PFAS planning document

February 2021

Minnesota’s PFAS Blueprint

A plan to protect our communities and our environment from
per- and polyfluorinated alkyl substances

MINNESOTA

This document was written by a large number of staff and managers from the MPCA, MDH, DNR and MDA. The initial drafts of issue papers were written by PFAS Lateral Team subject experts. Primary coordination, compilation, and editing was done by Sophie Greene, MPCA's PFAS coordinator.

Drafts of issue papers were reviewed by the relevant program management, the entire Staff PFAS Lateral Team, and the entire Manager PFAS Lateral Team. Finally, the document was reviewed by commissioners of participating agencies.

Authors

Sophie Greene
Catherine Neuschler

Contributors/acknowledgements

Justin Barrick (MPCA)
Anthony Bello (MPCA)
Sheryl Bock (MPCA)
Andri Dahlmeier (MPCA)
Jane de Lambert (MDH)
Mark Elliott (MPCA)
David Fairbairn (MPCA)
Helen Goeden (MDH)
Rebecca Higgins (MPCA)
Alister Innes (MPCA)
James Jacobus (MPCA)
Todd Johnson (MPCA)
Scott Knowles (MPCA)
Dorian Kvale (MPCA)
Jaramie Logelin (MPCA)
Laura Marti (MPCA)
Catherine O'Dell (MPCA)
Mark Rys (MPCA)
Yodit Sheido (MPCA)
Summer Streets (MPCA)
Katherine Sullivan (MPCA)
Randy Thorson (MPCA)
Kayla Walsh (MPCA)
Virginia Yingling (MDH)
Rajinder Mann (MDA)
Kristie Ellickson (MPCA)
Angela Preimesberger (MPCA)
Barbara Keller (DNR)
Bruce Monson (MPCA)
Phil Monson (MPCA)
Michelle Carstensen (DNR)
Patricia Mccann (MDH)
Melissa Peck (MPCA)
Kathleen Hall (MDA)
Deanna Scher (MDH)
Timothy Farnan (MPCA)
Sarah Yost (MPCA)
Will Backe (MDH)
Betsy Edhlund (MDH)
Gary Krueger (MPCA)
Alycia Overbo (MDH)
Tannie Eshenaur (MDH)
Ling Shen (DNR)
Tom Burri (DNR)
Paul Radomski (DNR)
Josh Burman (MPCA)
John Gilkeson (MPCA)
Nicole Neeser (MDA)

Editing and graphic design

Paul Andre
Amanda Scheid
Elizabeth Tegdesch

Minnesota Pollution Control Agency

520 Lafayette Road North | Saint Paul, MN 55155-4194 |

651-296-6300 | 800-657-3864 | Or use your preferred relay service. | Info.pca@state.mn.us

This report is available in alternative formats upon request, and online at www.pca.state.mn.us.

Document number: p-gen1-22

Contents

Figures

Tables

Acronyms

5:3 FTCA	5:3 Fluorotelomer carboxylic acid
AFFF	Aqueous film-forming foams
ARARs	Applicable or relevant and appropriate requirements
ARAM	Alternative Risk Assessment Methodology
ATP	Aquatic Toxicity Profile
C&D	Construction and demolition
CAA	Clean Air Act
CAPs	Criteria Air Pollutants
CDC	Centers for Disease Control and Prevention
CEC	Contaminant of emerging concern
CEH	Center for Environmental Health
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLP	Closed Landfill Program
CWA	Clean Water Act
CWS	Community water system
DNR	Department of Natural Resources
DoD	Department of Defense
DWRF	Drinking Water Revolving Fund
ECCC	Environment and Climate Change Canada
ECOTOX	ECOTOXicology knowledgebase
EFSA	European Food Safety Authority
EPA	US Environmental Protection Agency
F3	Fluorine-free firefighting foam
FCMP	Fish Contaminant Monitoring Program
FDA	Food and Drug Administration
FOSA	Perfluorooctane sulfonamide
FTOH	Fluorotelomer alcohol
GAC	Granular activated carbon
HAP	Hazardous air pollutant
HBV	Health Based Value
HHRAP	Human Health Risk Assessment Protocol
HRL	Health Risk Limit
ITRC	Interstate Technology and Regulatory Council
LCCMR	Legislative-Citizen Commission on Minnesota Resources
LSTS	Large Subsurface Treatment Systems
MACT	Maximum achievable control technology
MCL	Maximum contaminant level
MDA	Minnesota Department of Agriculture
MDH	Minnesota Department of Health
MERLA	Minnesota Environmental Response and Liability Act
MNELAP	Minnesota Department of Health Environmental Laboratory Accreditation Program
MPCA	Minnesota Pollution Control Agency
MPG	Multi-purpose Grant

MSW	Municipal solid waste
NAM	New approach methodology
NPDES	National Pollutant Discharge Elimination System
ORD	Office of Research and Development (EPA)
P2	Pollution Prevention
PBT	Persistent, bioaccumulative and toxic
PCB	Polychlorinated biphenyl
PFAS	Per- and polyfluoroalkyl substances
PFBA	Perfluorobutanoic acid
PFBS	Perfluorobutane sulfonate
PFC	Perfluorochemical
PFCA	Perfluorinated carboxylic acid
PFDA	Perfluorodecanoic acid
PFDoDA	Perfluorododecanoic acid
PFDS	Perfluorodecane sulfonic acid
PFHpA	Perfluoroheptanoic acid
PFHpS	Perfluoroheptane sulfonic acid
PFHxA	Perfluorohexanoic acid
PFHxS	Perfluorohexane sulfonate
PFNA	Perfluorononanoic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonate
PFPeA	Perfluoropentanoic acid
PFSA	Perfluorinated sulfonic acid
PFTeDA	Perfluorotetradecanoic acid
PFTrDA	Perfluorotridecanoic acid
PFUnDA	Perfluoroundecanoic acid
PHL	Public Health Lab
PIGE	Particle induced gamma emission
RCRA	Resource Conservation and Recovery Act
REACH	Registration, Evaluation, Authorization and Restriction of Chemicals
RMAD	Resource Management and Assistance Division
SDS	State Disposal System
SSOM	Source-separate organic material
TOF	Total organic fluorine
TOP	Total oxidizable precursor
TRI	Toxics Release Inventory
TSCA	Toxic Substances Control Act
UCMP	Unregulated Contaminant Monitoring Project
UCMR	Unregulated Contaminant Monitoring Rule
USDA	United States Department of Agriculture
USGS	United States Geological Survey
vPvB	Very persistent and very bioaccumulative
WIC	Women, Infants, and Children
WQC	Water Quality Criteria (site-specific)
WQS	Water Quality Standards
WWTP	Wastewater treatment plant

Executive summary

Per- and polyfluoroalkyl substances (PFAS) are a large family of chemicals that are ubiquitous in the environment due to use across economic sectors since the 1930s. Substances in the PFAS family are either persistent in the environment or transform to different PFAS that are persistent. Some PFAS bioaccumulate in living organisms. At certain levels they are toxic, causing adverse health effects in humans, fish, and wildlife.

Over the last 20 years, PFAS have been considered important emerging contaminants. Actions have been taken around the world to study them. Minnesota was one of the first states to identify PFAS pollution and has been a leader in studying the impacts of PFAS and responding to PFAS contamination. Once considered "contaminants of emerging concern," PFAS have now truly "emerged" as worrisome contaminants in the regulatory and scientific communities. Hundreds of thousands of reports on PFAS environmental occurrence, human toxicity, and animal toxicity have been published.[1]Across the United States, federal and state health and environmental regulators are taking steps to incorporate PFAS into their programs.

PFAS are present in the environment and will remain so for a long time. Significant actions are needed to prevent adverse effects of PFAS by interrupting the pathways that result in people and organisms being exposed. While management and mitigation actions have significant positive effects, ultimately we cannot clean up our way out of the PFAS problem. Instead, the pollution must be prevented from the outset through restrictions or bans on PFAS uses, assistance and financial support for reformulation, and regulation of PFAS releases to the environment.[2]

This document provides an overview of PFAS, followed by an in depth discussion of PFAS in 10 key issue areas. Each issue paper describes the many PFAS initiatives taken and underway in Minnesota and identifies key areas of opportunity moving forward on managing and addressing PFAS. The papers also highlight the significant interconnections between different areas, illustrating the complexity and difficulty of managing PFAS. The issue papers cover a broad range of topics. Across all those topics, themes emerge among the needed actions.

Pollution prevention: The persistency of PFAS mean that they do not break down in the environment. Treatment and destruction of PFAS is expensive and not always feasible or complete. Effort is needed to limit non-essential PFAS uses and find alternatives to PFAS when uses are currently needed.

Investigation of PFAS discharges: To prevent PFAS pollution, we need to understand the wide range of places where PFAS has been or are currently used and how these uses result in PFAS releases to the environment.

Environmental monitoring: More detailed information about which PFAS are in the environment and at what levels is needed. This may require use of non-traditional analytical methods like non-targeted analysis. Non-targeted analysis allows for the detection of hundreds of PFAS in a sample, without requiring the availability of traditional analytical methods.

Toxicity research: Additional research is needed to understand the toxicity of PFAS to people and environmental organisms. Without this research, it can be impossible to develop risk-based values for a given PFAS.

[1]Dimensions. (2020, December 9) PFAS keyword search. Retrieved from: https://app.dimensions.ai/discover/publication?search_mode=content&search_text=PFAS&search_type=kws&search_field=full_search

[2] Similarly persistent and bioaccumulative toxics such as polychlorinated biphenyls (PCBs) and dichlorodiphenyltrichloroethane (DDT) were banned as their impacts became clear.

Regulatory development: PFAS are generally not yet well incorporated into environmental regulatory programs. Program development needs to consider necessary and appropriate changes to incorporate PFAS monitoring, limits, or best management practices into facility permits.

The issue papers are intended to provide a shared grounding on key topics related to PFAS and to direct the conversation to areas of focus for future needs. Some of the opportunities would represent an expansion of existing efforts to manage PFAS; some would require additional resources and structures to build them into comprehensive and holistic PFAS programs. Choosing to pursue some of these future opportunities would involve program development, detailed discussions with potential partners, stakeholder engagement, and collaboration across impacted Minnesotans.

This blueprint identifies (in Appendix A), actions that could be taken over the short-term and those that would take longer to complete based on current resources and priorities. Combined with items being advanced in the current legislative session, the "short-term" initiatives include opportunities to reduce and prevent PFAS pollution, advance key areas of PFAS research, begin to incorporate PFAS into regulatory programs, and improve the efficiency of clean-ups at PFAS-contaminated sites.

The future needs and opportunities related to PFAS are extensive, and the state agencies and our partners in Minnesota, other states, and the federal government will need to work together to advance projects strategically towards the collective goal to protecting human health and the environment from the impacts of PFAS. The medium/long-term opportunities identified in this report represent a broad range of activities, some of which are connected and dependent on each other. The state of science and regulation of PFAS is dynamic; research and policy are being advanced by state agencies, federal agencies, academics, and corporations. The ongoing work of others will almost certainly fill some of the gaps identified in this report, and will influence the work that needs to be done in Minnesota. Minnesota expects to revisit this plan over time to adjust to the changing scientific and regulatory landscape.

2021 legislative proposals
Conduct additional investigations of PFAS groundwater plumes down-gradient of closed landfills
Conduct routine PFAS monitoring in fish
Engage with WWTPs to identify industrial PFAS sources and opportunities for pretreatment
Establish authority for MPCA to request data regarding contaminants of potential environmental concern
Conduct study of biosolids fate and transport following land-application
Formally define PFAS as hazardous substances under MERLA
Accelerate existing PFAS Pilot Inventory

Short-term actions
Compile information on inhalation PFAS toxicity
Issue guidance on the collection and disposal of PFAS-containing firefighting foam concentrate and wastewater
Research cutting-edge risk assessment techniques for data-poor PFAS
Update guidance for recommended analyte sampling at clean-up sites to include PFAS
Develop statewide water quality standards for PFAS - Class 1 drinking water
Develop a plan for monitoring PFAS in groundwater at active landfills
Develop a plan for monitoring PFAS at NPDES permitted facilities
Develop a plan for performance testing for PFAS at permitted air sources

Introduction

Per- and polyfluoroalkyl substances (PFAS), previously called perfluorochemicals or PFCs, are a large family of chemicals that are widely present in the environment. When a new or unexpected pollutant is found in the environment, that discovery can lead to a wide range of actions like monitoring to determine where the pollutant is found, investigation to determine how the pollutant is getting into the environment, and research to identify potential adverse impacts the pollutant might have on human or wildlife health. When a pollutant is suspected to be in the environment and a cause for concern, it is often called a "contaminant of emerging concern." As the impacts of a pollutant become more clear, federal and state environmental agencies may take steps to reduce or regulate levels of the pollutant. Once regulated, pollutants are no longer considered an "emerging concern" and are instead included in the routine regulatory processes managed by state and federal governments.

Over the last 20 years, PFAS have been considered important "contaminants of emerging concern" and actions have been taken around the world to study them. Minnesota was one of the first states to identify PFAS pollution and has been a leader in studying their health effects and in responding to contamination. At this point, in 2021, PFAS have truly "emerged" in the regulatory and scientific landscape as contaminants of concern. Although they are not fully regulated, it is clear that PFAS are ubiquitous in the environment and, at certain levels, have adverse effects on both human and wildlife health. Across the United States, federal and state health and environmental regulators are taking steps that are moving PFAS from the space of being "emerging contaminants" to ones that are regularly managed and incorporated into our health and environmental programs. Navigating this transition is complex.

Minnesota's state agencies have already undertaken significant efforts to address PFAS. However, the incorporation of PFAS into regulatory work and research has occurred generally in response to specific events and as resources arise. While good work has been done, more is needed.

Working together, the Minnesota state agencies plan to take a holistic and systematic approach to addressing PFAS. To that end, the Minnesota Pollution Control Agency (MPCA) has established a PFAS Coordinator position and designed an interagency lateral team to manage PFAS issues in a way that is efficient and prevents unintended consequences. This blueprint is the first major work product from the PFAS Coordinator and lateral team. It presents an overview of PFAS generally, followed by a discussion of PFAS concerns in 10 key issue areas. Each issue paper describes the many PFAS initiatives taken in Minnesota relevant to that topic and those currently underway. The issue papers then identify areas of opportunity for moving forward on managing and addressing PFAS and highlight the significant interconnections or overlaps between different topic areas, illustrating the complexity and difficulty of managing PFAS through regular regulatory mechanisms.

The 10 issue areas are:

1. Preventing PFAS pollution
2. Measuring PFAS effectively and consistently
3. Quantifying PFAS risks to human health
4. Limiting PFAS exposure from drinking water
5. Reducing PFAS exposure from consuming fish and game
6. Limiting PFAS exposure from food
7. Understanding risks from PFAS air emissions
8. Protecting ecosystem health
9. Remediating PFAS contaminated sites
10. Managing PFAS in waste

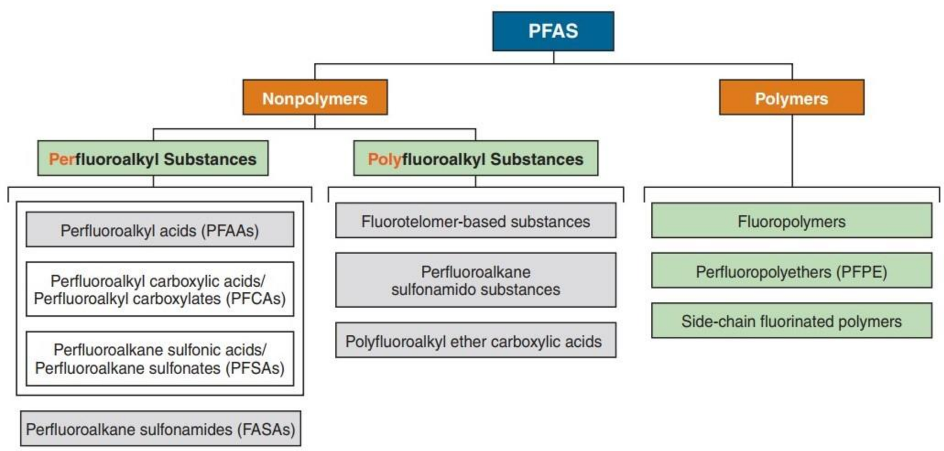
The papers are intended to provide a shared grounding in past work on issues related to PFAS, and to direct the conversation to key areas of focus for future needs in managing PFAS to protect human health and the environment. The identified future opportunities are not directives or fully realized program proposals. In many cases, additional resources and structures (and in some cases additional authorities) would be needed to allow the agencies to build projects under consideration into comprehensive and holistic PFAS programs. The issue papers are meant to open space for discussion on how to move forward with managing PFAS in each area. Choosing to pursue many of the future opportunities would involve stakeholder engagement, discussion, and collaboration across impacted Minnesotans.

Background

What are PFAS?

PFAS are a large group of manmade chemicals containing at least one fully fluorinated carbon in a chain attached a "functional group" that has specific characteristics.[3] Invented in the 1930s, PFAS have been used in multiple applications across many industries for uses including repelling water and grease, reducing friction, reducing fire risk, and acting as an insulator, especially under conditions where materials are needed that are non-reactive and heat-resistant. PFAS are desirable in commercial and industrial applications because of their durability, but that durability also means that they do not readily break down over time in environmental conditions. In addition, they are not easily removed through conventional pollution treatment at facilities like wastewater treatment plants (WWTP). The persistence of PFAS in the environment has led to the nickname of "forever chemicals." PFAS are unlike other classes of environmental contaminants in terms of the number of unique structures in the group, their persistence in the environment, and their widespread societal use.

Figure 1. Summary of PFAS families, retrieved from ITRC.



It is difficult to identify all PFAS with specificity. There are currently over 5,000 PFAS structures included in the US Environmental Protection Agency's (EPA) master list of structurally defined PFAS, and over 9,000 identified PFAS chemistries.[4] New PFAS are being invented, used in industry, incorporated into commercial products, and released to the environment every day. A key challenge in understanding and regulating PFAS is the currently limited but ever-expanding knowledge about their use, their presence in the environment, the resulting health and environmental effects, and how these characteristics may differ based on the specific type of PFAS. Figure 1 provides a basic summary of the different subfamilies of PFAS. PFAS are sometimes discussed as being "long-chain" or "short-chain," depending on the

[3] Interstate Technology Regulatory Council (ITRC). (2020, April). Naming Conventions and Physical and Chemical Properties of Per- and Polyfluoroalkyl Substances. https://pfas-1.itrcweb.org/fact_sheets_page/PFAS_Fact_Sheet_Naming_Conventions_April2020.pdf

[4] EPA, National Center for Computational Toxicology. (2020, September 16). PFAS Master List of PFAS (Version 2). https://comptox.epa.gov/dashboard/chemical_lists/PFASMASTER

number of fluorinated carbons in the chain; the more carbons, the longer the chain. The precise definition of “long-chain” depends on the exact PFAS and their functional groups, but in general “long-chain” refers to perfluorinated carboxylic acids (PFCAs) with eight or more carbons (seven or more carbons are perfluorinated) or perfluorinated sulfonic acids (PFSAs) with six or more carbons (six or more carbons are perfluorinated). *Short-chain* refers to PFCAs with seven or fewer carbons (six or fewer carbons are perfluorinated) and PFSAs with five or fewer carbons (five or fewer carbons are perfluorinated).[5] Table 1, below, provides some basics on PFAS naming conventions.

Table 1. PFAS naming system, retrieved from ITRC.

X	Y	Acronym	Name	Formula	CAS No.
B = buta (4 carbon)	A = Carboxylate or carboxylic acid	PFBA	Perfluorobutanoate	$C_3F_7CO_2^-$	45048-62-2
			Perfluorobutanoic acid	C_3F_7COOH	375-22-4
	S = Sulfonate or sulfonic acid	PFBS	Perfluorobutane sulfonate	$C_4F_9SO_3^-$	45187-15-3
			Perfluorobutane sulfonic acid	$C_4F_9SO_3H$	375-73-5
Pe = penta (5 carbon)	A = Carboxylate or carboxylic acid	PFPeA	Perfluoropentanoate	$C_4F_9CO_2^-$	45167-47-3
			Perfluoropentanoic acid	C_4F_9COOH	2706-90-3
	S = Sulfonate or sulfonic acid	PFPeS	Perfluoropentane sulfonate	$C_5F_{11}SO_3^-$	NA
			Perfluoropentane sulfonic acid	$C_5F_{11}SO_3H$	2706-91-4
Hx = hexa (6 carbon)	A = Carboxylate or carboxylic acid	PFHxA	Perfluorohexanoate	$C_5F_{11}CO_2^-$	92612-52-7
			Perfluorohexanoic acid	$C_5F_{11}COOH$	307-24-4
	S = Sulfonate or sulfonic acid	PFHxS	Perfluorohexane sulfonate	$C_6F_{13}SO_3^-$	108427-53-8
			Perfluorohexane sulfonic acid	$C_6F_{13}SO_3H$	355-46-4
Hp = hepta (7 carbon)	A = Carboxylate or carboxylic acid	PFHpA	Perfluoroheptanoate	$C_6F_{13}CO_2^-$	120885-29-2
			Perfluoroheptanoic acid	$C_6F_{13}COOH$	375-85-9
	S = Sulfonate or sulfonic acid	PFHpS	Perfluoroheptane sulfonate	$C_7F_{15}SO_3^-$	NA
			Perfluoroheptane sulfonic acid	$C_7F_{15}SO_3H$	375-92-8
O = octa (8 carbon)	A = Carboxylate or carboxylic acid	PFOA	Perfluorooctanoate	$C_7F_{15}CO_2^-$	45285-51-6
			Perfluorooctanoic acid	$C_7F_{15}COOH$	335-67-1
	S = Sulfonate or sulfonic acid	PFOS	Perfluorooctane sulfonate	$C_8F_{17}SO_3^-$	45298-90-6
			Perfluorooctane sulfonic acid	$C_8F_{17}SO_3H$	1763-23-1
N = nona (9 carbon)	A = Carboxylate or carboxylic acid	PFNA	Perfluorononanoate	$C_8F_{17}CO_2^-$	72007-68-2
			Perfluorononanoic acid	$C_8F_{17}COOH$	375-95-1
	S = Sulfonate or sulfonic acid	PFNS	Perfluorononane sulfonate	$C_9F_{19}SO_3^-$	NA
			Perfluorononane sulfonic acid	$C_9F_{19}SO_3H$	474511-07-4
D = deca (10 carbon)	A = Carboxylate or carboxylic acid	PFDA	Perfluorodecanoate	$C_9F_{19}CO_2^-$	73829-36-4
			Perfluorodecanoic acid	$C_9F_{19}COOH$	335-76-2
	S = Sulfonate or sulfonic acid	PFDS	Perfluorodecane sulfonate	$C_{10}F_{21}SO_3^-$	126105-34-8
			Perfluorodecane sulfonic acid	$C_{10}F_{2}1SO_3H$	335-77-3

[5] ITRC. (2020). PFAS Chemistry, Terminology, and Acronyms. Retrieved from: https://pfas-1.itrcweb.org/2-2-chemistry-terminology-and-acronyms/. Note that this is definition is a simplification that does not consider replacement chemistries with non-carbon substitutions to the backbone of the chemical.

To date, work on PFAS has focused on two of the most studied PFAS, perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA). The major manufacturers of PFAS in the United States agreed to phase out the use of PFOS and PFOA in 2006, but production of PFOA and PFOS continued through 2010 and regulations still allow PFOS and PFOA to be incorporated in some products manufactured elsewhere but sold in the United States.[6]

Where are PFAS used?

PFAS are used in a wide variety of industrial process and commercial products. PFOS and PFOA were once manufactured by 3M in Minnesota. PFOS was a key ingredient in the stain repellant Scotchgard and was used in surface coatings for common household items such as carpets, furniture, and waterproof clothing. PFOS was also included in fire-fighting foams used at airports, fuel refineries, and other facilities. PFOA was used in the production of many products, included (but not limited to) nonstick coatings for cookware, coatings for carpets, coatings for upholstery, coatings for clothing, floor wax, sealants, and even some dental flosses. Products containing PFOA and PFOS produced before the "phase out" are still in circulation in homes and businesses around Minnesota. These products are currently in use or making their way into landfills, compost facilities, and WWTPs around the state. Other PFAS that transform to PFOA or PFOS are still being imported. For these reasons, though PFOA and PFOS are considered "legacy" PFAS and are no longer being manufactured locally, new contributions of PFOA and PFOS to the environment continue. Other PFAS are regularly manufactured and used in a variety of industries and products ranging from cross country ski wax to car wax, medical devices, textiles, and many more. A non-exhaustive list of industries known to use PFAS and the corresponding applications are included in Table 2.

Table 2. A non-exhaustive list of PFAS past or ongoing uses in various industries.[7]

Industry branch	Examples of uses
Aerospace	Brake and hydraulic fluids, wire and cable, thermal control and radiator surfaces
Air conditioning	Working fluid
Ammunition	Reduces likelihood of unplanned explosion due to shock, prevents degradation of polymer coatings
Apparel	Breathable membranes, water-resistant finish
Automotive	Automotive waxes (resistant), windshield wiper fluid (prevents icing), heat transfer fluid, stain-resistant coatings on carpets and seats, glass, and some engine parts
Biotechnology	Cell cultivation, filtration and microporous membranes
Building and construction	Architectural membranes (e.g. roofs), cement additive, cable and wire insulation
Chemical industry	Production of chlorine and caustic soda, processing aids, extrusion films, solvents, inert reaction media
Cleaners	Wetting agent, stabilizes dry cleaning fluids
Coatings, paints and varnishes	Emulsifier in paint, anti-stick coatings, coatings for food contact materials
Cookware	Prevent sticking to the pan
Electronics	Heat transfer fluids, etching solution, cleaning solvent, dielectric fluids

[6] EPA, Office of Chemical Safety and Pollution Prevention. (2020, February 20). EPA Continues to Act on PFAS, Proposes to Close Import Loophole and Protect American Consumers. [Press release]. Retrieved from: https://www.epa.gov/newsreleases/epa-continues-act-pfas-proposes-close-import-loophole-and-protect-american-consumers

[7] Adapted from Glüge, J., Scheringer, M., Cousins, I.T., DeWitt, J.C., Goldenmann, G, Herzke, D., Lohmann, R., Ng, C.A., Trier, X., & Wang, Z. (2020). An overview of the uses of per- and polyfluoroalkyl substances (PFAS). *Environmental Science: Processes and Impacts*, *22*, 2345. https://doi.org/10.1039/D0EM00291G

Industry branch	Examples of uses
Electroplating	Chrome, nickel, copper, tin, and zinc plating
Energy (non-oil or gas)	Photovoltaic cells (repels dirt, highly transparent coating), coal power plants (filters ash fly from smoke), lithium ion batteries: binder for electrodes, prevents thermal runaway reactions, electrolyte solvent
Firefighting foam	Film former, foam stabilizer, flame retardant
Floor coverings	Soil-release finishes for carpets, stain resistant coatings, added to floor polish as wetting agent, additive to laminated floor covering
Glass	Dirt-repellant and mist prevention, wetting agent, etching baths, solvent displacement when drying
Laboratory supplies	Polymeric PFAS used for consumable materials like vials and caps, some columns filter with polymeric PFAS
Leather	Water and oil resistant coatings, aids in manufacturing leather (hydrating, degreasing)
Machinery and equipment	Coating metal surfaces, etching baths, water removal from processed parts
Medical equipment	Contrast agents in ^{19}f NMR imaging, wetting agents, emulsion additives, and stabilizers in x-ray films, raw material for contact lenses, delivery agent for eye drops, surgical patches, toothpaste (enhances fluoroapatite formation), dental floss, UV-hardened dental restorative materials, artificial heart pump (blood compatible and durable)
Mining	Ore floatation/separation, copper and gold ore leaching,
Musical instruments	Guitar strings, piano keys
Nuclear industry	Lubricants for valves and ultracentrifuge bearings in enrichment plants
Oil and gas	Foaming agent in drilling fluid, fracking fluid, pipe lining, preventing evaporation loss during storage
Optical devices	Optical lenses with low refractive index and high transparency
Personal care products	Emulsifiers, lubricants, stabilizers in cosmetics and hair conditioners
Pesticides	Active ingredient for killing houseflies or cockroaches, antifoaming agent, dispersant to facilitate spreading of active ingredients on insects and plant leaves, wetting agent for leaves (PFAS is not currently used as an active or inert ingredient in us pesticides, but may be used in packaging materials for pesticides)
Pharmaceutical industry	Reaction vessels, stirrers, and other lab equipment, polymeric PFAS as filters, polymers used as packaging
Photographic industry	Antifoaming agent in processing solutions, wetting agent for photographic films and papers, anti-reflective agent for paper and plates
Plastic and rubber production	Mold lining, etching plastic, anti-blocking agent for rubber production, additive in curatives for fluoroelastomer formation, improves weather resistance
Printing	Toner and printer ink to improve ink flow, improve wetting, aid pigment dispersion and impart water resistance to water-based inks
Refrigerant systems	Heat transfer fluids, lubricants
Semiconductor industry	Wetting and etching agent, cleaner to remove cured epoxy resins or films, non-stick coatings, increases photosensitivity of the photoresist layer, provides anti-reflective coating
Sports	Ski wax (highly water repellant), weather protection of sailing boat equipment, coatings for tennis rackets, fishing line, artificial turf

Industry branch	Examples of uses
Stone, concrete, and tile	Oil and water repellant coatings (improves durability, reduces oxidation of surface)
Textile production	Wetting agent, antifoaming agent during dyeing and bleaching of textiles, dye transfer material, emulsifying agent for fiber finishes, coating for PPE used by firefighters
Watchmaking	Aid in drying after cleaning parts, used in lubricants
Wood industry	Coatings for food surfaces, part of adhesive resin for wood particleboard

Not all uses of PFAS in industrial settings are known. Currently, there are no requirements to label products containing PFAS, limiting information availability. PFAS use while making a product does not necessarily mean that the product itself contains PFAS or, if it does, that the PFAS is bioavailable. However, even in these cases, production of the product could result in PFAS releases and disposal of the products could result in PFAS passing through waste facilities to the environment. Although information remains limited on where specific PFAS are used, how they are used, and why they are used, the wide variety of applications is clear.

Where are PFAS found in the environment?

As PFAS were first emerging as contaminants of concern, the general expectation was that PFAS would only be found (or only be found at levels of concern) at areas where they had been manufactured, where that manufacturing waste was disposed of, or where there had been a spill or accidental release of PFAS. However, when regulators and researchers look for PFAS in the environment using appropriately sensitive analytical techniques, PFAS are frequently detected. The US Centers for Disease Control and Prevention (CDC) regularly conducts the National Health and Nutrition Examination Survey, which, among other objectives, measures levels of environmental contaminants in the blood and urine of Americans. National Health and Nutrition Examination Survey has been including PFAS in blood and urine monitoring since the 1999-2000 survey cycle, and finds that exposure to PFOA and PFOS continues to be "universal," even for Americans who were born after these PFAS were phased out of production in the US[8] A recent global study of PFAS in soils (which used consistent sampling, extraction and analytical procedures), found detections of PFAS in every soil sample, including samples from remote locations in every continent.[9] PFAS are known to occur in remote areas like the Arctic, where they have been found to accumulate in high concentrations in snow and biota due to patterns of long-range atmospheric transport.[10] PFAS can exist in the gas phase or can sorb to particulate material suspended in the air – both particulate and gaseous PFAS can transport long distances in the atmosphere.

The ubiquity of PFAS coupled with their long environmental half-lives contributes to the widespread occurrence of PFAS in the environment and in our bodies. PFAS cannot be considered solely a problem around areas where large quantities have been manufactured, disposed of, or spilled. PFAS are present in nearly all parts of our environment. The breadth and diversity of PFAS pollution, coupled with a lack of research on health impacts of many members of the PFAS family, complicates the development of regulatory and non-regulatory approaches to managing PFAS.

[8] Calafat, A.M., Kato, K., Hubbard, K., Jia, T., Cook Botelho, J. & Wong, L. (2019). Legacy and alternative *per*- and polyfuoroalkyl substances in the US general population: Paired serum-urine data from the 2013-2014 National Health and Nutrition Examination Survey. *Environment International, 131*, 105048. https://doi.org/10.1016/j.envint.2019.105048

[9] Rankin, K. Mabury, S.A., Jenkins, T.M., & Washington, J.W. (2015). A North American and global survey of perfluoroalkyl substances in surface soils: Distribution patterns and mode of occurrence. *Chemosphere, 161*, 333-341. http://dx.doi.org/10.1016/j.chemosphere.2016.06.109

[10] Joerss, H., Xie, Z. Wagner, C.C., von Appen, W., Sunderland, E.M., & Ebinghaus, R. (2020). Transport of legacy perfluoroalkyl substances and the replacement compound HFPO-DA through the Atlantic Gateway to the Arctic Ocean – is the Arctic a sink or source? *Environmental Science and Technology*, *54* (16), 9958-9967. https://doi.org/10.1021/acs.est.0c00228

What are risks from PFAS to human health and the environment?

Part of the reason that PFAS affect the body at low doses is that many of them accumulate in blood, as many of their structures mimics common fatty acids. In pregnant women, the PFAS body burden that has accumulated over many years can be passed to the developing fetus through the placenta and to the infant through breast milk. Fetuses and infants are especially vulnerable to toxicants because their body is still developing – disruptions to organ system development during this time can potentially cause life-long impacts. The amount of time that many PFAS remain in the human body is longer than would be expected based on observations from animal studies. This difference can complicate interpretations of animal toxicology data and its extrapolation to human impacts. Multiple individual PFAS exhibit toxic effects on the same organ or organ systems, like the liver. As most PFAS contamination is likely a mixture of many PFAS, this may result in an additive toxic effect. Considerations of total PFAS toxicity are important when assessing potential health risks.

An entirely complete dataset for toxicity and exposure is rarely available for environmental contaminants. For obvious reasons, it is not ethical to test the effects of a toxic compound on humans. Instead, risk assessors often reference experiments on animals. These animal studies could be of various durations, including "chronic" studies, meaning that the experiment lasts the majority of the laboratory animal's expected lifetime, or studies that are "multigenerational," meaning that the laboratory animals are bred during the experiment, and toxic effects are observed in the pregnant animals and in the new offspring through maturity. These chronic and multi-generational studies can be important for identifying adverse health effects that could emerge if there is prolonged exposure to an environmental contaminant over all stages of life, including pregnancy and infancy. These effects could include reductions in fertility, developmental effects, and cancer. In the PFAS family, some compounds have shown carcinogenic effects (PFOA) and others have shown sensitive immunological effects in infants exposed during gestation and early life (such as PFOS). Other sensitive effects for PFAS include thyroid effects, liver effects, and effects on energy metabolism. Most PFAS have data gaps in some areas of concern – for example, many PFAS do not have chronic or multigenerational studies available, or even shorter-duration studies measuring effects in organ systems that have been shown to be sensitive to exposures to PFAS. Risk assessors can account for uncertainties associated with data gaps using established risk assessment tools like uncertainty factors. For most PFAS, there are so many data gaps that risk assessors have limited ability to draw conclusions about the amount of exposure that could cause adverse health outcomes over a lifetime. In these cases, conducting traditional risk assessments is not possible.

There is less information available on effects of PFAS on wildlife as there is on humans. However, it is known that PFAS can cause toxic effects in birds, terrestrial species, and aquatic life. In birds, PFAS has been shown to reduce the survival rates in hatchlings and in fish, PFAS has also been shown to reduce survival rates.[11] There is currently significant research underway to better understand the effects of PFAS on aquatic life, aquatic-dependent wildlife, and terrestrial wildlife.[12]

[11] Environment and Climate Change Canada. (2018). Federal Environmental Quality Guidelines, PFOS. Retrieved from: https://www.canada.ca/en/environment-climate-change/services/evaluating-existing-substances/federal-environmental-quality-guidelines-perfluorooctane-sulfonate.html

[12] EPA (n.d.) ECOTOX Knowledgebase. Per- and Polyfluorinated Substances. Retrieved from: https://cfpub.epa.gov/ecotox/explore.cfm?cgid=36

Addressing and managing PFAS

Ideally, chemicals that could cause environmental and human health concerns are regulated through the EPA's chemical registration program in a way that appropriately manages risk and prevents harmful pollution. However, if there has not been proactive management through restrictions placed on a new chemical's use or disposal under the EPA's chemical registration program,[13] addressing contaminants of emerging concern generally begins with a discovery of the presence of the compound in drinking water, fish, air or elsewhere in the environment. From this discovery flows research into the sources of the compound, its patterns of occurrence in the environment, and the risks to humans or wildlife. From this research, regulators can set risk-based values for levels of that pollutant that should not be exceeded in the environment, and work to ensure pollution stays below those levels. Sometimes managing pollution also involves restricting the uses of the compound, or regulating how substances are stored, transported, and disposed of. Reducing pollution and keeping it low happens through a combination of pollution prevention (which can be regulatory or voluntary), permitting (rules and limits on releases that can result in treatment to remove the pollution), and other pollution reduction strategies.

In Minnesota, the first "discovery" of PFAS pollution occurred in the early 2000s, when drinking water contamination was found in the East Metropolitan Area of the Twin Cities (East Metro). Since that discovery, there has been a plethora of state, federal, corporate, and academic research into the toxicity and occurrence of PFAS. Though much research is still ongoing and some data gaps remain, Minnesota is now entering the phase of incorporating PFAS into the regular regulatory structures used for environmental contaminants that reduce or eliminate ongoing PFAS releases and manage existing PFAS pollution.

History of PFAS in Minnesota

Minnesota's journey to begin managing and addressing PFAS contamination began in 2002, when 3M alerted the MPCA of PFAS in its Cottage Grove production and drinking water wells. In 2004, 3M notified the Minnesota Department of Health (MDH) that additional PFAS disposal sites were located in the East Metro, and MDH began investigating potentially impacted drinking water wells in that region. In 2006, the addition of Perfluorobutanoic acid (PFBA) to the PFAS monitoring analyte list resulted in the need for even more widespread investigation. In all, the East Metro investigations have spanned nearly 20 years and identified an area of groundwater contamination covering over 150 square miles that impacts the drinking water supplies of over 174,000 Minnesotans.

A public health intervention to reduce exposure to PFAS began in 2006. This effort included installing filtration systems for polluted public and private wells, which reduced PFAS concentrations in drinking water to levels below health-based guidance. In 2007, Minnesota and 3M agreed to a consent order outlining that 3M is responsible for providing safe drinking water to the affected residents. Various remediation actions were also taken to address the source of PFAS contamination at the 3M PFAS disposal sites, including excavation of PFAS-contaminated soil and sediment or waste containment at each of the four 3M PFAS disposal sites. Biomonitoring showed that the drinking water interventions reduced PFAS concentrations in the blood serum of residents.[14]

In 2010, Minnesota filed a lawsuit against 3M Company seeking payment for natural resource damages caused by 3M's disposal of PFAS in the East Metro. Minnesota and 3M reached an agreement to settle

---

[13]EPA. (n.d.) Reviewing new chemicals under the Toxic Substances Control Act (TSCA). Retrieved from: https://www.epa.gov/reviewing-new-chemicals-under-toxic-substances-control-act-tsca

[14] Minnesota Department of Health (2015, December). East Metro PFC3 Biomonitoring Project, Report to the Community. Retrieved from: https://www.health.state.mn.us/communities/environment/biomonitoring/docs/pfc2015communityreport.pdf

the state's Natural Resource Damage lawsuit in 2018. Under the terms of the agreement, 3M provided $850 million to Minnesota to be used for safe and sustainable drinking water and natural resource projects. After legal and other expenses were paid, about $720 million remained to invest in drinking water and natural resource projects in the East Metro. The top priority for the grant money is to improve the quality and quantity of drinking water in the East Metro including, but not limited to the cities of Afton, Cottage Grove, Lake Elmo, Lakeland, Lakeland Shores, Maplewood, Newport, Oakdale, Prairie Island Indian Community, St. Paul Park, Woodbury, and the townships of Denmark, Grey Cloud Island, and West Lakeland. The second priority for grant spending is to enhance water resources, wildlife habitat, and outdoor recreational opportunities in the east metropolitan area, or downstream of the area on the Mississippi and St. Croix Rivers. Efforts to remediate impacted groundwater and surface water continue today.

Funding from the 2007 Consent Order allowed MPCA to conduct additional investigations into PFAS in drinking water, surface water, and fish tissue around the state. These investigations lead to the discovery of more PFAS sources and more sites requiring PFAS remediation actions that are not related to 3M waste disposal. This information supported the issuance of fish consumption advice for PFOS and the development of site-specific water quality criteria for PFOS and PFOA. MPCA is now overseeing investigations and clean-ups at sites associated with metal plating facilities, sites associated with firefighting training and testing, and sites associated with other industries.

Present and future PFAS activity

Minnesota's state agencies have been working to respond to PFAS and incorporate managing this pollution into regular research, guidance, and regulatory work. However, efforts have largely been focused around reacting to new PFAS discoveries and specific discrete concerns. More systematic initiatives have occurred as resources arise, but have been scoped to the level of available resources. While important work has been completed, ongoing resources are needed to allow the agencies to build comprehensive and holistic PFAS programs. The following is Minnesota's generally desired strategy for PFAS management:

1. Prevent PFAS pollution wherever possible
2. Manage PFAS pollution when prevention is not feasible or pollution has already occurred
3. Clean up contaminated sites

The costs and burden of these activities increases from prevention (which may require large efforts to establish but is relatively easy to maintain) to site clean-ups (which can be quite costly and time consuming). The state could play different roles depending on its authorities and the stage of management, including writing regulations to ban or restrict uses, providing technical or financial assistance for pollution prevention, regulating PFAS through permitting or other actions, helping educate the public about PFAS, deriving risk-based values for PFAS, and leading clean-up efforts.

PFAS represent a large and diverse class of compounds where not all structures in the group are defined and chemical or physical properties of the compounds can be unexpected. Because regulators have limited information about which PFAS are included in products, industrial processes, or waste streams, before PFAS pollution can be prevented, managed, or cleaned-up, it must be discovered which substances are occurring and where. Exploratory monitoring (both traditional quantitative monitoring and non-targeted analytical approaches) is a key step in every stage of the PFAS response process.

PFAS exposure in over-burdened communities

Across the US and in Minnesota, communities of color and low-income communities are exposed to higher levels of pollution than the average person. These communities also experience substantial health inequities. While the state agencies are committed to promoting equity (MPCA is working on environmental justice – making sure that pollution does not have a disproportionate impact on any group of people[15] — and MDH is committed to advancing health equity[16]), it will take long-term systemic changes to the ways environmental contaminants are regulated to reach these goals.

Racial and socioeconomic trends in pollution exposures are the result of historic and ongoing structural racism in the form of inequitable governmental policies and practices. These include widespread housing policies such as racial covenants and red lining,[17] and can be seen in specific projects with long-lasting impacts, such as the destruction of Black neighborhoods to build Interstates 94 and 35.[18,19, 20] The increased impact of pollution on communities of color and low-income communities is especially well documented in Minnesota in instances of air pollution,[21] but these inequities can manifest in many other areas.

