical structures of Perfluorooctane Sulfonic Acid (PFOS) and Perfluorooctanoic Acid (PFOA)

2 Equipment and Materials

Chromatographic separation was achieved using a PerkinElmer LX-50 UHPLC system coupled with the QSight MS/MS detector. PerkinElmer Brownlee SPP columns were used for the delay, guard and analytical columns. All instrument control, data acquisition, and data processing were performed using Simplicity3Q™ software.

2 Equipment and Materials cont.

PFAS compounds are common in the environment and the laboratory since these materials are frequently used in many products which include materials used to construct SPE apparatus and LC/MS/MS systems. Careful steps were taken to reduce or eliminate background levels of PFAS compounds to help ensure the measurement of the PFAS target analytes at parts per trillion levels. PFAS background potentially generated from mobile phase solvents and the UHPLC pump were remediated using a delay column installed between the pump solvent mixer and the autosampler valve. Potential PFAS contamination arising from the LX-50 UHPLC Autosampler was remediated by installing a LX-50 PTFE free injection kit, PN: N9306948. Materials used in this experiment were tested through the injection of blanks and found to be PFAS free.

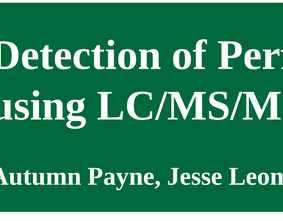


Figure 2: PerkinElmer LX-50 UHPLC Autosampler equipped with the PTFE-Free Injection Kit

Figure 3: PerkinElmer LX-50 UHPLC and QSight MS/MS

3 Experiment

LC Conditions	
Analytical Column	Brownlee SPP C18 Column, 75 x 4.6 mm, 2.7 µm (PN: N9308415)
Guard Column	Brownlee SPP C18 Column, 5 mm x 4.6 mm, 2.7 µm (PN: N9308532)
Delay Column	Brownlee SPP C18 Column, 50 x 3.0 mm, 2.7 µm (PN: N9308408)
Mobile Phase A	10 mM ammonium acetate in water
Mobile Phase B	Methanol
Flow Rate	0.8 mL/min
Column Oven Temperature (°C)	40
Auto Sampler Temperature (°C)	15
Injection Volume	10

Table 1: Optimized LX-50 UHPLC parameters

MS Source Conditions	
Electrospray Voltage	-3500
Drying Gas	110
Nebulizer Gas	400
Source Temperature (°C)	350
HSID Temperature (°C)	280
Detection Mode	Time Managed MRM

Table 2: Optimized QSight 420 ESI negative ionization source parameters

3 Experiment cont.

UHPLC Method: In the initial demonstration of the LC method capability, baseline separation of branched vs. linear isomers was achieved for PFHxS, PFOS, PFOA, PFOSA, NMeFOSAA, NEtFOSAA, NMeFOSA, NEtFOSA, NMeFOSE, and NEtFOSE, an example is shown in Figure 4 and conditions are listed in Table 1.

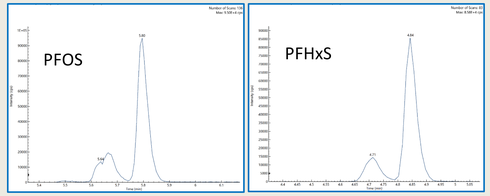


Figure 4: MRM chromatograms of PFHxS and PFOS showing the baseline separation of linear and branched chain isomers

MS Method: MS/MS multiple reaction monitoring (MRM) experiments were developed for all analytes, surrogates and internal standards by syringe pump infusion directly into the QSight MS/MS electrospray ionization source (ESI). All MRMs were in negative ion ESI mode and two MRMs were established to monitor quantifier and qualifier ions for each analyte. The optimized MS source conditions are shown in Table 2.

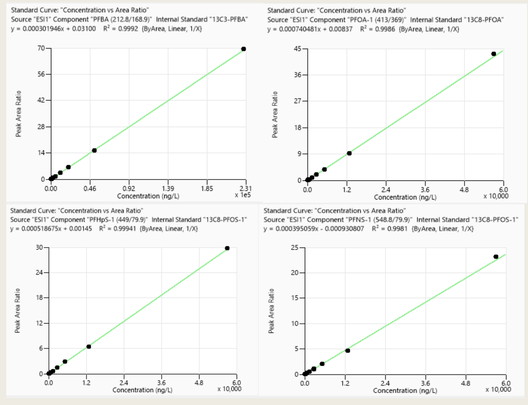
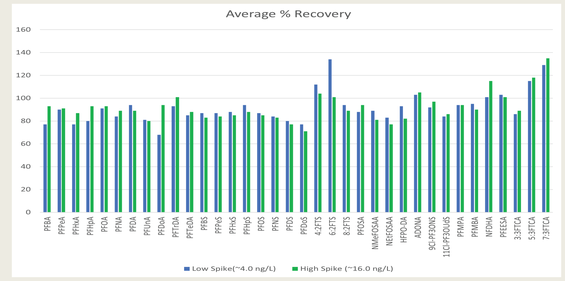


Figure 4: Calibration curves for representative analytes PFBA, PFOA, PFHpS, and PFNS

4 Results Discussion

Field samples of non-potable water were collected from different sources as well as lab grade reagent water; 4 samples at each location. Prior to extraction, samples were spiked with EIS and two samples were fortified with method analytes. Blanks were evaluated to confirm that all analytes were either absent or less than estimated method limit (ML), as required.

Figure 6 summarizes the recovery results for the target analytes spiked into samples in duplicate at 2 different levels. The LFSM % recoveries were all within the method requirements. Recoveries in aqueous samples met or exceeded the EPA 1633 recoveries for all analytes and standards.



4 Results Discussion

This work has demonstrated the fast and robust chromatographic separation and quantitation of non-potable water samples for PFAS detection via the LX-50 UHPLC/QSight tandem quadrupole mass spectrometer as an excellent analytical solution for the application of EPA Method 1633 with ample sensitivity to measure all analytes.

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70 ANALYTE PFAS TEST METHOD HIGHLIGHTS NEED FOR EXPANDED TESTING OF PFAS IN DRINKING WATER

Katie Pelch[1], Anna Reade[1], Taryn McKnight[2]
[1]Natural Resources Defense Council, [2]Eurofins Environment Testing

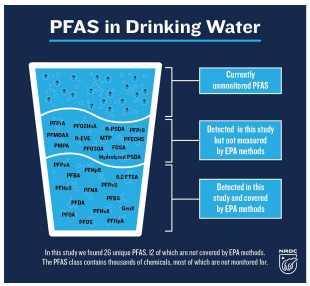
WHY WAS THIS STUDY NEEDED?

- Out of thousands of PFAS, EPA's validated methods only test for a total of 29 individual chemicals in drinking water.
- Eurofins Environment Testing offers an expanded test for 70 PFAS based on EPA's validated methods.
- NRDC supported a community-led pilot study to understand the utility and impact of expanding PFAS testing in drinking water.

METHODS

- Samples were collected in collaboration with community partners from 44 locations in 16 states (AK, AL, AZ, CA, CO, FL, LA, MA, ME, MI, MN, NC, NH, OR, SC, TX) from June 2021 through April 2022.
- Sample kits (250 mL HDPE containers) were sent directly to community partners who collected samples and field blanks which were returned on ice to Eurofins Environment Testing in Sacramento, CA.
- Detailed methods are available in the published paper. In short, samples were extracted using a solid phase extraction cartridge and analyzed with LC/MS/MS.
- Isotope dilution was used for quantitation of PFAS with labeled standard analogs. For PFAS without labeled standards, analytes were quantitated by the internal standard method using a closely related labeled analog.

RESULTS

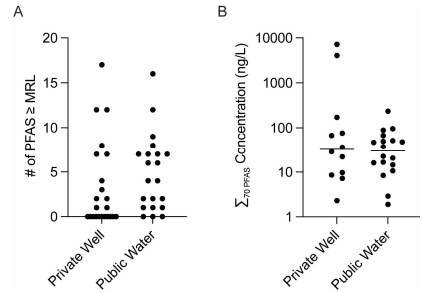


TOP 10 PFAS DETECTED

PFAS	Frequency	Concentration Range (ng/L)
PFPrA	24	2.5-140
PFOS	18	1.9-1,700
PFOA	17	2.0-2,100
PFHxA	17	2.1-610
PFPeA	15	1.8-570
PFHxS	15	1.8-390
PFBS	10	2.1-95
PFBA	9	5.3-140
PFHpA	5	2.1-1,100
R-PSDA	4	2.3-27

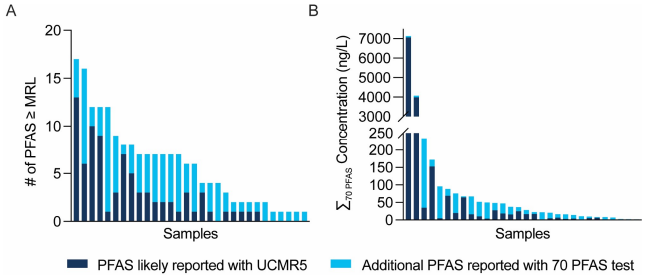
Ultrashort chain PFPrA (C3) was present in 80% of samples and often at the highest concentration of all PFAS detected.

PFAS DETECTED IN 30 OF 44 SAMPLES



Number and sum of PFAS reported in 70 PFAS test. (A) Scatterplot showing the number of PFAS ≥ Method Reporting Limit (MRL) and (B) scatterplot showing the sum of PFAS quantified (ng/L) using Eurofins' 70 PFAS test for samples with PFAS ≥ MRL. Medians in (B) indicated by horizontal line. PFAS are not regulated in private wells under the new federal drinking water standards.

COMMUNITIES WITH UNMONITORED PFAS COULD BE MISSED IN UCMR5



UCMR5 reporting requirements are predicted to under-report the number of PFAS (A) and the sum of PFAS (ng/L) (B) in these samples. Samples sorted greatest to least value for each panel independently.

SOME COMMUNITIES COULD BE LEFT BEHIND BY NEW FEDERAL STANDARDS

Some samples had significant levels of PFAS present, but were not in exceedance of the new federal standards.

# of PFAS	$\sum_{PFAS}$ (ng/L)	PFAS
6	88.7	PFPeA, PFPrA, PFBA, PFO2HxA, PFHxA, PFMOAA
7	51.7	PFPrA, PFHxS, PFHxA, PFOA, PFPeA, PFBS, PFOS
7	50.1	PFPrA, PFBS, PFOA, PFOS, PFHxS, PFPeA
9	47.3	PFPrA, PFBA, PFPeA, PFHxA, PFOS, PFOA, PFBS, PFHpA
2	22.6	PFBA, PFPrA
2	22.1	MTP, FOSA

MAIN TAKEAWAYS

- Detected 12 PFAS chemicals not currently being monitored under EPA's testing methods (out of a total of 26 PFAS chemicals detected in the study).
- All samples with PFAS detected had at least one PFAS not included in EPA methods.
- The most frequently detected chemical was an ultrashort chain PFAS, PFPrA, that is not covered by EPA methods.
- UCMR5 reporting requirements are predicted to significantly underreport the presence of PFAS in drinking water.
- 14 out of 30 samples in which we found PFAS would be in exceedance of the finalized federal drinking water standards.
- However, because the finalized drinking water standards are focused on only 6 PFAS, there are multiple communities in our study that have substantial levels of total PFAS that would not qualify for drinking water protections.
- This further highlights the need for broad spectrum testing methods and the management of PFAS as a class.