Studies tracking which communities are most impacted by PFAS pollution reflect similar general trends of increased impact to communities of color and low-income communities that have been shown with other types of pollution. Broad biomonitoring studies, like those conducted by the CDC across the entire US , indicate that higher-income groups have historically had somewhat higher blood serum levels of PFAS, perhaps due to higher use of non-stick cookware, higher likelihood of purchasing of stain resistant clothing and furniture, or dietary habits that result in consuming more food with PFAS-containing packaging.[22] However, considering exposure from environmental sources shows different trends. For example, researchers from the Northeastern University's Social Science Environmental Health Institute recently completed an assessment using data from PFAS monitoring in Michigan.[23] This report revealed that when considering 23 non-military sites known to have PFAS contamination in Michigan, about 36,000 more low-income households lived within five miles of a site contaminated with PFAS than would be expected if there were no increased likelihood of exposure based on socio-economic status. Similarly, approximately 134,000 more people of color lived within five miles of a site contaminated with PFAS than would be expected if there were no increased likelihood of exposure based on race. These trends represent a 49% increased likelihood of living in proximity to a PFAS contaminated site based on low socioeconomic status and a 48% increased likelihood based on racial status. Though the distribution of PFAS contamination relative to racial and socioeconomic status in Minnesota may not be identical to that of Michigan, it is reasonable to assume that these trends may hold true throughout the US

[15] MPCA. (n.d.). MPCA and environmental justice. Retrieved from https://www.pca.state.mn.us/about-mpca/mpca-and-environmental-justice

[16] MDH. (n.d.). Health Equity. Retrieved from: https://www.health.state.mn.us/communities/equity/index.html

[17] For one example of these racially motivated policies, see the Mapping Prejudice project at https://www.mappingprejudice.org/index.html.

[18] Beer, T. (2019, November). Neighborhood Resistance to I-94, 1953-1965. *MNOPEDIA*. Retrieved from: https://www.mnopedia.org/event/neighborhood-resistance-i-94-1953-1965; Minnesota Department of Transportation. (n.d.) Rethinking I-94 and Twin Cities Public Television. Interstate 94: A History and Its Impact. Retrieved from: https://www.dot.state.mn.us/I-94minneapolis-stpaul/background.html (accessed 7/23/2020)

[19] A Public History of 35W, https://35w.heritage.dash.umn.edu/ (accessed 7/23/2020)

[20] Institute on Metropolitan Opportunity, University of Minnesota. *Redlining in the Twin Cities in 1934: 1960s and Today*. https://umn.maps.arcgis.com/apps/MapSeries/index.html?appid=8b6ba2620ac5407ea7ecfb4359132ee4 (accessed on 7/27/2020)

[21] MPCA. (n.d.) Understanding environmental justice in Minnesota. Retrieved from: https://mpca.maps.arcgis.com/apps/MapSeries/index.html?appid=f5bf57c8dac24404b7f8ef1717f57d00

[22] Buekers, J., Colles, A., Cornelis, C., Morrens, B., Govarts, E., & Schoeters, G. (2018). Socio-economic status and health: evaluation of human biomonitored chemical exposure to per-and polyfluorinated substances across status. *Environmental Research and Public Health, 15*, 12, 2818. doi: 10.3390/ijerph15122818

[23] Northeastern University, Social Science Environmental Health Research Institute, The PFAS Project Lab. (2019, October 31) *PFAS Contamination Is an Equity Issue, and President Trump's EPA Is Failing to Fix It*. Retrieved from: https://pfasproject.com/2019/10/31/pfas-contamination-is-an-equity-issue-and-president-trumps-epa-is-failing-to-fix-it/

PFAS exposure, however, is not simply a matter of proximity to a contaminated site. Certain communities of color and low-income communities may be at a higher risk of PFAS exposure due to factors like higher rates of local fish consumption. Similarly, low-income groups may be less able and less likely to pay for things like home drinking water systems that filter PFAS. PFAS-free items may not be marketed to these groups. Communities of color and low-income communities may be more likely to have older carpeting, furniture, cookware, clothing or other products containing PFAS like PFOS and PFOA that have now been phased out of use. In general, these communities are likely to be more susceptible to adverse health impacts due to historical disenfranchisement, disinvestment, and disproportionate exposure to pollution.

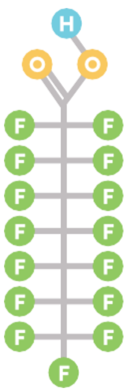
Reversing these racial and socioeconomic disparities in exposure to PFAS will require proactive efforts on the part of policy makers and regulators across a broad range of public policy spaces. Efforts to dismantle the deeply-rooted structural racial and economic inequities that cause disproportionate burdens of pollution should be included in every project Minnesota agencies undertake. The issue papers included in this document aim to discuss opportunities to advance environmental justice and health equity within each PFAS topic area.

PFAS summary and needs

The issue papers following in this report will describe the many PFAS initiatives taken in Minnesota and those currently underway, and identify key areas of opportunity for moving forward on managing and addressing PFAS. The papers also highlight the significant interconnections and overlaps between different areas, illustrating the complexity and difficulty of managing PFAS. The papers are intended to provide a shared grounding in past work and open spaces for discussion about future needs. The discussion of future opportunities focuses primarily on those that could be undertaken in Minnesota through actions by the state agencies or the Legislature, though in some cases deferring to federal agencies for action may also be an option. Minnesota will continue to collaborate closely with state and federal partners to leverage each other’s data and learn from each other’s scientific and regulatory experiences.

Preventing PFAS Pollution

Background



- Pollution prevention (P2) approaches are designed to **reduce exposure** to toxic chemicals and **prevent the need for expensive treatment and remediation efforts**.
  - P2 approaches can be **regulatory or voluntary**. Examples include manufacturers reformulating products to eliminate or minimize use of toxics or consumers purchasing products with safer, less persistent alternatives.
- P2 approaches are especially important for managing PFAS: all PFAS are resistant to environmental degradation or transform to PFAS that are persistent in the environment.
  - Continued use of PFAS results in **increased loading to the environment**, making it more likely that, over time, PFAS reach levels associated with toxic effects in humans and damage to ecosystems.
  - PFAS **concentrate in effluent, biosolids, landfill leachate, and composting contact water**. Removing PFAS using **treatment technology** requires cutting-edge, complex, multi-step processes that are often **cost prohibitive** for the businesses and municipalities that operate waste facilities.
  - Because **PFAS are resistant to destruction**, treatment and management strategies often remove PFAS from one media only to transfer them, along with their risks and potential liabilities, to another.
- Chemical use regulations mainly occur at the federal level. EPA regulates chemicals under the **Toxic Substances Control Act** (TSCA), which was passed in 1976 and significantly amended in 2016. The TSCA amendments were intended to place responsibility on chemical producers to prove new chemicals are safe **before** they can be registered for use.
  - Many PFAS were registered prior to the 2016 TSCA amendments, and **limited to no data on toxicity** to humans or ecosystems are available. However, even under the new TSCA rules, many PFAS are **continuing to be registered for use** without publicly available environmental safety information.
- There are many **challenges** in implementing P2 policies for PFAS.
  - PFAS is a broad class of compounds used in many industries – some estimate **thousands could exist in the environment** – and available analytical methods measure only a small portion of total PFAS.
  - Toxicity, use, and release data for many PFAS are considered "**confidential business information**," and are often not available to the public.
  - **Some PFAS uses are essential** for functions in society (for example, PFAS uses for protective equipment used by medical professionals), increasing the importance of nuanced and tailored regulatory approaches.

What is Minnesota doing now?

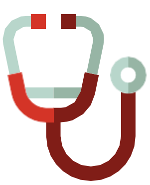
- Minnesota has banned the use of PFAS-containing firefighting foams for training or testing purposes, and is working with fire departments and others to encourage use of fluorine-free firefighting foams (F3) during emergencies.
- MPCA has amended state contracts (used by agencies, universities, cities, counties, municipalities, and non-profits) to **remove compostable products containing PFAS**.

What are remaining gaps and opportunities for action?

Filling gaps to better support preventing PFAS pollution would require legislative action for agencies to gain new authorities or secure additional resources. The opportunities described below are ideas – based on successes implemented in the past for other compounds (DDT, Polychlorinated biphenyls (PCBs), etc.) or implemented for PFAS in other states and international agencies – that would require additional planning and discussion before they could be moved into action.

- **Gap**: In many cases, PFAS are not providing an essential purpose and could be banned without significant impact to society (i.e., PFAS used in ski wax or food packaging).
    - **Opportunity**: Lawmakers could ban PFAS uses that are currently known to be non-essential, such as PFAS used for food packaging. Additionally, MPCA could create a workgroup that would further define "essential," "substitutable," and "non-essential" uses of PFAS. With the recommendations of this workgroup, legislators or regulators could more easily devise a strategy for tackling PFAS pollution prevention based on the "essential use" framework.
- **Gap**: Currently, many businesses and consumers are using PFAS-containing products but are not aware that they are doing so, or are not aware of the potential health risks and liabilities associated with them.
    - **Opportunity**: MPCA could consider proposals for mandatory labeling of PFAS in products, which would help business owners and individuals make environmental, health-conscious, and business-friendly purchases while encouraging manufacturers to pursue alternatives to PFAS.
    - **Opportunity**: MPCA could provide technical and financial assistance to business to reduce PFAS pollution. Existing frameworks (e.g. MnTAP, Small Business Grant Program) could be expanded to implement PFAS reduction strategies.
- **Gap**: Government agencies and other groups using state purchasing contracts have significant spending power and can model environmentally-friendly supply chain practices. Many materials purchased using these contracts contain PFAS.
    - **Opportunity**: Minnesota could remove all products with PFAS serving a non-essential use from state purchasing contracts.

How does this work benefit human health and the environment?



- Discouraging PFAS use subsequently **reduces opportunities for PFAS exposure**, which improves the health of humans and the environment.
- Pollution prevention techniques **improve health of workers** in businesses with PFAS use and reduces exposures in other vulnerable groups with the highest pollution burdens.

How does this work benefit Minnesota's economy?

- P2 strategies reduce liability for businesses and reduce the need for costly site clean-ups.
- PFAS alternatives may be better and cheaper, potentially improving profitability for businesses.
- Waste facility operators have limited ability to control PFAS inputs. P2 measures decrease loading of PFAS to waste facilities, and ultimately to the environment.
- Farmers across the country have been burdened with PFAS contamination of milk, livestock, and produce despite having no intentional PFAS uses on their land. P2 measures protect farmers by reducing PFAS levels in biosolids, animal feed, surface water, soil, and groundwater.

Background

Compounds with some of the most notorious legacies for causing harm to human health and the environment, like PCBs, dioxins and arsenic, share a common trait – persistence. Though PFAS include a variety of structures with a variety of physical and chemical properties, all PFAS are either themselves incredibly resistant to degradation in the environment or degrade to other PFAS that are persistent. As a result, continued use of PFAS in industry and in commercial products will necessarily result in increased loading of these chemicals to the environment over time. As concentrations increase in water, fish, soil, air, and in human bodies, it becomes increasingly likely that environmental concentrations of PFAS will meet levels associated with adverse health effects in humans or adverse outcomes in ecosystems. Preventing the pollution from these persistent compounds is necessary to ensure that negative outcomes for human health and the environment do not continue to manifest.

Pollution prevention

Environmental regulations are generally designed to encourage treating pollutants where they are emitted or discharged so that they are not released into the environment – whether that be air, water, or soils. However, some persistent pollutants can be extremely difficult and expensive to treat either at the source of pollution (like at an air stack or discharge pipe) or at outputs from facilities like landfills, wastewater treatment plants, or composting sites. Well-intentioned pollution control and management solutions sometimes remove pollutants from one media only to transfer them, and their potential liabilities, to another. P2 approaches may involve manufacturers taking steps such as product reformulation to eliminate or use less of a toxic chemical, commercial users replacing a product with a safer, less persistent alternative, or industrial users reducing chemical waste production through better training or preventing spills and leaks. When implemented successfully, P2 approaches can also often be more resource and energy-efficient for manufacturers, producing significant savings while reducing liability and damage to the environment.

P2 for PFAS

PFAS are ubiquitous in consumer products and have applications spanning many industrial sectors. There are many types of industrial facilities that may be discharging PFAS to water or emitting PFAS to air, where it has been shown to deposit on soils and surface waters.[24] Options are limited for PFAS control systems in facilities that are emitting PFAS from stacks – research has shown that no control technologies are effective at fully removing PFAS emissions and no control technologies are effective for all types of PFAS.[25] Once PFAS-containing products are removed from the manufacturing process, at some facilities residual PFAS emissions may continue despite efforts to clean equipment and replace ductwork. The many challenges associated with controlling emissions of PFAS at facilities indicates that avoiding PFAS use in industrial contexts is likely the most effective way for industrial users to limit liability and for regulators to manage potentially harmful releases.

Due to widespread use in industrial and commercial products, PFAS can concentrate to significant levels in waste like effluent, biosolids, landfill leachate, and composting contact water. Consumer products containing PFAS such as clothing, food packaging, carpeting, and other materials have been shown to significantly contribute to PFAS loading into leachate, effluent, biosolids, and composting contact water

[24] Prevedouros, K., Cousins, I.T., & Buck, R.C. (2006). Sources, Fate and Transport of Perfluorocarboyxylates. *American Chemical Society, 40*(1), 32-44. https://doi.org/10.1021/es0512475

[25] EPA. (2019) *PFAS Environmental Contamination Associated with Manufacturing Sites in New Hampshire.* Retrieved from: https://www4.des.state.nh.us/nh-pfas-investigation/?p=1019

when they are eventually discarded.[26] Removing PFAS from waste products using treatment technology requires cutting-edge, complex, multi-step processes that are often cost-prohibitive for the businesses and municipalities that operate these types of facilities. In many cases, treatment of PFAS from waste like leachate ends up simply transferring PFAS back into a landfill, where it may move back into leachate, requiring additional costly treatment. Preventing PFAS from entering waste facilities in the first place is key to stemming releases. Though pollution prevention cannot reduce the PFAS in commercial products already in circulation, preventing new PFAS from entering commerce going forward will help tackle the challenge of managing ongoing PFAS emissions from industrial sources and PFAS discharges from waste facilities in the years ahead. This prevention of PFAS pollution to waste facilities will likely require that industrial and consumer products containing unnecessary PFAS be phased out of use.

When PFAS are released to the environment, humans may be exposed and the PFAS may adversely impact ecosystems, contaminating groundwater, surface water, and soils. Once PFAS has polluted a site, remediating the water and soil to meet health-based guidance levels has proven to be exceedingly expensive. Sometimes driving PFAS concentrations in environmental media (like surface water) down to health-based standards is not possible with currently available technologies. Given the widespread use of PFAS in industry and commercial products, using site remediation as the main tool for environmental risk reduction is not feasible or strategic. Pollution prevention is a better long-term choice.

This issue paper discusses the work Minnesota has already completed to reduce PFAS use in the state, and outlines some of the many remaining gaps and opportunities for new policy, research, and agency actions towards pollution prevention.

Chemical use regulation

The rules and regulations that have the largest impacts on PFAS pollution prevention currently occur at the federal level. The EPA regulates chemicals used in commerce under the TSCA, which was passed in 1976 and was significantly amended in 2016. Under the original TSCA rules, the onus to prove that a compound should not be allowed (or registered) for use because of concerns over biological or human health rested with the EPA. The amendments to TSCA passed in 2016 revised the law to place responsibility on chemical producers to prove their new chemicals were safe for use before they are registered. The EPA restructured the TSCA program into a section that reviews new chemicals (seeking registration after the 2016 TSCA amendments) and a section that reviews existing chemicals (registered before the 2016 TSCA amendments). Many PFAS were registered for use in the US before the new TSCA rules went into place, and as a result limited or no data on their toxicity to humans and ecosystems are available. However, even under the new TSCA rules, many new PFAS are continuing to be registered for use in the US without toxicity data requirements or publicly available environmental safety information. Part of this failing under the new TSCA program stems from how EPA has managed the new chemical approval program to date.

There have been several paradigms proposed to determine which compounds should be allowed for use in commerce and which compounds should receive extra regulatory scrutiny before they are registered. Many of these ideas are being applied to registration applications for new chemicals, but agencies in the US and internationally are also applying these frameworks retroactively to chemicals introduced into commerce and industry before modern rules were put in place. The process of reviewing the thousands of existing chemicals in commerce and industry is time consuming and, in most instances, has only recently begun.

[26]Vermont DEP. (2019). *PFAS Waste Testing Report for New England Waste Services of Vermont.* Retrieved from: https://dec.vermont.gov/pfas

The most common framework is that compounds that are persistent, bioaccumulative and toxic (or PBTs) need extra scrutiny. This is the framework used to prioritize compounds for review under TSCA. Under the PBT paradigm, a compound must have all three characteristics before it is considered a compound of high concern. While this strategy captures many compounds of high concern, there are other compounds that are only known to have only one or two of these characteristics that should perhaps receive additional scrutiny. That includes compounds that have low relative toxicity but persist and bioaccumulate to a degree that toxic thresholds can eventually be exceeded after prolonged exposure.

The European Chemicals Agency, the European Union's regulatory authority over chemical registration, implements a regulation called Registration, Evaluation, Authorization and Restriction of Chemicals (REACH). In general, the European Union's approach to chemical registration is more precautionary than EPA's TSCA program and requires more upfront identification of risks. REACH recognizes the limitations of relying on PBT classification alone, and also uses a paradigm for escalating review of compounds that are "very persistent and very bioaccumulative" - called vPvB. The chemical registration program in Canada takes a similar approach to REACH, and will require "virtual elimination" of certain uses of compounds should risks associated with persistence and bioaccumulation be identified.[27] These paradigms escalate review of compounds that bioaccumulate and persist in the environment but have either low or unknown toxicity.

While the PBT and vPvB strategies would capture a large percentage of PFAS currently in use in commerce, perhaps justifying use restrictions or bans, advocates for additional reform in chemical registration frequently take the position that manufactured compounds that are simply "very persistent" should also require significant additional scrutiny regarding the necessity of use before they are allowed into commerce. This approach, shorthanded as the "p-sufficient" approach, would identify all PFAS because they are all either very persistent or transform to other persistent PFAS.[28] The p-sufficient approach does not rely on complete knowledge of a compound's potential for bioaccumulation or its potential toxicity to sensitive subpopulations like developing fetuses (information that is rarely captured in toxicity studies submitted during chemical review) if the compound is known to be excessively persistent in environmental media, thereby posing a high risk of human exposure.

Unless the state were to pass new legislation authorizing the development of chemical use regulations in Minnesota, chemical registration will continue to be controlled by federal authorities. Minnesota could advocate that EPA move towards approaches that would result in extra scrutiny on more PFAS as they are evaluated for ongoing or new use, like the vPvB or "p-sufficient" approaches used in other countries.

Despite limited influence over the chemical registration processes in the US, Minnesota has other mechanisms for managing PFAS use and preventing additional pollution. Minnesota has already banned the use of PFAS-containing firefighting foams for training or testing purposes, a measure that will substantially decrease PFAS emissions to surface waters, soils, and groundwater.[29] Other legislative actions could be considered that would put in place bans or restrictions for other PFAS uses in the state and mandate labeling of PFAS in products.

[27] Environment and Climate Change Canada. (2017). *Canadian Environmental Protection Act: virtual elimination*. Retrieved at: https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/general-information/fact-sheets/virtual-elimination.html

[28] DeWitt, J., Gluge, J., Goldenman, G., Herzke, D., Lohmann, R., Miller, M., Ng, C.A., Scheringer, M., Vierke, K. & Wang, Z. (2020). Strategies for grouping per- and polyfluoroalkyl substances (PFAS) to protect human and environmental health. *Environmental Science: Processes Impacts, 22*, 1444-1460. Doi: 10.1039/D0EM00147C

[29] MPCA. (n.d.) PFAS in firefighting foam. Retrieved from: https://www.pca.state.mn.us/waste/pfas-firefighting-foam

Considering highly exposed groups when planning PFAS P2 initiatives

Minnesotans in communities already overburdened with pollution due to past policies motivated by or resulting in racial and socioeconomic discrimination, may also be at an increased risk of experiencing higher exposures to PFAS. This compounded exposure to multiple types of environmental pollutants may exacerbate adverse health effects observed in these communities. Studies have shown that people from cultures with traditional hunting and fishing diets have high concentrations of long-chain PFAS in their blood due to PFAS bioaccumulation in game and fish.[30] Though PFAS contamination in Minnesota drinking water has spanned communities with different racial and socioeconomic profiles, individuals within those communities who rely on locally caught fish and game as a source of healthy protein for themselves and their families are the most likely to have high levels of exposure to long-chain PFAS like PFOS. There are also some individuals exposed to PFAS through their job, like firefighters, who may have added exposure from environmental routes. It is important that decisions regarding allowed use of PFAS consider risks to those who are likely to have the highest exposure.

Challenges to preventing use and release of PFAS

There are many challenges associated with preventing PFAS pollution. Firstly, PFAS is a broad class of compounds used in many industries. We know that standard methods frequently measure only a small portion of total PFAS in the environment.[31] Because most PFAS are difficult to measure in environmental media, it is hard to prioritize PFAS that have existing approved uses for additional regulatory review based on occurrence of the compound. The classification of much PFAS use data, release data, and toxicity data as “confidential business information” additionally hinders prioritization efforts. With this limited information for prioritization and a huge number of PFAS, it can be difficult to know where to start with pollution prevention efforts. The industries that produce PFAS and use PFAS have found them to be profitable, which complicates efforts to impose restrictions or bans. Despite these challenges, it is important to remember that each effort to reduce PFAS loading to the environment results in fewer sites requiring costly remediation down the road, fewer people being exposed to dangerous levels of pollution, and a healthier environment.

Past and ongoing efforts

The following sections describe completed and ongoing work related to reducing PFAS loading to the environment. So far, this work has focused on encouraging safer alternatives to PFAS-containing firefighting foams and eliminating some PFAS-containing products from Minnesota purchasing agreements.

Removing PFAS-containing products from Minnesota contracts for compostable products

MPCA works closely with the Department of Administration’s Office of State Procurement to provide products on state contracts that are environmentally preferable. In addition to state agencies, universities, cities, counties, municipalities, and non-profits are all eligible to use these state contracts. In 2017, Office of State Procurement and MPCA created a contract for compostable food service items (e.g. plates, cups, utensils, take out containers) that included specifications restricting the use of PFAS in

---

[30]Caron-Beaudoin, E., Ayotte, P., Clanchette, C., Muckle, G., Avard, E., Ricard, S., & Lemire, M. (2020). Perfluoroalkyl acids in pregnant women from Nunavik (Quebec, Canada): Trends in exposure and associations with country foods consumption. *Environment International*, *145*, 106169. https://doi.org/10.1016/j.envint.2020.106169

[31]Chem, F., Ericksson, U., Aro, R., Yeung, L., Kallenborn, R., & Karrman, A. (2018 Screening of per- and polyfluoroalkyl substances (PFAS) and total organic fluorine in wastewater effluent from Nordic countries [Conference poster]. SETAC 2018 Convention, Rome, Italy. Retrieved from: https://www.oru.se/contentassets/7afa1d1a8df7415a9498720de4151d41/setac_rome_2018_chen_screening-of-per--and-polyfluoroalkyl-substances-PFAS-and-total-organic-fluorine-in-wastewater-effluent-from-nordic-countries.pdf

products offered. Concurrently, the Center for Environmental Health (CEH), an independent non-profit organization, was conducting testing for a report on PFAS in compostable foodware.[32] The CEH used a total fluorine method to estimate if there was likely added PFAS to compostable products. If results indicated "high fluorine," meaning the product had at least 10-fold higher levels of fluorine than a "low fluorine" product, CEH suggested that the product likely contained fluorine additives in the form of PFAS. CEH's testing indicated that many compostable products on the state contract claiming to not contain PFAS actually did contain added PFAS. Upon learning the results of the CEH testing, MPCA followed up with vendors regarding the products believed to contain PFAS. The vendors confirmed that PFAS were added. With this information, Minnesota was able to remove the PFAS-containing products from the state contract. Minnesota was also able to stipulate that any products offered on the contract were required to have accompanying test results indicating low or no fluorine levels going forward. While this decreases the purchase and use of PFAS containing products at state agencies and other entities, these PFAS-containing compostable food service items are still available in the consumer market.

Work status: completed

Leaders: MPCA RMAD Sustainable Materials Management Unit, Minnesota Department of Administration, Office of State Procurement. **Partner**: Center for Environmental Health.

Benefits: Removing PFAS from supply chains, particularly sources to composting facilities, is beneficial for several reasons. Waste facilities concentrate water-soluble and mobile PFAS – like PFOS, PFOA, Perfluorohexane sulfonate (PFHxS), and PFBA – from commercial products into leachate and contact water. MPCA recently completed a study of PFAS in contact water collected at composting facilities that found elevated levels of PFAS in all participating facilities' contact water.[33] The largest source of PFAS in facilities accepting food waste is suspected to be grease-resistant coatings on compostable foodware products. These facilities do not have treatment technologies in place to remove PFAS from leachate or contact water before it is discharged to the environment. Furthermore, because leachate and contact water are rich in organic matter, these wastewaters can be especially difficult to treat. A PFAS treatment system may not be economically feasible for some individual waste facilities, including composting facilities. Preventing PFAS from entering these facilities is the most cost-effective method of preventing their ultimate release into the environment. The restrictions on the state purchasing contract reduce loading of PFAS to Minnesota's composting facilities.

The effort to remove PFAS-containing products from purchasing agreements has the additional benefit of creating an economic incentive for companies to find safer alternatives to PFAS products and reduce PFAS in their own supply chains. Minnesota's efforts to inquire about PFAS additives signaled to compostable product producers that PFAS is problematic and will not be accepted as an additive by many high-volume buyers. This effort additionally contributed to a decision by the Biodegradable Products Institute – a compostable product certification – to begin screening for PFAS and restrict PFAS use in certified products.

Challenges: On the state's disposable (non-compostable) foodware contract, equivalent PFAS restrictions have not yet been incorporated. A separate effort is needed to remove PFAS containing products from this contract as well as from other state contracts offering product categories that are known to contain PFAS.

Resources: This effort required staff time from MPCA's RMAD Sustainable Materials Management unit and the Department of Administration, Office of State Procurement, but no additional resources.

---

[32] Center for Environmental Health. (2018). *Avoiding Hidden Hazards, a purchasers guide to safer foodware.* Retrieved from: https://www.ceh.org/wp-content/uploads/2019/05/CEH-Disposable-Foodware-Report-final-1.31.pdf

[33] MPCA. (n.d.). Composting and PFAS. Retrieved from: https://www.pca.state.mn.us/waste/composting-and-pfas

Encouraging the use of fluorine-free firefighting foams

PFAS-containing firefighting foams are used to extinguish fires of liquids like oil, fuel, or flammable solvents. Foams that are designed to put out these fires of flammable liquids are called "Class B firefighting foams." PFAS have historically been used in these products because of their surfactant and oxygen-scavenging properties. However, uses of PFAS-containing Class B firefighting foams (which include aqueous film-forming foams or AFFF) have proven to be some of the largest known contributors of PFAS releases to the environment. This ongoing initiative by the MPCA aims to encourage entities to transition away from PFAS-containing foams towards fluorine-free firefighting foams (F3), ideally F3 that are also free of other chemical hazards. The MPCA has encouraged Class B firefighting foam manufacturers to certify their fluorine-free products with third-party environmental health and safety certifiers (e.g., GreenScreen). Additional outreach to users of Class B firefighting foam is ongoing.

Work status: ongoing

Leaders: MPCA Resource Management and Assistance Division and Remediation and Emergency Response Unit. **Partners**: State Fire Marshal, fire service and user associations, the Interstate Chemicals Clearinghouse, partner states, standard-setting and testing entities like GreenScreen.

Benefits: Though PFAS-containing firefighting foam has already been banned for most testing and training purposes in the state, ending all uses of PFAS-containing foam, including in actual fire emergencies, would reduce a substantial source of PFAS release to the environment. Additionally, facilitating the transition to F3 will reduce the long-term expense to firefighting departments of safely managing and disposing of discharged or unused PFAS-containing foams.

Challenges: Encouraging use of F3 is challenging for several reasons. There are some federal requirements that firefighting foams containing fluorine (i.e. PFAS) must be available to extinguish Class B fuel fires at some Department of Defense (DoD) and airport facilities. Congress has directed the Federal Aviation Authority to no longer require fluorinated foams at airports by 2021 and has also directed the DoD to establish an updated firefighting foam standards and performance testing requirements by 2024 so that PFAS-containing firefighting foams are no longer used by 2029. To date, F3 have not fully met the existing military performance specifications needed to fight certain Class B fires.

Currently, there are a limited number of certified F3 products available for private and government purchasers. Increasing the number of certified foams will take time. MPCA and partners will also have to overcome resistance to F3 among the firefighting community. Early F3 were not perceived to perform as needed (partially due to lower quality products in the early days of alternative foam development and partially due to limited training for firefighters on using F3), cementing the false belief the F3 would never perform as needed for Class B fires. Overcoming this negative perception will be aided by the planned new military specification and alternatives research currently being undertaken by the DoD.

Resources: This effort requires time from MPCA staff to conduct research and outreach, but no project funding.

Gaps and opportunities

There are many gaps in effectively managing PFAS to prevent harmful pollution. Many of these gaps would require legislative action for Minnesota agencies to gain new authorities or secure additional resources. For this reason, the projects described below are ideas of ways that Minnesota could advance work on preventing PFAS pollution in the state, based on successes in managing other persistent, bioaccumulative compounds in the past and successes in other states and international regulatory agencies in regulating PFAS. Many of these ideas would require additional planning and discussion before they could be moved into action. In some cases, it may be determined that state action is not feasible or strategic but that Minnesota should push for or support broader federal action to support similar goals.

As described in the background of this issue paper, chemical registration and use regulation currently primarily rests with the EPA. Minnesota statutes contain bans for certain types of chemicals and products (such as PCBs, or bisphenol A and formaldehyde in children's products), but no explicit bans on PFAS. The Legislature could consider banning or restricting uses of PFAS, or could grant the MPCA the authority to review and restrict uses of PFAS or other pollutants of concern in commercial and industrial products. Alternatively, MPCA could continue to lobby the EPA to consider improved TSCA regulations for PFAS.

Many groups have proposed regulations such as use restrictions or bans on certain PFAS, but these groups also acknowledge that some applications of PFAS are important for the health and safety of society. The lack of knowledge about which PFAS applications are critical or "essential" (like using PFAS for protective equipment in surgical operating rooms, where no other existing technologies provide equivalent safety and effectiveness) and where they could be replaced with safer alternatives (like PFAS in water-resistant surfing shorts or cosmetics) makes it challenging to focus on the best opportunities to replace already-registered PFAS uses. There are opportunities to make progress by conducting a prioritized alternatives analysis for the PFAS in uses that are causing the largest environmental impacts. This effort would involve determining essential use criteria that could be used for coordinated chemical regulation. However, there is also a gap in available information and knowledge of which products contain PFAS due to a lack of federal reporting requirements. This makes it difficult to conduct reviews of existing PFAS uses.

The lack of transparency about which products contain PFAS also prevents businesses and individuals from engaging in voluntary P2 strategies like limiting or ending their purchases of PFAS-containing products. Requirements for labeling PFAS-containing products would help inform the public. Labeling requirements would also be useful if Minnesota were to make additional efforts to remove PFAS-containing products from state purchasing contracts.

Finally, there may be opportunities to provide financial or technical assistance to help businesses transition away from using PFAS-containing products using the existing infrastructure at MPCA to issue grants and provide technical assistance to businesses. These suggestions for potential opportunities to fill the identified gaps are described in more detail in the action proposals below.

Regulate PFAS using a framework of essential, substitutable, and non-essential uses

PFAS are used in a multitude of products and industries around Minnesota. In some cases, PFAS are not providing an essential use and could be banned without significant impact to society. For example, though fluorinated cross country ski waxes are more effective than alternatives at repelling water for fast skiing, recreational and professional cross country skiing is entirely possible without PFAS-containing waxes. In fact, international cross country ski races have already banned PFAS-containing waxes in their competitions based on concerns about human health and ecological impacts. Sufficient research exists to ban some of these clearly non-essential PFAS uses currently. However, for other uses of PFAS, analysis would be required to determine if safer alternatives to PFAS exist that could fill the need. Under this proposal, MPCA would create and lead a workgroup tasked with creating a framework for future regulation of PFAS-containing products based on "essentiality" criteria. In general, an "essentiality" framework groups products into the following three categories:

1. Non-essential – not essential for health and safety and the functioning of society.
2. Substitutable – now-familiar uses that perform useful functions but for which there are feasible and demonstrated-safe alternatives, rendering PFAS use non-essential.
3. Essential – considered necessary for health and safety or other very important purposes, where safer alternatives to PFAS are not feasible or available.

This effort would likely involve identifying the highest priority PFAS uses in Minnesota and evaluating safer alternatives to PFAS in families of essential PFAS applications. A model for this work is Washington State's 2018 revisions to its Toxics in Packaging law, which required Washington's Department of Ecology to undertake an alternatives analysis for each application of PFAS in food packaging and determine availability of feasible alternatives. Once the Department of Ecology publishes a report or findings that an alternative is feasible and available for a specific application, the law prohibits the sale of PFAS containing food packaging two years after the date of publication of the report.[34] In 2019, Maine banned PFAS in food packaging, effective January 2022, drawing on their conclusion that PFAS was unnecessary in food packaging.[35] In 2020, New York also banned PFAS in food packaging, effective January 2023.[36] The potential for a ban on PFAS-containing food packaging is discussed in more detail in the Limiting PFAS Exposure from Food Issue Paper.

With the recommendations of this workgroup and documentation of PFAS alternatives assessments for high-priority uses, legislators in Minnesota could more easily devise a strategy for tackling PFAS pollution prevention through law and policy based on an "essential use" framework. For example, the Legislature could phase out sales and importation of some PFAS products that fit into a non-essential use category, require end of life stewardship programs for products that fall into essential use categories, or authorize MPCA to regulate PFAS in this way.

Work status: under consideration, actions on recommendations would require legislative involvement

Leaders: MPCA Resource Management and Assistance Division. **Partners**: Interested participating agencies or partner states.

Benefits: Alternatives analysis is an important step in determining if PFAS product bans or voluntary phase-outs are feasible – PFAS bans would have the direct benefit of reducing environmental release of PFAS, which corresponds to decreased exposure to humans and other ecological receptors. Any effort to conduct alternatives analysis and designate PFAS uses based on "essentiality" criteria would require expertise from many technical, regulatory, and industry experts. By including a variety of experts the workgroup, perhaps even including partner states, Minnesota would be more likely to have access to the relevant experts to propose an "essentiality" framework that is feasible, fair, and reasonable for multiple industries.

Challenges: Some parties feel that product bans or restrictions are most effectively managed by the federal government. While federal bans may be the most effective, lack of federal action thus far means states motivated to reduce harmful loading of PFAS in their water, soil, and air are looking for other options. Currently there are no labeling or reporting requirements for PFAS use in industry on commercial products and the structures and uses of many PFAS are considered proprietary information. For this reason, there is a large data gap on which industries or products use PFAS, and for what purposes. Pending changes to federal laws on this topic, for the workgroup to be

[34] WA Toxics in Packaging Law - Chapter 70.95G RCW; 2018 revisions in Engrossed Substitute House Bill 2658, Chapter 138, Laws of 2018.

[35] Maine Act to Protect the Environment and Public Health by Further Reducing Toxic Chemicals in Packaging – Chapter 277, 2019. Retrieved from: http://www.mainelegislature.org/legis/bills/display_ps.asp?ld=1433&PID=1456&snum=129.

[36] An Act to amend the environmental conservation law, in relation to the use of perfluoroalkyl and polyfluoroalkyl substances in food packaging. Retrieved from: https://www.nysenate.gov/legislation/bills/2019/s8817.

successful, there would likely need to be collaboration with many industries in the state to provide information on the PFAS uses. Even then, there would likely still be significant data gaps for products produced outside of Minnesota. Fleshing out the definitions of each "essentiality" category and sorting known PFAS uses into those categories would likely be time consuming and contentious.

Anticipated resource needs: The effort would require considerable staff time, primarily at the MPCA. A staff position to help coordinate PFAS pollution prevention activities would also be important for a successful outcome.

Require labeling of PFAS-containing products

An additional P2 initiative would be requiring all PFAS-containing products to include a disclosure on the product or package indicating that the product contains PFAS. Design considerations for this policy would include:

- If the producer of the product would be required to disclose the specific PFAS structures included and in what quantities they are included
- If the producer of the product would be required to submit the PFAS composition information to a centralized database
- If there would be any minimum thresholds for mandatory reporting to account for inadvertent PFAS inclusion (such as PFAS inadvertently included in recycled paper)
- How such a labeling policy would be enforced

This labeling would allow consumers to be alerted to the potential exposure to PFAS from the products. Currently, many businesses are using PFAS-containing products but are not aware that they are doing so, or are not aware of the potential health risks and legal liabilities associated with them. Labeling of PFAS in products would help business owners make smart environmental, health conscious, and business-friendly purchases. Additionally, many landfill operators, WWTPs, and composting facilities are currently struggling to identify the sources of PFAS into their facilities. Mandatory labeling of PFAS in products and reporting of the quantities would help waste facility operators make decisions about which products to accept at their facilities. Finally, this labeling would encourage manufacturers to pursue preferable alternatives to PFAS.

Work status: under consideration – action on any policy recommendations would require legislative involvement

Leader: MPCA Resource Management Assistance Division.

Benefits: Overall, product labeling for PFAS would help individuals, businesses, and government entities reduce PFAS exposure and emissions while also increasing demand for products that contain safer alternatives to PFAS. Labeling would inform purchasing decisions and end of life management decisions regarding disposal options.

Challenges: Industries that produce PFAS or PFAS-containing products will likely oppose this effort, especially because no international, federal or state governments have yet mandated such labeling. Enforcement of labeling requirements will also require resources to test and confirm claims. An education effort would also likely needed for the public so they can understand what any required label is conveying.

Resources: Though researching the policy proposal for this effort requires relatively limited staff time, should this proposal be implemented, significant resources would be required to coordinate and enforce the rules.

Develop public sector purchasing guidelines to end purchases of PFAS-containing products

Government agencies and other groups using state purchasing contracts have significant spending power and can model environmentally-friendly supply chain practices. MPCA has worked with the Department of Administration to remove PFAS-containing products from Minnesota's contract purchasing agreements. To date, these efforts to restrict PFAS have been focused on compostable products like compostable food containers and serviceware, where PFAS is added to repel water and grease from the product surface. Many other items, including stain-repellent carpeting or furniture, have been shown to contain PFAS. This project seeks to expand on the existing work to remove PFAS from supply chains by excluding PFAS from all non-essential uses in any product purchased using state contracts. These purchasing guidelines could be used as a model for private groups or individuals intending to reduce PFAS purchasing.

Work status: under consideration

Leaders: MPCA Sustainable Materials Management Unit and the Department of Administration Office of State Procurement.

Benefits: MPCA and others have documented that PFAS from compostable and disposable products are making their way into compost facilities, landfills, and eventually the environment. Expanding work on removing PFAS from contract purchasing agreements would reduce overall loading of PFAS to waste facilities, reduce demand for PFAS-containing products when PFAS is not necessary, and incentivize product manufacturers or vendors to produce less toxic and less persistent alternatives to PFAS.

Challenges: This effort would be challenging for several reasons. When there are not PFAS labeling requirements in place, it is difficult to ascertain which products contain PFAS without laborious efforts to contact producers and verify claims. With or without labeling requirements in place, prioritizing which state contracts offer the most PFAS-containing products would be necessary. Considerations would be needed to not restrict purchases of PFAS-containing products that fall into essential use categories, like protective equipment for healthcare workers. Additional effort would be needed to ensure accountability so product manufacturers do not distribute PFAS-containing products in violation of the contract terms. Education would likely be needed to explain why such reductions in PFAS purchasing would be necessary given that sometimes alternatives can be more costly.

Resources: This effort would require staff time from MPCA Sustainable Purchasing Program and the Department of Administration, Office of State Procurement. This work would be most efficient if conducted in coordination with other efforts proposed above, including defining essential use categories for PFAS. If such an effort to reduce PFAS purchasing across many contracts were to be undertaken, funding for product testing may be needed.

Consider providing financial and technical assistance to businesses for switching from PFAS-containing products

PFAS are ubiquitous in products that may be used in many industries around Minnesota, from car washes to metal plating facilities. Some businesses may not even be aware that they are using, and possibly emitting or discharging, PFAS-containing products. MPCA has multiple existing programs that provide financial or technical assistance for existing and new businesses that seek to improve environmental performance and prevent pollution.[37] For example, the MPCA small business grant program provides funding opportunities to business facilities and community organizations across Minnesota to improve their systems while reducing overall environmental burden. The Minnesota Technical Assistance Program (MnTAP), located at the University of Minnesota, provides on-site and

[37] MPCA. (n.d.). Technical Assistance. Retrieved from: https://www.pca.state.mn.us/quick-links/technical-assistance

telephone assistance, interns, an information clearinghouse, and a coordinating role in the state materials exchange program.[38] The proposed project would allow the current technical and financial assistance programs to incorporate PFAS reduction intro their programs.

Work status: under consideration – would require additional funding

Leaders: MPCA Business Assistance Unit.

Benefits: By providing financial and technical assistance, businesses are given the incentive to switch from PFAS to a preferable alternative. By doing so, businesses are also put in a position to make a more economically feasible choice for their operations and serve as an environmental leader within their industry. The development of this program would increase the awareness about PFAS in many industries, which would lead to further PFAS emission reductions. Incorporating PFAS reduction strategies into existing programs that help businesses to find safer alternative chemistries will increase demand for these safer alternatives and encourage more innovation in green chemistries.

Challenges: One existing technical and financial assistance programs, the Small Business Grant program, is largely focused on air pollutant reduction due to its present funding source. While the Business Assistance Unit has the capacity to administer additional grants targeting PFAS not related to air emission reduction, additional funding must be made available to achieve that goal. Consultation with green chemistry experts at MPCA and MnTAP would be needed to ensure that replacement products for PFAS do not contain "regrettable substitutions" with other environmental concerns.

Anticipated resource needs: Funding will be needed to provide financial and technical assistance to businesses. Projects would largely involve a switch from products that include PFAS to a preferred alternative. Grant funding would also be available for equipment needs.

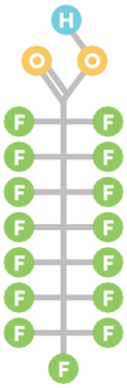
Overview of intersectional issues

- **Managing PFAS in waste**: Landfill leachate, effluent and biosolids from WWTPs, and contact water from composting facilities all contain PFAS stemming from industrial and commercial uses of PFAS-containing products. Preventing pollution of PFAS will reduce the regulatory burden of waste facility operators to manage PFAS waste when they have limited control over PFAS entering their facilities. The carbon-fluorine bonds in PFAS are extremely difficult to destroy. Though new technologies are being invented to improve options for PFAS destruction, these technologies at this time are often expensive, energy intensive, and not available at large scale.
- **Protecting drinking water**: Treating drinking water for PFAS contamination is very costly for municipalities and private well owners. Even when drinking water meets health-based criteria, consumers often demand that no PFAS be detected in their water at all. Preventing pollution of groundwater, one of Minnesota's most precious natural resources, will prevent the need for treatment and other interventions to reduce PFAS exposure from drinking water in the future.
- **Reducing exposure from fish and game consumption**: PFAS can be emitted to air or discharged to water, ultimately contaminating surface water, soil, and plants. This contamination can cause high concentrations of certain PFAS to accumulate in fish, deer, and other commonly consumed game. Preventing pollution of PFAS will ensure that those who hunt in Minnesota, either for sport, as part of their cultural heritage, or for subsistence, are not exposed to harmful levels of PFAS.
- **Remediating PFAS-contaminated sites**: Cleaning up sites that have already been polluted with PFAS is costly and time intensive. In some cases, technology does not yet exist to remediate contaminated media to levels that meet health-based guidelines. Preventing the need for PFAS site remediation is the strategic approach to PFAS moving forward.