OUTREACH AND COMMUNICATION

We worked with partners to develop a coordinated release of:

- Peer reviewed paper
- Community response blog
- Fact sheet
- Press releases and talking points
- Embargoed WSJ exclusive

ACKNOWLEDGEMENTS

We are extremely grateful to the community members who supplied samples of their drinking water for analysis in this study and to the National PFAS Contamination Coalition and Community Water Center.

This work was supported by charitable contributions to the Natural Resources Defense Council and in-kind contributions from Eurofins Environment Testing.

Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) Contamination in Texas

Janet Petruska Hamilton Toxicology, Risk Assessment, and Research Division, Texas Commission on Environmental Quality, Austin, TX

Abstract

Perfluoroalkyl and polyfluoroalkyl substances (PFAS) refer to a complex group of synthetic fluorinated organic chemicals that have been used worldwide since the 1940s in various industries, aqueous film forming foam (AFFF), consumer products, and products that resist grease, water, and oil. There are numerous potential sources of environmental contamination including manufacturing sites, wastewater treatment plants, landfills, and firefighter training facilities. Texas has several remediation sites with PFAS contamination including former chemical manufacturers, fire training facilities, and Department of Defense sites. In response to PFAS measured at remediation sites, in June 2011 the Texas Commission on Environmental Quality (TCEQ) set reference doses for 16 PFAS, which were used to derive protective concentration levels (PCLs) in our remediation program. These toxicity factors are concentrations or doses of a chemical that are considered to be health protective to humans, including sensitive individuals, and TCEQ is updating these PCLs with the emerging new information on PFAS. As part of the unregulated contaminant monitoring rules (UCMR3 and UCMR5), the TCEQ is assessing the potential for PFAS contamination in public water systems (PWS). Here we summarize the known PFAS contamination in remediation sites and PWS and provide information on the toxicity factors developed for various PFAS.

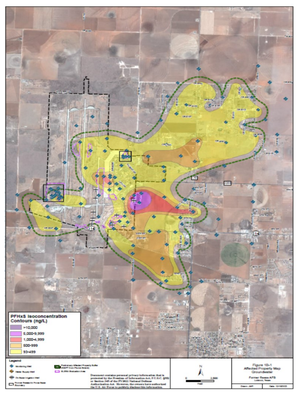
PFAS remediation sites in Texas

Texas has approximately 45 remediation sites with PFAS contamination being addressed in our remediation programs.

- Former manufacturers
- Fire training facilities
- Most are Department of Defense sites

Former Reese Air Force Base in Lubbock, TX

- As of March 4, 2024, 529 private and 6 public water supply wells sampled for PFAS
- 255 private wells and 4 public wells exceed an EPA health advisory level or TCEQ PCLs
- 252 individual treatment systems on private water wells installed so far; more being installed, bottled water provided
- 1 public system has been connected to City of Lubbock, 2 belong to a private company that has since been closed. Bottled water is supplied to 80 households that are hooked up to the 4th affected public system until a treatment system can be installed or connected to City water.
- PFAS plume extends approximately 2½ miles to the east, south, and southeast of the site boundary



The Air Force used AFFF at the former Reese Air Force Base, which led to PFAS within the foam seeping into the groundwater. The Air Force discontinued use of AFFF following base closure in 1997. The base has since been converted into a business and research park, the Reese Technology Center.

Unregulated Contaminant Monitoring Rules 3 and 5: PFAS in Drinking Water in Texas

UCMR3 sampling occurred in 2013-2015 and included 6 PFAS (PFOS, PFOA, PFNA, PFHxS, PFHpA, PFBS; minimum reporting levels were 10-90 ppt, EPA Method 537)

- 388 Public Water Systems (PWS) in Texas participated
- 283 systems that serve > 10,000
- 105 systems that serve < 10,000

Texas results UCMR3:

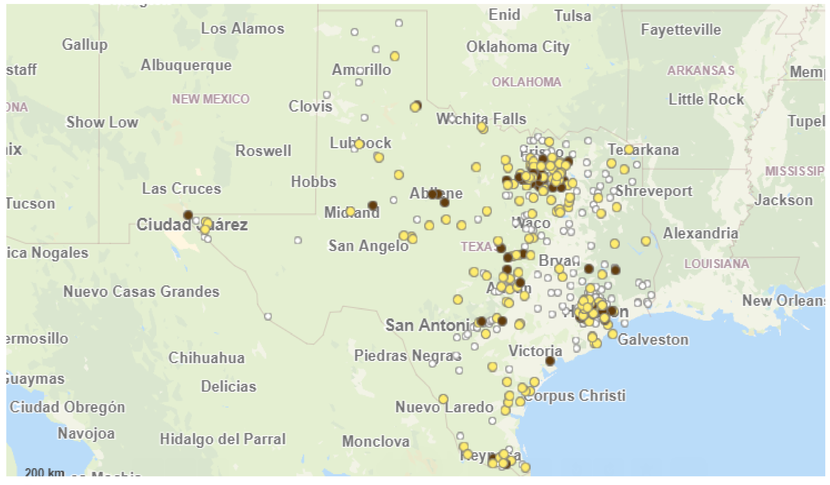
- 4 PFAS with measurable concentrations (maximum) PFHpA (16 ppt), PFHxS (52 ppt), PFOS (46 ppt), and/or PFOA (26 ppt) occurred in 2 PWS
- 7 detections/17,748 samples
- All detections below 2016 EPA health advisory level (70 ppt for PFOA and PFOS, individual or combined).

UCMR5 sampling scheduled for 2023-2025. Sampling for the 6 PFAS from UCMR3 plus 23 additional PFAS; minimum reporting levels (MRLs) are 2-20 ppt (EPA Methods 533 and 537.1)

- Requires monitoring from all systems serving 3,300 or more people and a national sampling of 800 systems serving less than 3,300. In Texas, this represents approximately 1,157 total systems.

Texas results UCMR5:

- As of May 22, 2024, results are available from 417 PWS
- 12 PFAS detected across various PWS
- 1,579 detections/49,491 samples (3.2%). 207 PWS had PFAS levels ≥ MRL.
- 107 results/49,491 samples (0.22%) above health advisory levels for PFOA and PFOS. 47 PWS had concentrations of PFOA and PFOS above EPA health advisory levels (0.004 and 0.02 ppt, respectively).



- PWS with results above EPA health advisory level
- PWS with results at or above the UCMR Minimum Reporting Level (MRL)
- PWS with no results at or above the UCMR MRL

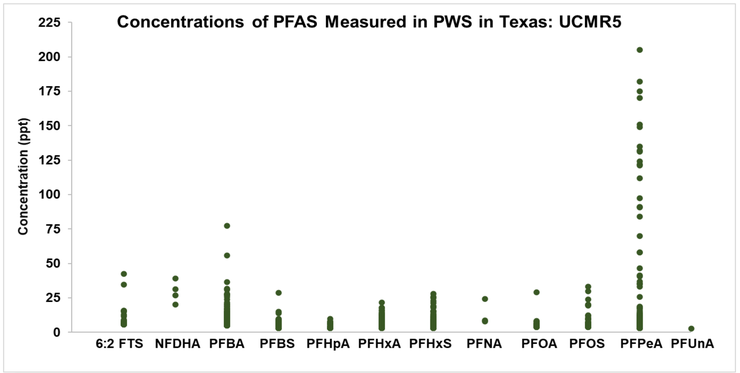
Map of PWS sampled in Texas as of May 22, 2024 as part of UCMR5. All PFAS data from UCMR5 were downloaded from the US Environmental Protection Agency (EPA) website. As of May 22, 2024 results of 49,491 samples from 417 PWS were available.

PFAS Analytic Tools (epa.gov)

PFAS	6:2 FTS	NFDHA	PFBA	PFBS	PFHpA	PFHxA	PFHxS	PFNA	PFOA	PFOS	PFPeA	PFUnA
MRL (ppt)	5	20	5	3	3	3	3	4	4	4	3	2
No. ≥ MRL	23	4	401	226	27	310	123	3	27	80	354	1
Minimum (ppt)	5.6	20.4	5	3	3	3	3	8	4	4	3	2.7
Maximum (ppt)	42.6	39	77.2	28.7	10	21.7	27.9	24.3	29.1	33.1	205	2.7
MCL (ppt)							10	10	4	4		
No. > MCL							18	1	23	74		

Abbreviations: 6:2 FTS, 1H,1H,2H,2H-perfluorooctane sulfonic acid; MCL, maximum contaminant level; MRL, minimum reporting level; NFDA, nonafluoro-3,6-dioxaheptanoic acid; No., number; PFBA, perfluorobutanoic acid; PFBS, perfluorobutane sulfonic acid; PFHpA, perfluoroheptanoic acid; PFHxA, perfluorohexanoic acid; PFHxS, perfluorohexane sulfonic acid; PFNA, perfluorononanoic acid; PFOA, perfluorooctanoic acid; PFOS, perfluorooctane sulfonic acid; PFPeA, perfluoropentanoic acid; PFUnA, perfluoroundecanoic acid

As per the final rule to regulate PFAS in drinking water, 5 PFAS (PFOA, PFOS, PFNA, PFHxS, and HFPO-DA [GenX chemicals]) will have individual MCLs. For the UCMR5 data sampled in Texas thus far, 116 detects/49,491 (0.23%) exceed individual MCLs.



TCEQ Toxicity Factors for 16 PFAS

PFAS	Chemical name	RfD (mg/kg-day)	RfC (mg/m^3)
PFBA	Perfluorobutanoic acid	1.0E-03	3.5E-03
PFBS	Perfluorobutane sulfonic acid	1.4E-03	4.9E-03
PFPeA	Perfluoropentanoic acid	5.0E-04	N/A
PFHxA	Perfluorohexanoic acid	5.0E-04	N/A
PFHxS	Perfluorohexane sulfonic acid	3.8E-06	1.3E-05
PFHpA	Perfluoroheptanoic acid	2.3E-05	N/A
PFOA	Perfluorooctanoic acid	1.2E-05	4.1E-06
PFOS	Perfluorooctane sulfonic acid	2.3E-05	8.1E-05
PFOSA	Perfluorooctane sulfonamide	1.2E-05	4.1E-06
PFNA	Perfluorononanoic acid	1.2E-05	2.8E-05
PFDA	Perfluorodecanoic acid	1.5E-05	5.3E-05
PFDS	Perfluorodecane sulfonic acid	1.2E-05	N/A
PFUA	Perfluoroundecanoic acid	1.2E-05	N/A
PFDoA	Perfluorododecanoic acid	1.2E-05	4.2E-05
PFTrDA	Perfluorotridecanoic acid	1.2E-05	N/A
PFTeDA	Perfluorotetradecanoic acid	1.2E-05	N/A