[38] University of Minnesota. (n.d.). Minnesota Technical Assistance Program. Retrieved from: http://www.mntap.umn.edu/

Measuring PFAS effectively and consistently

Background



- The first step in managing pollution is understanding which pollutants occur in the environment, where, and at what levels. This work requires **effective sampling techniques** and **established analytical methods**.
- If methods are not available or if detection limits make it impossible to determine if PFAS are exceeding protective levels, it presents **challenges to risk assessment and regulation**.
- Although early focus on PFAS method development was on drinking water, **there are now PFAS methods for multiple media** -- several new EPA methods are also in development.
  - The **Public Health laboratory** at MDH is capable of measuring PFAS in multiple media, including biological matrixes, soils, and water.
  - Agencies can also contract with private **commercial labs** to run analyses for PFAS.
  - Costs associated with PFAS analysis are generally **$300 - $400 per sample**.
- Despite progress in method development, it is not possible to quantitatively measure the vast majority of PFAS – **available methods represent less than 1% of all PFAS in the environment**.
  - **Knowing what to look for**: Many new PFAS are currently being designed by chemical companies and registered for use at the EPA – information about these compounds is often considered “confidential business information” and not publicly available.
  - **Designing new approaches**: Developing new PFAS methods is time consuming and uncertain. Some new ideas and techniques are successful, but many fail. It can be difficult to predict how much time developing a new method will take and the detection limits a method will be able to achieve.
  - **Measuring at levels relevant to human and environmental health**: As toxicologists learn more about PFAS toxicity, health protective concentrations have decreased, sometimes to levels below what analytical methods can reliably detect.

What is Minnesota doing now?

- MDH’s Public Health Lab (PHL) continues to **develop and improve** PFAS analytical methods.
  - PHL developed a simple PFAS method for **drinking water** and **groundwater**, created PFAS methods for **dust**, **soil**, and **vegetables**, and developed and improved methods to measure PFAS in **blood serum**, **plasma, and breastmilk**.
  - PHL **validated the newest EPA drinking water method** for PFAS (EPA Method 533), which will allow PHL to support testing for the next round of EPA-mandated drinking water monitoring (UCMR5).
- MPCA and MDH have multiple efforts underway to ensure consistent and accurate PFAS analytical results, whether work is done by Minnesota staff or others.
  - MPCA is collaborating with EPA Office of Research and Development (ORD) on **PFAS sample collection strategies**.
  - MPCA continues revising the **PFAS Analytical Guidance document**.
  - MPCA and MDH are considering changing the way that labs are accrediated for PFAS in the MDH lab accreditation program (MNELAP).

What are remaining gaps and opportunities for action?

- **Gap**: With potentially thousands of PFAS occurring in the environment, the vast majority of PFAS are not currently included in analytical methods. Further, it is difficult to know which PFAS should be targeted for method development – companies are not required to report the PFAS they produce or use in all cases, and if the information is reported to EPA, it is often protected as "confidential business information" and not released.
  - **Opportunity**: A technique called non-targeted analysis allows researchers to identify hundreds of chemicals in a sample at one time. Increasing availability and accessibility to non-targeted methods in public labs would help prioritize method development, improve site investigations, and generally improve the understanding of the entire landscape of PFAS mixtures present in environmental media.
  - Non-targeted analysis requires technical and laborious data processing, as well as instruments that are in high demand for many competing projects. Increasing capabilities for non-targeted analysis could require purchasing or renting additional instruments and hiring of staff with expertise in non-targeted methods for PFAS.
- **Gap**: The current toolbox of analytical methods is effective at measuring a discrete number of PFAS at low detection limits. Other tools may be more cost-effective and efficient in contexts where precise measurements of many PFAS analytes are not necessarily required.
  - **Opportunity**: Minnesota could consider researching and possibly adopting screening methods for PFAS in public labs.
  - Aggregate PFAS methods measure groups of PFAS and have been applied in scenarios like screening-level analysis of environmental media or in rapid analysis to determine if PFAS is present in a consumer product. Examples of aggregate PFAS methods include total organic fluorine (TOF) analysis and particle induced gamma emission analysis (PIGE). Total oxidizable precursor (TOP) analysis measures the increase in some terminal PFAS degradate concentrations in a sample after precursors are chemically transformed, which provides total PFAS precursor concentrations for those terminal degradates.
  - Another option for PFAS screening methods could involve developing simple PFAS methods that are faster and cheaper to run at scale than existing methods, but look for a small number of PFAS likely to be risk-drivers in a given site (often analytes like PFOS, PFOA, and PFHxS).

How does this work benefit human health and the environment?

- The ability to measure PFAS allows MDH and MPCA to **identify exposures,** which is necessary to protect human health and prevent negative environmental outcomes.

How does this work benefit Minnesota's economy?

- In-house method development allows Minnesota agencies to **design methods relevant to the state**, which can save time and money during research projects or site investigations.
- Getting ahead of issues of environmental releases by monitoring for PFAS with advanced methods would allow MPCA to be **proactive**, potentially preventing PFAS emissions before costly remediation efforts are needed.

Background

The first step of managing pollution is understanding which pollutants occur in the environment, where, and at what levels. Answering these questions requires sampling techniques and analytical methods that allow chemists to accurately and reliably measure presence and levels of pollutants. These pollutants could be present in commercial or industrial products and various environmental media like water, air, soil, and biota. Sampling techniques focus on how samples of media (air, water, soil, fish tissue) are collected and stored so that they accurately represent the environmental conditions. Effective sampling techniques ensure that the way samples are collected and transported does not add additional pollution or cause existing pollution to go unmeasured (for example, from contaminants sticking to the sampling container). The preferred sampling methods for PFAS in different environmental media have evolved over time as researchers have learned more about PFAS. Analytical methods describe how media are analyzed in a lab to determine the levels of pollutants present in a sample. In order to compare results from multiple labs, EPA will sometimes publish "EPA approved methods" that are proven to give the same results regardless of which lab is using them, but EPA is often slow to develop, validate, and publish these methods. MDH's PHL and commercial labs also develop reliable and robust PFAS methods, in many cases before any EPA approved methods for the PFAS analytes in a given media are available.

There are now a variety of types of analytical methods for PFAS that are designed to answer different questions – this diversity of methods is helpful in ensuring researchers and regulators have a full toolbox for environmental work. Standard analytical methods are media and chemical-specific. They enable the lab to measure the specific amount of specific pollutants in a sample, and they will only detect those pollutants. These methods can change over time as techniques and technology improve, usually resulting in detection of more types of pollutants and lower levels of pollutants. These standard methods (looking for levels of specific PFAS) are expensive and only include a small subset of all PFAS, but they give results that allow environmental programs to determine if specific PFAS remain below levels that may cause adverse impacts to human health and the environment. For these programs, availability of standard analytical methods is critical. When standard methods are not available for a certain compound in a certain media, or when detection limits make it impossible to determine if the level of PFAS in samples exceed protective levels in all cases, it presents challenges to risk assessment, regulating pollution, and reducing pollution. Newer analytical techniques for PFAS have emerged that may help answer different questions than the standard pollutant-specific approaches. For example, some analytical techniques can be used to determine if PFAS have been added to a product. Other techniques can return a concentration of a group of PFAS. Some techniques can determine if a large number of individual PFAS are present, but cannot determine the concentrations of those PFAS. Together, standard analytical methods and these newer analytical techniques provide a useful toolbox for PFAS management.

History of method development for PFAS

Analytical methods for PFAS are relatively new and actively developing. In the early 2000s, PFAS were not understood in the way they are now -- as ubiquitous and toxic chemicals. The chemists with the tools to measure PFAS were mainly those working for the chemical companies that produced them. When MPCA was notified about PFAS contamination in drinking water in the East Metro, the state PHL had to quickly develop their own new method for measuring them. The PHL first developed a method to measure two PFAS (PFOA and PFOS) in water, and then expanded that method to include seven PFAS, albeit with relatively high detection limits. That meant that if any of the seven PFAS in the method occurred below the detection limit, they would not be measured, and if any other PFAS were present, it would not be known. At the time, there were no other commercial or public labs measuring PFAS in drinking water or any other media.

Over time, as attention to PFAS contamination has grown, the analytical methods used to measure them have improved. From measuring two PFAS, methods improved to measure 13 compounds, and they are still improving. Newer methods can measure around 40 PFAS with detection limits many times lower than the ones in early PFAS methods. Although most focus and advancement has been on methods for detecting and measuring PFAS in drinking water, there are now at least some methods for PFAS in multiple media. This includes methods for "clean" water like treated drinking water, "dirty" water like surface water and wastewater, biological media like fish tissue and blood serum, and solid media like soils, dust, and vegetables. EPA-approved methods for many matrices are in development.[39] These improvements in our capability to see PFAS in lower concentrations and in more media has been one of the major reasons why PFAS are now known to be ubiquitous in everything from tree leaves to the blood of Americans around the country.

Despite this progress in method development, scientists are still in the unfortunate position of not being capable of quantitatively measuring the vast majority of PFAS. There are over 5,000 PFAS with defined chemical structures that exist – some are compounds intentionally produced for use in industry and commerce, but others are products of transformation within the environment or byproducts of manufacturing. Many more PFAS structures are being designed by chemical companies every day. The PFAS that we can measure represent less than 1% of all PFAS in the environment. In addition, as toxicologists learn more about the toxic effects of some PFAS, the concentrations of PFAS that MDH has determined to be health protective have been decreasing over time, in some cases to levels that are below what analytical methods can reliably detect in the relevant media. To address ongoing interest in a wider variety of PFAS, chemists have begun to develop new approaches to measuring larger groups of PFAS. Each of these new approaches has benefits and limitations when compared to traditional analytical methods.

Role of the MDH Public Health Lab in PFAS method development

The PHL at MDH was established in 1873 as a chemical laboratory to test water and food.[40] Today, the lab has evolved into a sophisticated facility capable of testing thousands of samples a day, including samples containing potentially hazardous substances. MPCA also has laboratory facilities capable of measuring environmental contaminants in air and water to support its programs, but does not conduct PFAS analysis. The MDH PHL provides a critical resource to Minnesota in addressing public health concerns, including the development of analytical methods when no standard method is available. MDH and MPCA have the PHL available as an in-house partner for research and monitoring projects. Working with public labs has many advantages including ease of collaboration, full transparency over exactly how and when samples are tested, and the assurance that there are no potential conflicts of interest at play.

MPCA has samples processed in the PHL or sends them to commercial labs. Commercial labs can run methods that are not available at the state labs, covering more analytes and more media. The public labs also have significant demands on their services, and sometimes contracting with private labs results in capacity to run larger numbers of samples for large projects.

Benefits of non-targeted analysis in PFAS investigations

Traditionally, analysis of environmental pollutants is compound-specific. Concentrations are determined by comparing the signal from the sample to the signal from solutions made by chemists where the specific compound in question has a known concentration (analytical standards). Due to the large number of PFAS and the lack of analytical standards for many of them, research scientists are working to

[39] EPA. (n.d.). PFAS Analytical Methods Development and Sampling Research. Retrieved from: https://www.epa.gov/water-research/pfas-analytical-methods-development-and-sampling-research
[40] MN Health. (2018, Feb 28). The Public Health Laboratory [Video file]. Retrieved from: https://www.youtube.com/watch?v=45q7rxSAsEg&feature=emb_logo

develop new strategies to try to identify and measure more PFAS. One strategy is a technique called "non-targeted analysis." In essence, non-targeted analytical techniques use high-resolution mass spectrometers to collect structural information called "spectra" on all chemicals in the sample and use software to match the signal from the sample to the signals of thousands of known chemicals. Then, if analytical standards are available, chemists can later confirm the identity or concentration of the PFAS that is suspected to be present in the sample. Though non-targeted analysis provides information about the presence of more PFAS in a given sample, this technique does not provide information about the concentration of each PFAS in the sample. Despite this limitation, non-targeted analysis can be very useful in various contexts. Non-targeted analysis can be used to inform which PFAS are present in samples and in what proportion, thereby helping prioritize the development of traditional analytical methods or procurement of analytical standards that could be used to collect concentration data. Knowing which structures are present in various samples can also inform information requests for toxicity data or production data on compounds that would otherwise be protected as "confidential business information."

Non-targeted approaches have already discovered significant and high-profile instances of PFAS pollution that would have otherwise gone undetected due to the lack of traditional analytical methods and monitoring. The discovery of "Gen-X" compounds, which are new PFAS chemistries developed by DuPont as a replacement for PFOA, was due to chemists conducting non-targeted analysis of river water downstream from the production plant.[41] Similarly, the discovery of a new class of chlorinated PFAS that have widely contaminated soils in the northeastern US through air emission and subsequent deposition was through non-targeted analysis of soils.[42] This information about previously unknown or unidentified PFAS in the environment is crucial to advance understanding of PFAS impacts and exposure potential.

Currently the PHL has the ability to conduct non-targeted PFAS analysis (and has done so on some water samples), but may have capacity limitations to do so on a regular basis. The instruments available in the lab for non-targeted analysis are used for many other projects, and there is limited time on the instrument to conduct these types of analyses. Additionally, conducting non-targeted analysis is still a relatively niche specialty. MDH is lucky to have some of this expertise on using non-targeted analytical techniques on PFAS in house, but more staff with this knowledge would be needed to conduct non-targeted analysis with frequency.

Benefits of PFAS screening methods

While traditional analytical methods for PFAS are crucial for many applications, using them to analyze PFAS samples is often quite expensive ($300-400 per sample), takes considerable time to complete, and does not capture all PFAS that could exist in the sample. In order to get around some of these challenges, chemists have proposed several possible options for reducing costs to run samples, reducing time and effort to run samples, or increasing the ability to measure more PFAS. Firstly, there could be opportunities to develop simple PFAS methods that are faster and cheaper to run at scale, but only look for a small number of PFAS that are thought to drive risk in a scenario. If the goal is to estimate the total amount of PFAS in a given sample, but not necessarily the composition or concentrations of each PFAS present, methods like TOF analysis could be used to quantify large groups of PFAS in environmental samples. Another newer PFAS method, called TOP analysis, is used to determine the total concentration of PFAS precursors that transform to persistent "terminal degradation PFAS" like PFOS, PFOA, and

[41] Sun, M., Arevalo, E., Strynar, M., Lindstron, A., Richardon, M., Kearns, B., Pickett, A., Smith, C., & Knappe, D.R. (2016) Legacy and Emerging Perfluoroalkyl Substances Are Important Drinking Water Contaminants in the Cape Fear River Watershed of North Carolina. *Environmental Science & Technology Letters*. (*3*) 12**:** 415-419. https://doi.org/10.1021/acs.estlett.6b00398

[42] Washington, J., Rosal, C.G., McCord, J.P., Strynar, M.J., Lindstrom, A.B., Bergman, E.L., Goodrow, S.M., Tadesse, H.K., Pilant, A.N., Washington, B.J., David, M.J., Stuart, B.G., & Jenkins, T.M. (2020). Non-targeted mass-spectral detection of chloroperfluoropolyether carboxylates in New Jersey soils. *Science*, *368,* (6495), 1103-1107. Doi: 10.1126/science.aba7127

PFHxS. Though TOP analyses do not measure the individual PFAS precursors, the approach provides information to understand if increases in concentrations of terminal PFAS in a material, like wastewater, could be observed as PFAS precursors oxidize over time. Currently, EPA is developing approved methods for TOF and TOP – it is not yet clear how low detection limits may be for these methods, though existing TOP approaches have similar detection limits as standard methods for the terminal degradate PFAS. Other options for grouped PFAS analysis include methods like PIGE analysis. PIGE is a rapid screening method (capable of processing over 20 samples per hour) that can measure the presence of total fluorine in the surface of solid samples, such as samples of food packaging or textiles.[43] This method could be useful identifying if products have added PFAS and in prioritizing samples or sites for further analysis.[44] These screening methods for PFAS may be helpful to answer questions in some investigation scenarios, but may not have the precision needed for many other applications.

Ensuring consistency of PFAS results

Regardless of who collects and analyzes a sample, the results of that sample should be the same. To ensure consistency across projects and ensure that samples are taken in a way that is reflective of environmental conditions, sampling protocols must be followed. MPCA has developed a guidance document for PFAS analysis that includes recommendations for accurate sampling techniques. However, as scientists learn more about PFAS fate and behavior in the environment, strategies for sampling environmental media continue to evolve. MPCA regularly updates this document to reflect the most up-to-date science. In addition to using consistent sampling protocols, another tool to ensure reproducible and accurate PFAS results is to work with accredited labs. Labs can be accredited by EPA to run EPA-approved methods (the PHL is accredited by EPA), but MDH also has a lab accreditation program that allows contract labs in Minnesota to apply for accreditation for PFAS.

Challenges associated with developing and implementing PFAS methods

There are many challenges associated with developing and implementing PFAS methods. Existing methods for PFAS are complex – they measure a broad range of PFAS with very diverse physical and chemical properties that, for other classes of compounds, would likely be measured using many different methods. The widespread use of PFAS in commercial products means that samples can be easily contaminated. Extra care is needed to ensure no PFAS-containing materials are used in the lab or when collecting samples in the field, and many “blank” samples – designed to detect inadvertent lab or field-based introduction of PFAS -- are needed.

In Minnesota’s public lab and in private contract labs, PFAS analysis is expensive. Sample analysis runs between $300 and $400 per sample. Additionally, maintaining supplies of the reagents used to run those methods is expensive. Innovative approaches that could result in reduced effort to run PFAS samples, or a focus on the individual PFAS that are risk-drivers within PFAS mixtures, could reduce the overall cost of monitoring. Of course, understanding which PFAS are risk drivers requires a complete understanding of which PFAS are present and corresponding toxicity information – currently this information is incomplete.

Developing new PFAS methods is time consuming and uncertain. When developing methods for new PFAS, sometimes it is difficult to procure analytical standards needed for method development. Like any research venture, some new ideas and techniques are successful, but many fail. It can be hard to know how much time developing a new method will take, and very difficult to predict outcomes like the

[43] McDonough, C.A., Guelfo, J.F., & Higgins, C.P. (2019). Measuring Total PFAS in Water: the Tradeoff between Selectivity and Inclusivity. *Curated Opinions Environmental Science and Health, 7*, 13-18. doi:10.1016/j.coesh.2018.08.005.

[44] Ritter, E.E., Dickinson, M.E., Harron, J., Lunderberg, D.M., DeYong, P.A., Robel, A.E., Field, J.A., & Peaslee, G.F. (2017). PIGE as a screening tool for Per- and polyfluorinated substances in papers and textiles. *Nuclear Instruments and Methods in Physics Research, 407*, 47-54. DOI: 10.1016/j.nimb.2017.05.052

detection limits that the method will be able to achieve. Without knowing which PFAS are released into the environment, it is impossible to know if methods in development are targeting the PFAS posing the most significant health risks. In Minnesota's public labs, it has taken several full-time staff between one and two years to develop new PFAS methods. When the PHL develops new methods, these projects are nearly always completed as part of a collaboration with funding for a corresponding project aiming to measure PFAS.

Past and ongoing efforts

The following projects have been completed by MPCA and MDH, or are currently underway at those agencies. Overall, the PHL has contributed significantly to the state's ability to respond to PFAS contamination in the environment, especially in the early days of PFAS investigations when private contract labs did not have the capabilities to run PFAS samples. The PHL was one of the first to develop PFAS methods for water and went on to be one of the first labs to develop methods for biological samples like blood serum and vegetables. Ongoing efforts to validate methods that have been recently approved by the EPA (such as EPA Method 533) and to expand the lab's ability to measure PFAS in biological samples like breastmilk are continuing to grow the public lab's ability to measure PFAS moving forward.

Minnesota agencies have also worked to develop scientifically robust techniques for collecting PFAS samples and ensuring consistent PFAS measurement results, regardless of who is taking the sample and analyzing the results in a lab. In this effort for consistency, MPCA has published a PFAS Analytical Guidance document and updates the document regularly. MPCA is also continuing to learn more about improvements in sampling strategies and is working with partners in EPA's Office of Research and Development to leverage the most recent research on this topic.

Developing and improving PFAS analytical methods

Developed simple PFAS method for drinking water or groundwater

In 2006, MDH PHL (at the request of MPCA's Remediation program) developed a method to detect seven PFAS in drinking water. Aqueous samples are diluted with a solvent and analyzed using High Performance Liquid Chromatography/Mass Spectrometry (HPLC-MS/MS). This method takes about six hours to run a batch of 20 samples.

Work status: completed

Leaders: MDH Public Health Lab.

Benefits: Having access to in-house analysis for PFAS allowed MPCA and MDH to investigate drinking water contamination efficiently in house before commercial labs had PFAS methods available. Though newer methods have the ability to measure more PFAS at lower detection limits, the MDH PHL continues to use this method for its relative ease of sample preparation and its robustness (meaning that it is accurate when scaled to run with many samples at a time). This method is used for projects testing drinking water, surface water, and wastewater samples.

Challenges: The biggest challenges encountered while developing this method included the lack of analytical standards – or solutions of PFAS with known concentrations to compare against the samples with unknown concentrations – for the PFAS in the method. An additional challenge was ensuring that there were no PFAS-containing instrument components and equipment in the lab that may compromise samples.

Resources: It took two staff approximately two years to develop this method.

Developed and improved methods to measure PFAS in blood serum, plasma, and breastmilk

In 2007, MDH was directed by a Minnesota state law to conduct pilot-scale biomonitoring in two communities likely to be exposed to PFAS. This study was developed to understand how the drinking water PFAS exposure was impacting PFAS levels in resident's blood. In total, three biomonitoring studies were conducted in 2008, 2010, and 2014.[45] MDH's PHL has worked with other divisions within MDH to develop methods to support biomonitoring of PFAS in the East Metro. These methods have been used to support other programs, including processing biomonitoring samples for federal research projects run by the National Institute of Environmental Health Sciences. MDH initially developed a method for the analysis of seven PFAS in blood serum and have since added capacity for eight additional PFAS analytes. Over time, MDH has continued to update and improve these methods, aiming to increase the number of samples that can be processed without interruption. MDH has validated the method to include blood plasma and breastmilk in addition to serum. Current efforts involve improving the method for PFAS analysis in breastmilk.

Work status: ongoing

Leaders: MDH Public Health Lab. **Partners**: MDH Chronic Disease and Environmental Epidemiology.

Benefits: With the development of these biomonitoring methods in Minnesota's PHL, the state now has the capacity to do PFAS biomonitoring without relying on contract labs, of which there are a limited number capable of measuring PFAS in biological media. This allows Minnesota to be self-reliant and fully transparent about method results with the community. The PHL has also been able to leverage these methods to help other communities understand their exposures. Developing and maintaining these methods has allowed MDH to include specific PFAS that are of interest in our community. For example, PFBA is an important contaminant in the East Metro but is not commonly included in commercial biomonitoring methods.

Challenges: Blank contamination and finding clean materials have been challenges. The existing methods for PFAS biomonitoring did not include the short-chain analytes mandated by biomonitoring legislation, so PHL had to develop those capabilities. As new PFAS are discovered, more sensitive analytical equipment may be needed to do analysis.

Resources: The effort to develop this method required the time of one lab staff for about one year, and approximately $100,000 in funding for supplies and service time for the initial method development. Staff were trained at the CDC for method development. Over time, this method was revisited to improve various aspects, which resulted in additional effort. The instrument (which cost ~$500,000) used to measure these samples was acquired through the Public Health Emergency Preparedness Fund, Laboratory Response Network.

Developed PFAS methods for dust, soil and vegetable matrices

The MDH PHL developed methods for the detection of PFAS in dust, soil, and fruit and vegetable matrices in support of the "Perfluorochemicals in Homes and Gardens Study" (PIHGS). This study investigated PFAS found in homes in the East Metro that had drinking water contaminated with PFAS. In these homes, treatment was removing PFAS from tap water used for drinking, but PFAS were still present in water used for gardening and other non-drinking purposes. In support of this project, the MDH PHL developed multiple methods for detecting PFAS in various solid matrices. The vegetable method detected seven PFAS in a wide variety of different types of home-grown produce, each with different sample preparation and analysis concerns. The soil method measured seven PFAS in soil taken from the garden. The Perfluorochemicals in Homes and Gardens Study was also concerned about potential PFAS exposure from dust. Dust was collected from the entryway and one additional room of

[45] MDH. (n.d.). East Metro PFAS Biomonitoring Projects. Retrieved from: https://www.health.state.mn.us/communities/environment/biomonitoring/reports/index.html

each house. The dust method developed by the PHL analyzed for 12 PFAS, which allowed investigators to consider potential exposure contributions from garden soil tracked-in from the outdoors and PFAS in household items like carpeting making its way into dust. This study was conducted in 2010 and journal articles including method information were published in 2018 and 2019.[46,47]

Work status: completed

Leader: MDH Public Health Lab. **Partners**: MDH Site Assessment and Consultation and MPCA.

Benefits: The development of these methods for analyzing PFAS in solid matrices allowed Minnesota to directly respond to the concerns of citizens over the safety of consuming produce grown in their home gardens. Developing the method at the MDH PHL was necessary because few methods existed with the ability to analyze the wide variety of vegetable produce that home gardeners cultivate in Minnesota. This project also provided linked soil and dust data, which were useful in assessing if outside irrigation with contaminated water was leading to increased track-in of PFAS to the house. This was to assess potential exposure risks for small children, who are most highly exposed to soil and dust.

Challenges: The most significant challenge associated with developing these methods was finding blank matrices (samples that contain no PFAS to ensure that the instrument is correctly reporting) for dust samples. It was not possible to find PFAS-free dust, so researchers used clean sand as a blank matrix instead. Finalizing a sample collection method for dust was also challenging. At first, researchers intended to use dust from a vacuum cleaner, but the sieving of the vacuum cleaner contents resulted in dust going airborne, causing concerns about contamination between samples. Instead, dust was collected using device called a dust cartridge. There were also difficulties developing methods that would work for all of the vegetable matrices in the study. Some vegetables have high acid content, others have high water content or low water content. The final methods used for this study segregated the produce into four categories with four different methods for analysis based on the traits of the produce.

Resources: Development of methods for these three varied matrices took significant staff and instrument time, relationships with other PFAS investigators, and upfront costs for reagents and supplies.

Validated EPA Method 533 for drinking water

In December of 2019, EPA published a new method for measuring PFAS in drinking water called Method 533: Determination of Per- and Polyfluoroalkyl Substances in Drinking Water by Isotope Dilution Anion Exchange Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry.[48] If used in combination with EPA's previous drinking water method for PFAS (Method 537.1), these methods can detect 29 PFAS.[49] EPA reference methods are used for regulatory purposes and for monitoring programs like the mandatory Unregulated Contaminant Monitoring Rule (UCMR) under the Safe Drinking Water Act. Validating new methods requires the laboratory to demonstrate that it can generate accurate and

---

[46] Scher, D.P., Kelly, J.E., Huset, C.A., Barry, K.M., Hoffbeck, R.W., Yingling, V.L., & Messing, R.B. (2018). Occurrence of perfluoroalkyl substances (PFAS) in garden produce at homes with a history of PFAS-contaminated drinking water. *Chemosphere, 196*, 548-555. https://doi.org/10.1016/j.chemosphere.2017.12.179

[47] Scher, D.P., Kelly, J.E., Huset, C.A., Barry, K.M., & Yingling, V.L. (2019). Does soil track-in contribute to house dust concentrations of perfluoroalkyl acids (PFAAs) in areas affected by soil or water contamination? *Journal of Exposure Science & Environmental Epidemiology, 29,* 218-226*.* https://doi.org/10.1038/s41370-018-0101-6

[48] EPA. (2019). *Method 533: Determination of Per- and Polyfluoroalkyl Substances in Drinking Water by Isotope Dilution Anion Exchange Solid Phase Extraction and Liquid Chromatography/Tandem Mass Spectrometry*. Retrieved from: https://www.epa.gov/dwanalyticalmethods/method-533-determination-and-polyfluoroalkyl-substances-drinking-water-isotope

[49] EPA. (2019). Comparing EPA Analytical Methods for PFAS in Drinking Water. Retrieved from: https://www.epa.gov/dwanalyticalmethods/comparing-epa-analytical-methods-pfas-drinking-water

precise data through an instrument calibration, verification of the calibration, demonstration of low background analyte levels, analysis of laboratory controls that meet accuracy and precision criteria, a method detection limit study, and confirmation of the reporting limits. MDH's PHL validated this new EPA PFAS method, which means that it will be able to conduct monitoring for the EPA's UCMR program and increase PFAS analytical capacities for other Minnesota monitoring programs.

Work status: completed

Leader: MDH Public Health Lab.

Benefits: Having the PHL validated and equipped to run EPA Method 533 is beneficial because it will expand the laboratory's capabilities by increasing the number of PFAS analytes from 7 to 26 and achieve lower reporting limits. This capability would allow MPCA and MDH to send more samples to the PHL, and therefore rely less on commercial laboratories to for these sample analyses.

Challenges: There were several challenges faced when validating EPA Method 533. To achieve the reporting limits desired for this method, the laboratory purchased a new instrument. Setting up the new instrument and ensuring its components were as PFAS-free as possible was a difficult and time-consuming process. Additionally, optimizing an instrument for 26 analytes and their respective internal standards while learning new instrument software added to the time required to get the instrument operational. The sample preparation for EPA Method 533 is much more labor intensive than the simple seven-analyte "dilute and shoot" method PHL has been using and presented other challenges to the method validation. It was necessary to confirm that all aspects of the sample extraction procedure met performance standards and were free from PFAS contamination.

Resources: It took two staff approximately 11 months to complete method development and validation.

Efforts to ensure consistent and accurate PFAS analytical results

Collaborating with EPA Office of Research and Development on PFAS sample collection strategies

MPCA is currently working to investigate and remediate a region of surface water and groundwater contamination in the East Metro called the Project 1007 Corridor (*See* Remediating PFAS-contaminated Sites Issue Paper). This clean-up effort is one of the most complex and large-scale PFAS surface water remediation efforts undertaken in the US Because many elements of this investigation and clean-up are new, MPCA staff and contractors are continuing to learn about how to most effectively sample surface water and groundwater to accurately capture potential PFAS exposures. One especially challenging aspect to the Project 1007 investigation and remediation effort is the presence of PFAS-containing foams on surface water, which can be significantly enriched in PFAS compared to the surrounding water. Another challenge with surface water sampling for PFAS stems from the fact that many PFAS prefer to concentrate at the very surface of the water, in what is called the "air-surface microlayer." Collecting samples only below the surface would likely underestimate the true PFAS concentration in the waterbody. Sampling only the air-surface microlayer may not be representative of an overall PFAS surface water exposure in some settings, but in other settings (like considering potential exposure to an animal drinking from the surface of a waterbody) knowing the concentration of PFAS in the air-surface interface can be very informative. Additionally, there have been recent advances in passive samplers for PFAS in surface water and advances in understanding of PFAS dynamics in bedrock formations and during groundwater well sampling. In order to expand the available expertise to tackle challenges associated with sampling strategies, MPCA has developed an ongoing collaboration with EPA's ORD to compare sampling methods for PFAS foam, assess environmental conditions that lead to PFAS stratification in the water column, and evaluate passive monitoring well samplers for PFAS in groundwater.

Work status: ongoing

Leaders: MPCA Remediation Division. **Partners**: EPA Office of Research and Development.

Benefits: Technical assistance from EPA's ORD team will benefit Minnesota by providing comparative analysis of PFAS sampling methods and tools and a better understanding of the potential for PFAS to stratify in surface water. Evaluating methods for sampling PFAS-containing foam on surface water will provide consistency in comparison of analytical results from varying environmental conditions where PFAS-containing foam exists.

Challenges: Standardizing sampling protocols and tools is challenging in heterogeneous environmental conditions with varied hydrologic and geologic settings. Thought will be needed to clearly define the goal of the sampling strategy – for example, the goal could be to accurately capture the bulk water concentration for a surface water stream or to capture a likely exposure scenario for wildlife using the waterbody for drinking.

Resources: Investigating and remediating the Project 1007 Corridor is a cost and time-intensive process – through fiscal year 2021, $4 million will have been spent on this effort and work will continue thereafter. The additional collaboration and coordination with EPA's scientists in the Office of Research and Development will not require resources and may reduce the amount of funds spent on tackling these issues with MPCA's contractors and staff alone.

Revising PFAS Analytical Guidance Document

The purpose of the PFAS Analytical Guidance Document[50] is to provide guidance to MPCA programs. The criteria described within the document are considered minimum standards (the laboratory may use stricter criteria) that should be met when analyzing and reporting sample results to the MPCA. The guidance supports MPCA staff in reviewing the data collected and reported by contractors and regulated parties. Information included in the document includes specifications on how PFAS samples should be collected and stored for various media, how instruments should be calibrated, and which PFAS should be measured at what minimum reporting levels. This document is regularly revised to incorporate the rapid evolution of knowledge regarding PFAS contaminant analysis – revisions are currently underway.

Work status: ongoing

Leader: MPCA Environmental Data Quality Section.

Benefits: This document helps ensure that data are collected in an accurate and consistent manner, whether for research purposes or for regulatory purposes. This document is also a helpful reference for contract labs and private entities around the state looking to produce high-quality PFAS data that would be acceptable to MPCA or MDH. Though the MPCA Environmental Data Quality Unit encourages labs to reach out with phone calls or questions about the complications of PFAS analysis, having the basic quality assurance information in a short reference guide is a helpful tool.

Challenges: The analytical methods used to measure PFAS and the best practices for collecting PFAS samples are constantly evolving – there is not always immediate consensus on best practices. Additionally, as one of the purposes of this document is to ensure consistency of PFAS results measured in different laboratories, this document states what is acceptable to the MPCA, not necessarily all that is possible. For example, even if one lab can detect to new, lower detection limits, if this technology is not yet available to multiple facilities, the lower detection limits may not be included in the guidance document. This desire to balance high-quality data incorporating the most recent improvements with accessibility of methods makes updating the guidance document challenging.

---

[50] MPCA. (2020). *Guidance for Perfluorochemicals Analysis*. Retrieved from: https://www.pca.state.mn.us/data/mpca-quality-system

Resources: This effort requires MPCA staff time revisit the document approximately every year to determine if updates are needed.

Considering additional PFAS methods to add to the MDH lab accreditation program

The MNELAP was established in 1989 to ensure the accredited laboratory is capable of performing analytical measurements and to hold accredited labs accountable to standards that support the generation of defensible and accurate data. MNELAP offers accreditations to accommodate the needs of many state and federal environmental programs including testing required by the Clean Water Act (CWA), Resource Conservation and Recovery Act (RCRA), Underground Storage Tank Program, and the Safe Drinking Water Act (SDWA). Laboratories apply each year to MNELAP for accreditation, and MNELAP tracks proficiency of labs, works with approved third-party assessors to conduct on-site assessments every two years, and holds enforcement authorities should a lab deviate from method or quality assurance procedures.

In the early days of PFAS investigations in Minnesota, there were a very limited number of methods available to measure PFAS in various media, and there were no standardized EPA-approved methods. For this reason, MPCA worked with the MNELAP to use the guidance document on PFAS analysis published by MPCA (described in the section above) for accrediting labs in lieu of published analytical PFAS methods. The MPCA Environmental Data Quality unit, which is responsible for maintaining the PFAS analytical guidance document, is working closely with MNELAP and other programs within MPCA to consider which PFAS methods should be made available for the purpose of accrediting labs in the future.

Work status: ongoing

Leader: MPCA Environmental Data Quality. **Partner**: Minnesota Department of Health Environmental Laboratory Accreditation Program (MNELAP).

Benefits: Adding PFAS methods to the list of fields of testing available for accreditation will help ensure consistency from environmental laboratories to report defensible data from validated and standardized methods.

Challenges: Though PFAS methods are becoming available from EPA and other sources, there may still be PFAS analytes of concern in matrices without standardized methods available at this time. [51] The MPCA Environmental Data Quality program will need to consider if MPCA programs require that labs continue to be accredited based on the MPCA guidance document for PFAS analysis rather than a standardized method in some cases. Additionally, some outreach to labs may be needed to help explain any changes to the accreditation process for PFAS analysis.

Resources: Staff time in the MNELAP program and MPCA programs will be needed to review analytes, help communicate changes to labs, and potentially assist with onsite audits for new methods. Additional funding maybe required if the current accreditation database needs to be upgraded, modified, or improved to meet the needs of the laboratories and clients.

Gaps and opportunities

Researchers and regulators in Minnesota and across the nation are struggling with the many remaining gaps in measuring PFAS. With potentially thousands of PFAS occurring in the environment, the vast majority of PFAS are not currently included in widely available analytical methods. These undetectable

[51] EPA (2020). PFAS Analytical Methods Development and Sampling Research. Retrieved from: https://www.epa.gov/water-research/pfas-analytical-methods-development-and-sampling-research#:~:text=Standard%20Analytical%20Methods%20%20%20%20Media%20,for%20non-drinking%20...%20%209%20more%20rows%20

PFAS may pose a concern for human health, ecosystem health, or both. Compounding the problem, it is difficult to know which new PFAS should be targeted for addition to standard analytical methods because it is not known which PFAS we should expect to occur in the environment – companies are not required to report the PFAS they produce in all cases, and often if the information is reported to EPA, it is protected as "confidential business information" and cannot be released. Though this is an immense challenge, there are a number of opportunities for progress. Increased availability and accessibility of non-targeted analytical methods would help prioritize additional specific method development and greatly improve the understanding of the entire landscape of PFAS mixtures present in environmental media. Increasing Minnesota's capacity to conduct non-targeted analysis could be possible by implementing creative financing options for gaining access to instruments, like lease-to-own structures, and by employing post-docs or funding for graduate students to work on projects with set durations. Additionally, access to data like environmental release information for PFAS, importation data for PFAS, and labeling of PFAS in commercial and industrial products would greatly improve the understanding of which PFAS are likely to occur and where. This information would help prioritize the development of new analytical methods.

There are new methods available that may be helpful in answering questions in site investigation or product screening contexts when traditional analytical methods are either not available or not the most efficient tool. PFAS analysis using traditional analytical methods is expensive -- at a cost of $300-$400 per sample, costs for investigating PFAS can quickly become prohibitive. Having access to a screening level method may be able to help prioritize sites for further investigation. Additionally, if the goal of sampling is not to determine which PFAS are present but to understand the total level of PFAS, less expensive analytical methods for measuring TOF could reduce the burden of conducting PFAS analysis and increase the likelihood of identifying new PFAS contamination sites. Another new tool to identify whether PFAS is present in the surface of solids is called PIGE analysis. Gaining access to this tool could help identify PFAS-containing products, potentially increasing the ability for MPCA target source reduction efforts in waste streams and making it easier to enforce potential future regulations on PFAS-containing products. Overall, expanding the toolbox of PFAS methods available would be useful for many PFAS management efforts.

Ensure capacity to meet the demand for non-targeted PFAS analytical approaches

Currently, the PHL has skilled staff and instrumentation needed to conduct non-targeted analysis for PFAS, but staff time and scheduling time on the required instrument are limited. The goal of this project proposal would be to continue to develop and implement suspect screening and non-target approaches for PFAS in environmental samples and expand the availability to conduct non-targeted analysis as requested by MPCA or MDH programs. Non-targeted analysis can help identify PFAS that are present in a sample that otherwise would not be detected using targeted methods. While non-targeted analysis does not allow for quantifying PFAS, the signal responses can provide a qualitative estimate of which are likely to be the most abundant. This work could support investigations into sites where unknown PFAS may be present. Collaborations with partners at Minnesota Universities may be beneficial.

Work status: under consideration – would be paired with additional PFAS research and site investigations

Leader: MDH Public Health Lab. **Partners**: Partnering academic labs (if applicable).

Benefits: Studies have shown that targeted analytical methods for PFAS frequently capture only a small percentage of the total PFAS present.[52] Having the ability to run non-targeted analyses would allow site investigators and others at MPCA and MDH gain a more complete picture of the PFAS

[52] McDonough, C., Guelfo, J.L., & Higgins, C.P. (2018). Measuring Total PFAS in Water: The Tradeoff between Selectivity and Inclusivity. *Current Opinion in Environmental Science and Health*, 7, 13-18. doi: 10.1016/j.coesh.2018.08.005.

present in various samples. Suspect screening allows for the qualitative analysis of hundreds of known precursor PFAS for which analytical standards may not exist. While unequivocal identification requires analytical standards, probable identifications can be made and supported by additional chemical or contextual evidence. Additionally, non-targeted analysis can facilitate the discovery of unknown PFAS, as was recently done in New Jersey.[53]

Challenges: Suspect screening and non-target analysis requires highly technical and laborious data processing. Instrument availability is also a potential issue; currently Minnesota labs have two instruments capable of suspect screening and non-target analysis, but they are frequently used or dedicated for other projects.

Resources: Expanding access to non-targeted analysis for PFAS in Minnesota public labs may require purchasing or renting of additional instruments and hiring of additional staff with expertise in non-targeted methods for PFAS.

Ensure capacity to meet the demand for alternative PFAS methods

This proposal is to research and possibly adopt screening methods for PFAS in Minnesota public labs. Options for PFAS screening include TOF and PIGE analysis. These methods do not determine exactly which PFAS are present in a sample. However, they could be used for various applications including: determining the percentage of PFAS detected in a given sample using standard analytical methods, estimating the total PFAS in a given product, or estimating the total PFAS in a sample as a mechanism to prioritize investigations.

Work status: under consideration – would be paired with additional PFAS research and site investigations

Leader: MDH Public Health Lab.

Benefits: With potentially thousands of PFAS in the environment and used in commerce, measuring the tens of PFAS with standard analytical methods available only captures a piece of the entire PFAS landscape. Additionally, with novel PFAS being developed constantly, standard analytical methods are highly unlikely to capture PFAS being produced today. Having the ability to run screening PFAS analysis in MPCA and MDH labs would help staff in various program activities. For example, screening PFAS methods that are faster and cheaper than traditional analytical methods could help screen for PFAS concentrations in surface water foams, prioritize sites for PFAS investigation, and quickly track the movement of PFAS spills or plumes.

Challenges: Currently, Minnesota public labs do not have the equipment or staff availability to investigate new screening methods, and there are limited staff available with expertise in PFAS. Additionally, the preferred screening method for PFAS will likely depend on the application where it is needed. Collaboration between the lab and program staff, along with possible collaborations with academic labs, may be helpful.

Resources: Though researching possible screening methods for PFAS would not require significant additional resources, implementing new screening PFAS methods would likely require additional instrumentation, additional trained staff, and possibly additional reagents or other equipment.