Abbreviations: RfC, reference concentration; RfD, reference dose

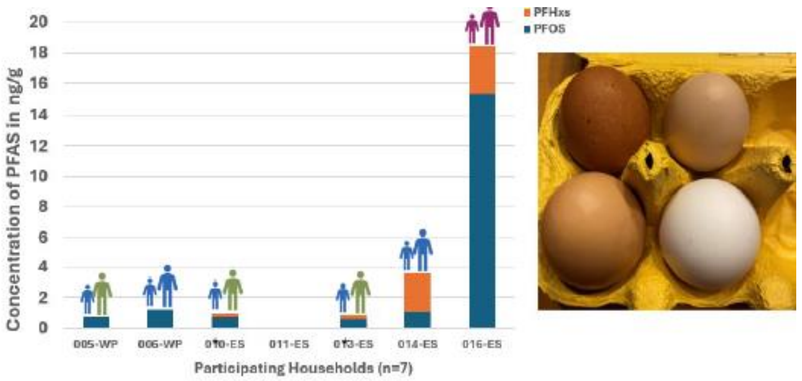
Due to PFAS contamination found in remediation sites, the TCEQ developed toxicity factors (PFAS (texas.gov)) which are used to calculate cleanup values for the agency remediation program, the Texas Risk Reduction Program (TRRP). Recently the TCEQ performed a systematic review of the literature for the PFAS listed in the above table, and some of the values may be revised based on the studies included in the systematic review. TCEQ develops toxicity factors based on the TCEQ Guidelines to Develop Toxicity Factors, 2015.

(Guidelines to Develop Inhalation and Oral Cancer and Non-Cancer Toxicity Factors (texas.gov)

PFAS in Home-Raised Livestock

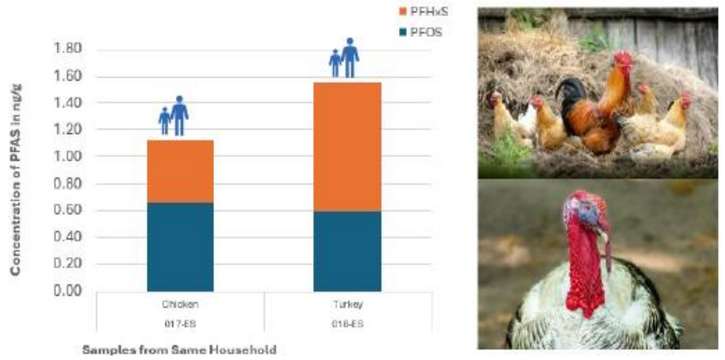
Barbara Morrissey, Washington Department of Health

PFAS in Backyard Chicken Eggs



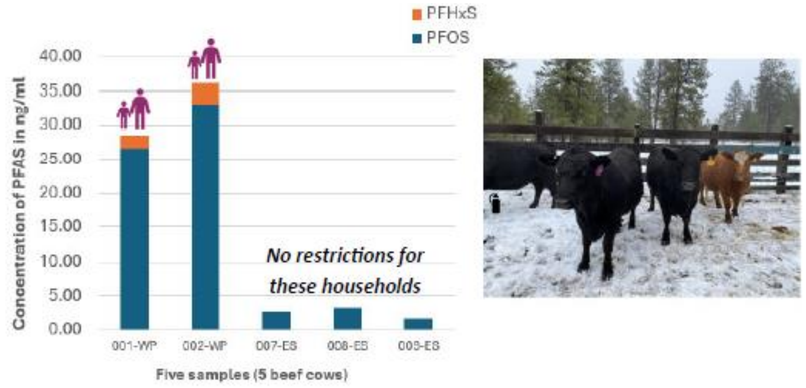
LODs - 0.250 ng/g PFOS, PFHxS
LOQs - 0.500 ng/g PFOS; 1.25 ng/g PFHxS
*PFHxS results are "j flagged" (< LOQ)14 other PFAS Not Detected in eggs

PFAS in Poultry Meat



LODs - 0.250 ng/g PFOS, PFHxS
LOQs - 0.500 ng/g PFOS; 1.25 ng/g PFHxS
*PFHxS results are "j flagged" (< LOQ) 14 other PFAS Not Detected in meat

PFAS in Cattle Serum



LODs - 0.250 ng/ml PFOS, PFHxS
LOQs - 0.500 ng/ml PFOS; 12.5 ng/ml PFHxS
*PFHxS results are "j flagged" (< LOQ) 14 other PFAS not detected in serum

Why did we do this project?

Rural WA communities (East Selah and West Plains) asked for more actionable advice about safety of eating home-raised livestock when PFAS are in animal's drinking water.

What did we do?

DOH partnered with the USDA Food Safety and Inspection Service lab to offer testing for PFAS in livestock (December 2023).

- 11 households volunteered 18 samples (eggs, beef and poultry meat, serum from live cows). All households had PFAS in their well water). Samples were tested for 16 PFAS chemicals.

We gave our participants: (March/April 2024)

- A summary of their test results.
- Advice on how much of their meat or eggs each member of their family can safely eat each week on average.
- Recommended steps to lower PFAS levels in their animals.

Food Safety Advice for Participants

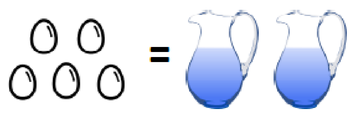
Slight restriction
- Adults: limit to 7-12 eggs/week; 3 servings meat/week
- Child: limit to 3-4 eggs/week; 5-6 oz meat/week

Moderate restriction
- Adults: limit to 4-7 eggs/week; 2 servings meat/week
- Child: limit to 1-2 eggs/week; 3-4 oz meat/week

Significant restriction
- Adults: limit ≤ 1 eggs/week; ≤1 servings meat/week
- Child: <1 egg/week; ≤2 oz meat/week

Results

- We recommended consumption limits in 7 of 11 participating households (see legend above).
- We detected only PFOS and PFHxS. Both were also common in the drinking water.
- No PFAS were detected in 4 beef samples – cow's exposure to PFAS in water was also low.
- Eggs had PFOS even when current drinking water was filtered. We suspect that soil contributes.



At one home with approximately 250 parts per trillion (ppt) of PFOS in their well water, adults eating 5 home-raised eggs per week would get the same exposure as drinking 2 liters of that same water every day for a week.

Steps we recommended to reduce exposure

- Switch livestock to PFAS-free or filtered water.
- Move chicken coop and pens to a new area. Chickens can shed PFAS into soil with their poop and be re-exposed when they forage.
- Avoid organ meats or product made from blood.
- Don't use manure from contaminated animals in home food gardens.

Key Take-Aways

- Livestock can be an important source of PFAS exposure when private wells are contaminated.
- Backyard chickens are a high priority for testing and mitigation.
- Direct testing of livestock can support actionable advice.

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PFAS Effects on Customary Practices of Native American Communities

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Introduction

The Great Lakes Inter-Tribal Epidemiology Center (GLITEC), a program of Great Lakes Inter-Tribal Council, Inc., has compiled research and data on PFAS (perfluoroalkyl and polyfluoroalkyl substances). This data helps communicate the PFAS public health risk to Tribal Nations and their community members in the Bemidji Area (Michigan, Minnesota, Wisconsin, and Chicago).

In the Bemidji Area, PFAS contamination intersects with Native American customary practices, which are deeply rooted in the land. For Indigenous communities, fishing, hunting, and agriculture are not only means of sustenance, but also sacred rituals and cultural identity. The infiltration of PFAS threatens these practices, raising concerns about health, sovereignty, and cultural survival. This poster illuminates this intersection, aiming to raise awareness and foster dialogue. Identifying future mitigation strategies can help safeguard these cherished practices from PFAS contamination, ensuring the preservation of cultural heritage for future generations.

Aim

To explore the impact of PFAS contamination on customary practices within Tribal communities, focusing specifically on communities in the Bemidji Area.

Objectives

- Analyze the correlation between PFAS contamination levels and customary practices in Tribal communities.
- Assess the health risks associated with PFAS exposure in relation to traditional activities.
- Increase the discussion around potential mitigation strategies to safeguard customary practices from PFAS contamination.

Methods

Collaboration with traditional knowledge holders led to the identification of relevant topics and helped interpret data.

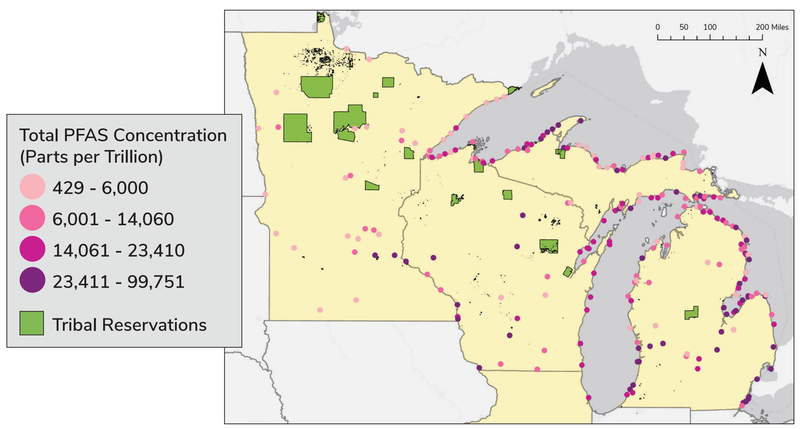
Data was collected from three organizations: the Environmental Working Group (EWG), Environmental Protection Agency (EPA), and Great Lakes Indian Fish & Wildlife Commission (GLIFWC).

Public water systems (PWS) are considered to be contaminated if they meet or exceed the EPA's fifth Unregulated Contaminant Monitoring Rule (UCMR 5) maximum contaminant level (MCL). The MCL is 4.0 ppt for drinking water and groundwater. Maps were made using ArcGIS Pro, and corresponding shapefiles were found through publicly available data from Esri.