[53] Washington, J., Rosal, C.G., McCord, J.P., Strynar, M.J., Lindstrom, A.B., Bergman, E.L., Goodrow, S.M., Tadesse, H.K., Pilant, A.N., Washington, B.J., David, M.J., Stuart, B.G., & Jenkins, T.M. (2020). Non-targeted mass-spectral detection of chloroperfluoropolyether carboxylates in New Jersey soils. *Science*, *368*, (6495), 1103-1107. Doi: 10.1126/science.aba7127

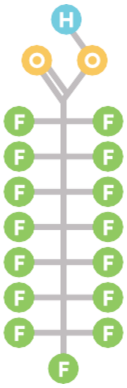
Overview of intersectional issues

- **Quantifying PFAS toxicity**: Understanding the potential health impacts of PFAS exposure is key in ensuring exposure stays below “safe” thresholds and communicating with the public. Health-based guidance values, however, have been revised to lower and lower concentrations as information about some PFAS emerges. It can be challenging to develop analytical methods with detection limits low enough to detect below health-based standards in most media.
- **Managing PFAS in waste**: Landfill leachate, effluent and biosolids from wastewater treatment plants, and contact water from composting facilities all contain PFAS stemming from industrial and commercial uses of PFAS-containing products. Developing methods capable of measuring PFAS in complex matrices like landfill leachate is challenging, and often these methods will have higher detection limits than those designed for “clean” matrices like drinking water.
- **Protecting Minnesota wildlife**: There is limited data on PFAS in various animal tissues. Developing methods in Minnesota public labs capable of measuring multiple PFAS in samples like fish tissue, deer tissue, and other biological specimens would be challenging and expensive.
- **Preventing PFAS Pollution**: Phase-outs or bans of certain PFAS uses in commercial or industrial products would likely require some level of enforcement. The availability of screening methods like PIGE would help identify products with PFAS in surface coatings. Screening methods like TOF could help enforce PFAS bans in liquids.

Summary

Quantifying PFAS risks to human health

Background



- **Risk assessments** are needed to ensure that the regulations or interventions controlling levels of contaminants in water, soil, air, or other media are protective of the community's health.
- Many PFAS occurring in environmental media **do not have enough toxicity data** to conduct risk assessments – EPA and other international regulators have allowed persistent compounds like PFAS into commerce without first requiring chemical producers to conduct and report sufficient toxicity testing or even publicly reveal the chemical structure.
- Despite challenging data limitations, **MDH developed health-based values for five PFAS** (PFOA, PFOS, PFHxS, PFBA, and Perfluorobutane sulfonate [PFBS]) and is currently reviewing a sixth, PFHxA.
- Existing risk assessments for PFAS have indicated they have **many toxic effects**, impacting **multiple organ systems**. Toxic effects can occur during sensitive life stages like pregnancy and early-life development. These effects have been observed in laboratory-based animal studies and epidemiological studies conducted in exposed communities.
- Health-based values derived by MDH for drinking water assessments are also used by MPCA to develop risk assessments for other media, such as **surface water, fish tissue, and soils**.
- There are many **challenges** to conducting additional risk assessments for PFAS.
  - Many PFAS do not have widely available **analytical methods** to quantify their concentrations in water, soil, sediment, or air.
  - Most PFAS have **significant data gaps** in toxicological information that preclude the derivation of risk-based values.
  - The **scientific literature regarding PFAS toxicity and occurrence is evolving rapidly**; MDH is conducting ongoing literature searches to identify if new data warrant revising existing risk assessments. This is a significant effort.

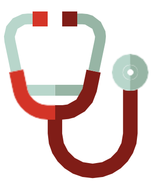
What is Minnesota doing now?

- MDH **continues to revise** the existing PFAS toxicity assessments as new information becomes available.
- MDH is also evaluating exposure and toxicity data availability for **new PFAS nominated through the Contaminants of Emerging Concern (CEC) Initiative** process.
- MDH has established formal **collaborations with scientists from EPA's Office of Research and Development** to identify how New Approach Methodologies (NAMs) could potentially advance our understanding of PFAS risks to humans.
  - Collaboration includes **developing alternative risk assessment methodologies** and testing these methods to see if they are useful in providing risk context for data-poor PFAS that may be occurring in Minnesota.
  - NAMs can be used to **prioritize PFAS for review** and to conduct **screening-level toxicity or exposure assessment**.
- Staff from Minnesota continue to **collaborate with risk assessors in other states** through the Great Lakes PFAS Taskforce and other inter-state information sharing organizations to leverage each other's work on quantifying PFAS risks to humans.

What are remaining gaps and opportunities for action?

- **Gap**: PFAS are found in air. There are currently no health-based air guidance values from federal agencies and a limited number from state sources. Inhalation-based PFAS studies are limited; the absorption, distribution, metabolism, and elimination of volatile PFAS are poorly understood.
  - **Opportunity**: MDH could conduct systematic literature reviews every six months to compile data relevant to PFAS inhalation routes and determine if inhalation risk assessments are possible with the remaining data gaps.
- **Gap**: Repeat-dose animal studies for most PFAS are not available. Similarly, there are not sufficient exposure data for most PFAS to understand the likelihood of exposure from various routes, such as through drinking water, fish, other food, products, or air.
  - **Opportunity**: New authorities to request data from entities using or producing PFAS could help fill gaps in exposure and toxicity information. These new authorities would require legislative action.
  - **Opportunity**: Continuing to partner with multiple teams of scientists in EPA's Office of Research and Development could help MDH capitalize on new research projects to understand PFAS toxicity and exposure.
- **Gap**: Though previous studies measured PFAS levels in the blood of East Metro residents exposed through drinking water, MDH has not conducted an epidemiological study aimed at understanding how PFAS exposure relates to adverse health outcomes.
  - **Opportunity**: Funding for MDH to conduct an epidemiological-based health study in the East Metro.

How does this work benefit human health and the environment?



- Understanding the thresholds at which adverse effects from PFAS exposure are unlikely to occur allows for **health-protective guidance and regulation**. This guidance or regulation can then be implemented to ensure that interventions take place if there are potential health risks to the community.
- Minnesota has **in-house expertise** to develop risk-based values – this allows agencies to develop guidance for contaminants that are specifically relevant in our state and not to wait for the many years that it often takes for EPA to publish new risk assessments.
- Given the lack of toxicity and exposure data for nearly all PFAS found in the environment, exploring new approach methodologies for **contextualizing PFAS risk** will help prioritize PFAS for additional research and potentially allow for development screening-level toxicity assessment.

How does this work benefit Minnesota's economy?

- **Preventing adverse physical health outcomes** associated with PFAS exposure and **preventing negative mental health outcomes** associated with concern over exposure to these compounds is financially beneficial for families and individuals.

MINNESOTA

Background

Many environmental regulations are designed so that the concentration of chemicals in water, soil, air, or other media are kept below levels deemed protective of the community's health (though some regulations take into consideration available technology, cost-benefit analysis, and other factors in addition to purely health-based risk assessments). Calculating health-protective concentrations requires a comprehensive synthesis of toxicity and exposure information, along with an accounting of what risks may be associated with any data gaps that exist. In Minnesota, staff at MDH and MPCA develop risk assessments used to develop health-protective environmental guidance and regulation.

Understanding the health and environmental risks of chemicals

Understanding the doses at which a chemical is unlikely to impact health is critical to determining safe concentrations of the contaminant in various media like water or soil in the environment. Risk assessment is the process of understanding the negative health effects associated with exposure to chemicals and identifying the levels that are unlikely to cause those negative effects. In order to complete risk assessments, scientists compile and synthesize data describing a compound's toxic effects, the way the compound moves through the body, and the way and degree to which various communities could be exposed. The goal of these assessments is to determine the dose threshold at which adverse health effects from exposure to a compound are *not* likely to occur. Sometimes this dose is given the shorthand term of "safe dose" or "reference dose." Assessing toxicity is a technical process practiced by a team of experienced toxicologists and other specialists.

When conducting risk assessments, scientists can consider the type of exposure (exposure from breathing, ingesting, or absorbing through the skin), the duration of exposure (from "acute" studies spanning a day to "chronic" studies spanning an entire lifetime), the timing of the exposure (for example, exposure during pregnancy or during stages of early-life development), and the organ systems that might be most sensitive to adverse effects (for example, the liver or the nervous system). In the context of environmental exposures to toxicants, "safe doses" are calculated so that the most sensitive organ systems and the most sensitive population groups are protected.

An entirely complete dataset for toxicity and exposure is rarely available for environmental contaminants. It is not ethical to test the effects of a toxic compound on humans. Instead, risk assessors often reference experiments on animals. These animal studies could be of various durations, including "chronic" studies, meaning that the experiment lasts the majority of the laboratory animal's expected lifetime, or studies that are "multigenerational," meaning that the laboratory animals are bred during the experiment, and toxic effects are observed in the pregnant animals and in the new offspring through maturity. These chronic and multi-generational studies can be important for identifying adverse health effects that could emerge if there is prolonged exposure to an environmental contaminant over all stages of life, including pregnancy and infancy. These effects could include reductions in fertility, developmental effects, and cancer. In the PFAS family, some compounds have shown carcinogenic effects (PFOA) and others have shown sensitive immunological effects in infants exposed during gestation and early life (such as PFOS). Other sensitive effects for PFAS include thyroid and liver effects, and effects on energy metabolism. Many PFAS have data gaps in some areas of concern – for example, many PFAS do not have chronic or multigenerational studies available, or even shorter-duration studies measuring effects in organ systems that have been shown to be sensitive. Risk assessors can account for uncertainties associated with data gaps using established risk assessment tools like uncertainty factors. For some PFAS, there are so many data gaps that risk assessors have limited ability to draw conclusions about the amount of exposure that could cause adverse health outcomes over a lifetime. In these cases, conducting traditional risk assessments is not possible.

Developing health-based guidance values

MDH has authority and ability to promulgate health-based guidance values for pollutants in groundwater that may impact human health when consumed in drinking water (Minn. Stat. 103H.201). Conducting new risk assessments and revising existing assessments in order to develop these values requires significant time from experienced staff and the availability of toxicity and exposure data. Many states do not employ risk assessors and toxicologists capable of quantifying toxicity values for contaminants of emerging concern, and instead rely on federal agencies or others to derive health-protective values. In Minnesota, we have the capacity to derive toxicity values for oral and inhalation routes of exposure, which can then be used in many contexts including the issuing of guidance or development of regulatory values. In fact, Minnesota has derived over 100 health-based values for potential contaminants of concern, including five PFAS, and regularly updates those values to reflect the most recent research. This expertise allows Minnesota agencies to have risk-based values available for contaminants that are specifically relevant in our state and not to wait for the many years that it often takes EPA to publish new risk assessments.

Understanding the potential effects of prolonged exposure to an environmental toxicant often requires data from animal studies. Even when performing these studies in laboratory animals with short lifespans, like mice and rats, experiments frequently take two years of dosing and observation. Costs for assessing the chronic or multi-generational toxicity can exceed several million dollars per chemical. Even conducting shorter-duration studies (like sub-chronic studies), requires significant time and funding. For most PFAS, important toxicity experiments have not been conducted or have been conducted but are not publicly available. These gaps leave risk assessors with limited data to draw conclusions about the amount of exposure that could cause adverse health outcomes over a lifetime.

Once MDH has determined the amount that is protective over a specified time period, an exposure assessment is conducted to ensure that total exposure to the compound (from all routes) is unlikely to exceed the protective level. In the context of drinking water consumption, the exposure assessment estimates the amount of water a person drinks and the percentage of a person's total exposure that could be expected to come from drinking water.[54] MDH takes care to consider exposures in sensitive life-stages (such as bottle-fed infants) and in population groups that may have elevated exposures. With synthesized exposure data, it is possible to calculate the concentration of a contaminant in drinking water that would keep total exposure within a range that is unlikely to result in adverse health effects.

These resulting "health-based" concentrations for groundwater used for drinking water are risk-based values. They have different names depending on the process used to publish the results. A health based value (HBV) is a guidance value that represents the amount of a chemical in drinking water that is considered safe for people to drink over a specific time period. When HBVs promulgated through the rule-making process, they become Health Risk Limits (HRLs). While both HBVs and HRLs are drinking water guidance values – meaning that their publication or promulgation does not result in regulatory action related to groundwater or finished drinking water – some programs, particularly at MPCA, use these drinking water guidance values in regulatory contexts such as in remediating contaminated sites.

The "reference doses" used to calculate HRLs and HBVs are also useful to other programs assessing potential risks from exposure in contexts other than groundwater used as drinking water. For example, risk assessors in MPCA may use the toxicity assessment of a "reference dose" from MDH to derive guidance values that are protective in scenarios where exposure is coming from recreating in surface water or from children's accidental ingestion of soil. The resulting risk-based values for these

[54] MDH has authority under the Groundwater Protect Action, under Minn. Stat. 103H.201, to promulgate health risk limits (HRLs) for substances in groundwater that are potential drinking water contaminants.

assessments are different than the corresponding HRL or HBV for the compound due to the differences in exposure from various types of contaminated media.

What is known about PFAS toxicity

MDH has prioritized risk assessments for PFAS currently known to occur most frequently in Minnesota's drinking water and for those that are known to occur at sites with PFAS contamination, assuming toxicity data are available. For the PFAS with toxicity data available and complete risk assessments, toxicologists have identified a range of adverse effects associated with exposure. Those effects involve multiple organ systems, including sensitive effects in developing immune systems in fetuses and infants. The "reference doses" derived in the assessments for PFAS are protective of the most sensitive effects in the most sensitive groups or life stages (such as infants or pregnant mothers). In many cases, human epidemiological studies have confirmed the findings of adverse outcomes seen in animal studies and identified additional correlations between PFAS exposure and other adverse outcomes including increased incidences of ulcerative colitis, thyroid disease, testicular cancer, kidney cancer, and pregnancy-induced hypertension. To date, there have been hundreds of studies of human health effects and their association with PFAS exposure, including a large study of people living in the Mid-Ohio Valley who had been exposed to PFOA.[55] The assessments for PFAS with health-based guidance values are available on the MDH webpage.[56]

Challenges to quantifying PFAS toxicity

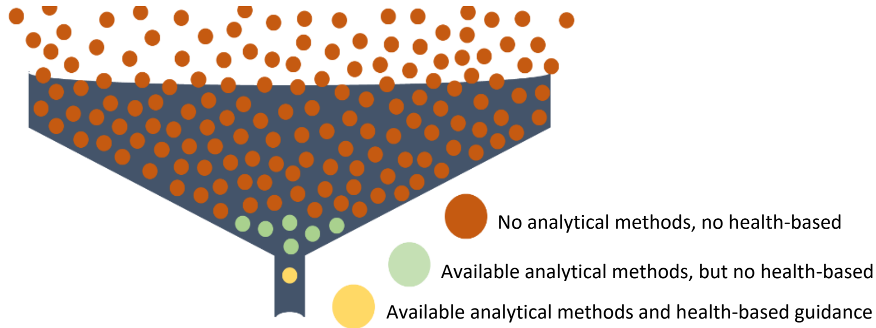
There are many PFAS in the environment without the toxicity data required to assess if those compounds exist in concentrations that may pose a risk to human health. There are over 5,000 known PFAS structures by some estimates,[57] hundreds of which are currently used in commerce or industry in the US The chains of carbon-fluorine bonds in PFAS make them extremely persistent in the environment – in many cases environmental degradation is so slow that it is, for practical purposes, non-existent. This persistence is often paired with a high degree of mobility in water, so that PFAS can spread rapidly through and between aquifers and surface water. Though some PFAS follow common patterns in absorption, distribution, and elimination from the body, there are exceptions to the observed trends. For example, though longer-chain PFAS tend to stay in the body longer (have longer biological half-lives), there are exceptions to this trend like PFHxS, which has a longer biological half-life than PFOS despite having six carbons on its per-fluorinated chain compared to eight carbons for PFOS. This diversity in PFAS traits makes it difficult to make broad conclusions about the toxicity of PFAS based on chemical structure.

[55] C8 Science Panel (2020). http://www.c8sciencepanel.org/

[56] MPCA. (n.d.). Human Health-Based Water Guidance Table. Retrieved from: https://www.health.state.mn.us/communities/environment/risk/guidance/gw/table.html

[57] EPA (2020). Chemistry Dashboard, PFAS Master List. Retrieved from: https://comptox.epa.gov/dashboard/chemical_lists/pfasmaster

Figure 2. Schematic diagram of PFAS risk assessment and method availability.



A key barrier to understanding the toxicity of various PFAS is that US regulations do not require toxicity research before compounds enter commerce. Approval of chemical use occurs at the EPA through the Toxic Substances Control Act (TSCA) program. TSCA requires manufacturers to submit only basic information on new products and product chemistries before the EPA approves them for use and does not stipulate that chemical companies conduct toxicity experiments before compounds are introduced into commerce. For this reason, even EPA, the entity which collects and reviews toxicity information from chemical manufacturers in the TSCA program, states that they do not have the data required to conduct risk assessments for most PFAS found in water.[58] When these compounds appear in drinking water, surface water, air, and soils, risk assessors have limited ability to determine if observed concentrations potentially pose health risks. Toxicological studies by academic or government researchers tend to occur only after the compounds are found in the environment. However, many PFAS do not even have widely available methods to measure their concentrations in water or other media. The identity of all PFAS used in commerce and the amounts entering the environment annually is currently unknown. Figure 2 illustrates how the number of PFAS in the environment greatly outnumber the PFAS with laboratory analytical methods available for measuring them and the PFAS with health-based guidance available.

Past and ongoing efforts

The following section describes the completed and ongoing work related to quantifying the toxicity of PFAS. Minnesota agencies have been leaders in PFAS risk assessment since 3M contamination of some of Minnesota's groundwater and drinking water was discovered in 2002. MDH staff have extensive toxicological expertise on PFAS, and MDH was the first in the nation to derive health-based values for two PFAS: PFOA and PFOS.

Since the early days of concerns about PFAS in drinking water and the environment, the science regarding PFAS toxicity has rapidly evolved. Staff at MDH have gone on to conduct risk assessments for three additional PFAS (PFHxS, PFBA, PFBS) in drinking water and continue to update their PFAS risk assessments as new data becomes available.

[58] EPA (2020). Announcement of Preliminary Regulatory Determinations for Contaminants on the Fourth Drinking Water Contaminant Candidate List. Retrieved from: https://www.federalregister.gov/documents/2020/03/10/2020-04145/announcement-of-preliminary-regulatory-determinations-for-contaminants-on-the-fourth-drinking-water

Established and revised HRLs and HBVs for five PFAS

MPCA requested soil and groundwater guidance values from MDH in 2002 to assist with investigations in the Superfund program, nearly 20 years ago. Detections of PFAS by the 3M Company at their Cottage Grove facility resulted in MPCA requesting that MDH develop Health Based Values (HBVs) for PFOA and PFOS to assist the MPCA in their site investigations. The first PFAS HBVs in 2002 were chronic HBVs of 7 µg/L for PFOA and 1 µg/L for PFOS, which were based on the limited toxicity information available at the time. New laboratory methods became available in 2006 that expanded the list of chemicals that could be identified in water to include five more PFAS: PFBA, PFBS, PFPeA, PFHxA and PFHxS. In the absence of toxicity information, the HBVs for PFOA and PFOS were at times used as surrogates for PFBA and PFHxS, the two additional PFAS of most concern.

Figure 3. How PFAS guidance has been revised to reflect new findings in the toxicological literature.

<table>
<tr><th></th><th>PFOA µg/L</th><th>PFOS µg/L</th><th>PFHxS µg/L</th><th>PFBA µg/L</th><th>PFBS µg/L</th></tr>
<tr><td>2002</td><td>7</td><td>1</td><td></td><td></td><td></td></tr>
<tr><td>2006</td><td>1</td><td>0.6</td><td></td><td rowspan="2">1</td><td></td></tr>
<tr><td>2007</td><td>0.5</td><td rowspan="3">0.3</td><td></td><td></td></tr>
<tr><td>2008</td><td rowspan="2">0.3</td><td rowspan="2">0.3</td><td rowspan="5">7</td><td></td></tr>
<tr><td>2009</td><td rowspan="2">7</td></tr>
<tr><td>2016</td><td>0.07 (EPA)</td><td>0.07 (EPA)</td><td>0.07</td></tr>
<tr><td>2017</td><td rowspan="2">0.035</td><td>0.027</td><td>0.027</td><td rowspan="2">2</td></tr>
<tr><td>2019</td><td>0.015</td><td>0.047</td></tr>
</table>

Blue = interim; Orange = Surrogate

Revised chronic HBVs for PFOA and PFOS were derived in 2007 and promulgated as HRLs in 2009. As new toxicity information, population-wide exposure, and half-life information continued to accumulate, MDH derived new subchronic and chronic values for PFBA, PFBS, and PFHxS. In order to keep using the best available science for the two longest-established PFAS HBVs, MDH conducted re-evaluations of PFOA and PFOS following the release of EPA's Health Advisories for PFOA and PFOS in 2016. The revised value for PFOA was promulgated as a HRL in 2018. Figure 3 illustrates how PFAS health guidance has evolved over time.

Since 2008, MDH has developed guidance for over 100 chemicals, five of which are in the PFAS family. To maintain accurate and current guidance values, all chemical guidance derived since 2008 is re-evaluated on an approximately five-year schedule. This process identifies whether existing health-based guidance values are up to date with the current available scientific information and current MDH methodology. A chemical may be selected for re-evaluation based on a variety of factors, including the following: substantive new toxicological information, programmatic need for an updated value (including selection of the chemical for rulemaking), and/or an update to MDH risk assessment methodology. A distinct part of this effort is identifying and evaluating high quality, well-designed published studies that have the potential to change the established water guidance values. PFAS water guidance values established by MDH are part of the overall effort MDH maintains to keep guidance values up to date.

As part of the re-evaluation of PFAS, MDH developed a model to better understand how maternal PFAS levels impact infant exposures and used this model to help set the water guidance value at a level protective of all segments of the population, including breastfed infants. Numerous other states also used this open access, publicly available peer-reviewed model to help them set water guidance values for PFAS. Notably, the EPA's health assessments for PFOA and PFOS do not directly consider the additional exposure to infants from exposure to their mother during gestation and breast-feeding. It is possible that when EPA revises their guidance for PFOA and PFOS, they will consider relying on MDH's model or a similar model to ensure protection of the most sensitive groups.

Work status: ongoing

Leader: Health Risk Assessment Unit, Environmental Health Division, MDH. **Partners:** MPCA Remediation, MPCA Environmental Analysis and Outcomes.

Benefits: MDH was the first governmental agency in the nation to develop health-based guidance values for per- and polyfluoroalkyl substances (PFAS) in drinking water -- the EPA did not issue provisional drinking water advisories for PFOA and PFOS until 2009, seven years after MDH derived the initial values for PFOA and PFOS. MDH's health-based values provide risk-based and public health protective guidance to Minnesotans impacted by PFAS in their drinking water, giving Minnesotans vital information regarding when to act on PFAS contamination in water supplies. In collaboration with MDH, municipalities and water utilities across Minnesota use the PFAS HBVs and HRLs to understand the impact to their water resources and when to consider treatment. MPCA additionally uses HBVs and HRLs to determine where bottled water and installation of water treatment should be provided to impacted residents on private wells. The toxicity values derived as part of MDH's guidance development are used by MPCA to develop values for other media with different exposure scenarios than drinking water, such as soil and surface water.

Challenges: As public awareness and concern regarding PFAS has increased, so has research into some of the most commonly monitored PFAS, like PFOA and PFOS. Keeping up with the many journal articles published each month to assess if revisions to HRLs or HBVs are warranted requires significant effort. PFAS are high priority chemicals for review in the Health Risk Assessment Unit and it is anticipated that further evaluations of public health protective water guidance values for PFAS will be needed over the next several decades.

Resources: Since 2015, MDH has completed approximately 30 re-evaluations for chemicals with existing guidance. For PFAS, keeping the guidance for PFOS and PFOA up to date has been a high priority over the past five years. The development of HBVs and HRLs requires sufficient available data, and highly trained exposure scientists, risk assessors, and toxicologists. Establishing new guidance or re-evaluating PFAS guidance can require up to two years for each PFAS. Due to the ever-increasing body of research on PFAS, the future anticipated resource needs are considerable as revision of existing of values and creation of new guidance values are undertaken. The promulgation of the HBVs into HRLs requires legal expertise and management support. Responding to public comments during promulgation can also be time intensive. Access to the scientific publications, as well as establishing and maintaining strong links to other state and federal experts are also required. A new dedicated PFAS toxicologist position would be helpful in continuing to advance this work.

Evaluating additional PFAS for possible new health values under the CEC Initiative

Through this initiative, MDH collaborates with partners and the public to identify contaminants of interest, investigate the health and exposure potential of contaminants of emerging concern (CEC) in water, and inform partners and the public of appropriate actions for pollution prevention and exposure reduction. The CEC Initiative supports the Clean Water Fund mission to protect drinking water sources and the MDH mission to protect, maintain, and improve the health of all Minnesotans. For the fiscal year 2021 work plan, the CEC Initiative received nominations for 24 contaminants to be reviewed and considered for a screening level evaluation of toxicity and exposure potential and then a potential in-depth toxicological review and guidance development. Fourteen of these nominations were for PFAS, underlining the importance of PFAS to MDH partners and stakeholders.[59]

[59] MPCA. (n.d.). Contaminants of Emerging Concern. Retrieved from: https://www.health.state.mn.us/communities/environment/risk/guidance/dwec/index.html#cecnom

Work status: ongoing

Leader: Health Risk Assessment Unit, Environmental Health Division, MDH. **Partners:** Minnesotans, local governments, non-profit organizations, state agencies, professional water resource organizations, the University of Minnesota

Benefits: MDH's CEC Initiative is well established and positioned to respond to citizen, state agency, or other stakeholder needs for PFAS health-based water guidance value development. The diverse stakeholders of the CEC Initiative provide more comprehensive perspectives regarding PFAS (and other chemical) needs in responding to water contaminants found in surface water and groundwater sources. Research, evaluation, and outreach activities around PFAS has been conducted. Developing PFAS water guidance values is a key role of the State's response to PFAS contamination.

Challenges: Evaluating all PFAS scientific studies as they are published is extremely difficult due to the volume of new research published on a wide variety of PFAS topics. Despite this immense volume of publications, key data gaps regarding exposure and toxicity potential persist for many PFAS. MDH has been a leader in developing PFAS water guidance values, and yet to date it only has water guidance values for five PFAS. An additional water guidance value for PFHxA (nominated through the CEC Initiative) is currently being developed.

Resources: The development of water guidance values for chemicals is a staff-time intensive endeavor. The resources needed are highly trained exposure scientists, risk assessors, and toxicologists to evaluate new and existing toxicity and exposure data in order to synthesize an accurate picture of the risks to the general population and the potency of the chemical in question. Only then can MDH arrive at a health protective guidance value that is appropriate for all (CWF) is slated to sunset in 2034, and additional funding would be needed to continue this program after 2034.

Gaps and opportunities

With potentially thousands of PFAS in the environment, there are many gaps remaining in our understanding of PFAS toxicity, exposure, and use. Chemicals are registered for use in commerce and industry at the Federal level, under the TSCA. The TSCA program is run by the EPA. Though there were some changes to TSCA made to tighten chemical regulations so that persistent, bioaccumulative, and toxic substances have more controls and limitations on their uses, there are still very limited data released on new PFAS being registered and PFAS already in use. There could be additional changes to rules under the TSCA to require chronic and multi-generational toxicity studies for persistent compounds *before* these compounds are allowed in commerce, but these rule changes fall under the federal regulatory authority of the EPA. MPCA and MDH have provided formal comments on federal rulemakings in the past and will have opportunities to continue advocating for health-protective evaluations of PFAS under TSCA and other federal programs in the future. At the state level, a potential mechanism to fill gaps in exposure and toxicity data left by the TSCA program is to provide Minnesota agencies with the authority to request toxicity, product use, and release data from industrial and commercial makers or users of PFAS. Though this proposed authority would not compel any entity to conduct toxicity studies, it would help identify which PFAS are present in environmental media and may result in confidential access to non-public toxicity studies. This proposal would require action by state legislators.

Despite the significant ongoing effort to develop and review PFAS health-based guidance values, continued opportunities remain to fill gaps in our understanding of toxicity from ingestion or inhalation of PFAS. MDH could begin conducting regular literature reviews and compile evidence to determine if inhalation risk assessments for various PFAS are possible given the current data landscape. These periodic reviews would allow MDH to derive inhalation risk-based values for PFAS as soon as possible -- these risk-based values would be used by MPCA and others to determine if indoor air or ambient air poses potential health risks. Additionally, MDH could continue the ongoing partnerships with researchers in EPA's ORD to capitalize on novel strategies to better contextualize PFAS risks. This work includes projects aimed at predicting the metabolism and elimination of various PFAS in humans; predicting the likelihood of PFAS exposure based on product use categories and probabilistic modeling; and extrapolating data from high-throughput *in vitro* testing and computational, structure-based, toxicity estimates. MDH is currently researching these cutting-edge risk assessment techniques and could continue testing these new methodologies in the future. Finally, Minnesota has previously applied to the CDC for funding to participate in a multi-state epidemiological study of PFAS health effects. Though CDC did not choose to include the population living in the East Metro as part of their multi-state study, MDH could conduct the proposed epidemiological study in the future if other funding is available. This effort would involve recruiting participants for PFAS biomonitoring and tracking health outcomes in these participants, including health indicators measured in blood and urine such as cholesterol levels and tests of liver, immune, and thyroid function. These proposals are discussed in more detail below.

Establish authority to request data regarding contaminants of potential environmental concern

Authority to allow the MPCA to request information about toxic compounds from companies that create or use them would not prevent the discharge of these compounds into the environment, but would likely help risk assessors gain the information they need to understand if environmental exposures to these toxicants could cause adverse health outcomes. Data gaps with respect to PFAS limit the ability to understand exposure levels in the environment, quantify toxic levels for humans or wildlife, and identify parties responsible for contamination. MPCA would benefit from authority to request information from entities on compounds in products when there is a concern over them. This authority would not require any additional regular reporting by industries or entities, but it would allow MPCA to collect information in a timely manner when concerns over a compound, including information that could help quantify the exposure or toxicity of a specific PFAS. *See* the Remediating PFAS Contaminated Sites Issue Paper for discussion of how this authority would also be relevant to identifying and investigating PFAS sites.

Work status: under consideration – requires legislative action

Leaders: MPCA Safer Chemicals Unit. **Partners**: MDH Health Risk Assessment Unit

Benefits: This authority could help MPCA identify PFAS actively used in Minnesota, which in turn could prioritize research into the toxicity and exposure potential for these compounds. Additionally, if there were an entity that had conducted non-public toxicity testing, this authority would also allow MDH toxicologists to review the information.

Challenges: This authority would allow MPCA to request information from entities, but some crucial data gaps like toxicity information may not filled; entities using or producing PFAS (or others) may not have conducted toxicity testing on the relevant PFAS. This authority would help MPCA respond to PFAS contamination, but it would not prevent entities from using or producing PFAS in the first instance.

Resources: Enacting this authority would not require significant resources. It may save MPCA and other agencies future efforts if they could acquire desired information directly from companies, instead of having MPCA and other agencies recreate studies, techniques, etc.

Compile information on inhalation PFAS toxicity

There is opportunity to better understand if there are potential risks from inhaling PFAS in ambient or indoor air. PFAS health-based guidance currently available from MDH considers PFAS exposure from ingestion, not inhalation. This is largely because there is little understanding of how inhaling PFAS may impact human health, and little understanding of how much exposure to various PFAS from ambient or indoor air could be expected. Despite these significant data gaps, interest in PFAS exposure from air is increasing, which is in turn resulting in additional toxicity and exposure studies being published.

In order to derive health-protective air guidance values, MDH must invest staff time and resources to identify and evaluate high quality peer-reviewed studies that describe health effects from inhalation exposure to PFAS. At this time, inhalation-based PFAS studies are very limited, as are air guidance values from other federal and state sources. MDH plans to begin regularly reviewing the scientific literature related to inhalation studies to identify if and when there is enough information available to conduct inhalation risk assessments. In an effort to keep abreast with new PFAS inhalation literature leading to the eventual development of air guidance, MDH toxicologists are conducting periodic (every six months) literature searches for relevant studies. This effort will be going on concurrently with an MPCA research project monitoring PFAS in air at various locations in the state (*see* the Understanding Risks from PFAS Air Emissions Issue Paper). With this combined effort, it may be possible to quantify health-based air values for PFAS occurring in Minnesota air.

Work status: planned

Leader: Environmental Impacts Analysis Unit, Environmental Health Division, MDH.

Benefits: Monitoring data from MPCA indicates that some PFAS are present in ambient air, and additional PFAS monitoring in air is currently underway. Regularly reviewing the availability of PFAS inhalation data in the scientific literature will allow MDH to develop of PFAS air guidance in a timely manner.

Challenges: The greatest challenge to updating air guidance values is the dearth of inhalation studies available in the literature. It may additionally be difficult to conduct systematic literature reviews with consistent search terms as knowledge about novel PFAS structures evolve over time. Working with experienced librarians to conduct these reviews would be beneficial for this project, and careful record keeping of search strategies and review results will be paramount.

Resources: The development of air guidance values for chemicals is a time-intensive endeavor. Highly trained toxicologists and risk assessors are needed to evaluate available toxicity and exposure data, synthesize an accurate picture of the risks to the general population, and draw conclusions about the potency of the chemical in question. Acquiring publications is costly because MDH does not have access to all journals with potentially relevant publications. Library services are helpful when conducting these types of systematic reviews because they can assist in designing search queries, maintaining and organizing literature review data, and requesting publications via inter-library loans when access is not immediately available. Only after a comprehensive literature review and data analysis can MDH arrive at a health-protective air guidance value that is appropriate for all Minnesotans, including sensitive subpopulations.

Research cutting-edge risk assessment techniques for data-poor PFAS

The availability of toxicity and exposure data, although increasing greatly over the past decade, is still a limiting factor when conducting risk assessments for most PFAS. This problem of scarce data applies to most (CECs beyond PFAS. To address this persistent problem of insufficient data and testing, MDH's CEC Initiative began work in 2011 on a special project called the Alternative Risk Assessment Methodology (ARAM) Project. To date, two phases of the ARAM Project have been completed. The focus of phase one was to identify candidate alternative risk assessment methods that could potentially provide some level of risk context for contaminants with little or no toxicity information. The second phase conducted basic testing of the methods selected as good candidates in phase one. Phase three is still in progress and involves integrating the identified alternative methods into a decision tree and testing if the decision tree is effective with a variety of contaminants and for a variety of health effects. Results from this project indicate that the identified alternative methods work well for many chemicals, including some of the shorter chain PFAS, but do not work well for bioaccumulative chemicals.

Another opportunity to advance understanding of PFAS toxicity could emerge through explorations of novel toxicity review strategies currently under research and development at the EPA and elsewhere. These new strategies are sometimes called "new approach methodologies" (NAMs). Scientists at MDH are currently collaborating with EPA to develop NAMs relevant to Minnesota's risk assessment process. These NAMs could allow for prioritization of PFAS lacking key toxicological and exposure studies, possibly resulting in characterizations of relative toxicity or relative likelihood for exposure among various PFAS. Implementing NAMs could allow for consideration of additional PFAS, especially those that are data-limited, but this effort would likely require additional resources in staff and funding. Because these new strategies for addressing data-poor PFAS are cutting edge, applying any results in a regulatory context would likely face challenges.

MDH has also been working collaboratively with EPA's Center for Computational Toxicology and Exposure on issues of toxicology and exposure for CECs. Part of this project will focus on using NAMs to provide novel toxicity information in cell-based or computer-based testing environments. NAMs are increasingly being used at the federal level to provide toxicity data in a faster way to bridge the data gaps surrounding PFAS and other CECs. To date, NAMs have been used to prioritize chemicals for more testing and to fill specific data gaps. However, the ongoing projects at MDH to develop and assess NAMs will also evaluate the potential of these methods to provide risk context.

Work status: ongoing, additional work planned

Leader: Health Risk Assessment Unit, Environmental Health Division, MDH. **Partners:** EPA, Center for Computational Toxicology.

Benefits: Creating new methods for use in risk assessment is a time-consuming task and requires experienced scientists. Risk assessment as a process requires substantial amounts of data on both toxicity and exposure. Alternative risk assessment methodologies hold great promise in speeding up risk assessment, applying risk assessment science more broadly across a related group of chemicals, and providing faster answers to our most important environmental questions.

While these two projects aimed at researching cutting-edge risk assessment techniques have different scopes and objectives, a shared benefit of both projects is to provide risk context for chemical exposures where traditional toxicology data are lacking or entirely absent. New approaches must be used to address data-poor chemicals and PFAS, and these projects have the potential to address this difficult problem.

Challenges: The challenges to interpreting and applying NAMs are considerable. These new methods for contextualizing risk are inherently less precise due to a lack of full testing data on a specific chemical compound. To date, these methods have primarily been used to prioritize the completion of traditional risk assessments. Additionally, it may take considerable effort to convince stakeholders that these novel risk assessment approaches are valid in various guidance or regulatory contexts.

Resources: MDH will need staff time to continue working with the EPA on NAMs and their application to PFAS risk assessments. Additional staff time will also be needed to see how PFAS can be evaluated under the protocols of the ARAM Project.

Develop of an epidemiological study of residents exposed to PFAS through drinking water

In 2019, the CDC announced that they established cooperative agreements with seven partner states to study the human health effects of exposures to PFAS.[60] Though Minnesota applied to have residents from the East Metro Area be part of this study, other study locations in the US were selected as higher-priority sites for investigation. Were MDH to have an alternative source of funding from the Legislature or another source to conduct this study, the Agency could move forward with the originally proposed epidemiological project. In this health study, MDH would work with the Washington County Department of Public Health and Environment, local water system operators, other local government agencies, and community groups to conduct outreach about the study and determine the best ways to share study findings with the communities. Participants in the study would have PFAS levels measured in their blood and urine and complete a survey to help reconstruct the participants' exposure to PFAS in the past. Then, health indicators measured in blood and urine such as cholesterol levels and tests of liver, immune and thyroid function, along with health surveys, would track the participant's health over time. The study could include adults and children living in a home that is served by a PFAS impacted public water system or a private well in the East Metro with detectible levels of PFAS.

Work status: under consideration, funding for this project would be needed

Leader: Environmental Surveillance and Assessment Section, Environmental Health Division, MDH.
Partners: Washington County Department of Public Health and Environment, local water system operators, other local government agencies, and local community groups.

Benefits: Though animal toxicity studies are able to show how increased PFAS doses damage organ systems under highly controlled conditions, these studies do not capture "real life" experiences of humans with varied exposure levels, genetic susceptibilities, and lifestyles who may be affected by environmental PFAS contamination. Studies that monitor PFAS levels in people and track health outcomes over time, while more difficult to interpret in a risk assessment context than highly controlled animal studies, provide important information for risk assessors and the impacted community about how PFAS exposure may be impacting health.

Challenges: Conducting epidemiological studies has many challenges, including the logistics of tracking the health outcomes from hundreds or thousands of participants over time, the technical challenges of reconstructing exposure histories for participants, and the complexities of communicating results to the impacted communities. It is possible that the results of the study would not be conclusive, or would show that there is not an association between PFAS exposure and the health outcomes tracked in the study. Conducting an epidemiological study would require ongoing effort from a number of staff with a variety of areas of expertise over the course of many years.

Resources: This effort would require approximately $8 million to $9 million in funding over the course of five years.

Overview of intersectional issues

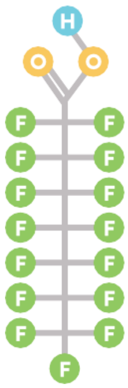
- **Drinking water monitoring**. Continuing to monitor for PFAS in drinking water will help prioritize risk assessments for oral routes of exposure.
- **Understanding air emissions**. Expanding emission reporting and monitoring for PFAS in air will help prioritize risk assessments for inhalation routes of exposure.

[60] ATSDR. (2020). Per- and Polyfluoroalkyl Substances (PFAS) and Your Health. Retrieved from: https://www.atsdr.cdc.gov/pfas/activities/studies.html

- **Analytical methods**. Measuring PFAS is expensive and time-intensive, and available methods include only a subset of all PFAS that may be occurring in drinking water. Improved access to and funding for non-targeted PFAS methods will help identify the complete landscape of PFAS that may be occurring in drinking water, food, soil, or other relevant media. This will help prioritize the development of new research and risk assessments.
- **Pollution prevention.** Reducing PFAS pollution at the source places the cost burden with polluters rather than impacted parties, like drinking water utilities and the general public. Though chemical registration occurs at the federal level, Minnesota could continue to enact chemical use regulations for PFAS in the state (like the existing ban on uses of PFAS-containing firefighting foam for training or testing purposes) and can continue to request that EPA require substantial evidence that a substance is has very low toxicity if it is environmentally persistent before it is allowed in industry or commerce.

Limiting PFAS exposure from drinking water

Background



- **Minnesotans value safe and sufficient drinking water** – when PFAS pollution is discovered, the first questions from the community are frequently about the safety of their drinking water.
- Historic disposal of PFAS waste in the East Metro caused PFAS contamination of drinking water, affecting over 174,000 Minnesotans. Temporary treatment systems were put in place to reduce PFAS concentrations at impacted drinking water supplies -- efforts to remediate this contamination and implement long-term drinking water supply plans are ongoing.
- Over time, decreases in detection limits for PFAS and improved understanding of PFAS toxicity have contributed to the realization that many PFAS are **ubiquitous in the environment** and that some PFAS are **toxic at low doses**.
- PFAS **contamination in drinking water is not limited to waste sites associated with PFAS manufacturers** – drinking water impacts associated with use of PFAS-containing firefighting foam and industrial activities have been discovered.
- Federal and state regulations align to protect water consumers. On the federal level, drinking water monitoring and regulation falls under the SDWA.
  - Though MDH has health-guidance values for five PFAS, there are currently **no federal or state drinking water standards for PFAS** (i.e. Maximum contaminant level [MCLs]).The process for federal rulemaking under SDWA has begun for PFOA and PFOS. Based on statutory deadlines in SDWA, implementation of the proposed regulations would likely begin in 2025.
  - Because there are no SDWA standards for PFAS, water systems may not be prioritized by the **Drinking Water Revolving Fund**, which provides below-market-rate loans and grants for improving or constructing treatment systems.

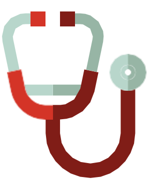
What is Minnesota doing now?

- MDH is prioritizing **monitoring drinking water** for PFAS – this effort fills gaps left by federally-required monitoring for PFAS.
  - MDH has planned and ongoing monitoring efforts in place that will cover **at least 90% of people served by community water systems by 2025**. This effort is expected to require at least $10-15 million in resources for sampling, analysis, and follow-up action.
  - MPCA and MDH work with property owners to **test private wells** in areas with known groundwater PFAS contamination. Minnesota has collected over 20,000 samples from approximately 4,000 private wells and continues to receive requests for sampling.
- If concentrations of PFAS are found in drinking water that exceed MDH guidance values or the Health Risk Index based on guidance values, MDH works with drinking water systems or private well owners on appropriate **next steps to reduce exposure**.
- MDH **continuously updates communication materials** related to PFAS and drinking water to ensure clear, complete, and up-to-date scientific information is included.
- MPCA has included PFAS in two rounds of monitoring in the Ambient Groundwater Well Network, which provides an **early warning system for PFAS migration into drinking water aquifers**.
- MPCA and MDH are continuing to collaborate on potential drinking water impacts at known or likely PFAS-contaminated sites.