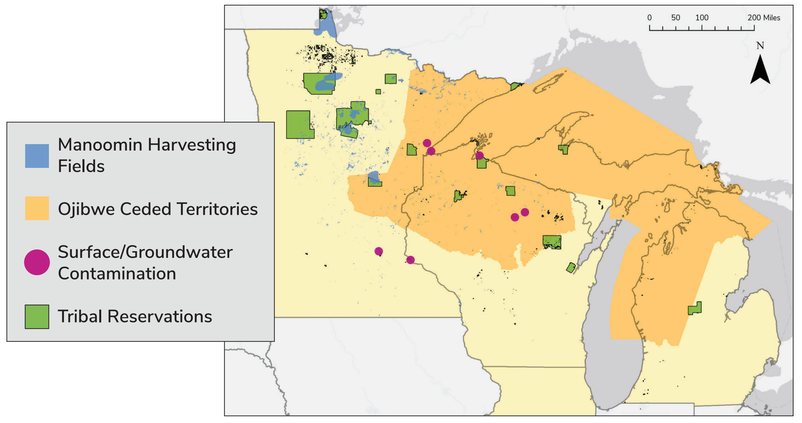
Resources: **1)** "Forever chemicals" in freshwater fish: mapping a growing environmental justice problem. Environmental Working Group (EWG). Published January 17, 2023. Accessed May 13, 2024. https://www.ewg.org/interactive-maps/pfas_in_US_fish/map **2)** GIS Maps. Great Lakes Indian Fish & Wildlife Commission (GLIFWC). Published March 20, 2023. Accessed May 13, 2024. https://maps.glifwc.org **3)** PFAS Analytic Tools. Environmental Protection Agency (EPA). Updated 2024. Accessed May 13, 2024. https://awsedap.epa.gov/public/extensions/PFAS_Tools/PFAS_Tools.html **4)** PFAS. Minnesota Pollution Control Agency (MPCA). Accessed June 5, 2024. https://www.pca.state.mn.us/pollutants-and-contaminants/pfas

Results

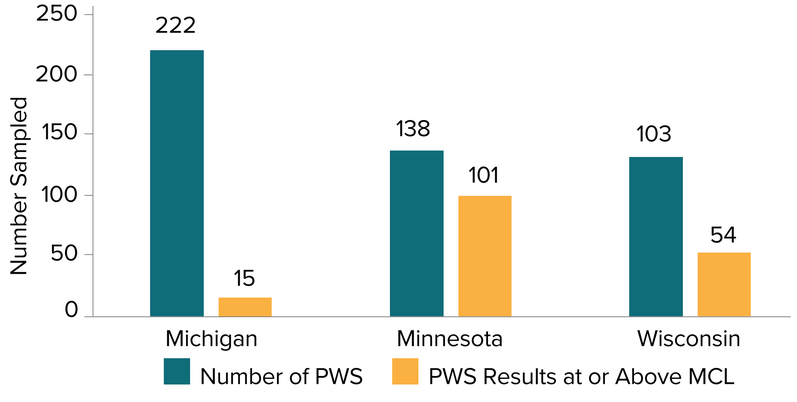
PFAS Fish Contamination in the Bemidji Area, 2010-2019[1]



Wild Rice (Manoomin) Harvesting Fields and Contaminated Surface Water and Groundwater in the Bemidji Area, 2020-2022[2]



PWS Contamination in the Bemidji Area, 2018-2023[3]



Discussion

PFAS contamination in fish, manoomin fields, and water poses a threat to the traditional practices and ceremonies of Tribal communities. With a number of fish samples, manoomin fields, and PWS testing positive for high levels of PFAS, Tribal members may have (and continue to) ingest high levels of PFAS in their everyday lives. The contamination of water, especially the Great Lakes, disrupts the sacred relationship that many Tribes have with their local bodies of water. Fishing and harvesting are rights given to Native peoples through treaties with the United States government. These rights should be honored and respected. Along with traditional practices, fish and manoomin are of cultural and economic importance for many Tribal communities.

Several of the PWS that were tested found high levels of PFAS in Michigan, Minnesota, and Wisconsin. Michigan shows the lowest incidence of contamination above the MCL, despite having the highest number of PWS sampled. This could suggest effective pollution control measures or fewer sources of PFAS pollution in the sampled area. Minnesota had a high proportion of contaminated PWS. This indicated significant PFAS presence in the water system, posing a major health risk to communities that rely on these sources. Wisconsin shows a moderate level of contamination. Although fewer than Minnesota, the Wisconsin data is still concerning, especially for communities with limited access to alternative water sources.

Conclusion

PFAS testing is still in its early stages. Existing data and known contamination sites indicate that PFAS poses a threat to waterways, fish, and potentially wild rice harvesting fields.

Safeguarding customary practices from PFAS contamination requires mitigation strategies that integrate traditional knowledge, community engagement, and scientific expertise. Collaboration between Tribal authorities, government agencies, and research institutions is essential to address this complex issue.

Limitations

- There is limited data availability and resources for comprehensive monitoring and remediation efforts.
- The full extent of PFAS contamination will not be fully understood until testing efforts expand.
- The ability of manoomin to uptake PFAS through methods similar to other plants is still unconfirmed. Research is being done to confirm this hypothesis.
- No mapping data for manoomin harvesting fields were found for Michigan or Chicago.
- Several possibly contaminated lakes in Minnesota have yet to been tested.[4]

Next Steps

- Continued community-based research to better understand the extent and effects of PFAS contamination.
- Development of culturally appropriate risk communication strategies to empower community members to make informed decisions.
- Advocacy for policy changes and resource allocation to support PFAS remediation efforts on Tribal lands.

FOREVER POLLUTION IN THE NETHERLANDS

The underlying causes of the DuPont/Chemours case: corporate context and state-corporate interactions

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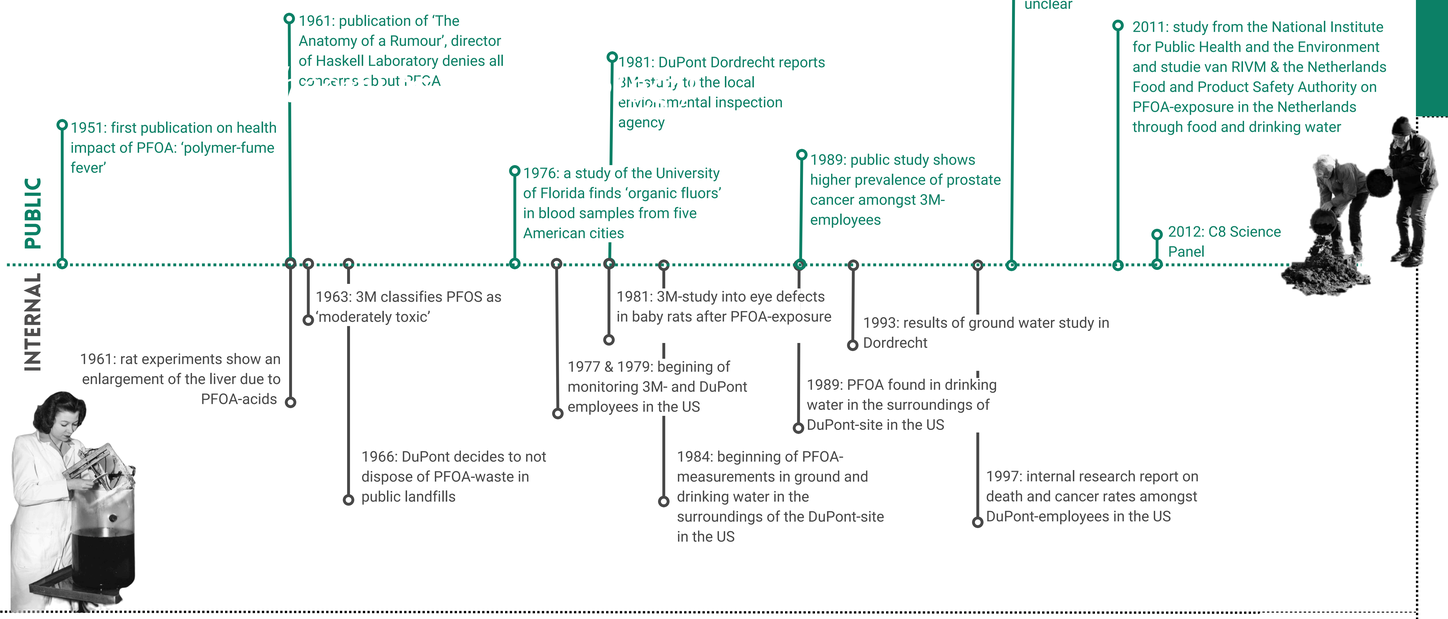
WHO KNEW WHAT & WHEN?



CORPORATE CONTEXT

(Im)measurable (un)certain harms

- 'Cannot measure yet', 'do not know enough yet'
- Techniques: 'No way to remove waste from air pollution' (1968) & 'this combination of techniques has never been applied to it's unrealistic' (2023)
- 'Causality' "Did not know it would fall to the ground" (Chemours 2023)

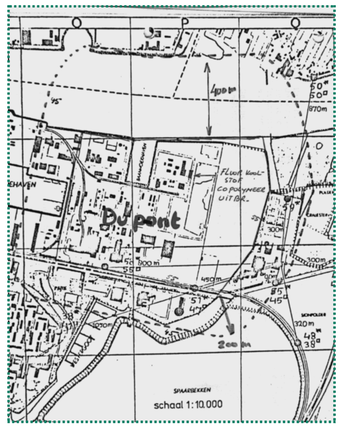
> "A lot escapes through the chimney. (…) And no one is measuring that. […] That is an invisible route, seriously. And you don't see it until it's in the surrounding waters, or the surrounding soil, or the vegetable gardens where it's measured accidentally." (RA2)

Knowledge asymmetry

- Questions about physical, chemical, toxicological characteristics of products > depend on industry for answer
- Decades of communication about 'insufficient' knowledge vs. concerns have long been raised internally within the company
- PFOA/C-8 in the permit application documents: 'Dispersing agent*' [*dispergeermiddel*], or 'other fluor-carbons' vs. other chemicals that are all named (PFIB, K-1234, KC-138, K-226)

STATE-CORPORATE INTERACTIONS

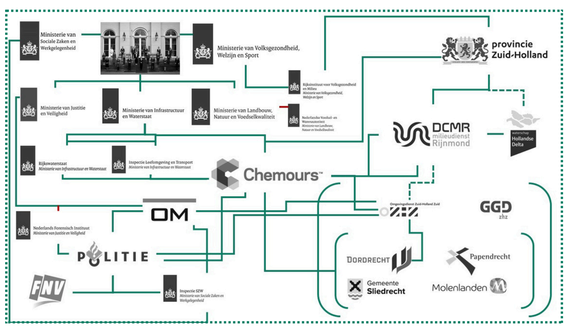
Permit process & legal challenges



- Companies in the lead in 1960s-1970s
- Lost in the details:
  - Many technical details back & forth in permits
  - Then no details about other aspects
- Regulated self-regulation (hard to change)
- Primate of administrative law
- Causal relation between (permitted) pollution and harms
- Recent developments:
  - Restriction proposal: 3600 comments
  - Juridification > numer of court cases

> "Highly desirable to replace the environmental permits already granted with a new, permit, covering the entire establishment." (Municipality of Papendrecht, 1983)

Fragmented regulation



- Permit process and inspection are divided amongst different governmental institutions
- Decades of decentralization, fragmentation and cutbacks
- Recent developments:
  - National PFAS-coördinator