What are remaining gaps and opportunities for action?

- **Gap**: Reducing or eliminating ongoing sources of PFAS to waterbodies used as drinking water supplies prevents the need for costly interventions like installing drinking water treatment systems for PFAS.
  - **Opportunity**: MPCA can revise the Class 1 Water Quality Standards, which protect drinking water sources from pollution, to include PFAS. These revisions would allow MPCA to set limits for permittees discharging PFAS to waters used as a source for drinking water.
- **Gap**: The past and ongoing initiatives to monitor drinking water systems for PFAS will capture at least 90% of all community water consumers by 2025, but not all consumers.
  - **Opportunity**: Expanding drinking water monitoring to all community water systems or monitoring planned systems faster would require additional funding and lab capacity.
- **Gap**: Twenty-one percent of Minnesotans (~1.2 million people) get drinking water from a private well, and currently private well monitoring only occurs near sites with known PFAS groundwater contamination.
  - **Opportunity**: As the Pilot PFAS Inventory Project (*see* the Remediation PFAS-Contaminated Sites Issue Paper) and drinking water monitoring efforts identify new PFAS plumes, additional funding may be needed to identify impacted private drinking water wells. Funding to include PFAS in annual monitoring of the Ambient Groundwater Monitoring Network would additionally help identify impacted or vulnerable aquifers.
- **Gap**: There are not currently drinking water standards (MCLs) for PFAS.
  - **Opportunity**: MDH could evaluate options for managing risks from federally unregulated contaminants, including PFAS. Federal rulemaking for PFAS drinking water standards has begun, but would not be completed until 2025.

How does this work benefit human health and the environment?



- Monitoring for PFAS in drinking water has the direct benefit of promptly **reducing PFAS exposure** with appropriate interventions if levels exceed those thresholds and **reducing consumer anxiety** about exposure if levels are below health-based thresholds.
- Drinking water monitoring **informs investigations** into sources of PFAS, which can sometimes result in cost recovery from parties responsible for the pollution.
- Reducing PFAS emissions to source waters for drinking water prevents harmful exposure to humans, but also **reduces exposure for fish and wildlife** using those waterbodies.

How does this work benefit Minnesota's economy?

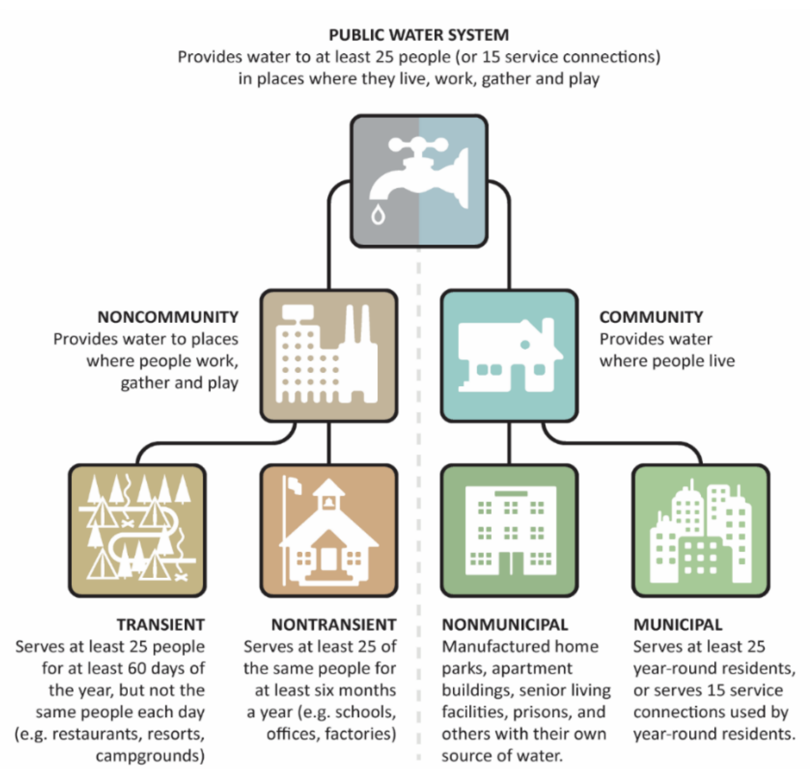
- Well-developed regulations for PFAS ideally **place the cost burden of PFAS controls with polluters** rather than imposing those costs on drinking water utilities and the general public.
- Safe and trusted drinking water is crucial **to business development** in Minnesota and growth in the **housing market**.
- **Preventing adverse physical health outcomes** associated with PFAS exposure and **preventing negative mental health outcomes** associated with concern over exposure is financially beneficial for families and individuals

MINNESOTA

Background

Minnesotans value safe and sufficient drinking water – when new instances of pollution are discovered, the first questions from the community are frequently about the safety of their drinking water. In many cases, assessments demonstrate that contaminated drinking water is a meaningful source of exposure to pollution. Because drinking water is an avenue for potential exposure to environmental pollutants and because there is high public interest in drinking water safety, there are a network of federal and state laws in place to ensure drinking water is safe.

Figure 4. Categories of public water systems.

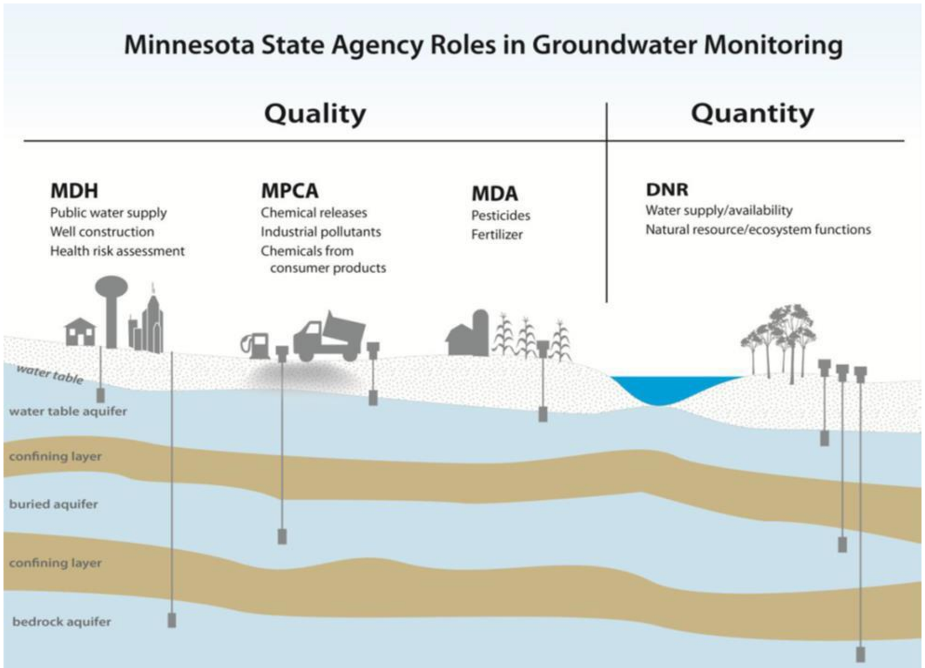


The structure for regulating public drinking water systems in the US is largely centralized at the EPA. Under the SDWA, a federal law enacted in 1972 and amended in 1986 and 1996, EPA has the authority to enact drinking water regulations that apply in every state. Notably, EPA has not regulated a new chemical under SDWA since the 1996 Amendments to the law were passed by Congress -- these amendments included a mandatory consideration of costs and benefits before a rule could be promulgated. The federal rules under SDWA for public drinking water systems require monitoring for regulated contaminants at specified intervals. However, SDWA also requires that a subset of all water systems monitor for up to 30 unregulated contaminants every five years. The data gathered in this unregulated contaminant monitoring program provides information used to determine if new drinking water regulations are needed.

These federal drinking water regulations do not apply to all drinking water consumed in Minnesota. Many federal drinking water standards apply only to “community” and “non-transient non-community” drinking water supplies, which includes water distributed by systems like municipalities, senior living facilities, apartment buildings, and manufactured home parks, but does not include water from “transient non-community” systems (like some campgrounds, rest areas, and resorts). Figure 4 illustrates the different regulatory categories of drinking water systems and who they serve. Federal regulations under SDWA also do not apply to private wells – there is no mandatory testing of private wells and there are no enforceable limits for contaminants in private drinking water wells. Most Minnesotans receive their drinking water through public water systems, but approximately 21% of Minnesotans (about 1.2 million people) obtain drinking water from private wells.

Some states have the authority under state law to enact additional drinking water regulations or protections that can help fill gaps in regulations set by the EPA. Minnesota does not currently have clear regulatory authority to enact state drinking water regulations (MCLs), but does have the ability to fill other gaps in federal drinking water regulatory authority. For example, there is a gap in federal drinking water regulations when it comes to drinking water from private wells. In Minnesota, the Groundwater Protection Act (Minn. Stat. 103H) articulates that groundwater should be "free from any degradation caused by human activities." Under this statute, the protection of groundwater is the shared responsibility of MPCA, Minnesota Department of Agriculture (MDA), MDH, and Minnesota Department of Natural Resources (DNR) (see Figure 5).

Figure 5. State agency roles in groundwater monitoring.



Though these agencies collaborate to protect groundwater used for private drinking water consumers, MDH is the lead agency in the regulation and monitoring of water systems that distribute water to the public. In general, states can set enforceable limits similar to federal regulatory standards (MCLs) for public water systems if state law provides that authority – these standards can result in more stringent protections for compounds that are already regulated under SDWA or set new limits for compounds not regulated under SDWA, but no state can promulgate less protective regulations than those enacted by the EPA. In Minnesota, developing and promulgating state regulatory values beyond those currently adopted by reference from SDWA would require a significant investment in changing statutory authority, creating a process that would likely include a cost benefit analysis in addition to the current guidance protocol, and adding the capabilities for this expanded work.

Funding is available through SDWA to help drinking water systems comply with federal drinking water regulations. The Drinking Water Revolving Fund (DWRF) provides below-market-rate loans and grants to municipalities and other community drinking water systems. Loans and grants can be used to improve or construct treatment, storage, and distribution systems. However, because PFAS are not currently regulated under SDWA, infrastructure projects related to treatment for PFAS are less likely to rank high on the priority list because they are not addressing a violation.

Monitoring PFAS in drinking water and groundwater

As state and federal awareness of PFAS emerged and expanded, there has been a patchwork of monitoring efforts undertaken as needs were identified and funding was available. Minnesota is currently working to synthesize existing data and enact a coordinated monitoring strategy for PFAS in public water systems and groundwater that may be tapped for private or public drinking water wells.

Monitoring of finished drinking water

The federal UCMR program required all public water systems serving more than 10,000 people to monitor for six PFAS between 2013 and 2015, which captured the community water systems (CWSs) in Minnesota serving the largest populations, including Minneapolis, St. Paul, Rochester, Duluth, and Bloomington. The same federal monitoring program will require additional monitoring for a larger group of PFAS at lower detection limits from 2023 to 2025. Though this mandatory federal monitoring of public water systems is extensive, it does not include all community water systems in Minnesota. MDH is working to fill those gaps.

Outside of the federally-mandated monitoring for PFAS in CWSs, MDH is taking on several additional public water system monitoring efforts. Some MDH monitoring efforts aim to explore whether there is an impact to drinking water in known areas of concern. These projects target monitoring at systems with higher risk for PFAS based on the location of known PFAS sources and the vulnerability to contamination of the aquifers sourcing the drinking water. Prioritizing monitoring in these areas also helps to protect areas of potential concern for environmental justice or health inequities, including communities of color and small rural communities.[61] These trends of increased environmental burden on communities of color are likely partially attributable to decades of zoning and housing policies common across America that segregated these communities into areas with higher pollution and allowed industries to develop in historically Black, Indigenous, and people of color neighborhoods. By prioritizing PFAS monitoring at CWSs near known or anticipated PFAS sources, MDH will be able to respond to PFAS in these communities if elevated concentrations in drinking water are found. Other MDH drinking water monitoring projects include monitoring randomly selected CWSs, which will help identify if there are currently unknown areas of PFAS contamination. Finally, some MDH monitoring projects include re-sampling systems that had already been monitored for PFAS to both understand how levels have changed over time and take advantage of new analytical methods with more PFAS analytes and the ability to detect PFAS at lower concentrations. Accounting for the planned and ongoing monitoring projects, MDH plans to sample approximately 295 of the 964 total CWSs in Minnesota by 2025 (see Table 3). These monitoring programs will cover approximately 4 million people, or over 90% of the population served by CWSs.

[61] Reed, Geena. (2019). PFAS Contamination Is an Equity Issue. Union of Concerned Scientists. Retrieved from: https://www.ucsusa.org/sites/default/files/2019-11/abandoned-science-summary-eng.pdf ; https://www.ucsusa.org/sites/default/files/2019-10/Appendix-Equity-Report-10-2019.pdf

Table 3. Summary of community water system monitoring efforts from 2006 to 2025.

Activity	Years	Number of new CWSs sampled for PFAS	Number of PFAS included	Description of CWSs sampled
PFAS Response Monitoring	2006-present	50*	7	Targeted sampling: CWSs known to have nearby sources of PFAS
UCMR3	2013-2015	55	6	General and random sampling: All CWSs serving > 10,000 people, some CWSs serving <10,000 people
UCMP	2019	30	30	Targeting sampling: CWSs sourced with surface water, CWSs potentially impacted by wastewater discharge
Statewide PFAS Monitoring	2020-2021	~100**	29	Combined targeted and random sampling: Random selection of statewide CWSs and additional sampling of prioritized sites
UCMR5	2023-2025	~60***	29	General and random sampling: All CWSs serving > 10,000 people, all CWSs serving 3,300-10,000 people if sufficient lab capacity and funding
Totals	2005-2025	~295**	varied	

*as of August 2020, monitoring is ongoing; ** subject to change ***assuming funds available for systems serving 3,300-10,000 people

In addition to monitoring CWSs, Minnesota has also sampled thousands of private drinking water wells for PFAS near areas of known PFAS contamination. Since 2003, MDH has been investigating groundwater contamination in the suburban communities east of St. Paul, near the 3M manufacturing facility and its legacy waste disposal sites. To date, approximately 3,900 private wells have been sampled in these communities. More recently, Minnesota has also been sampling private wells near firefighting foam-contaminated sites in Bemidji and Duluth. In total, the state has collected over 20,000 samples from approximately 4,000 private wells and continues to receive requests for sampling.

PFAS monitoring in Minnesota's Ambient Groundwater Well Network

In order to identify trends in groundwater quality over time and have an "early warning system" for contaminants threatening drinking water aquifers, both the MDA and MPCA have developed ambient groundwater monitoring networks. The Minnesota Groundwater Protection Act (Minn. Stat. ch. 103H) assigns the ambient groundwater quality monitoring responsibilities to the MDA and MPCA, with MDA responsible for assessing agricultural chemicals (including pesticides and fertilizers), and the MPCA responsible for assessing all other non-agricultural contaminants. The MPCA and MDA each maintain ambient groundwater-monitoring network that, combined, provide spatial coverage of groundwater quality conditions across the state. Funding provided by the Clean Water Legacy Amendment allowed MPCA to expand its network of ambient groundwater wells and begin monitoring for contaminants of emerging concern (CECs). MPCA's network mainly is comprised of shallow monitoring wells, which comprise an "early warning system" due to their vulnerability to contamination, but also includes some deep wells, which represent conditions in aquifers currently used for drinking water consumption. This monitoring network allows the agency to understand how quickly contamination from the surface is percolating downward into aquifers used for drinking water. PFAS monitoring is not regularly included, but the MPCA has conducted two rounds of PFAS monitoring in the full ambient groundwater network: one round in 2013 (with limited follow up in 2017) and another round in 2019.

Connecting monitoring results and PFAS remediation projects

Minnesota is focused on monitoring drinking water and groundwater because it helps the state identify sources of contamination, PFAS concentrations, and potential exposures so that exposures above safe levels can be prevented. Sometimes drinking water or groundwater monitoring has led to the discovery of new PFAS-contaminated sites that need to be cleaned up. In other instances, the discovery of a new industrial PFAS source leads to targeted monitoring to ensure that potentially impacted drinking water is not at levels that could adversely affect human health. The flow of information between the drinking water programs in MDH and the site remediation programs and groundwater monitoring programs in MPCA is crucial for both agencies' success in reducing and preventing PFAS exposures. The Pilot PFAS Inventory Project (described in the Remediation Issue Paper) combines data from MDH and MPCA to facilitate this exchange of PFAS information.

Proactively protecting source waters from PFAS contamination

Both groundwater and surface water are used as drinking water sources in Minnesota – several state agencies collaborate to limit pollution to all source waters for drinking water. This work is crucial in preventing and reducing the need for treatment or other costly interventions to remove contaminants from drinking water. MDH develops HRLs for ambient groundwater under the 1989 Groundwater Protection Act.[62] These HRLs are used by partner state agencies for contextualizing the results of groundwater water monitoring and making risk management decisions in scenarios where activities may be impacting groundwater quality. For example, MPCA uses HRLs derived by MDH as clean-up goals at sites with groundwater contamination.

MPCA also participates in protecting source waters for drinking water through its CWA authorities. MPCA regulates entities discharging contaminants to the environment using Water Quality Standards (WQS), which are the rules promulgated by Minnesota under the CWA framework to set effluent discharge limits for permittees. Water Quality Standards are designed to protect specific "beneficial uses," which are definitions of how people and wildlife may be using the natural resource of surface water. One of these beneficial uses in the CWA framework is the use of water for domestic consumption, which includes drinking water supplies, culinary uses, and food processing uses.[63] Minnesota has organized water bodies into "classes" where various combinations of "beneficial uses" apply. Class 1 is the class of waterbodies in Minnesota that includes the beneficial use of domestic consumption, and Class 1 WQS apply to waterbodies designated in this class.[64] Any updates to the Class 1 WQS require rulemaking. MPCA is considering adding PFAS standards, which would eventually be used to set any necessary limits for permittees discharging PFAS to waters used as a source of drinking water. This would limit PFAS pollution from permitted point sources to waterbodies before they are used as sources for private or public water consumption, potentially preventing the need for PFAS treatment or other costly interventions at the drinking water utility or private well.

Scientific challenges

Despite the progress made in understanding the landscape of PFAS drinking water exposure in Minnesota, challenges remain. There are thousands of compounds in PFAS family, but only about 40 PFAS have widely available analytical methods and only five PFAS have completed risk assessments from MDH. Because toxicity data for most PFAS are not available, performing risk assessments and deriving health-based guidance values for those compounds is currently not possible. Limitations in analytical methods (*see* the Measuring PFAS effectively and Consistently Issue Paper) and toxicity analysis (*see* Quantifying PFAS Risks to Human Health Issue Paper) mean that grouping PFAS for risk assessment or regulation by chemical structure, toxicity, or other mechanism has many remaining challenges. In

[62] The health risk limit is the concentration of a chemical in drinking water that, based on the current level of scientific understanding, is likely to pose little or no health risk to humans, including vulnerable subpopulations. See the quantifying human health effects issue paper for more information on PFAS health-based guidance.
[63] More information on water quality standards can be found at: https://www.pca.state.mn.us/water/water-quality-standards
[64] Minnesota Administrative Rules 7050.0221. Specific Water Quality Standards for Class 1 Waters of the State; Domestic consumptions. Retrieved from: https://www.revisor.mn.gov/rules/7050.0221/

addition, there are currently not requirements for chemical companies to share information on the use of PFAS and, until 2020, there were no requirements for industrial facilities to report releases of PFAS to the environment. This lack of information about which PFAS are in use and where PFAS emissions are occurring make it difficult to prioritize monitoring locations for drinking water. Finally, the costs and technological capabilities of PFAS treatment systems make removing PFAS from drinking water scientifically complex and financially burdensome (*see* the Managing PFAS Waste Issue Paper). All of these challenges make it difficult to prioritize which PFAS should be investigated in drinking water and expensive to respond to PFAS pollution when it is found.

Past and ongoing efforts

The following sections describe completed, ongoing, and planned projects related to drinking water monitoring, drinking water interventions (providing clean drinking water), and biomonitoring of exposed residents.

Drinking water interventions

Biomonitoring for PFAS in communities with impacted drinking water

After PFAS contamination was discovered in private and municipal wells in the Oakdale and Cottage Grove/Lake Elmo area, drinking water treatment technologies were installed to reduce exposure in 2006. The following year, MDH was directed by Minnesota law to conduct pilot-scale biomonitoring in two communities likely to be exposed to PFAS. This study was developed to understand how the drinking water PFAS exposure was affecting PFAS levels in resident's blood. The study results illustrated that reductions in PFAS exposure from drinking water treatment resulted in a decline in PFAS blood serum levels in the affected communities over time.

In total, three rounds of biomonitoring studies were conducted, in 2008, 2010, and 2014. The studies followed the same group of residents over time to see how their PFAS blood levels changed. Oakdale and Cottage Grove/Lake Elmo were selected in the initial 2008 study due to historic public and private well contamination. Adult residents who were longer-term residents of Oakdale, Cottage Grove, and Lake Elmo agreed to participate, providing a blood sample for PFAS testing and answering a short survey. The 2014 study also included a group of newer Oakdale residents who moved to the area after drinking water treatment was in place.

Biomonitoring results from this study demonstrated that these East Metro residents had considerably higher blood levels for PFOS, PFOA, and PFHxS than the general population of the US. Blood levels of PFOS, PFOA, and PFHxS declined in long-term East Metro residents over the six-year period, though they remained higher than the US population. PFAS levels were related to the number of years they drank untreated water in the East Metro before the drinking water treatment began and other factors. PFAS blood levels in the newer residents, who moved in after treatment began, were similar to the US population. This study was not designed to assess health impacts of PFAS.

Results from the biomonitoring studies demonstrated that efforts to reduce drinking water exposure to PFAS in the East Metro were successful in reducing PFAS blood levels. Due to the body's poor ability to get rid of PFOS, PFOA, and PFHxS, as well as ongoing exposures from sources beyond drinking water (e.g., diet, household dust, consumer products) these chemicals are still elevated in the blood of long-term East Metro residents even after a decade or more of public health interventions. MDH anticipates that, over time, East Metro residents' blood levels will continue to decline to the "background" level.

Work status: completed

Leaders: MDH Chronic Disease & Environmental Epidemiology Section, MDH Biomonitoring program, MDH PHL, MDH Environmental Health Division. **Partners**: East Metro communities, MPCA Remediation Division, Environmental Health Tracking and Biomonitoring Science Advisory Panel, local public health agencies.

Benefits: These studies were conducted to more fully understand the impact of contaminated drinking water on blood levels of PFAS in Minnesotans, and to determine whether public health interventions to reduce PFAS in drinking water were effective in reducing blood levels. The studies allowed MDH to analyze some demographic characteristics: MDH did not find differences in PFAS blood levels between people who rent verses own their homes, or between people of different income levels. Some PFAS were higher in non-Hispanic White people compared to other groups.

Challenges: PFAS biomonitoring is a time and resource-intensive endeavor. Developing robust and accurate laboratory methods needed to analyze PFAS in blood was challenging. Recruitment of participants using epidemiologic methods and collecting blood samples also required significant time and resources, particularly tracking participants over the course of many years. Careful public messaging and engagement with the community in the areas of risk communication and outreach also was resource intensive, requiring a long-term, sustained effort. Outreach to health care providers in the affected areas was another important area of attention. As PFAS blood testing is not a standard clinical test, providers needed background information and support to help their patients understand their blood testing results. Finally, working with different divisions of MDH and other state agencies, community members, elected officials, local public health officials, and the Environmental Health Tracking and Biomonitoring Science Advisory Panel all required thoughtful planning and coordination.

Resources: This project involved significant staff time for approximately eight years. The first round of biomonitoring conducted in 2008 cost approximately $250,000 for sampling and analysis. Subsequent rounds of biomonitoring had similar costs.

Drinking water and groundwater monitoring

Third Unregulated Contaminant Monitoring Rule (UCMR3) (2013-2015)

Every five years, the EPA implements the UCMR. The purpose of UCMR is to collect data from across the country on contaminants that may be present in drinking water. EPA uses this data to decide if the contaminants occur at frequencies and concentrations high enough to be regulated in the future. The third round of UCMR, UCMR3, required monitoring for 30 contaminants, including six PFAS (PFOA, PFOS, PFNA, PFHxA, PFHxS, PFBS), between 2013 and 2015. UCMR3 included all CWS serving more than 10,000 people and a statistically representative subset of systems serving 10,000 or fewer people. In Minnesota, MDH covered the analytical costs of UCMR sampling in large systems, while the EPA covered the analytical costs for small systems. From 2013-2015, 98 CWS were sampled; 55 of these were sampled for PFAS for the first time. MDH detected PFAS at five CWS: Oakdale, Bemidji, Hastings, Woodbury, and Cottage Grove. Bemidji was the only CWS where PFAS had not previously been detected. MDH worked with these CWSs to conduct on-going monitoring and discuss options for treatment. Data resulting from UCMR3 monitoring can be found at EPA website or the consumer confidence reports from any CWS that participated in monitoring.[65]

[65] EPA (n.d.) Occurrence Data for the Unregulated Contaminant Monitoring Rule. Retrieved from: https://www.epa.gov/dwucmr/occurrence-data-unregulated-contaminant-monitoring-rule#3

Work status: completed

Leaders: MDH Drinking Water Protection Section and EPA Office of Ground Water and Drinking Water. **Partner**: Public water suppliers.

Benefits: Participation in UCMR monitoring is mandated by the EPA, but the resulting data are useful for understanding the landscape of potential contaminants of emerging concern. This surveillance for PFAS in Minnesota and nation-wide drinking water is being used to support federal regulation for PFAS under SDWA. The resulting data also identified one location in Minnesota where further monitoring, interventions to reduce PFAS concentrations in drinking water, and investigations into PFAS sources were warranted. The reductions in PFAS resulting from voluntary interventions following monitoring directly benefited Minnesotans by reducing PFAS exposure for drinking water consumers.

Challenges: Data collected as part of UCMR3 was useful in identifying previously unknown locations of PFAS in drinking water, but this survey had some limitations. Perfluorobutanoic acid (PFBA) was not included in UCMR3 sampling -- MPCA and MDH are now aware that PFBA is the most commonly detected PFAS in drinking water in Minnesota. Additionally, detection limits for sampling during UCMR3 were higher than detection limits that can be achieved currently. Notably, current HRLs for some PFAS are lower than UCMR3 detection limits for those compounds, meaning that a result reported as non-detect could still be an exceedance of an HRL. The number of systems with PFAS detections in UCMR3 may have been higher if PFBA had been one of the included contaminants or if detection limits had been lower. MDH is conducting several other monitoring initiatives to resample systems included in UCMR3, sample small systems not included in UCMR3, and sample private drinking water wells, which are not included in UCMR surveys.

Resources: MDH engineers helped conduct sampling and staff oversaw the project completion. MN covered the analytical for sampling in large systems (~$90,000), EPA covered the analytical costs for small systems.

PFAS Response Monitoring (2006 – ongoing)

The goal of the PFAS Response Monitoring project is to provide ongoing monitoring support to CWS that may be impacted by PFAS contamination as new PFAS sites are discovered. MDH has conducted ongoing sampling at 13 CWSs in the East Metro. Overall, approximately 250 samples are collected each year at these 13 CWSs. Response monitoring for PFAS also occurred in 2008 to investigate drinking water supplies near firefighting training sites known to be associated with use of PFAS-containing AFFF). MDH has additionally sampled 37 other CWSs for PFAS that are not associated with either the East Metro community or near AFFF sites. There is an ongoing collaboration between MPCA and MDH to share data and identify locations where drinking water monitoring is warranted based on potential impacts from PFAS pollution. This response monitoring effort also includes monitoring for PFAS in private drinking water wells. Approximately 3,900 private wells have been sampled in the East Metro area communities. More recently, the state has also been sampling private wells near AFFF sites in Bemidji and Duluth. To date, the state has collected over 20,000 samples from approximately 4,000 private wells. Drinking water advisories, based on health-based drinking water guidance values from MDH, have been issued to approximately 1,300 wells.

Work status: ongoing

Leader: MDH Drinking Water Protection Section. **Partners**: MPCA Remediation, participating public water suppliers, participating private well owners.

Benefits: This ongoing project allows MDH and partnering groups to monitor for PFAS in drinking water systems near known PFAS sources. Having a program in place to conduct this monitoring allows for more efficient collaboration between MDH and MPCA and a faster response when new

PFAS sites with potential drinking water impacts are discovered. This timely response, prepared communication plans, and the dedicated time of various hydrologists and engineers helps to minimize community concern if an issue arises. This response sampling has also added to MDH and MPCA's general understanding of the overall burden of PFAS in Minnesota drinking water.

Challenges: There are no mandatory PFAS emission reporting requirements currently in place, and future regulations on PFAS emission reporting by the EPA under the Toxics Release Inventory (TRI) will not require all PFAS emissions to be reported. This lack of information about industrial PFAS sources makes it difficult to identify potential PFAS sources impacting drinking water. There is a lack of drinking water regulations (MCLs) for PFAS, meaning that drinking water systems are not compelled to take actions if there are exceedances of health-risk levels. Financing treatment systems can also be a challenge, especially if there is not a "responsible party" under the Superfund program identified.

Resources: This effort involves multiple staff from MDH overseeing these drinking water monitoring efforts. Staff help with communication and coordination with water systems, formulating sampling plans, and providing expertise on PFAS hydrology. Some sampling associated with PFAS remediation sites can be funded through MPCA.

Unregulated Contaminant Monitoring Project (2019 - 2021)

The goal of the Unregulated Contaminant Monitoring Project (UCMP) is to understand the presence and abundance of a large number of unregulated contaminants in surface water, vulnerable groundwater drinking water sources, and finished drinking water around the state. The contaminants included in UCMP were selected based on detection in previous monitoring studies and public health interest – 30 PFAS were included alongside approximately 100 other analytes. In this effort, MDH has collected PFAS samples from 46 CWSs using surface water as a drinking water source or using groundwater that is potentially impacted by wastewater. Of the included systems, 30 had not previously been monitored for PFAS. Potential for wastewater impacts in groundwater was determined using past detections of contaminants associated with wastewater and geologic considerations. United States Geological Survey (USGS) collaborated in designing the monitoring plan and are currently assisting in analyzing results. Once complete, the results from this monitoring effort will be published in a publicly available report. If results from monitoring indicate that additional actions are needed to protect consumers, MDH will work with the CWSs and involve the MPCA Remediation program as needed.

Work status: ongoing

Leaders: MDH Drinking Water Protection and USGS Water Science Center. **Partner**: Participating public water suppliers, MPCA Remediation, MDA Pesticide Monitoring Group.

Benefits: Surface water and vulnerable groundwater are the most likely drinking water sources to be impacted by anthropogenic contaminants like PFAS. By focusing monitoring on drinking water systems that are most vulnerable, resources will be prioritized towards the most likely areas of concern. If there are exceedances of health-based values for any of these emerging contaminants, proactive monitoring will inform the need for additional monitoring and possibly interventions to reduce exposure.

Challenges: This is a large, interdisciplinary project that required significant one-time financial contributions to get off the ground. Continued work depends on additional funding. Analytical support from USGS continues to be especially helpful.

Resources: Several staff are involved in overseeing this project, including a project manager, and an advisory group with staff from MPCA, MDA, and USGS. There are additionally two full-time samplers who collected samples for this project. This project was made possible by funding from the Environment and Natural Resources Trust Fund, which contributed $1 million.

Statewide PFAS Monitoring Program (2020-2021)

The goal of this project is to monitor prioritized drinking water systems for PFAS and a select number of randomly selected drinking water systems. MDH has identified methods for assessing the vulnerability of aquifers to anthropogenic contaminants like PFAS, and has categorized aquifers into either "vulnerable" or "non-vulnerable" categories. This project is similar to the Unregulated Contaminant monitoring project in that it focuses on CWSs that are sourced from vulnerable aquifers; however, it prioritizes sites near known or suspected PFAS sources, only involves monitoring of PFAS analytes, includes a larger group of CWSs, and includes a number of non-community water systems. This effort is funded by EPA though a Multi-Purpose Grant and through the CWF. MDH collaborated with MPCA to determine high-priority systems based on proximity to sites anticipated to have PFAS uses, proximity to known PFAS contamination, and the vulnerability of the source waters. As part of this effort, MDH will resample approximately 30 CWSs near AFFF sites that had previously been monitored. This resampling is beneficial because current methods include a larger list of PFAS analytes and lower detection limits than previous methods could achieve. MDH will work with water systems if any next steps are needed. Some funding from this project will be set aside for following up on results of the previously described initiative, "targeted monitoring near likely PFAS sources."

Work status: ongoing

Leaders: MDH Drinking Water Protection and MPCA Remediation Division. **Partner**: Participating public water suppliers.

Benefits: This project specifically targets drinking water systems located near potential PFAS emission sites and vulnerable to contamination. Prioritizing monitoring in these sites will allow MDH to assist water systems with addressing PFAS contamination as quickly as possible, if such interventions are shown to be needed. The communities included in this sampling effort represent a variety of households, neighborhoods, and socioeconomic groups. Because this project will also randomly select systems to monitor, it may help MDH and MPCA find currently unknown PFAS contamination sources.

Challenges: The lack of PFAS labeling and use and emissions reporting requirements makes it difficult to identify industries or facilities that have historically used or may be currently using PFAS – assumptions based on known PFAS uses in certain industries are relied on to identify potential PFAS sources instead of more concrete data. Convincing water systems to participate in this voluntary monitoring effort can also be a challenge – because PFAS is not regulated on the federal level (there are no MCLs), discovering PFAS contamination in exceedance of health-risk values does not result in prioritization for funding through the DWRF.

Resources: Several staff from MDH and MPCA assist in project management and planning. One staff from MDH dedicated several months to collecting samples from participating CWSs. The EPA Multi-purpose Grant (MPG) includes $88,000 during Fiscal Year (FY) 2019 and an additional $63,000 in FY 2020 funds dedicated to sampling drinking water. This effort will additionally be funded through the CWF.

Measuring PFAS in the Ambient Groundwater Monitoring Network

The Minnesota Groundwater Protection Act (Minn. Stat. ch. 103H) splits the ambient groundwater quality monitoring responsibilities between the MDA and MPCA, which each agency maintaining their own ambient groundwater-monitoring network that, combined, provides good spatial coverage of groundwater quality conditions across agricultural regions and non-agricultural regions in the state. The MPCA's ambient groundwater monitoring primarily targets aquifers in urbanized parts of the state, and contaminants included in monitoring generally do not include agricultural compounds like pesticides. MPCA's network mainly is comprised of shallow monitoring wells which intersect the water table but also includes some deep wells. The shallow wells, which have a median depth of 22 feet, comprise an "early warning system" and allow the Agency to understand what chemicals can readily be transported to the groundwater and identify emerging trends in groundwater quality. The deep wells, which primarily are domestic wells installed in the Prairie du Chien-Jordan aquifer, provide information on the quality of the water that is consumed by Minnesotans and information about how quickly any contamination from the surface is percolating downward.

Funding from the CWF allowed the MPCA to install shallow monitoring wells in key areas where existing wells were not available, such as residential areas that use subsurface sewage treatment systems for wastewater disposal, and commercial or industrial areas. This funding also allowed the MPCA to expand the list of chemicals it routinely analyzed in water samples to include CECs. MPCA has also been able to do some specific, non-routine, sampling for PFAS. In 2013, with limited targeted follow-up in 2017, MPCA was able to include 13 PFAS analytes in the analysis of groundwater samples. The results of PFAS monitoring are available in a report on MPCA's website.[66] This report shows that PFAS were detected in most groundwater in the state, with PFBA being the most frequently detected PFAS (found in almost 70% of all sampled wells). In 2013, PFOA was detected in 30% of sampled wells, PFOS was detected in 12% of sampled wells, and PFHxS was detected in 11% of sampled wells.

An additional special sampling of the whole network was completed in 2019, and included 33 PFAS analytes. Preliminary analysis shows that 17 of the 33 analytes were detected. PFBS was detected in 42.4% of the groundwater wells in 2019, higher than the 9% presence seen in 2013, likely due to the lower analytical method reporting limits. Three PFAS (PFOA, PFOS, and PFHxS) were detected at least once at concentrations above MDH's health-based guidance. Samples with detections were primarily in shallow monitoring wells, but some detections were in deeper monitoring wells.[67]

Funding for PFAS monitoring in the Ambient Groundwater Well Network has not been specifically provided. MPCA has done the sampling as resources become available. To continue monitoring for PFAS in this network, additional funding would be needed.

Work status: ongoing, additional funding for continued PFAS monitoring would be needed

Leader: MPCA Environmental Analysis and Outcomes Division.

Benefits: Though many of the wells in the ambient groundwater well network tap into shallow, unprotected aquifers that are not used for drinking water, these wells provide an early warning system for contaminants that may contaminant drinking water aquifers in the future. Some of the wells in the network do sample drinking water aquifers – detections in these aquifers are important for assessing if there are currently potential human health risks due to drinking water exposure. This ambient well network helps the Agency identify unknown sources of PFAS exposure and assess potential near-term or long-term threats to the quality of Minnesota's drinking water aquifers.

Challenges: PFAS analysis is more expensive than monitoring for many other environmental contaminants – continued funding is required to ensure that PFAS monitoring in this network can proceed in the future. Additionally, the only PFAS that can be monitored for in this network are those with available analytical methods. In the most recent round of PFAS monitoring, samples were shipped to a lab in Canada with the capacity to monitor 33 PFAS analytes with low detection limits – it requires additional cost, staff time, and effort to ship a large number of samples internationally. Many PFAS without methods available may be present in groundwater and not be detected with current analytical approaches.

---

[66] MPCA. (n.d.) Groundwater data. https://www.pca.state.mn.us/water/groundwater-data

[67] Additional information is available on request from the MPCA (memo: 2019 Ambient Groundwater Sampling Results)

Resources: Including PFAS analysis in one complete round of ambient groundwater monitoring costs approximately $100,000.

Communications

Developing communication tools for drinking water systems and the general public

Developing communication plans and materials based on social science research is essential for effective communications with public water systems and the public when conducting PFAS monitoring in drinking water. MDH staff work closely with CWSs before sampling begins to explain the importance of understanding levels of these unregulated contaminants – because PFAS are unregulated, CWSs have no requirements to participate in monitoring. MDH develops communication guides and action plans for how to respond to various scenarios that may emerge as a result of unregulated contaminant monitoring. For example, MDH may meet with cities if steps like additional sampling or other investigations are needed, provide technical information about health effects to relevant local partners, and help craft informational messages for water consumers. MDH continues to develop informative and appropriate communication materials related to PFAS for various audiences as needs arise. MDH has developed an online Drinking Water Risk Communication Toolkit to support public water systems' communication efforts with their customers.[68]

Work status: ongoing

Leader: MDH Drinking Water Protection. **Partner**: Participating public drinking water systems.

Benefits: Effective, science-based communication materials allow MDH to explain steps MDH is taking to address PFAS in drinking water and why it is important to monitor for PFAS. MDH also helps facilitate discussions - both if a risk to public health arises and when the agency identifies no health risks.

Challenges: Communicating around PFAS contamination can be especially challenging due to the uncertainties and data gaps for the broad class of compounds. Additionally, the health-based guidance for several PFAS are derived specifically to be protective of vulnerable populations like fetuses and infants that could be exposed via mothers -- nuanced messages are needed to explain these complexities. Developing informative yet effective resources requires collaboration of many topic experts and communication staff.

Resources: Communication specialists at MDH help with website, information sheets, message blocks and other materials; also with designing public meetings, risk communication, and related outreach. Communication staff draft materials in collaboration with subject matter experts and coordinate with relevant outside partners. MDH also contracts with translation services to ensure health information is available to all impacted groups.

Gaps and opportunities

Despite the significant ongoing effort to monitor PFAS in drinking water, opportunities remain to continue to fill gaps in drinking water monitoring, drinking water regulations, and protecting source waters from PFAS contamination using CWA standards. The sections below describe two projects that are planned to help fill gaps in monitoring and source water protection. No additional authorities would be required to undertake those planned projects within MPCA or MDH programs, though support from the legislative branch and the public would be helpful for rulemaking related to CWA standards. Planned and ongoing drinking water monitoring projects would capture approximate 90% of all community water consumers by 2025, but additional funding would be needed to expand these projects to capture

[68] MDH. (n.d.). Drinking Water Risk Communication Toolkit. Retrieved from: https://www.health.state.mn.us/communities/environment/water/toolkit/index.html

all community water consumers or to conduct planned monitoring on a compressed timescale. A third project describes the possibility of evaluating the processes that would be needed to develop state drinking water regulations for contaminants with no federal drinking water regulations or regulations that do not incorporate the most recent science. This project would a long-term initiative.

There are no federal or state standards (MCLs) limiting PFAS concentrations in drinking water. Though PFAS are currently unregulated by the EPA in drinking water, the EPA has recently begun the process of possibly regulating two PFAS – PFOA and PFOS. In the announcement of this decision, the EPA also discussed PFAS grouping strategies that may be appropriate for a future federal rule. The implementation of federal PFAS standards for drinking water is not likely to go into effect until at least 2025.

Currently, if CWSs or private wells in Minnesota exceed MDH's non-regulatory health-based guidance, MDH has procedures in place to alert water systems and private consumers, and to support systems or households in taking voluntary actions to reduce exposure. MDH can support systems by giving advice on blending water or applying treatment aimed at reducing PFAS concentrations to below health-based guidance values. MDH also supports private well owners in installing and maintaining point-of-use filters that remove PFAS from water. So far, drinking water advisories, based on Minnesota's health-based drinking water guidance values, have been issued to approximately 1,300 private well owners. Eight CWSs have treatment or other management plans in place to reduce PFAS concentrations to safe levels.

Regulation, either a state or federal MCL, could benefit consumers by mandating testing of public water systems, increasing the availability of funding for treatment, having statewide standards that could be used as clean-up levels in federal clean-up projects, and adding visibility to PFAS source reduction efforts. Fortunately, to date, the desire of communities to provide a trustworthy water supply and access to financial resources for treatment has translated into protective public health actions that address PFAS contamination in both public and private water systems. However, as our understanding of the extent and sources of PFAS contamination in water expands, this may not continue to be the case.

The option to pursue the establishment of state regulatory values has arisen in informal discussions at MDH. Developing and promulgating state regulatory values beyond those currently adopted by reference from the federal SDWA would require a significant investment in changing statutory authority, creating a process that would likely include a cost benefit analysis in addition to the current guidance protocol, and adding the capabilities for this expanded work. Given the current context and agency commitment to responding to COVID-19, weighing the pros and cons of state regulatory values awaits the restoration of full staff capacity for core functions and workload. Until then, Minnesota will continue to rely on the good will and relationships established with community water systems and commitments to finding the necessary resources for treatment as new areas of PFAS contamination are discovered. Given the widespread PFAS monitoring in CWS and the voluntary actions on the part of drinking water utilities to meet health-based guidance values for drinking water, MDH is not currently developing drinking water standards for PFAS at this time. The process to develop a state MCL regulatory process and program would take a considerable amount of time and resources, and the federal government is in the midst of SDWA rulemaking for PFAS. Though there are benefits to having drinking water regulations for PFAS, MDH is currently focusing on monitoring PFAS in drinking water and collaborating with MPCA on source water protection efforts.

Future drinking water monitoring

Conduct drinking water monitoring under the Fifth Unregulated Contaminant Monitoring Rule (UCMR5) (2023-2025)

The next round of UCMR monitoring will take place in Minnesota between 2023 and 2025. This monitoring is currently scheduled to include, at a minimum, 29 PFAS, including PFBA. UCMR5 will include lower reporting limits than UCMR3 and, due to changes in UCMR monitoring requirements, will include all systems serving greater than 3,300 residents (assuming sufficient funding and lab capacity). MDH estimates that 180 CWSs will be included in UCMR5 monitoring, 58 of which will be sampled for PFAS for the first time.

Work status: planned – required participation under the Safe Drinking Water Act

Leaders: MDH Drinking Water Protection and EPA Office of Water. **Partner**: Participating public water suppliers.

Benefits: Monitoring for a longer list of PFAS analytes at lower detection limits and the increased scope of UCMR to include all systems serving between 3,300 and 10,000 residents will be helpful in broadening the understanding of PFAS contamination in drinking water state-wide. The federal government will cover analytical costs for sampling at participating small drinking water systems, and MDH will cover analytical costs for large systems. MDH will also provide guidance to CWSs on communication, outreach, and potential interventions to reduce PFAS concentrations (if needed).

Challenges: The inclusion of the new EPA Method 533 in addition to the EPA Method 537.1 will likely increase the time required to process samples and increase the cost of monitoring compared to UCMR3.

Resources: MDH engineers will help conduct sampling and staff will oversee the project completion. MDH will cover the analytical for sampling in large systems, which will likely be higher than the costs associated with UCMR3 (~$90,000) due to the new method including more analytes and lower detection limits. EPA will cover the analytical costs for small systems.

Future considerations for regulation

Develop Clean Water Act Water Quality Standards for Class 1 waters

The Clean Water Act (CWA) is a federal law that allows states to protect surface waters by determining the "beneficial uses" of the waterbody, and setting WQS to protect those uses. States then monitor waterbodies to compare levels of pollution to the applicable standards and list waterbodies as "impaired" if they exceed the WQS and therefore do not meet their beneficial uses. States also permit facilities that discharge into waters in order to ensure that their discharges do not have the reasonable potential to cause or contribute to an exceedance of any WQS. Examples of beneficial uses for waterbodies include things like recreating, fishing, irrigation, and aesthetic enjoyment. One important beneficial use designation in Minnesota is "domestic consumption," which protects water so it can be used as a drinking water supply, in food processing, and other related activities. Minnesota groups waterbodies based on combinations of designated uses that apply to the waterbodies, and derives WQS for those classes. Waterbodies with "domestic consumption" beneficial use designations are protected by Class 1 WQS under Minn. R. ch. 7050.

The MPCA is currently reviewing and planning to update Minnesota's Class 1 WQS, including where they are applied and the narrative or numeric water quality standards needed to ensure the water meets the beneficial use. The agency is considering adding numeric Class 1 WQS for multiple pollutants, including PFAS.

The existing Class 1 WQS include the maximum contaminant levels (MCLs) and secondary drinking water standards developed under the federal SDWA, which are incorporated into Minnesota's WQS by reference. Currently there are no SDWA standards (MCLs) for PFAS. Because the MCLs are derived for application to finished (and in most cases, treated) drinking water, they are not ideal for protecting source waters in their natural state. Also, most MCLs were developed prior to 2000, and consequently there are no standards for recently recognized pollutants of concern. For both reasons, MPCA is considering revising the Class 1 WQS and potentially adding standards for PFAS along with other recently recognized pollutants of concern such as pharmaceuticals, algal toxins, and certain pesticides and industrial chemicals.

MPCA anticipates that any new approach to developing and/or adding Class 1 WQS to Minn. R. 7050 will be based on the approach developed for human health protection by the MDH and used to develop Health Risk Limits (HRLs) or Health Based Values (HBVs) for groundwater. Among other benefits, this would enable MPCA to utilize MDH's toxicological risk assessments to develop Class 1 WQS. Accordingly, Class 1 WQS could be adopted for pollutants for which MDH has developed a HRL or HBV – which currently includes PFOA, PFOS, PFHxS, PFBA, and PFBS. Any changes would go through the rulemaking process, with multiple opportunities for public engagement. *See* the Reducing PFAS Exposure from Consuming Fish and Game Issue Paper for discussion of WQS protective of people consuming fish and the Managing PFAS in Waste Issue Paper for a general discussion WQS in the context of waste facilities.

Work status: planned

Leaders: MPCA Water Quality Standards Unit.

Benefits: Updating the Class 1 WQS will improve the foundation for protecting Minnesota's source waters by introducing standards that are health protective and developed based on current science. Once adopted, the Class 1 WQS will be available to evaluate discharges that are subject to regulation through National Pollutant Discharge Elimination System/State Disposa System (NPDES/SDS) permits, which will facilitate any needed actions to reduce the loading of PFAS from regulated dischargers to surface waters that supply drinking water. In addition, with adoption of Class 1 WQS for PFAS, these contaminants would likely be added to those that are monitored as part of the watershed monitoring program for waters classified as Class 1. Should this monitoring result in identification of an impaired waterbody, development of a total maximum daily load (TMDL) plan to address the impairment would follow.

Challenges: WQS are a regulatory tool that often carry significant economic impacts to permittees. While the cost of discharging environmental pollutants that are harmful to human health and the environment should be borne by the entities generating that pollution, there are some permittees like wastewater treatment plants (WWTPs) that are not likely to generate significant PFAS or purchase PFAS products, but instead pass other commercial and industrial PFAS through to the environment. The economic reality of meeting new and revised discharge requirements can be daunting to those permittees like WWTPs. This is likely more true for PFAS than is typical, given the complexities and costs associated with designing and operating treatment in complex waste streams like effluent.

Strategies like implementing industrial pre-treatment programs have been shown in other states to be successful at significantly reducing PFAS loads to WWTPs and passing the financial burden of PFAS pollution to the industrial producers and users of the compounds.[69] Industrial pre-treatment may not be enough to reduce PFAS loads down to levels below health-based standards in all cases. Additional strategies to reduce PFAS pollution at the source (see Preventing PFAS Pollution Issue Paper) could also significantly reduce the PFAS loading to permittees such as WWTPs. However, even with concurrent actions to reduce PFAS sources to WWTPs and other permittees that act as "conduits" rather than PFAS sources, CWA tools like variances may be still necessary to meet health-based standards for PFAS. MPCA would need to work closely with the EPA and regulated parties to chart a feasible and strategic path forward for ensuring that discharges of PFAS do not occur at levels that could cause exceedances of health-based guidance for drinking water.

[69]EGLE (n.d.). IPP PFAS Initiative. Retrieved from: https://www.michigan.gov/egle/0,9429,7-135-3313_71618_3682_3683_3721-531869--,00.html

Once adopted, a WQS for PFAS would likely require periodic revision to incorporate the rapidly expanding knowledge about PFAS fate, transport, and toxicity. These revisions to future PFAS WQS trigger additional rulemaking, which is a time consuming and politically intensive process.

Finally, PFAS monitoring is generally more expensive than monitoring for other contaminants. Currently, costs for PFAS monitoring range from $300-400 per sample. Monitoring Class 1 waters for PFAS to determine if they are meeting their designated use would increase the costs to the MPCA's regular watershed monitoring program, and would likely require additional resources.

Resources: Development of WQS typically requires significant staff resources over an extended period of time to develop the scientific, technologic, and economic analyses that are required for WQS promulgation. The upfront scientific work and development of the technical support documents usually falls to staff in the WQS unit; once a rule begins to move forward into rulemaking, significant effort is needed to ready the project for promulgation via Minnesota's Administrative Procedures Act. WQS development and promulgation is routine business of the MPCA, but monitoring for PFAS in Class 1 waters for drinking water would increase costs associated with watershed monitoring programs.

Evaluating options for managing risks from federally unregulated contaminants

The lack of enforceable federal standards for PFAS has led to a patchwork of state approaches to managing the risks in drinking water. In the continuum of approaches that extends from state regulatory numbers all the way to essentially no action, Minnesota sits in the middle. Minnesota was the first to develop health-based guidance values that are advisory in nature and has not pursued regulatory standards at the state level to date. Fortunately, the desire of communities to provide a trustworthy water supply and access to financial resources for treatment has translated into protective public health actions that address PFAS contamination in both public and private water systems. However, as our understanding of the extent and sources of PFAS contamination in water expands, this may not continue to be the case.

Developing and promulgating state regulatory values beyond those currently adopted by reference from SDWA would require a significant investment in changing statutory authority, creating a process that would likely include a cost benefit analysis in addition to the current guidance protocol, and adding the capabilities for this expanded work. The Minnesota Department of Health's (MDH) preferred approach is to adopt federal drinking water standards developed by the EPA into Minnesota rules by reference. However, EPA has been slow to regulate PFAS, and may not ultimately regulate PFAS at levels that are health-protective. Given the current context and agency commitment to responding to COVID-19, weighing the pros and cons of state regulatory values awaits the restoration of full staff capacity for core functions and workload. However, once MDH returns to full staff capacity, the agency will consider the needs and challenges associated with developing state regulatory values for drinking water.

Leader: MDH Environmental Health Division.

Benefits: Regulation, either a state or federal MCL, could benefit consumers by mandating testing of public water systems and increasing the availability of funding for treatment. Having statewide standards that could (along with existing HRLs) be considered applicable or relevant and appropriate requirements (ARARs) in federal clean-up projects would be beneficial (see the Remediating PFAS Contaminated Sites Issue Paper for more information on ARARs). A state process for developing drinking water standards could also be helpful for managing the increasing number of other federally unregulated contaminants or contaminants with federal regulations that do not consider current scientific literature.

Challenges: The process to develop a state MCL regulatory process and program would take a considerable amount of time and resources. MDH would solicit input from stakeholders, including the water industry, local government partners and a diverse set of citizens.

Resources: Significant resources would be needed to reach out to stakeholders and assess the pros and cons of moving forward with state regulatory values for drinking water.

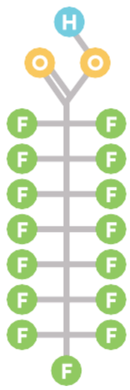
Overview of intersectional issues

- **Pollution prevention**: Reducing PFAS pollution at the source places the cost burden of treatment with the polluters rather than receptors, like drinking water consumers and publicly-owned utilities. *See* the PFAS Pollution Prevention (P2) issue paper for actions related to reducing the overall production and emission of PFAS products.
- **Quantifying PFAS toxicity**: Understanding of the potential health impacts of PFAS exposure is key in ensuring exposure stays below "safe" thresholds and communicating with the public. Health-based guidance values, however, require data on toxicity and exposure that are not available for the vast majority of all the PFAS found in the environment. *See* the Quantifying PFAS Risks to Human Health Issue Paper for more information on challenges stemming from PFAS toxicity data limitations.
- **Developing and expanding access to analytical methods**: Analytical methods for PFAS are expensive and time-intensive to run, and include only a subset of all PFAS that may be occurring in drinking water. Non-targeted methods are a promising alternative tool to determine the landscape of PFAS occurring in many media, including drinking water, but additional resources are needed to expand access to this new methodological approach – *see* the Measuring PFAS Effectively and Consistently Issue Paper for more information on the costs and challenges associated with measuring PFAS in various matrixes.
- **Remediating PFAS contaminated sites**: Because costs associated with treating PFAS contamination can be very high, identifying responsible parties for pollution can be important in assisting with costs of drinking water treatment – *see* the Remediating PFAS-contaminated Sites issue paper for more information on identifying sites with ongoing or historic PFAS contamination.

Summary

Reducing PFAS exposure from consuming fish and game

Background



- **Hunting and fishing are cherished activities** in Minnesota, with long-standing cultural significance for many populations. In some cases, locally harvested fish and game are relied on as healthy sources of protein and a **key component of a family's diet**.
- Nearly all of Minnesota is ceded territory, and members of **tribal nations retain hunting, fishing, and gathering rights**.
- Continued research on PFAS in fish and wildlife has indicated that some PFAS can **accumulate in commonly consumed tissues of fish and game**, potentially to levels causing health concerns for those consuming the meat.
- Several agencies in Minnesota participate in **monitoring** PFAS in fish and game, **providing consumption advice**, and **regulating PFAS discharges** with the intention of removing the need for consumption advice in the future.
  - The Fish Contaminant Monitoring Program (FCMP) is an inter-agency group including staff from MDH, MPCA, and DNR that collects fish from lakes and rivers throughout Minnesota. The resulting fish tissue data is used to inform **scientific understanding of accumulation patterns** in fish, issue fish **consumption advice**, and develop **water quality standards** protective of fish consumers.
  - MDH is responsible for providing **statewide** and **site-specific fish consumption advice**.
  - Statewide advice is developed based on mercury and PCB levels found in fish harvested around the state. Site-specific advice is developed if local levels of PCB, mercury, or PFOS contamination warrant more restrictive consumption advice than would apply statewide.
  - MPCA can develop **statewide water quality standards** and **site-specific water quality criteria** protective of fish consumers under the CWA.
  - There are no statewide water quality standards for PFAS, but there are site-specific water quality criteria in waterbodies with known PFAS contamination, including in the East Metro region.
  - The DNR can conduct monitoring of PFAS in commonly consumed game, as funding and capacity allows.

What is Minnesota doing now?

- **Monitoring**: The FCMP has monitored for PFAS in fish from 178 lakes and 12 rivers, but does not include PFAS as part of routine analysis of fish collected in the monitoring program. Additionally, the DNR is conducting a pilot project to monitor PFAS levels in deer harvested in regions with known PFAS surface water contamination.
- **Advice**: The MDH has provided site-specific fish consumption advice for PFOS in some waterbodies.
- **Regulation**: MPCA has issued site-specific water quality criteria for PFOS protective of fish consumers applicable to waterbodies with known PFAS surface water contamination.

What are remaining gaps and opportunities for action?

- **Gap**: The Interagency FCMP collects fish from lakes and rivers throughout Minnesota. Though this group has conducted some PFAS analyses through this monitoring program, funding has not been available to routinely include PFAS widely in monitoring efforts.
  - **Opportunity**: Sustained ongoing funding for monitoring PFAS in fish would provide updated fish contaminant data for the impaired waters inventory (MPCA) and fish consumption guidance (MDH).
- **Gap:** There is limited information about PFAS concentrations in edible tissues of game, especially game harvested near areas with surface water or soil PFAS contamination.
  - **Opportunity**: DNR could continue the existing pilot monitoring project underway for PFAS in deer. DNR, MDH, and MPCA would work together to determine the need for consumption advisories depending on the result of this monitoring work.
- **Gap:** Despite efforts to phase some PFAS, such as PFOA and PFOS, out of production, discharges of these PFAS and others continue.
  - **Opportunity**: MPCA could consider the need for a statewide water quality standard for PFAS, prioritizing PFAS that are especially bioaccumulative and toxic to humans.
    - After development of a standard, implementation needs to be considered – particularly for pollutants like PFAS that are difficult to treat and where standards are likely to be very stringent.

How does this work benefit human health and the environment?

- Understanding PFAS levels in fish and game, providing advice to consumers about safe levels of consumption, and applying regulations to dischargers to prevent further contamination all contribute to **ensuring that people are not exposed to harmful levels of PFAS**.
- Work done to protect human consumers of fish and game has the **ancillary benefit to helping to prevent wildlife exposures**.
- **Fish consumption is beneficial for our health** – regulations on dischargers of bioaccumulative pollutants like PFOS help encourage consumption of fish by ensuring surface waters used for fish harvesting are free of harmful levels of toxins.

How does this work benefit Minnesota's economy?

- The **commercial fishing and game industries** in Minnesota benefit from work done to ensure fish, deer, and waterfowl do not accumulate harmful levels of PFAS.
- **Tourism related to recreational hunting and fishing** also supports some to local economies, which would benefit from ensuring safe consumption of fish and game.
- Fishing and hunting provide a **healthy and inexpensive source of food** for many families.
- **Preventing adverse physical health outcomes** associated with PFAS exposure and **preventing negative mental health outcomes** associated with concern over exposure to these compounds is financially beneficial for families and individuals.

Background

Hunting and fishing are cherished activities in Minnesota, with long-standing cultural significance for many populations. Nearly all of Minnesota is ceded territory, with Tribal nations that pre-date the establishment of Minnesota retaining hunting, fishing, and gathering rights. Beyond providing opportunities to engage in cultural heritage, entertainment, and enjoyment of the outdoors, these activities also provide healthy sources of food for many Minnesotans. In some cases, locally harvested fish and game are relied on as a key component of a family's diet. Unfortunately, continued research on PFAS in fish and wildlife has indicated that some PFAS can accumulate in commonly consumed tissues of fish and game, potentially to levels causing exposure concerns for those consuming the meat.

Ensuring that the fish and game harvested in Minnesota are safe for consumption is an important goal of MDH, MPCA and DNR. Most work has focused on safe consumption of fish. The Fish Contaminant Monitoring Program (FCMP) is an inter-agency program that collects fish from lakes and rivers throughout Minnesota with the cooperation of the DNR Fisheries and MPCA Biomonitoring teams. The primary role of the program has been to analyze fish tissue for levels of mercury and polychlorinated biphenyls (PCBs), but Minnesota has provided and received occasional funding that has enabled additional analysis for PFAS, coordinated through this program. The data gathered support the MDH's Fish Consumption Guidelines and MPCA's development of water quality standards for aquatic consumption. In addition to fish monitoring, DNR can conduct additional ad hoc monitoring of animals like deer by working with hunters in areas with known contamination, as funding and capacity allows. These monitoring projects provide the basis for any issuance of guidance or regulation by MDH or MPCA.

Risks to fish and game consumers from PFAS pollution

Though there is much still unknown about the health effects associated with PFAS, health assessments conducted by MDH indicate that toxic effects can potentially occur after exposure to low levels of PFAS like PFOS, PFOA and PFHxS. Additionally, early work conducted by MPCA to understand PFAS levels in fish indicate that some PFAS accumulate to high concentrations in edible portions of fish tissues. Ongoing work in states like Michigan and Wisconsin indicate that some PFAS similarly accumulate in the organs and tissues of deer, and research at sites with contaminated surface water in Australia resulted in consumption advice for many commonly consumed species, including waterfowl.

Work is currently underway at the EPA and at Minnesota agencies to gain a better understanding of PFAS accumulation in fish and game and where there may be risks to consumers from this exposure. Overall, evidence collected by Minnesota agencies and other researchers indicate that there are several avenues for PFAS to make their way into commonly consumed fish and game. Studies of exposure to bioaccumulative PFAS (such as PFOS) have indicated that in scenarios where an individual is consuming fish and game that have been significantly impacted by PFAS releases, fish consumption and game consumption can be the most significant source of overall exposure.[70,71] Whether or not these levels of PFAS in game are potentially hazardous to human health depends on individual consumption habits, if the person exposed is at a particularly sensitive life stage, and if the person is harvesting from a region proximal to a PFAS source.

[70] Augustsson, A., Lennqvist, T., Osbeck, C.M.G., Tibbin, P., Glynn, A., Nguyen, M.A., Westberg, E., & Vestergren, W. (2021). Consumption of freshwater fish: a variable but significant risk factor for PFOS exposure. *Environmental research*. *192* (2021) 110264. https://doi.org/10.1016/j.envres.2020.110284

[71] European Food Safety Authority. (2011). Results of the monitoring of perfluoroalkylated substances in food in the period 2000-2009. *EFSA Journal*. 9(2). https://doi.org/10.2903/j.efsa.2011.2016

Role of guidance and regulation related to ensuring safe consumption of fish and game

In Minnesota, the DNR, MPCA, and MDH collaborate to conduct research on PFAS levels in fish and game, develop consumption guidelines, communicate with fishers and hunters, and regulate PFAS emissions such that advice to limit fish consumption is not needed in the future. MDH guidance for eating fish contaminated with PFOS are based on the *Great Lakes Consortium for Fish Consumption Advisories Best Practice for Perfluorooctane Sulfonate (PFOS) Guidelines.* The best practice aims to result in consistent advice across states in the Great Lakes region and takes into account both the risks and benefits of eating fish.

The first step in addressing potential health risks from PFAS in fish and game is monitoring to understand what levels of PFAS exist in these animals. The agencies, working through the FCMP, have conducted analysis for PFAS in fish. Though this research has been crucial to advancing the knowledge of potentials risks to fish consumers from PFAS exposure, some of these data are now out of date and are likely not reflective of current PFAS levels. Once a database of PFAS levels is established, the MDH provides consumption advice to consumers if needed and DNR helps communicate that information. To date, MDH has issued fish consumption advice based on PFOS for several waterbodies. Deer monitoring is in the early stages – it is not clear if consumption advice for deer will be warranted once data from an ongoing pilot deer monitoring are analyzed. The consumption guidance and communication efforts by MDH and DNR are crucial for educating consumers, especially those who are pregnant or breast-feeding infants, about potential risks associated with exposure to PFAS.

In addition to issuing guidance, Minnesota also has opportunities to apply regulations that would reduce (and prevent) the need for restrictive consumption advice in the future. When it comes to fish consumption, MPCA has the regulatory authority under the CWA to enact either site-specific water quality criteria or statewide water quality standards protective of those consuming fish from Minnesota waterways. MPCA also has the authority to derive standards that would be protective of consumers of aquatic-dependent wildlife like ducks and geese, should those paths for exposure be the most impactful. MPCA has already issued site-specific criteria protective of fish consumers in several East Metro waterbodies known to be contaminated with PFAS. MPCA is also considering the benefits that would come from developing a statewide water quality standard for PFAS that would be protective of fish and game consumers, including those who rely on harvesting and consuming fish and game for subsistence or cultural heritage. Finally, MPCA could develop regulations on air emissions of PFAS that could cause fish to be contaminated with bioaccumulative PFAS. For example, in the past, air emission reductions for mercury were achieved using the implementation of TMDL approaches under the CWA standards.[72] Though discussion of regulatory standards for surface water are included in this issue paper below, discussion of opportunities to reduce PFAS loading to surface water from air emissions are included in the air issue paper.

There are many potential sources of PFAS to wildlife like fish and game. Some of these sources are considered "point sources" that could theoretically be controlled with permits of releases to air and water. Other PFAS sources are more diffuse, such as PFAS plumes originating from spilled PFAS-containing firefighting foam, land-applied biosolids with high PFAS concentrations, or atmospheric deposition of PFAS from far-away sources. Overall, controlling PFAS emissions is challenging due to the widespread use of PFAS products in consumer goods and industry – it is possible that regulatory standards on water and air emissions of PFAS will not entirely prevent the need for consumption advice for fish or game moving forward.

[72] EPA. (n.d.). Impaired Waters and Mercury. https://www.epa.gov/tmdl/impaired-waters-and-mercury

Past and ongoing efforts

The following sections describe the completed and ongoing work related to ensuring safe consumption fish and game in Minnesota. Ongoing work is primarily focused on monitoring for PFAS in fish and game, but the expense of PFAS analysis has limited the extent of this work. Additional work is ongoing to establish PFAS cleanup goals protective of fish consumers and to issue fish consumption advice when levels are observed in exceedance of the statewide fish consumption guidelines for PFOS.

Monitoring

Pilot monitoring of PFAS in deer

Deer and other wild game in Minnesota have the potential to bioaccumulate PFAS to a degree that could result in higher exposures to Minnesotans who frequently consume them. Recent efforts to monitor deer in Wisconsin and Michigan near areas of known surface water contamination have resulted in the respective DNRs issuing deer consumption advice for either deer liver or, in some cases, consumption of any deer tissue. After observing the results of these monitoring efforts in Wisconsin and Michigan, Minnesota's DNR initiated a deer monitoring pilot study in two areas in Minnesota with known PFAS contamination of surface water: near the Duluth airport and the East Metro. Starting in September 2020, Minnesota DNR is collecting liver and muscle tissues from 60 harvested deer that were either hunted or hit by cars within or near (a five-mile radius) the two areas where PFAS are known to be impacting surface water. The DNR is reaching out to hunters in these areas directly and ask them to voluntarily submit liver and muscle tissue samples from their harvested deer for testing purposes. Additionally, DNR is partnering with local road crews to collect samples from deer hit by cars in the East Metro region. Out of convenience and to broaden the study sample, the DNR may additionally test samples from deer taken during population control activities, including up to 30 deer from the Camp Ripley military facility. Deer harvested at Camp Ripley are frequently used by the DNR for research because data is relatively easy to collect. The level of PFAS in the environment at Camp Ripley is not known. Once the samples are collected and analytical results are finalized, DNR will work with MPCA and MDH to determine if additional deer monitoring or deer consumption guidance are warranted.

Work status: ongoing

Leaders: DNR Wildlife Health. **Partners**: MDH Environmental Health and MPCA Environmental Analysis and Outcomes.

Benefits: This project will directly benefit hunters in Minnesota by ensuring that deer harvested are safe for consumption. Additionally, given that the science of PFAS accumulation in deer is understudied, this effort will expand the understanding of PFAS accumulation in terrestrial ecosystems.

Challenges: PFAS analysis is expensive, which limits the number of samples that can feasibly be analyzed as part of this pilot project. Because samples from deer carcasses are being voluntarily collected from hunters, it may not be possible to identify the precise location where the deer was killed, and targeted sampling of deer in very close radius (< 1 mile) to surface water contamination is not possible. This may hamper DNR's understanding of the roaming radius for deer that may be impacted by PFAS exposure. Additionally, it is not known if the concentration of PFAS in deer tissue is dependent on factors such as the age or sex of the deer. Hunters are encouraged to submit incisor tooth samples from deer for aging purposes to account for the issue of age on accumulation of PFAS.

Resources: The pilot monitoring effort requires $43,000 in funding for PFAS analysis. Because most PFAS are known to accumulate in livers at greater concentrations than the rest of the body like muscle, if PFAS results in the liver of a given deer sample are non-detectable, the muscle of the animal will not be tested. This could reduce the overall analytical costs associated with the project. Sample collection and communication with hunters requires the time of several DNR staff.

Advice

Providing fish consumption advice for PFOS and conducting outreach and education

Using FCMP data for mercury, PCBs, and PFOS, MDH develops science-based fish consumption guidelines that encourage people to eat fish while keeping their exposure to contaminants in fish below a level that may cause adverse health effects. The developing fetus, children, and people who eat a lot of fish that are high in contaminants are most likely to be harmed from exposure to contaminants in fish. Fish consumption guidelines for PFOS were developed following protocols developed by the Great Lakes Consortium for Fish Consumption Advisories and risk assessment methods developed by the EPA.[73,74,75,76] The following fish consumption advisory levels were derived:

Table 4. PFOS fish consumption advisory levels.

Level of PFOS in fish fillet (ppb)	Meal frequency
<= 10	Unrestricted
>10-20	2 meals/week
>20-50	1 meal/week
>50-200	1 meal/month
>200	**DO NOT EAT**

MDH provides statewide Safe-Eating Guidelines developed based on mercury and PCBs in fish statewide and waterbody specific Safe-Eating Guidelines where advice for eating fish from specific waters and for specific species are more restrictive than the Statewide Guidelines based on consideration of levels of mercury, PCBs, and PFOS measured in fish fillets.[77] Fish harvest – how much a waterbody is used for fishing for consumption rather than catch and release – is a factor considered by FCMP when selecting lakes and rivers for fish collection, analysis, and considerations of guidance. For example, FCMP receives input from DNR about waters fished and species harvested by the Hmong community. MDH also shares data and consults with tribes on methods for determining fish consumption guidelines.

Higher levels of PFOS have been found in fish from some waters in Minnesota, including several waterbodies in the Twin Cities Metro. Based on PFOS levels measured in fish, MDH recommended not eating fish from Lake Elmo in Washington County. This *Do Not Eat* advice has been extended to lakes and streams in the Project 1007 storm water drainage area, also in the East Metro Area of the Twin Cities, with PFOS measured in the water at levels similar to or higher than Lake Elmo. MDH concluded that fish in these waters are likely to have PFOS concentrations as high or higher than in those in Lake

---

[73] MDH. (n.d.). Great Lakes Consortium for Fish Consumption Advisories. https://www.health.state.mn.us/communities/environment/fish/consortium/index.html

[74] Great Lakes Sport Fish Advisory Task Force (1993). Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory. Retrieved from: Protocol for a Uniform Great Lakes Sports Fish Consumption Advisory (PDF)

[75] Great Lakes Consortium for Fish Consumption Advisories. (2019). Best Practice for Perfluorooctane Sulfonate (PFOS) Guidelines. Retrieved from: Best Practice for Perfluorooctane Sulfonate (PFOS) Guidelines (PDF)

[76] EPA (n.d.) Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories Documents. https://www.epa.gov/fish-tech/guidance-assessing-chemical-contaminant-data-use-fish-advisories-documents

[77]MDH. (n.d.) Fish Consumption Guidance. Retrieved from: https://www.health.state.mn.us/communities/environment/fish/index.html#waterbody

Elmo. The waters are: Raleigh Creek, Eagle Point Lake, Horseshoe Lake, Tartan Pond, Rest Area Pond, and West Lakeland Ponds.

It is important that fish consumption guidance is communicated to the public. Safe-Eating Guidelines for fish are communicated using a variety of dissemination pathways. Information about the Guidelines is available in printed brochures, on the MDH and DNR websites, DNR Fishing Regulations, and through presentations at meetings and community gatherings. Outreach efforts are particularly directed toward women who are or may become pregnant, children, and people who eat a lot of fish. MDH also works to provide information to healthcare providers and others who may be in contact with these higher-risk groups. MDH typically issues a news release when updated information is available. In addition to highlighting revised guidelines and materials, these announcements include information on new or important issues related to the fish consumption program. Through these news releases, MDH tries to elicit media coverage (newspaper, radio and TV) to increase public awareness. MDH specifically requests that local public health agencies; local and state Women, Infants, and Children programs; and health care providers, including the major Health Maintenance Organizations in Minnesota distribute educational materials and discuss fish consumption with their clients. Other organizations that distribute MDH's printed brochures include local and state parks, environmental organizations, retailers, and other state agencies.

Work status: ongoing

Leaders: MDH Environmental Health Division. **Partners:** Interagency Fish Contaminant Monitoring Program (MDH, DNR and MPCA), Great Lakes Consortium for Fish Consumption Advisories (Consortium membership includes representatives from Indiana, Illinois, Michigan, Minnesota, New York, Ohio, Pennsylvania, Wisconsin, the Great Lakes Indian Fish and Wildlife Commission, and the Ontario Ministry of the Environment and Climate Change)**,** MDH WIC, Local Public Health, Health care providers in Minnesota, DNR State Parks, HealthPartners Institute.

Benefits: MDH Safe-Eating Guidelines are developed to help consumers minimize their exposure to contaminants in fish while promoting the health benefits of eating fish. Working with neighboring states increases the likelihood of compliance with voluntary fish consumption guidance because there are consistent messages across the region. By communicating PFOS Safe-Eating Guidelines through various media and targeting several audiences, MDH increases the likelihood that the public is aware of the guidance and understands the relative benefits and risks of eating certain types of fish or fish collected in various locations. These outreach efforts enable the public to make choices about which fish to eat and how often.

Challenges: The PFOS guidelines are developed to reduce exposure, but they are not a solution to the problem of contamination of PFAS in fish. Additional funding for PFAS fish sampling and analysis would identify which fish species and at which locations warrant PFOS-based fish consumption guidance.

PFAS bioaccumulate in fish with different patterns than are seen for PCBs and mercury. This means that the species of fish with the highest concentrations of mercury or PCBs may not be the same fish with high levels of PFOS or other bioaccumulative PFAS. More research is needed to understand which fish species accumulate the most PFAS so that these species can be included in monitoring. Additionally, there are limited data on PFAS levels in purchased fish, which limits the ability to derive statewide fish consumption guidance for PFOS and other bioaccumulative PFAS. Finally, there are limited toxicity assessments for PFAS, and some PFAS known to accumulate in fish do not have assessments available.

There are still many unknowns about which fish are likely to accumulate PFOS or other PFAS. Current trends indicate that the species of fish accumulating PFAS are not necessarily the predator fish that are likely to accumulate other toxicants of concern like PCBs and mercury. For this reason, messaging around recommended fish intakes is challenging.

Anticipated resource needs: Continued sampling and analysis of Minnesota fish for PFAS would be needed to continue assessing the need for fish consumption guidance statewide. The Fish Contaminant Monitoring Program estimates that this expanded PFAS monitoring effort would require $640,000 per biennium of additional funding. The agencies might also require extra staff if additional fish are collected.

Regulation

Deriving site-specific water quality criteria for PFAS protective of fish consumption

Water Quality Criteria (WQC) are site-specific surface water values that are applied to address pollution in areas of known surface water contamination. These WQC are different than WQS in that they do not apply to the entire state, only to waterbodies explicitly included in the criteria. WQC are developed based on methods and authorities in state statute and the federal CWA (*see* Minn. R. ch. 7050).

The MPCA Remediation program is managing sites with PFAS surface water contamination and requested WQC for PFAS be derived for impacted waters to inform cleanup efforts. In October 2020, MPCA released a new PFOS WQC that applied to targeted waterbodies including Lake Elmo and connected waterbodies in Washington County. When deriving WQC for those sites, MPCA also took the opportunity to update existing WQC for PFOS elsewhere in the state (Bde Maka Ska, and Pool 2 of the Mississippi River). MPCA prioritized deriving a PFOS WQC because PFOS has the highest bioaccumulation potential in fish compared to the other PFAS with health-based guidance values available. This high propensity of PFOS to accumulate in fish means that the largest pathway of exposure for those interacting with PFOS-contaminated water is through consuming fish caught in that waterbody. MPCA is in the process of developing WQC for other PFAS found in surface waters in these impacted waterbodies.

The site-specific WQC for PFOS required an assessment of PFOS toxicity and exposure from fish tissue. The criteria incorporate a model-based toxicological and exposure approach similar to that used by the MDH to develop drinking water guidance. The criteria are based on protecting the populations most vulnerable to PFOS toxicity, which are the developing fetuses and newborn infants being exposed to PFOS through the placenta during pregnancy and through breastmilk in early life. In selecting the fish consumption values for the criteria, MPCA reviewed new fish consumption survey datasets from the MDH, Great Lakes Consortium for Fish Consumption Advisories, and other regional and national studies relevant to the amount and types of freshwater-caught fish consumed by women of childbearing age (ages 15 to 50). Because PFOS and other PFAS are developmental toxicants, characterizing potential exposure to this subgroup of fish consumers from PFOS is very important. The interim fish consumption rate for women of childbearing age used in this PFOS WQC is over twice the default rate for adults who eat freshwater-caught fish and is based on a study led by MDH called, “Fish are Important for Superior Health” (FISH).[78]

The new WQC for PFOS can be expressed either as a fish tissue concentration or as a water concentration. For fish tissue, the WQC is a maximum 0.37 nanograms PFOS per gram (ng/g). The corresponding WQC for water is a maximum 0.05 nanograms per liter (ng/L). The goal of these WQC is to reduce the levels of PFOS in water so that freshwater fish consumption does not contribute to a person’s total exposure to PFOS, resulting in body burdens of PFOS greater than those associated with health effects.

[78]MDH. (n.d.). Great Lakes Restoration Initiative Grants. Retrieved from: https://www.health.state.mn.us/communities/environment/fish/consortium/glrigrant.html#keyfindings

Work status: completed for PFOS, ongoing for other PFAS

Leader: MPCA Water Quality Standards Unit. **Partners**: MPCA Water Assessment and MDH Environmental Surveillance and Assessment.

Benefits: PFOS WQC are based on protecting people's health from the presence of this toxic pollutant in Minnesota's surface waters and fish. The criteria provide numeric targets for MPCA programs to use in remediation cleanup, wastewater permitting, and other environmental protection authorities. Reductions of PFOS have already been documented in some surface waters due to national restrictions by EPA on some PFAS, including PFOS, and ongoing remediation activities. Any efforts to reduce PFOS pollution also benefit fish and wildlife.

Challenges: The PFOS WQC consist of an applicable fish-tissue concentration and surface water concentration. These values are very low and require the use of the most recently developed analytical methods to assess. The MPCA has a contract with SGS AXYS Analytical, who recently lowered reporting limits for PFOS and a few other PFAS. The fish-tissue WQC of 0.37 ng/g can be accurately quantified by SGS AXYS, but the water concentration of 0.05 ng/L cannot. The MPCA's Effluent Limit Unit is working with the Environmental Data Quality Unit to develop guidance for permitees related to these analytical issues.

Minnesota's impaired waters or 303(d) list contains 10 existing impairments for PFAS. These include impairments based on MDH's fish consumption advice (an approach MPCA no longer uses for listing waters that are impaired for consumption of fish tissue) and on site-specific water quality criteria. There are a large number of new surface water and fish-tissue PFOS datasets available since the last time PFAS was assessed statewide, and the new site-specific WQC is much more stringent than prior values. The MPCA is continuing to work on identifying the best path forward in assessing and listing impaired waters for PFAS. MPCA is considering the long-term need for a statewide PFOS WQS, which would result in statewide assessment for impaired waters listing wherever PFOS fish tissue data were available.

Resources: The development of the PFOS WQC took an MPCA staff person approximately two years and involved the support of several other technical staff at MPCA and MDH. This effort was only possible because MDH had already conducted a human health assessment for PFOS containing toxicity values and a serum model for understanding PFOS transfer to infants. Currently, the Water Quality Standards Unit is developing new site-specific WQC for PFOA (which would allow for additional updates to existing WQC for Bde Maka Ska and Pool 2), PFBA, PFHxS, and PFBS. These PFAS also have MDH toxicological values and health based guidance for drinking water that are relevant for this work. The development of the new interim fish consumption rate for women of childbearing age took almost a year to obtain and review survey datasets; this rate needs further review and consultation with Tribes and other subsistence fishing communities before adopting into rule

Gaps and opportunities

Several gaps remain in the scientific understanding of PFAS exposure from fish and game consumption and in the regulatory and advisory programs that ensure safe consumption for Minnesotans. PFAS are a diverse class of compounds with differences in toxicity, bioaccumulation potential, and environmental fate and transport. Though there are trends in toxicity and bioaccumulation patterns amongst various PFAS, such as the trend that longer chain PFAS tend to accumulate more readily in fish and wildlife, there are also exceptions to these trends. Much is still unknown about how factors like species type, water chemistry, and age of the organism influence PFAS levels in that sample. Ongoing fish and game monitoring will help fill this gap and prioritize risk assessment for PFAS.

Another gap is in developing a broader and up-to-date understanding of PFAS levels in commonly consumed fish. Expanding the existing Interagency Fish Contaminant Monitoring Program to regularly include PFAS sampling (in addition to the existing PCB and mercury sampling) would greatly improve the overall understanding of PFAS exposure from fish consumption, supporting the updates of statewide fish consumption guidelines and site-specific fish consumption guidelines. This work would have the additional benefits of improving understanding of locations with PFAS sources that may be currently unknown and improving the overall knowledge base about which fish are most likely to accumulate PFAS.

Finally, there are gaps in the regulatory structures that control PFAS loading to waterbodies. Developing a statewide WQS for bioaccumulative PFAS would prevent ongoing discharges of PFAS at levels that would cause PFAS to accumulate beyond safe levels in fish, and possibly also waterfowl and deer tissues. This effort, along with similar efforts to reduce PFAS emissions to the air, would gradually reduce the need for additional consumption guidance for fish and other game.

Monitoring

Conduct routine PFAS monitoring in fish

The interagency FCMP collects fish from lakes and rivers throughout Minnesota with the cooperation of DNR Fisheries and MPCA biomonitoring programs. The primary role of the program has been to analyze fish tissue for levels of mercury and PCBs. However, since the realization that PFAS may be bioaccumulating in Minnesota fish, the group has conducted some PFAS sampling as part of the monitoring program. Since PFAS testing began in Minnesota's lakes and streams in 2004, fish have been collected for PFAS from 178 lakes and 12 rivers, many of which have led to fish consumption advisories based on observed levels of PFOS in fish tissue. In the recent 2018 survey 73 waterways were tested and 94.5% of the waterways (n = 69) had at least one fish with detectable PFOS concentration in the fillet; 43 of those waters had been tested previously and all but one continued to have detectable PFOS concentrations. Monitoring has shown that in instances where sources of PFOS to a waterbody declined and past pollution migrated downstream, there are subsequent declines in fish tissue PFOS concentrations.

PFAS contamination in fish appears to be pervasive across Minnesota: 84% of the Metro lakes and 22% of the Non-metro lakes sampled to date had fish with detectable levels of PFOS. Of the lakes with a known PFAS source nearby, all lakes had fish with detectable levels of PFOS, in both Metro and Non-metro waters. Sampling in Non-metro waters has been mostly convenience survey sampling, while sampling in Metro waters was more targeted at likely but not "known" PFAS sources. Metro lakes had 3.8 times the risk of having fish with detectable levels of PFOS compared to Non-metro lakes. Non-metro lakes near a PFAS source had 5.6 times the risk of having fish with detectable levels of PFOS compared to lakes not near a known PFAS source.

Work status: ongoing – additional funding proposed to fill monitoring gaps

Leaders: The Interagency FCMP (including representatives from MPCA, DNR, MDA, and MDH).

Benefits: This ongoing project provides necessary updated fish contaminant data for the impaired waters inventory (MPCA) and fish consumption guidance (MDH). The project is efficient and cost-effective because it relies on the existing structure of the Interagency FCMP for planning, collection, laboratory testing, data management, and data analysis.

Challenges: PFAS laboratory analysis must be done through a master contract with a private laboratory, unlike mercury and PCBs analyses which can be performed by MDA Environmental Laboratory. The high cost of PFAS analysis (~$400/sample) requires supplemental funding, which has not been consistent or predictable. Given the limited funding and uncertainty of PFAS sources, selecting lakes and streams for first-time testing is an ongoing challenge. PFAS contamination in fish does not follow the patterns seen for other contaminants, making it challenging to know how often to resample known contaminated sites.

Anticipated resource needs: To address the need for expanded PFAS fish monitoring, the Interagency FCMP propose that PFAS become a routine analysis along with mercury and PCBs. It is estimated that this effort would require $640,000 per biennium of additional funding for extra analysis of fish that are already collected. It might also require extra staff if additional fish are collected.

Regulation

Develop statewide water quality standards for PFAS

The MPCA sets WQS to protect multiple beneficial uses – including domestic consumption (drinking water), aquatic consumption (human consumption of fish and shellfish), aquatic life (a healthy assemblage of aquatic biota) and wildlife (drinking water for wildlife). Preliminary data from monitoring PFAS in fish indicate that several PFAS – and particularly PFOS - bioaccumulate in fish tissue at levels that may be a concern for human consumption or the health of the aquatic ecosystem. Implementing statewide WQS for PFAS would provide regulatory basis for reducing PFAS loading to aquatic ecosystems, thereby removing the need for fish consumption guidance or other restrictions on the beneficial uses of waterbodies in the state.

Every three years, the CWA mandates that MPCA review existing WQS and propose revisions or additions as needed. The MPCA's Water Quality Standards Unit is currently undertaking the Triennial Standards Review process to determine if the development of a statewide PFAS standard will be placed on the MPCA's 2021 – 2024 water quality standards work plan. If MPCA determines there is a need to develop new PFAS WQS for any of these beneficial uses, the development of these numeric standards and adopting them into rule would be a multi-year process with several steps including economic analysis; outreach to potentially impacted partners, stakeholders, and Minnesotans; public comment and process steps (stipulated by the Administrative Procedures Act); and EPA approval. If the EPA does not publish recommended CWA criteria for PFAS and MPCA needs to develop standards itself, the standards will also require external peer review, which adds additional time and review to the process. *See* the Limiting PFAS Exposure from Drinking Water Issue Paper for discussion on developing WQSs applicable to waterbodies used as sources for drinking water and the Managing PFAS in Waste Issue Paper for a general discussion of WQSs in the context of waste facilities.

Work status: under consideration

Leader: MPCA Water Quality Standards Unit. **Partners**: MPCA Water Assessment and MDH Health, Environmental Surveillance, and Assessment Section.

Benefits: Water Quality Standards are regulatory values that are important tools to prevent and abate toxic pollutants affecting the beneficial uses of water resources. PFOS and other PFAS are pollutants known to occur in Minnesota surface waters. Their presence results from many ongoing water discharges and air emissions of PFAS. The levels of PFAS in some of Minnesota's waterbodies are causing some municipalities to install treatment of drinking water for PFAS, at great expense to taxpayers. Levels of PFAS are also impacting fish, triggering the need for fish consumption guidance, up to and including "do not eat" for fish at popular fishing locations. Minnesota's DNR is currently investigating potential uptake of PFAS from surface water to game people eat, like deer. These damages to natural resources hurt all Minnesotans, but especially those who rely on locally caught fish and game as a healthy source of protein for themselves and their families. Statewide WQS would provide transparent regulatory values and allow for the implementation of all related water quality programs – including effluent limits, assessment and impaired waters listings. These related actions would reduce ongoing PFAS releases to the environment and support continued progress on reducing the presence and concentration of these toxic pollutants in already impacted regions.

Challenges: WQS rulemaking involves significant agency staff resources. The benefits and costs of implementing WQS into statewide permitting and impaired waters listing would need to be evaluated. Rulemaking for PFAS WQS is especially complex because PFAS is a family of compounds consisting of thousands of known structures. Given the current state of knowledge regarding PFAS toxicity, MPCA would likely only be able to adopt WQS for human health based beneficial uses (drinking water and aquatic consumption) for those PFAS with health assessments completed by MDH or another risk assessment organization like the EPA or CDC. Additionally, research into appropriate fish consumption rates would be needed, including outreach to high fish consuming communities. Considerations of fish-eating wildlife and water to terrestrial organism impacts (like deer-drinking contaminated surface water) could also be considered. This effort would require a team of staff scientists and program managers with various areas of expertise.

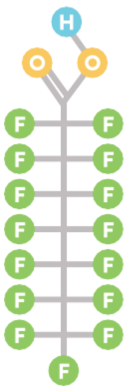
Resources: Adopting WQS requires support from the Governor's Office and other state agencies, in addition to time dedicated by many MPCA staff across multiple units.

Overview of intersectional issues

- **Pollution prevention**: Reducing PFAS pollution at the source places the burden with the polluters rather than receptors like consumers of locally harvested fish and game. The breadth of PFAS in use in products and industry and ongoing registration of new PFAS means that environmental monitoring and risk assessment cannot keep up. *See* the Preventing PFAS Pollution Issue Paper for actions related to reducing the overall production and emission of PFAS products.
- **Quantifying PFAS toxicity**: Having an understanding of the potential health impacts of PFAS exposure is key in ensuring exposure stays below "safe" thresholds and communicating with the public. Health-based guidance values, however, require data on toxicity and exposure that are not available for the vast majority of all the PFAS found in the environment. *See* the Quantifying PFAS risks to Human Health issue paper for more information on challenges stemming from PFAS toxicity data limitations.
- **Protecting Minnesota wildlife**: The limited data available for a small number of PFAS currently indicate that health-based values protecting humans from PFAS exposure from drinking water and fish consumption are more stringent than benchmarks protective of wildlife – therefore, protecting surface water for accumulation of PFAS in commonly consumed fish will also protect those fish and wildlife against toxic effects of those PFAS. However, ongoing review of wildlife research is needed to ensure that research continues support that conclusion, and that these conclusions also hold for other PFAS that are currently unstudied.
- **Developing and expanding access to analytical methods**: Analytical methods for PFAS are expensive and time-intensive to run and include only a subset of all PFAS that may be occurring in fish and game. Increased access to non-targeted analysis and cheaper screening-level PFAS methods would be beneficial for protecting consumers of fish and game – *see* the Measuring PFAS Effectively and Consistently Issue Paper for more information on the costs and challenges associated with measuring PFAS in biological matrixes.
- **Managing PFAS in waste**: Although waste facilities like landfills, composting facilities, and wastewater treatment plants are generally not sources of PFAS, they serve as conduits of PFAS to the environment from PFAS sources like industrial PFAS users or producers and consumer of PFAS-containing products. In some instances, PFAS concentrations from waste streams may result in levels of bioaccumulative PFAS like PFOS in surface water or soil that could lead to human health concerns for consumers of fish and game. Care is needed to capture PFAS pollution before it reaches waste facilities so that the operators of these facilities do not bear the full financial burden of mitigating PFAS emissions from other polluters.

Limiting PFAS exposure from food

Background



- Minnesotans should have confidence that their food is **free from harmful toxins**.
- Data collected by the Food and Drug Administration (FDA) and others indicate that widespread PFAS contamination of food products is not occurring in the US. However, if the environment where food is grown or raised has PFAS contamination, this **PFAS can accumulate into vegetables, grains, meat, and dairy products**.
    - Generally, foods with the highest PFAS concentrations are fish and game (especially organ meat) harvested from areas with PFAS contamination. For this reason, there is a separate issue paper on ensuring safe consumption of fish and game harvested in Minnesota. **This paper focuses on PFAS in food systems broadly**.
    - There is a wide range of potential exposure to PFAS from food based on individual consumption habits and geographic proximity to PFAS sources.
- There are multiple avenues by which PFAS can contaminate food. PFAS can accumulate in produce and livestock from **contaminated water, biosolids, air, soil, or animal feed** or migrate into food from **PFAS-coated cookware** and **food packaging**.
    - Though most produce, meat, and dairy does not contain detectible levels of PFAS, there have been several examples of **farms around the US forced to shut down** operations after realizing that PFAS contamination on their property was resulting in accumulation in food.
    - FDA's **regulation of food contact materials considers direct exposure** due to migration of the PFAS from the food contact material to the food – it does not consider risks associated with environmental releases (including releases to farmlands) following disposal of such food contact materials.
- After public concerns over exposure to the PFAS 6:2 fluorotelomer alcohol FTOH, FDA recently negotiated a phase-out of its use in food packaging.
    - Containers used to store and transport pesticides can contain PFAS. Pesticide active ingredients and inert materials used in Minnesota are not known to contain PFAS.

What is Minnesota doing now?

- Assessed risks from produce grown in home gardens
    - MPCA partnered with MDH to conduct a study of PFAS levels in exterior tap water, garden soil, and garden produce of homes in the East Metro to determine the extent to which current or past use of contaminated water for irrigation influenced levels of PFAS in garden soil and homegrown produce. This study concluded that there were no health risks associated with consuming homegrown produce.
- Investigated the presence of PFAS in pesticides used in Minnesota
    - In 2007, the MDA examined pesticide active and inert ingredients as a potential source of PFAS. Based on the information received from the EPA and the Minnesota pesticide registration database, MDA concluded that pesticides are not a significant source of PFAS. MDA was not aware of and did not consider any potential contribution from the pesticide containers.

What are remaining gaps and opportunities for action?

- **Gap**: Recent research shows that high levels of PFOS in milk may be possible if avenues of exposure to PFOS for dairy farms, and the animals on those farms, are not controlled. Because this is a relatively new discovery, livestock producers and associated industry stakeholders are not always knowledgeable about PFAS, including PFOS, and the potential paths of exposure to farms.
    - **Opportunity**: MDA could work with MPCA to identify and limit PFOS pollution in agricultural areas so that impacts to farms are limited. Voluntary free testing of feed, biosolids, or other potential upstream PFAS sources could encourage farmers to help proactively identify potential pathways for contamination. The goals of this work are not regulatory, but rather to expand knowledge and identify areas for future interventions that would protect farmers and food systems.
- **Gap**: While land application of biosolids has benefits for farming, land application has potential to contribute PFAS to groundwater, soil, surface water, crops, and, in some cases, livestock. These gaps in knowledge about PFAS fate and transport in biosolids make it difficult to proactively manage biosolids in a way that prevents contamination of food systems and protects farmers against the financial burdens associated with PFAS contamination.
    - **Opportunity**: With funding, MPCA could implement an existing proposal to 1) to evaluate and characterize PFAS concentrations in land-applied biosolids; leaching from those wastes; and subsequent movement of PFAS into water and food, and 2) to analyze alternative disposal and treatment options.
- **Gap**: Many studies have indicated that food packing is a source of PFAS exposure through food, but these products continued to be used around the country.
    - **Opportunity**: FDA has begun working with manufacturers to take voluntary steps to remove some PFAS from food packaging materials, Congress has banned the use of PFAS in food packaging for military meals, and many states and international groups have already mandated phase-outs of PFAS in food packaging. Minnesota could consider legislative action to ban the addition of PFAS to packaging, leveraging the policy research already completed by the Toxics in Packaging Clearing House and the existing laws in other states. These considerations could be part of a larger effort to review PFAS uses in consumer products or could be a standalone effort.

How does this work benefit human health and the environment?

- Collaborating with farmers to understand the ways that PFAS may be incorporated into food and **stopping PFAS loading from other industries to land and water used for agriculture** prevents PFAS concentrations from reaching levels that could result in significant accumulation in food.
- Preventing PFAS exposure from food packaging materials would have the direct benefit of **decreasing overall exposure to PFAS**, which lessens the likelihood of adverse health outcomes.

How does this work benefit Minnesota's economy?

- **Protecting agricultural businesses** from the financial impacts associated with PFAS contamination ensures that these businesses do not bear the burden of PFAS pollution caused by other industries.
- **Preventing adverse physical health outcomes** associated with PFAS exposure and **preventing negative mental health outcomes** associated with concern over exposure to these compounds is financially beneficial for families and individuals.

Background

Minnesotans should be confident that their food is free of harmful toxins. Understanding potential human exposure to PFAS from food is complex and requires investigating the multiple ways PFAS gets into food. Higher levels of PFAS on farmland can result in contaminated food products like produce, livestock, eggs, and dairy products as PFAS moves from water or soil to accumulate in the plants or grazing livestock. However, PFAS can also become incorporated into the foods we eat through PFAS used in food packaging or PFAS used to coat the cooking materials we use to prepare them. Adding to the complexity of food exposure is the wide variety of PFAS, all of which vary in uptake and sorption depending on their chemical structures. Studies have indicated that there is a large range of potential exposure to PFAS from food based on individual consumption habits, differences in geographic locations, and proximity to PFAS sources that may be impacting the local food production systems. Unlike some other contaminants of concern in food, such as pesticide residues, PFAS bioaccumulate into the plant and animal tissue itself and are therefore not removed by washing or cooking.[79]

This issue paper aims to provide background information on how PFAS can make their way into agricultural products, ongoing efforts to understand PFAS levels in food, and the regulatory structures in place to control levels of environmental contaminants like PFAS in food products. Next, this document will discuss the past and ongoing efforts underway at MDA and MPCA to understand potential PFAS impacts on Minnesota food systems, the gaps in current knowledge and policy, and opportunities to fill those gaps.

Potential avenues for PFAS to impact food systems

So far, data collected by the FDA indicate that widespread PFAS contamination of food products is not occurring in the US However, there are several known mechanisms by which PFAS can enter the food system and potentially contaminate agricultural products; discrete instances of PFAS contamination of fish, dairy products, meat products, and produce have been observed at farms that were impacted by localized environmental contamination of PFAS. The following sections describe mechanisms for PFAS to make their way into foods.

Contaminated water, soil, and feed for livestock

There have been several examples across the country of farms being forced to shut down after PFAS contamination in water and feed for livestock was found to lead to PFAS accumulation in milk and meat products. In New Mexico, a dairy farmer was forced to close his farm after finding that groundwater contamination from PFAS-containing firefighting foam use at a nearby Air Force base resulted in PFOS contamination of the milk, beef, and crops produced on his property.[80] In Maine, a farmer was notified that his drinking water was contaminated with PFOS. As this water was also used for livestock drinking water, the farmer voluntarily tested the soil on his property, the hay used for feed, the cows' milk and both his and his wife blood – all showed elevated levels of PFAS.[81] Further investigation revealed that the sources of PFAS to the livestock in this case likely included land-applied biosolids that had been contaminated with PFAS, land application of bioash and sludge from a local paper mill that likely included PFAS, and PFAS-contaminated drinking water. After this discovery, Maine set up a screening

---

[79] FDA. (n.d.). Questions and Answers on PFAS in Food. Retrieved from: https://www.fda.gov/food/chemicals/questions-and-answers-pfas-food

[80] Linn, A. (2019, February 19). Groundwater contamination devastates a New Mexico dairy – and threatens public health. *Searchlight New Mexico*. Retrieved from: https://nmpoliticalreport.com/2019/02/19/groundwater-contamination-devastates-a-new-mexico-dairy-and-threatens-public-health/

[81] Valdmanis, R. & Schneyer, J. (2019, March 19). The curious case of tainted milk from a Maine dairy farm. *Reuters.* Retrieved from: https://www.reuters.com/article/us-usa-dairy-chemicals/the-curious-case-of-tainted-milk-from-a-maine-dairy-farm-idUSKCN1R01AJ

program for PFAS in milk sold in the state and developed a health-based screening level for PFOS levels in milk (210 parts per trillion, equivalent to 210 ng/L). This screening process resulted in the discovery of another PFAS impacted dairy farm, this time in central Maine, which had levels up to 32,200 ng/L in raw milk.[82] Both farms in Maine have been forced to shut down due to the contamination. In Colorado, a farm near an Air Force base that used PFAS-containing firefighting foam was forced to stop all agriculture production after finding that PFAS had contaminated every type of food the farmer grew on the property, including spinach, garlic, and carrots, eggs, pork, and beef.[83] These are just examples of farms impacted by PFAS in water, soil, and biosolids that go on to impact produce, livestock feed, and livestock themselves – it is likely that other farms also have PFAS impacts on their properties but are currently unaware of the contamination.

Uptake into produce from air, water and soil

In addition to pathways for PFAS to contaminate livestock, it is also important to consider the mechanisms for PFAS to enter plants. Many PFAS are known to be transferred from soil to plants, with higher rates generally observed for short-chain PFAS like PFBS and PFBA than for longer-chain PFAS. However, some PFAS have also been shown to be incorporated into plants from the air.[84] MDH's study of PFAS content in produce grown in home gardens found that water loading of PFBA (calculated as the PFBA water concentration × minutes of watering/season) correlated to the PFBA concentration in the produce, indicating plant uptake from water. Much is still unknown about which PFAS are most likely to accumulate in plants, and which plant species are most likely to absorb PFAS.[85] Some plant species have shown such a high affinity for PFAS sorption from soils that there has been discussion of intentionally using these plants as a tool to remove PFAS and remediate contaminated soils.[86] Should there be commonly consumed plants with similar "hyperaccumulating" properties, care should be taken to ensure that any such plants grown for human or livestock consumption are not planted in an area with PFAS soil impacts.

Pesticide application

PFAS have, in the past, been used in a small number of pesticides both as the active ingredient to kill the targeted pests and as inactive parts of the formulation. Recent investigation has also indicated that PFAS are unintentionally present in at least one pesticide (Anvil 10-10, a pesticide used for mosquito spraying), which is believed to have been introduced from PFAS-containing packaging materials.[87,88] Given the extreme persistence of PFAS, there are concerns about the presence of PFAS in pesticides or containers that could be used to store and transport pesticides. Pesticides are applied to Minnesota fields or household lawns to kill insects, weeds, and microorganisms. When pesticide registrants have

---

[82] Miller, K. (2020, July 24). State investigating 'very startling' levels of PFAS chemicals on central Maine dairy farm. *Portland Press Herald*. Retrieved from: https://pfascentral.org/news/state-investigating-very-startling-levels-of-pfas-chemicals-on-central-maine-dairy-farm

[83] Subbaraman, Nidhi. (2019, July, 3). Farmers Losing Everything After 'Forever Chemicals' Turned Up In Their Food. *BuzzFeed News*. https://pfasproject.com/2019/07/03/farmers-losing-everything-after-forever-chemicals-turned-up-in-their-food/

[84] Wang W., Rhodes, G., Ge, J., Yu, X., & Li, H. (2020). Uptake and Accumulation of Per- and Polyfluoroalkyl Substances in Plants. *Chemosphere*. 261 (2020) 127584. https://doi.org/10.1016/j.chemosphere.2020.127584

[85] Jiao X., Shi, Q., & Gan, J. (2020). Uptake, accumulation and metabolism of PFAS in plants and health perspectives: A critical review. *Critical Reviews in Environmental Science and Technology*, DOI: 10.1080/10643389.2020.1809219

[86] Huff, D. K., Morris, L.,A., Sutter, L., Costanza, J. & Pennell, K.D. (2020). Accumulation of six PFAS compounds by woody and herbaceous plants: potential for phytoextraction. *International Journal of Phytoremediation*, *22* (14) 1538-1550. https://doi.org/10.1080/15226514.2020.1786004

[87] Abel, D. (2020, Dec 1). Toxic 'forever chemicals' found in pesticide used on millions of Mass. Acres when spraying for mosquitoes. *Boston Globe*. Retrieved from: https://www.bostonglobe.com/2020/12/01/metro/toxic-forever-chemicals-found-pesticide-used-millions-mass-acres-when-spraying-mosquitos/

[88] EPA. (n.d.) Per- and Polyfluoroalkyl Substances (PFAS) in Pesticide Packaging. Retrieved from: https://www.epa.gov/pesticides/pfas-packaging

registered PFAS as pesticides with the EPA, regulators acknowledged the potential to contaminate groundwater and surface water and restricted the registered uses. Such pesticides have generally been limited to residential settings where they were used for applications like for wasp nest or roach control. One such pesticide is Sulfluramid, which rapidly degrades in the environment to PFOS. Products containing Sulfluramid were never registered for food or crop use, but were allowed for indoor and outdoor use in residential buildings. In 2001, EPA negotiated an agreement with Sulfluramid producers to phase out sales of the product.[89] Despite efforts to reduce uses of pesticides that contained PFAS as an active ingredient, the other substances that go into pesticide formulation (often called "inert" ingredients) do not receive the same level of scrutiny as pesticide active ingredients. When EPA created a Significant New Use Rule for PFOA and PFOS under TSCA, this rule banned the use of PFOA or PFOS as inert ingredients in pesticides.[90] MDA has concluded that other inert ingredients used in Minnesota do not contain intentionally added PFAS (see the past project titled "Investigated presence of PFAS additives to pesticides registered for use in Minnesota" on page 102).

Transfer from food contact materials

The FDA regulates the substances used in food contact materials, with the goal of ensuring that these substances do not pose a risk to human health due to transfer of toxics into food. FDA states: "The authorization of the use of a food contact substance requires that available data and information demonstrate that there is a reasonable certainty of no harm for that use. To ensure food contact substances are safe for their intended use, the FDA conducts a rigorous review of scientific data prior to their authorization for market entry. This includes reviewing data on migration of the food contact substance into food, expected consumer exposure to the food contact substance from this and other uses in food, and potential health impact from this exposure."[91]

The FDA has approved several PFAS for use in different food contact applications including manufacturing non-stick cookware coatings. FDA states that because PFAS coatings are made of molecules that are polymerized and applied to the cookware through a heating process that tightly binds the polymer coating to the cookware, there is a "negligible" amount of PFAS migrating to food. Similarly, FDA argues that PFAS used in manufacturing of gaskets that come into contact with food do not pose a safety risk because they are also made of molecules that are polymerized. FDA has also approved PFAS uses on paper or paperboard and acknowledges that this PFAS can potentially migrate to food – however, FDA states that the "rigorous premarket safety review" ensures that the use of PFAS in food contact applications is safe.[92] Despite this stance, due to ongoing concerns about potential human health risks from PFAS authorized for use in food contact papers, FDA negotiated a phase-out of one PFAS (6:2 fluorotelomer alcohol), subject to the voluntary agreements.[93] FDA's regulation of food contact materials considers direct exposure due to migration of the contaminant from the food contact material to the food – it does not consider potential environmental contamination and subsequent contamination of food systems associated with disposal of such food contact materials. (*See* the Managing PFAS in Waste Issue Paper.)

---

[89] EPA. (n.d.). Office of Pesticides. Sulfluramid. Retrieved from: https://iaspub.epa.gov/apex/pesticides/f?p=CHEMICALSEARCH:31:::NO:1,3,31,7,12,25:P3_XCHEMICAL_ID:3957

[90] Perfluoroalkyl Sulfonates; Significant New Use Rule. 67 FR 72854. 72854-7286. (proposed Dec 2002, final Jan 2003). Retrieved from: https://www.federalregister.gov/documents/2002/12/09/02-31011/perfluoroalkyl-sulfonates-significant-new-use-rule

[91] FDA. (n.d.). Authorized Uses of PFAS in Food Contact Applications. Retrieved from: https://www.fda.gov/food/chemicals/authorized-uses-pfas-food-contact-applications

[92] FDA. (n.d.) Questions and Answers on PFAS in Food. Retrieved from: https://www.fda.gov/food/chemicals/questions-and-answers-pfas-food

[93] FDA. (2020). FDA Announces the Voluntary Phase-Out by Industry of Certain PFAS Used in Food Packaging. Retrieved from: https://www.fda.gov/food/cfsan-constituent-updates/fda-announces-voluntary-phase-out-industry-certain-pfas-used-food-packaging

PFAS monitoring in food

Various government agencies around the globe have recently made efforts to monitor for PFAS in food and compile publicly available data. Though the US FDA has only conducted a handful of studies of PFAS in food, the European Food Safety Authority (EFSA) published a comprehensive review on the topic in 2020.[94] Efforts by both agencies indicate that the food products with the highest concentrations and highest rate of detections of PFAS are fish, shellfish, and organ meat (offal). In other categories of food, PFAS are rarely detected. However, when PFAS are detected in other types of food, concentrations can be quite high. The results of FDA and EFSA monitoring work are summarized in the following sections.

FDA monitoring – milk survey and Total Diet Study

The FDA is responsible for ensuring food safety from physical, chemical, and biological hazards. In 2012, FDA analyzed 12 raw and 49 retail milk samples using a method developed specifically for PFAS analysis in milk and found only one detection of PFOS (160 ng/L) which was later traced to a farm that amended soils using contaminated biosolids. However, detection limits in this study were relatively high, at 130 ng/L. In 2019, FDA published a validated testing method for an expanded group of foods including breads, cakes, fruits, dairy, vegetables, meats, poultry, fish, and bottled water. This method includes 16 PFAS analytes and has relatively high detection limits due to challenges associated with measuring PFAS in a variety of foods with different chemical properties.[95] The FDA went on to use this method to analyze samples that were collected in the FDA's regular "Total Diet Study."[96] Results from the initial testing of PFAS in foods were used to determine how the FDA will monitor PFAS in foods going forward, including whether steps should be taken to include PFAS in the Total Diet Study analytes, and if targeted sampling for certain foods would be necessary. Results of preliminary Total Diet Study monitoring for PFAS found that PFAS was only detected in two samples of fish (tilapia) and one sample of meat (ground turkey). All other foods tested had PFAS concentrations below detection limits.[97] FDA has not announced intentions to conduct any additional PFAS surveys in food.

European Food Safety Authority – exposure assessment for PFAS in food

The EFSA is the regulatory body in the European Union responsible for protecting the public, livestock, and the environment against food-related risks. EFSA recently conducted an exposure assessment for PFAS in food to serve as the basis of regulatory thresholds for PFAS in agriculture products.[98] This exposure assessment included the review of 69,433 measurements of PFAS in food samples obtained from 16 European countries. Overall, 92% of the data were below detection limits. Of the 26 PFAS with data available, nine had no detections in food. The exposure assessment continued for the remaining 17 PFAS – PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFNA, PFDA, PFUnDA, PFDoDA, PFTrDA, PFTeDA, PFBS, PFHxS, PFHpS, PFOS, PFDS, and FOSA. The most data were available for PFOS, which had 8,498 measurements available in the database and PFOA, which had 8,197 measurements. There was also a large amount of data available for PFNA, PFDA, PFHxA, and PFHxS, all of which had over 4,000 measurements available. In general, this assessment found that PFAS were found more frequently in fish and other seafood and in meat and meat products (especially liver) than in other food groups. For PFOA, PFOS and PFHxS, it appeared that prior agreements to phase out use of these substances resulted in a

[94] EFSA. (2020). Outcome of a public consultation on the draft risk assessment of perfluoroalkyl substances in food. Retrieved from: https://www.efsa.europa.eu/en/supporting/pub/en-1931

[95] FDA. (2019). Determination of 16 Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) in Food using Liquid Chromatography-Tandem Mass Spectrometry (LC-MS/MS). *FDA Foods Program Compendium of Analytical Laboratory Methods: Chemical Analytical manual (CAM).* Retrieved from: https://www.fda.gov/media/131510/download

[96] FDA. (n.d.). Total Diet Study. Retrieved from: https://www.fda.gov/food/science-research-food/total-diet-study

[97] FDA (2019). FDA Makes Available Results from Second Round of Testing for PFAS in Foods from the General Food Supply. Retrieved from: https://www.fda.gov/food/cfsan-constituent-updates/fda-makes-available-results-second-round-testing-pfas-foods-general-food-supply

[98] EFSA. (2020). *Risk to human health related to the presence of perfluoroalkyl substances in food.* Retrieved from: https://www.efsa.europa.eu/en/efsajournal/pub/6223

decrease in concentration in food over time -- statistically significant decreasing trends were observed for concentrations of PFOS and PFHxS in fish and eggs. Concentrations of PFOS in fish and eggs decreased by a factor of 10 and 40, respectively. Overall, this report finds that most samples have no PFAS or very low levels of PFAS that fall below the limit of detection. However, in locations where there has been environmental contamination, it appears that PFAS can readily accumulate in fish, meat, eggs, dairy products, fruits, and vegetables.

Regulation of contaminants in food

The FDA is the regulatory agency in the US responsible for measuring and regulating contaminants in food. Tolerances are limits at or above which FDA will take legal action to remove products from the market. When no established tolerance exists, FDA may take legal action against the product at the minimal detectable level of the contaminant.[99] When it comes to PFAS, FDA has not set tolerances, as they do for other environmental contaminants like PCBs and inorganic arsenic. FDA's current policy is to collaborate with states when they identify foods that are grown or produced in a specific geographic area of PFAS contamination and provide technical assistance. This technical assistance can include analyzing samples and assessing the likely safety of the levels of the contaminants found, if any. FDA uses the EPA's reference dose – the dose at which long-term exposure is unlikely to cause harm – as a toxicity reference value for PFOA and PFOS when conducting a safety assessment at request of a state agency. The PFOS and PFOA reference dose is of 0.02 µg of PFOS and PFOA ingested per kilogram of bodyweight per day (2×10^{-5} mg/kg-day). The FDA does not currently have toxicity reference values for dietary exposure to any PFAS other than PFOA and PFOS.

The MDA also participates in ensuring food safety. Much of MDA's regulatory work currently focuses on foodborne pathogens like salmonella, listeria, and other biological contaminants. MDA responds to contamination issues in food and adopts federal standards for contaminants in food like those for heavy metals and dioxins, but does not actively survey food products for the presence of toxins. Because of the variety of foods consumed and produced in Minnesota, creating an effective surveillance system would be very difficult; even conducting monitoring of one food, such as milk, comes with many questions about logistics, enforcement, and unintended consequences for the agricultural industry. A proactive approach to managing PFAS, especially PFOS, is important to ensure that potential PFAS contamination is halted upstream of the farm businesses. The burden of PFAS pollution should fall on sources of PFAS (chemical production, industries with heavy PFAS use and emission) rather than the agricultural community. MDA hopes to collaborate with farmers to identify upstream PFAS sources with the potential to impact groundwater or feed and address this pollution at the industrial source before it impacts livestock and crops.

Challenges to managing PFAS in food systems

There are many remaining challenges to effectively ensure that PFAS do not contaminate food sources in Minnesota. Scientists are still studying several key subject areas including the relative contributions of PFAS to plants and livestock from soil, water, and air, the variability in plant uptake based on plant species and PFAS structure, PFAS transfer and accumulation from soil to feed to livestock, and spatial variation in PFAS impacts. These topics are areas of interest and investigation at MPCA, MDA, and MDH.

Past and ongoing efforts

The following sections describe the efforts taken by MDH and MDA to investigate the potential for PFAS exposure through food.

[99] 21 CFR 509. (2019). Unavoidable contaminants in animal food and food-packaging material. Retrieved from: https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?CFRPart=509&showFR=1&subpartNode=21:6.0.1.1.5.1

Monitoring

Conducted study of PFAS in produce grown in East Metro home gardens

After PFAS contamination was discovered in the drinking water of several communities in the East Metro Area, citizens raised concerns about the safety of consuming homegrown produce irrigated with PFAS-contaminated water. MPCA partnered with MDH to conduct a study using funding from the 3M settlement to investigate this question. The study was conducted at homes in Lake Elmo, Oakdale, and Cottage Grove during the 2010 growing season to assess levels of PFAS in exterior tap water, garden soil, and garden produce. The objective of the study was to determine the extent to which current or past use of contaminated water for irrigation influenced levels of PFAS in garden soil and homegrown produce. A secondary objective was to build the capacity of the MDH public health lab to conduct multi-media analysis of PFAS.

Homes were eligible to be included in the study if they were served by the Oakdale public water system or private wells known to have detectible levels of PFOA or PFOS. Drinking water mitigation measures were already in place at these homes, but exterior taps were not treated. Produce gardens had to be at least 50 square feet and in use continuously for the last five years in the same location. The first 20 households that responded to MDH's invitation letter and met eligibility requirements were enrolled. MDH also enrolled three households outside the groundwater contamination area with large home produce gardens as a comparison group. Pre- and post-gardening surveys were administered to homeowners to assess gardening practices. The MDH Public Health Lab (PHL) analyzed exterior tap water, soil, and the mature, edible portions of plants for PFBA, PFPeA, PFHxA, PFOA, PFBS, PFHxS, and PFOS. Laboratory methods were published in a peer-reviewed journal.[100]

A total of 343 water, soil, and produce samples were analyzed in this study. In outside tap water, PFBA was found most often (85%) and at the highest concentrations (median=0.98 µg/L); followed by PFPeA (40%) and PFOA (25%). In garden soil, PFBA, PFOA and PFOS were found in 100% of samples; median concentrations in soils in the groundwater contaminated area were 2-3 times higher compared to garden soil at homes outside the groundwater contaminated area. In produce, PFBA was detected most often (98%) and at the highest concentrations, followed by PFPeA (38%). The median PFBA produce concentration (0.68 µg/kg) was 10 times higher inside versus outside the groundwater contaminated area. The level of PFBA in produce depended on which produce type was analyzed, the part of the produce measured (i.e., floret, stem, root), and the amount of garden watering reported in the gardening survey. Detailed results were published in a peer-reviewed journal.[101] MDH conducted a risk assessment based on the results. No health risks of concern were found for those living in East Metro communities when considering combined risk from multiple exposure pathways.

Work status: completed

Leaders: MDH Environmental Surveillance and Assessment**. Partners:** MDH Public Health Lab and MPCA Remediation.

Benefits: This study highlighted the high leaching potential and high plant uptake rate of shorter-chain PFAS. This study found that when longer-chain PFAS like PFOS and PFOA were present in soil, they were not as readily translocated through plants as short chain PFAS like PFBA. This study was able to address concerns expressed by East Metro community members about eating fruits and vegetables that have been grown in soil or irrigated with water that contains PFAS. Additionally,

[100] Huset C.A. & Barry K. (2018). Quantitative determination of perfluoroalkyl substances (PFAS) in soil, water, and home garden produce. *Methods*, *28*; (5), 697-704. doi: 10.1016/j.mex.2018.06.017.

[101] Scher D.P., Kelly J.E., Huset C.A., Barry K.M., Hoffbeck R.W., Yingling V.L., & Messing R.B. (2018). Occurrence of perfluoroalkyl substances (PFAS) in garden produce at homes with a history of PFAS-contaminated drinking water. *Chemosphere*, *196*, 548-555. doi: 10.1016/j.chemosphere.2017.12.179.

samples of dust and soil conducted during this investigation allowed MDH to draw conclusions about relative risks of children's exposure to PFAS through dust or incidental soil ingestion in the groundwater contaminated area. This study also contributed to the availability of analytical methods for PFAS. Before MPCA conducted this study, there were no published methods for measuring PFAS in produce and limited study of PFAS exposure from garden produce.

Challenges: Developing analytical methods to quantify PFAS concentrations in various types of produce was challenging. Because the produce tested in this study had different characteristics – such as high acidity, or high moisture – methods needed to be tailored to groups of produce with similar chemical characteristics (*see* the Measuring PFAS Effectively and Consistently Issue Paper for more information).

Resources: The initial 2010-2011 budget in the MDH-MPCA interagency contract was $468,512. This budget also included costs related to collection and analysis of house dust samples at each home.[102] Staff resource needs were high, as study staff had to visit homes several times over the growing season to collect samples and administer surveys. This was helped by the proximity of the study area to the MDH offices and laboratory.

Source reduction

Investigated presence of PFAS additives to pesticides registered for use in Minnesota

In 2007, the MDA examined pesticide active and inert ingredients as a potential source of PFAS. Based on the information received from the EPA and the Minnesota pesticide registration database, MDA concluded that pesticides are not a significant source of PFAS. The MDA was not aware of and did not consider any potential contribution from PFAS in pesticide containers. The MDA's review found that Sulfluramid (a pesticide with an active ingredient that rapidly degrades to PFOS) was registered in Minnesota from 2006 to 2012. Sulfluramid-based products were sold as prefilled bait stations for control of ants, cockroaches, and termites in buildings, or bait stations for termite control around foundations, but had limited use in Minnesota. Sales of Sulfluramid in Minnesota remained near zero (0.01 to 0.21 lbs. per year) from 2006 to 2012 because of the limited need for termite control in Minnesota.

The review additionally found that PFAS were components of only one pesticide inert ingredient (Fluowet PL-80). Federally registered pesticide products containing this inert ingredient were registered for use from 2001 to 2008. The EPA cancelled all uses for this inert ingredient by February 2008. Products that contained this inert ingredient were registered in Minnesota from 2001-2006. The registered pesticide products carried low concentrations (≤ 0.5%) of PFAS in the final product formulation, suggesting very low rates of PFAS application through pesticides containing this inert ingredient. Additionally, recent testing of a pesticide used for mosquito control (Anvil 10-10) found PFAS that were introduced through packaging.[103] MDA has investigated potential PFAS releases from use of Anvil 10-10: the active ingredient in this product is phenothrin. There are several products registered in Minnesota which have phenothrin as an active ingredient. Phenothrin sales from all field applied products in Minnesota were on average about 1,000 lbs/year. MDA has concluded that Anvil 10-10 use is not a significant source of PFAS in the state.

Work status: completed

Leader: MDA Pesticide and Fertilizer Management Division.

---

102 Scher D.P., Kelly J.E., Huset C.A., Barry K.M., & Yingling V.L. (2019). Does soil track-in contribute to house dust concentrations of perfluoroalkyl acids (PFAAs) in areas affected by soil or water contamination? *Journal of Exposure Science Environ Epidemiology*, *29*, (2), 218-226. doi: 10.1038/s41370-018-0101-6.

103 Abel, D. (2020, Dec 1). Toxic 'forever chemicals' found in pesticide used on millions of Mass. Acres when spraying for mosquitoes. *Boston Globe*. Retrieved from: https://www.bostonglobe.com/2020/12/01/metro/toxic-forever-chemicals-found-pesticide-used-millions-mass-acres-when-spraying-mosquitos/

Benefits: Inclusion of PFAS in pesticides could be damaging for several reasons. Spraying of PFAS-containing pesticides could cause widespread PFAS contamination of soil, surface water, and groundwater. Additionally, any use of PFAS in pesticides on plants grown for human consumption could result in increased exposure to consumers. Even use of PFAS-containing pesticides on plants grown for feed could result in human exposure through bioaccumulation from the plants into livestock. Ensuring that no PFAS containing pesticides were currently registered for use in Minnesota and that historic applications of PFAS containing pesticides likely resulted in minimal amounts of environmental release helped focus attention to other opportunities for PFAS source reduction to agriculture.

Challenges: All inert ingredients in pesticide products, including those in inert mixtures, must be approved by the EPA. However, not all inert ingredients are required to be disclosed on the product label. Ensuring that PFAS were not included as inert ingredients required contacting pesticide manufacturers and federal regulators. Only PFOS and PFOA are restricted for use in pesticide products – so there could be new pesticides incorporating PFAS as inert ingredients. Although it is unlikely that EPA would approve PFAS as active ingredient or as an inert ingredient in new pesticide formulations, PFAS are not disallowed for use in these products.

Resources: This effort required time of MDA staff to investigate potential undisclosed PFAS additions to pesticides registered in Minnesota, but it did not require any supplemental funding. Repeating this investigation would be needed to determine if new PFAS inert ingredients were used in Minnesota after this investigation took place in 2008.

Gaps and opportunities

There are many remaining gaps in information and action around PFAS and Minnesota's food systems. Many farmers in Minnesota are likely unaware of the potential risks that environmental PFAS contamination can pose to their products. Farmers generally do not use PFAS themselves, and may not be aware of the PFAS emissions by other entities that may have pathways to reach their property. MPCA is taking many actions to reduce the overall release of PFAS into the environment (*see* the Preventing PFAS Pollution Issue Paper), but additional interventions may be needed to address past and ongoing sources of PFAS that may reach farms. MDA and MPCA could help farmers identify upstream sources of PFAS and collaborate with farmers prevent those sources from causing PFAS loading in their farms. These agencies could provide grants to aid in this upstream source identification process.

Additionally, there are significant gaps in understanding of how contaminated biosolids may be impacting PFAS levels in food. Due to the many beneficial outcomes of land-applying biosolids, there is a desire to develop screening levels and tools to determine in what contexts land-applying biosolids is a safe and responsible practice. Additional research on the fate of PFAS in land-applied biosolids is needed to develop these tools and continue reaping the positive effects of biosolids application.

Education

Inform and engage with farmers about potential upstream sources of PFAS

Recent research shows that high levels of PFOS in milk may be possible if avenues of exposure to PFOS for dairy farms, and the animals on those farms, are not controlled. Because this is a relatively new discovery, livestock producers and associated industry stakeholders are not always knowledgeable about PFAS, including PFOS, and what the potential paths of exposure for farms might be. This project would be designed to educate farmers on PFOS contamination as a public health problem, and the possible pathways for PFOS exposure to dairy farms. With a baseline understanding of this issue, dairy farmers can make decisions to ensure that they are limiting, to the extent possible, exposure and are preventing contamination of milk *before* it occurs.

The MDA could work with MPCA to identify and limit PFOS pollution from point sources in agricultural areas so that the impacts to dairy farms are limited. Voluntary and free testing of feed, biosolids, or other potential upstream PFAS sources would help proactively identify potential routes for PFAS to enter farmland and to provide information that could be used to stop pathways for PFAS contamination before they reach the farm. The goals of this work are not regulatory in nature, but rather to expand the knowledge base and identify areas for any needed upstream intervention that would protect farmers from PFAS pollution caused by other industries.

Work status: under consideration

Leader: MDA Dairy and Meat Inspection Division, Dairy Inspection Program. **Partners**: MPCA Remediation, dairy cooperatives, livestock producers.

Benefits: Educational programs equip farmers with the knowledge and, in some cases, the means to address issues proactively. This program will encourage action, but not penalize the dairy producer for things that are largely unknown or out of their control. It would also provide a means to collect information that may further our understanding of these issues with respect to animal agriculture and our food supply.

Challenges: Effective outreach depends upon adequate knowledge and planning, good strategies for working cooperatively with farmers, and trusted relationships between agency staff and farmers. MDA and MPCA both have regulatory and outreach functions -- it is important to separate outreach from regulation in this project. Any negative implications to a farmer's ability to market their products would significantly impact the success of the project, especially during times when the dairy and other agricultural industries are challenged. Agricultural industries are not expected to have funds to support such work, even on an informal basis.

Resources: This effort would involve multiple staff from MDA and MPCA to oversee these efforts and conduct outreach activities. Staff would be needed to develop communication and education materials and deliver training, both on a one-on-one basis, and with group outreach efforts. Additionally, if sampling of potential upstream sources or surveys were included, funding would be needed to pay for sampling and for staff to coordinate sampling and collection of survey information in conjunction with sampling projects undertaken.

Research

Conduct a study of biosolids and feed crop uptake

While land application of biosolids has benefits for farming, land application has been a source of PFAS to groundwater, soil, surface water, crops, and, in some cases, livestock. There are many unknowns regarding how PFAS moves out of biosolids and into the environment and food supplies. These gaps in knowledge about PFAS fate and transport in biosolids make it difficult to proactively manage biosolids in a way that prevents contamination of food systems and protects farmers against the financial burdens associated with PFAS contamination. The goal of this study is to collect data that would inform tools used to evaluate PFAS risks in land-applied biosolids and manage biosolids appropriately. Specifically, this project proposes 1) to evaluate and characterize PFAS concentrations in land-applied biosolids; leaching from those wastes; and subsequent movement of PFAS into water and food and 2) to analyze alternative disposal and treatment options and develop tools for managing PFAS-contaminated waste streams. This project was recommended for funding under the Legislative-Citizen Commission on Minnesota Resources (LCCMR) process, but funding for all LCCMR projects was not secured for the entire 2020 set of proposals. Nevertheless, a full description of the project, as proposed to LCCMR, is available online.[104] This project is also discussed in the Managing PFAS in Waste Issue Paper.

[104] LCCMR (2020), Environment and Natural Resources Trust Fund, 2020 Request for Proposals (RFP). Retrieved from: https://www.lccmr.leg.mn/proposals/2020/originals/098-b.pdf

Work status: proposed

Leader: MPCA Environmental Analysis and Outcomes Division. **Partners**: Participating wastewater treatment plants and academic partners at University of Minnesota and Texas Tech University.

Benefits: This project will develop pollution prevention, treatment, and disposal options that can be applied statewide. Long-term implementation of these strategies will safeguard drinking water and food supplies for current and future needs. Additionally, proactive biosolid management strategies with regard to PFAS will prevent financial hardship to farmers who would otherwise be challenged to sell PFAS-contaminated products.

Challenges: There will likely be challenges that would need to be overcome to complete this (or a similar) project. Analytical costs for conducting sampling are high (most PFAS samples cost between $300-400 for each sample to be analyzed). Understanding the fate of PFAS after land-application requires sampling in multiple media, including surrounding surface water, pore water in soils, down-gradient groundwater, crops planted on the biosolids amended field, and the soil itself. Finding fields for biosolid amendment that do not already have PFAS present would be a challenge. Using the results of the Minnesota study (and similar studies currently being undertaken by Wisconsin, Michigan, and New Hampshire) to develop a tool to determine risk levels and application strategies for biosolids would require significant time and effort.

Resources: This project proposal is complex, and would likely require about $1.4 million to complete in full. However, some aspects of the project proposal could be completed as standalone projects that require less funding.

Regulation

Limit or ban PFAS in food packaging materials

Many studies have indicated that food packing is a potential source of PFAS exposure through food,[105] and that disposal of food packaging materials containing PFAS results is a significant loading of PFAS to landfill leachate.[106] As noted previously, food contact substances – such as those in food packaging – are regulated by the FDA: "Food packaging manufacturers must prove to the US FDA that all materials coming in contact with food are safe before they are permitted for use in such a manner."[107] The FDA has taken some actions to remove authorization for the use of long-chain PFAS in food-contact uses, primarily with voluntary participation by manufacturers. The FDA's website states:

> "The FDA had authorized the use of long-chain PFCs for specific food-contact uses such as coatings on fast-food wrappers, to-go boxes, and pizza boxes before new scientific information brought safety concerns to light. In 2010, the FDA identified safety concerns through a comprehensive review of the available literature. These safety concerns included systemic and developmental toxicity in combination with biopersistence. The FDA then worked with industry to stop distribution of the long-chain PFCs most commonly used in food packaging at that time, which are authorized under food contact notifications. By October 1, 2011 these manufacturers had assured the FDA that they had voluntarily stopped distributing these long-chain PFCs."[108]

[105] Susmann, H., Schaider, L., Rodgers, K., & Rudel, R. (2019). Dietary habits related to food packaging and population exposure to PFAS. *Environmental Health Perspectives*. *127*, 10. https://doi.org/10.1289/EHP4092

[106] PFAS waste source testing report, New England Waste Services of Vermont. (2019).

[107] FDA. (2010). Overview of Food Ingredients, Additives & Color. Retrieved from: https://www.fda.gov/food/food-ingredients-packaging/overview-food-ingredients-additives-colors

[108] FDA. (2016). FDA Removes Approval for the Use of PFCs in Food Packaging Based on the Abandonment. Retrieved from: https://www.fda.gov/food/cfsan-constituent-updates/fda-removes-approval-use-pfcs-food-packaging-based-abandonment

Subsequently, in 2016, 3M informed the FDA that they were no longer making two additional long-chain PFAS, and so those were also proposed to be removed from the list of authorized substances. [109] In early 2020, additional concerns arose at FDA over short-chain PFAS. FDA "published findings from a post-market scientific review and analysis of data…on 6:2 fluorotelomer alcohol (6:2 FTOH).The data raise questions about the potential human health risks from dietary exposure resulting from these authorized uses of short-chain PFAS that contain 6:2 FTOH. Four manufacturers hold 15 food contact notifications for 11 compounds that may contain 6:2 FTOH."[110] This concern over exposure to 6:2 FTOH in food packaging led to the voluntary phase-out of its use (by 2024) by manufacturers.[111]

The voluntary nature of FDA action to date has led to Congressional proposals to ban PFAS in food containers and cookware, such as the *Keep Food Containers Safe from PFAS Act*, HR 2827, introduced in May 2019 by Rep. Dingell (D-MI)[112] and the *Prevent Future American Sickness Act of 2020,* S.3227, introduced in January 2020 by Sen. Sanders (I-VT).[113] Some regulatory action has been taken – the 2020 National Defense Authorization Act (P.L. 116-92), "prohibits the use of PFAS in food packaging for military meals ready-to-eat after October 1, 2021." [114]

Without bans at the federal level, some states are taking action. California, Washington, New York, and Maine have taken actions to phase-out all intentionally added PFAS to food packaging materials.[115,116,117,118] The Toxics in Packaging Clearing House, a non-profit that promotes consistent packaging regulation across states and supports companies seeking information on food packaging requirements, recently developed model legislation for a state-level PFAS in food packaging ban.[119] Legislative action of some kind would be needed to ban PFAS in food packaging at either the state or federal level. Minnesota could consider legislative action to ban the addition of PFAS to packaging, leveraging the policy research already completed by the Toxics in Packaging Clearing House. This proposal could be part of a larger proposal to review PFAS uses in consumer projects or could be a standalone proposal to ban PFAS in food packaging. The state could also be more active in pushing for action on PFAS in food contact materials at the federal level.

Work status: under consideration, would require legislative action

Leader: MPCA. **Partners**: Other state agencies.

[109] FDA. (2016). FDA Removes Approval for the Use of PFCs in Food Packaging Based on the Abandonment. Retrieved from: https://www.fda.gov/food/cfsan-constituent-updates/fda-removes-approval-use-pfcs-food-packaging-based-abandonment

[110] FDA. (n.d.). Authorized Uses of PFAS in Food Contact Applications. https://www.fda.gov/food/chemicals/authorized-uses-pfas-food-contact-applications

[111] FDA. (2020). FDA Announces the Voluntary Phase-Out by Industry of Certain PFAS Used in Food Packaging. https://www.fda.gov/food/cfsan-constituent-updates/fda-announces-voluntary-phase-out-industry-certain-pfas-used-food-packaging

[112] Keep Food Containers Safe from PFAS Act of 2019. (2019). H.R. 2827. 116 Cong. (2019-2020). https://www.congress.gov/bill/116th-congress/house-bill/2827/text/ih

[113] Prevent Future American Sickness Act of 2020. (2020). S. 3227. 116 Cong. (2019-2020). https://www.congress.gov/bill/116th-congress/senate-bill/3227

[114] The National Review. (2020, March 23). Attack on PFASs Extends to Food Packaging. Retrieved from: https://www.natlawreview.com/article/attack-PFAS-extends-to-food-packaging

[115]Attack on PFASs Extends to Food Packaging. (2020). *National Law Review.* https://dtsc.ca.gov/scp/food-packaging-containing-pfass/

[116]An Act To Protect the Environment and Public Health by Further Reducing Toxic Chemicals in Packaging. Retrieved from: http://www.mainelegislature.org/legis/bills/display_ps.asp?ld=1433&PID=1456&snum=129

[117] WA Toxics in Packaging Law - Chapter 70.95G RCW; 2018 revisions in Engrossed Substitute House Bill 2658, Chapter 138, Laws of 2018

[118] An Act to amend the environmental conservation law, in relation to the use of perfluoroalkyl and polyfluoroalkyl substances in food packaging. Retrieved from: https://www.nysenate.gov/legislation/bills/2019/s8817

[119] Toxics in Packaging Clearinghouse. https://toxicsinpackaging.org/

Benefits: Humans have been shown to be exposed to PFAS through eating food that has been in contact with PFAS-containing food packaging materials. Phasing-out the sales of PFAS-containing food packaging will have the direct benefit of reducing dietary exposure to PFAS. Additionally, PFAS have been shown to accumulate in landfill leachate, compost contact water and biosolids from wastewater treatment plants; a study of sources of PFAS to a landfill in Vermont indicated that the most "leachable" PFAS sources to the landfill were PFAS in food packaging materials. Reducing the loading of PFAS to landfills, composting facilities, and wastewater treatment plants will reduce the PFAS leaving those facilities and entering into the environment (including farmlands).

Challenges: Some food packaging materials have small amounts of PFAS due to use of recycled paper and incidental inclusion of PFAS from other sources (like PFAS in the trees used to make the paper). Regulations of PFAS in food packaging would likely need to set thresholds above which it is assumed that PFAS has been intentionally added, and therefore the product is not allowed to be sold. Enforcement of PFAS bans would likely require equipment, such as a Particle-Induced Gamma Ray Emission (PIGE) spectrometer, which can be used to rapidly determine if PFAS has been added to a material.

Resources: Though developing a legislative proposal to phase-out PFAS uses in food packaging materials in Minnesota would not require significant additional resources, enacting a Minnesota specific phase-out (should it be passed into law) would likely require significant funding for testing and enforcement. A federal ban would not have resource implications for Minnesota agencies because it would be developed and enforced at the federal level.

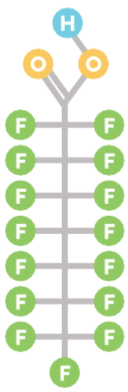
Overview of intersectional issues

- **Pollution prevention**: Reducing PFAS pollution at the source places the burden with the polluters rather than farmers and the public. The breadth of PFAS in use in products and industry and ongoing registration of new PFAS means that environmental monitoring, risk assessment and management strategies cannot keep up. *See* the Preventing PFAS Pollution Issue Paper for actions related to reducing the overall production and emission of PFAS products.
- **Reducing PFAS exposure from consuming local fish and game:** Though action is needed to better understand potential PFAS exposure from agriculture products like produce, dairy, and meat, hunters and fishers consuming animals caught in PFAS-contaminated areas are known to have potentially high levels of PFAS exposure. Minnesotans who eat organs from game, like animal liver or heart muscle, are especially vulnerable. Understanding total dietary exposure to PFAS will require consideration of exposure from contaminated game and fish along with any potential dietary exposure from other food sources.
- **Quantifying PFAS toxicity**: Having an understanding of the potential health impacts of PFAS exposure is key in ensuring exposure stays below "safe" thresholds and communicating with the public. Health-based guidance values, however, require data on toxicity and exposure that are not available for the vast majority of all the PFAS found in the environment. *See* the Quantifying PFAS Risks to Human Health Issue Paper for more information on challenges stemming from PFAS toxicity data limitations.
- **Developing and expanding access to analytical methods**: Analytical methods for PFAS are expensive and time-intensive to run, and include only a subset of all PFAS that may be occurring in food. Increased access to non-targeted analysis and cheaper screening-level PFAS methods would be beneficial for protecting consumers of food – *see* the Measuring PFAS Effectively and Consistently Issue Paper for more information on the costs and challenges associated with measuring PFAS in biological matrixes.

Summary

Understanding risks from PFAS air emissions

Background

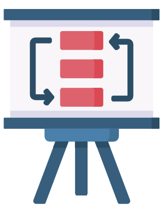


- **Clean air is essential** for maintaining health of our communities, thriving ecosystems, and a sustainable economy.
- PFAS can exist in the air in multiple forms: PFAS can be a gas or attached to particulate material suspended in the air. Particulate and gaseous PFAS can transport long distances.
- PFAS emissions to air result in concerns over **toxicity to humans from inhaling PFAS** and **transfer of PFAS from air to other environmental media like soil, surface water, and fish**.
  - There is currently limited information about toxicity of PFAS from air exposure, and there are no PFAS screening values available from MDH or EPA.
  - There are multiple examples from Minnesota and other states of facilities emitting PFAS to the air that goes on to contaminate soil, surface water, and other media. For example, a recent study of PFAS emissions indicates that a single facility in New Jersey resulted in PFAS soil contamination as far away as New Hampshire.
  - New site-specific criteria for PFOS developed under the CWA indicate that very low levels of PFOS in surface water can result in PFOS accumulating in fish to concentrations exceeding health-based values – this generates concern that air emissions of PFOS could cause or contribute to water quality impairments for PFOS.
  - The ability of a single facility to pollute a widespread region with highly persistent and toxic compounds makes controlling PFAS emissions to the atmosphere an important element of the PFAS management strategy.
- The Clean Air Act (CAA) is the foundational law for protecting air quality in the US Under the CAA, EPA regulates emissions of 187 air toxics (called Hazardous Air Pollutants or HAPs).
  - PFAS are not included as HAPs under the CAA.
- Though there are currently no regulations on PFAS emissions to the air in Minnesota, there are mechanisms in the state and federal government to either **voluntarily request** or **mandate reporting on some PFAS emissions** from facilities that use or produce PFAS products.
- The federal Toxics Release Inventory (TRI) requires some facilities to report releases of listed contaminants. **PFAS were added to the TRI** list for reporting year 2020, but **exemptions will result in continued unreported PFAS releases**.
  - Emissions reporting is not required for PFAS considered "confidential business information," and therefore the TRI only includes 172 PFAS.
  - Reporting is not required if the facility releases less than 100 pounds (~45,000 g) per year of PFAS-containing materials. (For comparison, it is estimated that 0.4 - 1 g/year of PFOS released from a metal plating site resulted in exceedances of a site-specific surface water criteria and a "do not eat" fish consumption advisory in a nearby lake).
  - Reporting is not required if the material released contains less than 1% PFAS or 0.1% PFOA.
  - Facilities employing fewer than 10 full-time staff are not required to participate in TRI reporting.
- MPCA requests that facilities **voluntarily provide emissions data every three years** on air toxics; MPCA uses this information to prepare the statewide air toxics inventory submittal to EPA's National Emissions Inventory. This is separate from the federal TRI program.

What is Minnesota doing now?

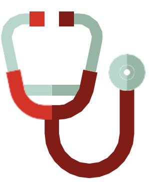
- For reporting year 2020, **MPCA requested voluntary reporting of PFOS, PFOA, PFBS, PFHxS, and PFBA** to the Air Emissions Inventory as part of a larger request that facilities report on several contaminants not designated as HAPs under the CAA.
  - Not all facilities will participate in this voluntary reporting request for various reasons, which may include the costs associated with estimating emissions and preparing the report.
- MPCA is conducting a year-long PFAS monitoring project, which includes the collection of ambient air, wet deposition, and dry deposition samples at four sites across Minnesota.
  - One "background" air monitoring site is located in Grand Portage, and three urban sites (St. Louis Park, Eagan, and Duluth) are located near potential emission sources. These locations were chosen to increase our understanding of PFAS sources and atmospheric transport.

What are remaining gaps and opportunities for action?



- **Gap**: Despite recent progress in requiring mandatory reporting of PFAS releases to the EPA through the TRI, exemptions in this federal program will result in gaps in the PFAS release data.
  - **Opportunity**: MPCA could consider making air toxics (including PFAS) emission reporting mandatory.
  - **Opportunity**: MPCA could require permitted facilities to conduct performance tests for PFAS and report results.
- **Gap**: There is currently a lack of modeling capability to understand how PFAS emissions to the air influence surface water, soils, sediment, and fish in the surrounding region.
- **Opportunity**: Developing a model that includes cross-media considerations of exposure for persistent and bioaccumulative compounds, starting with PFOS, could be used to assess cross-media risks and fill gaps associated with unknown degrees of environmental loading from air.

How does this work benefit human health and the environment?



- Efforts to understand which facilities are releasing PFAS will help MPCA and MDH **prioritize investigations into drinking water, surface water, fish, and soil**.
- Having the tools to demonstrate how air emissions may cause exposures to humans through multiple routes may help MPCA develop future strategies to reduce emissions and health impacts.

How does this work benefit Minnesota's economy?

- Reducing PFAS pollution by controlling PFAS releases from industrial sources **places the financial burden of PFAS controls with polluters.** This reduces the costs borne by waste and drinking water facilities -- many of which are publicly funded – who otherwise may need to manage and treat PFAS.
- Reducing PFAS pollution also prevents costs to consumers associated with decreased opportunities to harvest local fish and game that may be contaminated due to air emissions.
- Preventing adverse physical health outcomes associated with PFAS exposure and preventing negative mental health outcomes associated with concern over exposure to these compounds is financially beneficial for families and individuals.

MINNESOTA

Background

Clean air is essential for maintaining the health of our communities, thriving ecosystems, and a sustainable economy. In the context of environmental management of PFAS, air is a critical topic for two reasons. First, there is limited information about human exposure to PFAS in the air, especially in communities surrounding facilities that are likely releasing PFAS to the atmosphere through their production of PFAS, use of PFAS products, or burning of PFAS-containing waste. These concerns about the potential for direct toxicity to humans from inhalation of PFAS is motivating ongoing research. Secondly, air is a critical topic in PFAS management because there have been many documented cases of PFAS emissions to air resulting in significant impacts in other environmental media like surface water, soil, and biota.[120]

PFAS may transform to other PFAS, but the carbon-fluorine bonds characteristic of PFAS do not break down in the environment. When PFAS are released to the air, they can sometimes travel long distances in the atmosphere before they are deposited to the surface in rain or through dry settling processes. For example, a recent study of PFAS emissions indicates that a single PFAS facility in New Jersey potentially resulted in PFAS soil contamination as far away as New Hampshire.[121] PFAS have been found to accumulate in high concentrations in snow and biota in the Arctic due to patterns of long-range atmospheric transport.[122] PFAS can exist in the gas phase or can sorb to particulate material suspended in the air – both particulate and gaseous PFAS can be transported long distances. This high potential for PFAS to move through the atmosphere and contaminate other environmental media is the second reason why there is continued focus and concern regarding PFAS emissions to the air.

Regulatory structure controlling air emissions

The CAA is the foundational law for protecting air quality in the US Under the CAA, EPA sets National Ambient Air Quality Standards for six important air pollutants called Criteria Air Pollutants (CAPs), which include particulate matter in two size fractions, sulfur dioxide, nitrogen oxide, ozone, and carbon monoxide. The CAA additionally requires the EPA to regulate the emissions of 187 specific air toxics, referred to as Hazardous Air Pollutants (HAPs). The EPA regulates HAPs through National Emission Standards for Hazardous Air Pollutants (NESHAPs), which require the maximum degree of reduction achievable with modern pollution control technologies (known as maximum achievable control technology, or MACT). In Minnesota, potential health effects from air This process involves using risk screening tools to assess the potential for adverse health impacts from those air toxics, and potentially conducting more detailed risk assessments, as needed. PFAS are not included as CAPs or HAPs under the CAA, and are therefore largely unregulated in air. However, if a facility is shown to be causing or contributing to a water quality impairment, meaning that releases of the pollutant to any media are causing a surface water to not meet its “beneficial uses” under the CWA, then an enforcement action such as instituting a schedule of compliance (which could include requirements to reduce all PFAS emissions) might be an option to reduce air emissions.

---

120 Ahrens. L., & Bundschuh, M. (2014). Fate and effects of poly- and perfluoroalkyl substances in the aquatic environment: A review. *Environmental Toxicology and Chemistry*, *33* (9):1921-1929. DOI: 10.1002/etc.2663

121 Washington, J., Rosal, C.G., McCord, J.P., Strynar, M.J., Lindstrom, A.B., Bergman, E.L., Goodrow, S.M., Tadesse, H.K., Pilant, A.N., Washington, B.J., David, M.J., Stuart, B.G., & Jenkins, T.M. (2020). Non-targeted mass-spectral detection of chloroperfluoropolyether carboxylates in New Jersey soils. *Science*, *368*, (6495), 1103-1107. Doi: 10.1126/science.aba7127

122 Joerss, H., Xie, Z. Wagner, C.C., von Appen, W., Sunderland, E.M., & Ebinghaus, R. (2020). Transport of legacy perfluoroalkyl substances and the replacement compound HFPO-DA through the Atlantic Gateway to the Arctic Ocean – is the Arctic a sink or source? *Environmental Science and Technology*, *54,* (16), 9958-9967. https://doi.org/10.1021/acs.est.0c00228

Risks associated with PFAS air emissions

There are two types of risk associated with PFAS in the air: risks from direct inhalation exposure to PFAS in air and risks from exposure to PFAS from drinking water, food, dust, or other media that was contaminated via the atmospheric deposition of PFAS from air. Comparing pollution levels to "health benchmarks" is one way to estimate risk. A health benchmark is a level below which a pollutant is unlikely to cause adverse health effects in sensitive populations. Benchmarks are calculated for each type of media. PFAS benchmarks have been derived by MDH and MPCA for media such as drinking water and soil, but no MPCA-specific PFAS benchmarks have been derived for air due to a lack of relevant toxicological and occurrence data. Although PFAS are not designated HAPs under the CAA, there is interest in developing more tools – like health benchmarks – that recognize the potential for PFAS inhalation toxicity.

Based on the limited data available, PFAS exposure from drinking water, food, and dust is a larger source than exposure directly from air inhalation in most residential settings. Proximity to an air emission source for PFAS, like a PFAS remediation site or an industrial facility using PFAS, may result in different exposure patterns. Though Minnesota does not currently have inhalation health-based screening levels available for PFAS, Michigan has derived inhalation health-based screening levels for PFOA and PFOS. Michigan found that most PFOA and PFOS levels reported in outdoor air in the published literature were below the inhalation health-based screening levels. The only areas with PFAS concentrations that exceeded the health-based standards were found around a large PFAS manufacturing facility in West Virginia.[123] While these are encouraging preliminary findings about risks from direct exposure to PFAS in the air for the general public, those living near PFAS producing facilities and PFAS remediation sites may have higher exposure to PFAS via air. As more is learned about the health impacts from inhalation and about levels of PFAS in the air over time, inhalation health-based screening levels may be developed and refined. Currently, it is known that managing PFAS in air is a way to prevent PFAS contamination of soil, water, and food like fish, game, and produce. New studies of PFAS and plants indicate that PFAS in air is contributing to uptake or sorption to plant leaves (*see* Limiting PFAS Exposure from Food Issue Paper), which can contribute to contamination of livestock or exposure directly to humans. Additionally, dry and wet deposition of PFOS or PFOS-precursors from air emission sources could be significant enough to cause an exceedance of MPCA's site-specific water quality criteria for PFOS in fish tissue and water. More research is needed into what levels of PFOS and PFOS-precursor air emissions cause sufficient loading of PFOS in surface waters to result in water impairments under the CWA.

PFAS emissions and monitoring data

Although there are currently no state or federal regulations limiting PFAS emissions to the air, there are mechanisms in the state and federal government to either voluntarily request or mandate reporting on some PFAS emissions from facilities that use or produce PFAS products. At the federal level, amendments to the 2020 National Defense Authorization Act required that EPA, using the TRI, mandate reporting on emissions of PFAS that have a structural identity determined not to be "confidential business information." Despite the new reporting requirements under TRI, there are several exemptions that result in situations where PFAS will not need to be reported. TRI requirements only apply to facilities that employ more than 10 staff. If the PFAS emissions are less than 100 pounds per year, the facility does not need to report any release data. Additionally, if the PFAS-containing product emitted contains less than 1% PFAS or 0.1% PFOA, these emissions do not need to be reported, regardless of the quantity of product released. Finally, the facilities will only need to report PFAS emissions for the listed PFAS (172 are listed), not all PFAS (of which there are over 5,000). This reporting data will be available for the first time in the summer of 2021. In a comment letter to EPA on the additions of PFAS to the TRI,

[123] Michigan PFAS Action Response Team (MPART). (n.d.). Air quality related issues. Retrieved from: https://www.michigan.gov/pfasresponse/0,9038,7-365-86704_94366---,00.html

MPCA argued that a reporting threshold of 0.1 g/year, as is in effect for dioxins, is the appropriate reporting threshold for mandatory PFAS emissions reporting. This conclusion was reached by calculating that 0.4 - 1 g/year of PFOS emissions associated with a metal plating facility in Minnesota caused exceedances of site-specific surface water criteria for PFOS and resulted in a "do not eat" fish advisory in a nearby lake.[124] The existing reporting thresholds of 100 pounds/year for PFAS would not capture smaller PFAS releases that are still significant.

At the state level, MPCA does not have mandatory reporting requirements for emissions data of contaminants that are not HAPs. However, MPCA requests that facilities voluntarily provide air toxics emissions data every three years; MPCA uses this information to prepare the statewide air toxics inventory submittal to EPA's National Emissions Inventory. If a facility does not respond to the voluntary request to report air toxics, the MPCA may estimate toxics emissions by using information from permits and the mandatory data submissions to the TRI to identify processes and the expected quantity of chemicals released. For the first time in 2020, MPCA requested that facilities voluntarily submit release information for five PFAS. Because PFAS have never before been included, MPCA's understanding of PFAS air emissions in Minnesota is currently extremely limited.

In addition to voluntary reporting for PFAS, there are some ongoing efforts to monitor for PFAS in the air in the upper Midwest. Minnesota is currently conducting air monitoring for PFAS at four different locations in the state. Indiana University is using a $6 million EPA Multi-Purpose Grant (MPG) to launch a PFAS monitoring effort in the Great Lakes region implemented by the Integrated Atmospheric Deposition Network.[125] More research into PFAS concentrations in air and rainwater would inform strategies to reduce PFAS loading to the environment.

Challenges to reducing risks associated with PFAS air emissions

All PFAS are either highly persistent or degrade to highly persistent PFAS. Ongoing emissions of PFAS cause increased loading to the environment, potentially to levels causing adverse health effects in humans or wildlife. The ability of some PFAS to move long distances in the atmosphere before they are deposited to the surface means that air emissions could potentially impact soils, surface water, and other environmental media hundreds of miles away from the original emission site. The ability of a single facility to pollute a widespread region with these highly persistent compounds makes controlling PFAS emissions to the atmosphere an important, but challenging, element to any holistic PFAS management strategy.

One challenge in controlling PFAS emission stems from the lack of EPA-approved stack testing methods for PFAS and the lack of any air methods that capture the diversity of PFAS being produced or used in the country today. Though EPA has planned publication of stack emission testing methods for PFAS in 2021, these methods will only include a subset of all PFAS being produced and used in industry or commerce. There are stack testing methods available that could be used in lieu of the EPA-approved methods, and these methods are being used in a regulatory context in other states. Many PFAS (such as the chlorinated PFAS recently discovered in New Jersey soils[126]), are considered "confidential business

---

[124] MPCA. (2020, Jan 30). Minnesota Pollution Control Agency's (MPCA's) comments on the Addition of Certain Per- and Polyfuoroalkyl Substances; Community Right-to-Know Toxic Chemical Release Reporting (EPA-HQ-TRI-2019-0375). Available upon request.

[125] EPA. (2019, September 26). EPA Awards Nearly $6 Million to Indiana University to Monitor Airborne Pollution in the Great Lakes. [Press release]. Retrieved from https://www.epa.gov/newsreleases/epa-awards-nearly-6-million-indiana-university-monitor-airborne-pollution-great-lakes

[126] Washington, J., Rosal, C.G., McCord, J.P., Strynar, M.J., Lindstrom, A.B., Bergman, E.L., Goodrow, S.M., Tadesse, H.K., Pilant, A.N., Washington, B.J., David, M.J., Stuart, B.G., & Jenkins, T.M. (2020). Non-targeted mass-spectral detection of chloroperfluoropolyether carboxylates in New Jersey soils. *Science*, *368*, 6495, 1103-1107. Doi: 10.1126/science.aba7127

information" and researchers are not able to include them in analytical methods for monitoring until they are first "discovered" using laborious non-targeted analytical techniques.

The widespread inclusion of PFAS in commercial products has led to concerns about PFAS entering the atmosphere at waste facilities. Some PFAS-containing commercial products are likely incinerated at trash collecting facilities – because standard incineration procedures are not likely to break the carbon-fluorine bond in PFAS, PFAS in commercial products could be emitted to the atmosphere. Other PFAS-containing commercial products are disposed of at landfills, where water-soluble PFAS can leach into the wastewater (leachate) over time. Procedures used by hazardous waste managers and non-hazardous landfills to reduce the volume of PFAS-containing leachate through evaporation could also lead to PFAS being emitted to the atmosphere. Volatile PFAS in waste could be released from landfills or composting facilities over time. Although PFAS destruction may be possible at high temperature hazardous waste incineration facilities, without reliable and consistent stack test methods, it can be difficult to conclude if complete destruction is occurring. There are currently lawsuits related to alleged PFAS contamination resulting from incineration of PFAS-containing firefighting foams in New York.[127] Due to the lack of air monitoring data and stack emission testing methods, there are many uncertainties about the amount of PFAS pollution resulting from incineration of PFAS-containing waste or volatilization of PFAS at landfills.

Another challenge related to managing PFAS emissions to air is the lack of information about direct PFAS toxicity from inhalation. Most PFAS have no publicly available toxicity information for inhalation routes or other routes of exposure, and little is known about PFAS concentrations in outdoor or indoor air. Many PFAS are considered "confidential business information" and their structures, uses, and emissions are not shared with the public. With this dearth of occurrence, environmental fate, and toxicity information for PFAS in the air, air risk assessment is highly uncertain.

Past and ongoing efforts

Despite the many challenges associated with measuring PFAS in the air and collecting data on PFAS emissions, Minnesota has undertaken several projects related to PFAS and air exposure. Other projects to gain a better handle on PFAS and air emissions and deposition are ongoing.

Emissions reporting

Adding Five PFAS to Minnesota Air Emission Inventory for 2020

Facilities with air permits are required to submit an Emission Inventory to the Minnesota Pollution Control Agency (MPCA) every year for the six CAPs in addition to ammonia, mercury, and greenhouse gases. Every three years, facilities are also required to report emissions of HAPS to MPCA for inclusion in the State Air Toxics Database. The upcoming year for emission reporting (2020) is a year that will include air toxics emission reporting to MPCA. Beginning with the 2020 reporting year, facilities will be *voluntarily* asked to submit additional air toxic compounds that are not formally designated as HAPs. Five of the newly asked for compounds are PFAS: PFOS, PFOA, PFBS, PFHxS, and PFBA.

In addition to reporting their air emissions to the MPCA, facilities also report their emissions to the EPA via the TRI program. The reporting requirements for TRI are different than the requirements facilities have for reporting to the state. Starting in 2020, EPA added 172 PFAS to the TRI mandatory reporting list. Though the TRI reporting is mandatory for all facilities, in general, voluntary emissions reporting to Minnesota are more detailed than to the TRI program. Minnesota requests reporting on specific amounts of compound released rather than a range (as is reported for TRI). Minnesota also requests

[127] Lerner, S. (2020). Toxic PFAS fallout found near incinerator in upstate New York. *The Intercept*. Retrieved from: https://theintercept.com/2020/04/28/toxic-pfas-afff-upstate-new-york/

process-specific emission values rather than aggregated emissions for all processes at the plant. This detailed information that is voluntarily submitted to MPCA can be compared to the mandatory TRI reporting results to determine if there are discrepancies.

Work status: completed, will go into effect for the 2020 reporting cycle

Leader: MPCA Environmental Analysis and Outcomes Division, Air Assessment Section.

Benefits: By asking facilities to voluntarily submit data on PFAS emissions, MPCA will have data that can be used to understand and improve air quality at a state, regional, and national level. This information will help evaluate health risks and identify areas of concern for environmental justice. In addition to the voluntary reporting emission inventory reporting, facilities will also be required to submit emission reporting to the EPA for 172 PFAS under the new TRI rules that go into effect for 2020. This combination of TRI data and more detailed voluntary emission data will help piece together a more complete picture of total PFAS emissions to air in the state.

Challenges: Because the submission of data on additional air toxics to the state is optional, often data are incomplete or inaccurate. The data submitted to the MPCA is crosschecked with the TRI data to identify differences in emissions totals reported or any missing pollutants. Some facilities are contacted by MPCA to clarify or correct differences in the reporting between the two programs. Though MPCA is currently only asking for voluntary reporting of five PFAS, it is possible that future requests will include data on more PFAS, especially volatile PFAS and novel PFAS replacement chemistries.

Resources: While there will be some additional efforts made to notify facilities of the PFAS and other air toxic compounds being asked for this year, as well as some additional Quality assurance/ quality control required, the resources needed for MPCA are not expected to be significant.

Ambient air monitoring

Ambient air concentrations and air deposition research project

This year-long ambient air PFAS monitoring project includes the collection of ambient air, wet deposition, and dry deposition samples at four sites across Minnesota. In this new ambient air monitoring effort, locations were chosen to increase MPCA's understanding of PFAS sources and atmospheric transport. The year-long sample collection effort will additionally increase MPCA's understanding of temporal trends and the influence of various weather conditions on PFAS atmospheric dynamics. One "background" air monitoring site is located in Grand Portage, and three urban sites (St. Louis Park, Eagan, and Duluth) are located near potential emission sources identified by the Remediation Division of MPCA, and one known PFAS emission source. Samples are collected at all sites every two weeks.

Air data for PFAS in the state are extremely limited. Previous air monitoring for PFAS in Minnesota had been limited to the East Metro, adjacent to local sources such as landfills known to be PFAS waste disposal sites. Since that prior monitoring effort in 2008, Michigan has developed inhalation health screening levels for PFOS and PFOA that will help provide a sense of relative risks from direct inhalation of PFAS.[128] In addition, Minnesota's new water quality criterion for PFOS is low, and may be exceeded solely through atmospheric deposition of PFAS. Understanding the relative contribution of PFAS loading to surface waters from atmospheric inputs could help focus regulatory priorities.

[128] Michigan PFAS Action Response Team. (n.d.) Air quality related issues. Retrieved from: https://www.michigan.gov/pfasresponse/0,9038,7-365-86704_94366---,00.html

Work status: ongoing

Leaders: MPCA. **Partners**: Grand Portage Band of Lake Superior Chippewa, SGS AXYS Analytical Services.

Benefits: Understanding ambient concentrations of PFAS at background sites and sites adjacent to sources will help us better understand fate and transport of PFAS, and to clarify the importance of air transport as a mechanism of environmental contamination of PFAS. If data from this study show potential harm, either directly via inhalation or indirectly via surface water and fish contamination, resources can be prioritized to reduce potential health risks to communities. Additionally, this research on potential air contributions to the environment is useful to regulatory partners in the Great Lakes region, who have expressed interest in Minnesota's results.

Challenges: Lack of existing standards or guidance for PFAS in Minnesota makes it difficult to draw conclusions about potential health risks and difficult to communicate with community partners eager to know if the levels of PFAS in their air are cause for concern. Lack of air toxics rules or permit limits mean that if detectable PFAS are measured in air, there will be limited regulatory avenues to stem the ongoing pollution.

Though this project is fully funded, the results may indicate a need for future and/or ongoing PFAS monitoring in air. PFAS monitoring in air is more expensive (about twice the cost per sample) and more complex than monitoring in other media like water. Given that there has been less attention to monitoring PFAS in air than in other media, determining the most appropriate sampling methods is also difficult. A monitoring site with electricity and a fence is required in order to deploy a sampler that will not be tampered with or disturbed and trained staff are needed to operate the samplers. Any future air monitoring efforts would require additional staff and funding.

Resources: This project is funded by MPCA and an EPA MPG, with a total cost of approximately $250,000. Though existing MPCA monitoring staff have been able to work on this project, it is probably not feasible for current staff to do extensive PFAS monitoring in the long-term because current staff are busy supporting the state's required air monitoring network.

Gaps and opportunities

There are several key gaps in research and policy related to PFAS and air. Though mandatory PFAS emission reporting to the EPA through TRI will go into effect for year 2020, exemptions in the TRI reporting requirements will leave gaps in the PFAS air emission database. Additionally, reporting to the federal TRI program is not as detailed as toxics reporting to MPCA's Air Toxics Database. There are currently no mandatory PFAS reporting requirements for PFAS in Minnesota, which means that MPCA has limited information available to assess which facilities may be major sources of PFAS. To fill this gap, MPCA could consider making PFAS reporting mandatory through a rulemaking process. Though PFAS are not listed as HAPs, a rulemaking for mandatory reporting of air toxics could include mandatory reporting of PFAS.

Once MPCA has an understanding of which PFAS are being emitted in the state, there are still significant gaps in our understanding of both direct toxicity of PFAS via inhalation and indirect toxicity caused by PFAS loading to other environmental media like surface water, fish, game, and soil. The gaps associated with quantifying direct PFAS inhalation toxicity are discussed in the Quantifying PFAS Risks to Human Health Issue Paper and are mainly driven by work completed at MDH. However, gaps associated with gaining an understanding of PFAS dynamics from air to other media fall under the purview of the MPCA's Environmental Analysis and Outcomes, Air Modeling, and Water Quality Standards units. Developing a model that includes cross-media considerations of exposure for persistent and bioaccumulative compounds, such as PFAS, could be used to assess PFAS cross-media risks and fill gaps associated with unknown impacts of loading to the air.

Consider a new rule to make air toxics reporting mandatory, including PFAS

Air toxics emissions reporting by permitted facilities in Minnesota is currently voluntary -- PFAS have not historically been included in the list of compounds for voluntary toxics reporting. In this proposal, Minnesota would join the growing list of states (including nearby and Region 5 states like WI, IA, ND, OH, IL, etc.) that require annual or once every three-year reporting of air toxics by certain permitted facilities that meet specified reporting requirements. The rulemaking to make this reporting mandatory could include PFAS in the proposed list of air toxics with required reporting. In the summer of 2020, MPCA presented a webinar to interested stakeholders explaining the current status of air toxics reporting in Minnesota, the gaps in the current approach, and the potential new reporting rule that MPCA could put in place. This presentation and a summary of stakeholder comments is available on MPCA's website. [129]

Work status: ongoing

Leader: MPCA Air Policy Unit. **Partners:** MPCA Emissions Inventory, Risk Evaluation, Small Business Assistance, and Air Permitting programs.

Benefits: Mandatory air toxics reporting would dramatically improve the emission inventory information that MPCA receives. This emission inventory information supports achieving MPCA's goals of eliminating the state's disproportionate air pollution impacts and ensuring the quality of ambient air exceeds health benchmarks. In addition to improving the quality of the air toxics inventory, mandatory air toxics reporting that includes cross-media pollutants will allow MPCA to have the data needed to address air emission of pollutants posing a threat to water quality and fish consumption, including PFOS. The proposed rulemaking would further support MPCA's strategic goal to "improve air quality in population centers" by pinpointing the largest emitters of air toxics in these cities and guiding business assistance programs to target pollutant reductions that provide the greatest health benefits. This would reduce the emissions and deposition of persistent pollutants, ultimately improving the air, soil, and water quality throughout the state.

Challenges: Because some PFAS-containing products do not contain labels indicating the PFAS present, a facility may be using a PFAS-containing product without knowing it, or at least without knowing the PFAS concentration or composition. This would make it difficult to accurately estimate emissions. In addition, inventorying PFAS emissions from permitted facilities will not capture all air releases relevant to Minnesota -- facilities in neighboring states would not be captured unless that state also requires reporting, and emissions from accidental spills or non-permitted sources within Minnesota would not be captured. It would also be challenging for MPCA to determine which PFAS should be included in mandatory reporting requirements. If the proposed rule including mandatory reporting for all PFAS (the most health-protective and inclusive option), facilities may particularly need assistance to accurately identify PFAS emissions from less well known PFAS. Just as there are challenges knowing what PFAS are present in other media, it will be difficult to know which PFAS are present in air emissions without non-targeted analysis of samples from a given facility. Facilities will likely be concerned about any new reporting requirements due to the challenges associated with measuring or estimating PFAS emissions and the administrative challenges associated with emissions reporting.

Resources: Rulemaking is a time intensive process, with many steps and requirements for agency staff. In addition to the challenges associated with rulemaking, the first year of implementation would likely require increased outreach to businesses and additional help from the MPCA Emissions

[129] MPCA. (n.d.). Potential changes to air toxics reporting. Retrieved from: https://www.pca.state.mn.us/air/potential-changes-air-toxics-reporting

Inventory program to assist facilities that are new to emissions reporting. Additional analysis time would be needed to quality assure and process the increase of emissions data and the number of facilities reporting.

Require performance testing for PFAS from permitted facilities

Facilities or stationary sources that emit pollutants to the air may be required to obtain an air quality operating permit. Minnesota issues multiple kinds of air permits, including individual Title V/Part 70 permits, individual state operating permits, capped permits, general permits, and registration permits. The specific permit required depends on the facility type and its potential to emit air pollutants. Air quality operating permits routinely include requirements for the facility to conduct performance testing. Performance testing, also known as stack testing, is a process of measuring the emissions from some or all of the permitted emission units at the facility. Minnesota rules specify when performance testing may be required. The MPCA may require testing to quantify the emissions from an emission facility where the agency has determined a possible environmental or public health concern exists.

Performance testing for PFAS is limited, but available. As described by the Michigan PFAS Action Response Team,[130] "some states have conducted stack testing using a modified US Environmental Protection Agency (EPA) Method 5. These states include: NY, NH, and NC." These stack tests focused on industrial facilities; for instance, New Hampshire in collaboration with EPA has investigated PFAS in air emissions from a performance plastics facility.[131] New York has looked at PFAS air emissions and deposition from a similar performance plastics facility.[132,133] For stationary source emission sampling and analysis, EPA Office of Research and Development (ORD) and Air Quality Planning and Standards has identified an "Other Test Method" for PFAS called "OTM-45: Measurement of Selected Per- and Polyfluorinated Alkyl Substances from Stationary Sources." This "other test method" does not have regulatory status (this test method has not been approved through federal or state rulemaking).

In order to better understand PFAS air emissions, the MPCA could develop a strategy to incorporate PFAS performance testing into air quality operating permits or compliance documents. Developing and implementing the strategy would require considering which types of facilities should conduct performance testing – likely focused on facilities most likely to have PFAS emissions. The strategy would consider the available performance test methods, which PFAS the test methods detect, and the necessary performance test frequency.

Leader: MPCA Industrial Division.

Benefits: Understanding sources of PFAS (such as PFAS producing facilities and other industrial facilities that use PFAS-containing products) and levels of PFAS emitted would help guide future PFAS reduction strategies. Performance test data could help support understanding of whether PFAS are destroyed in incinerators, and the feasibility of air emission control technology to control PFAS emissions. Performance test data could also be used to support future regulations of PFAS uses or restrictions on PFAS emissions.

---

[130] Michigan PFAS Response Team. (n.d.) Air Quality Related Issues. Retrieved from: https://www.michigan.gov/pfasresponse/0,9038,7-365-86704_94366---,00.html

[131] New Hampshire Department of Environmental Services (2019, April). 2018 Results for Per-and Polyfluoroalkyl Substances (PFAS)Analyses Performed by United States Environmental Protection Agency's Office of Research and Development for Samples Collected in Southern New Hampshire. https://www4.des.state.nh.us/OneStopPub/Air/330110016504192019TypeCR.pdf

[132] New York Department of Environmental Conservation. Hoosick Falls Area Information for Communities Impacted by Per- and Poly-fluorinated Akyl Substances (PFAS) https://www.dec.ny.gov/chemical/108791.html

[133] New York Department of Environmental Conservation. (2020, February 12). Presentation: PFAS Air Emission Testing Results from Manufacturing Sources. Retrieved from: https://gflawma.wildapricot.org/resources/Documents/2)%20Thomas%20Gentile%20AWMA%202-12-20.pdf

Challenges: There is currently no approved stack test methodology that is enforceable. In addition, current stack testing methods are expensive. Prioritizing which permits should require performance testing will require research and investigation into currently limited information about PFAS air emissions and discussion with regulated facilities. The newest set of federal TRI data, data from the PFAS ambient air monitoring project (*see* pg. 115), Pilot PFAS Inventory (*see* the Remediating PFAS Contaminated Sites Issue Paper), and mandatory air toxics emissions reporting rule (*see* pg. 117) might all provide information to support decisions about which facilities would be likely emitters of PFAS. The legal soundness of MPCA's authority to require PFAS performance testing should be well understood before requiring any testing since permitted facilities and industry groups may challenge the agency's authority. The regulatory focus of air permits is on "regulated air pollutants" and "applicable requirements."

Resources: MPCA would require moderate to significant staff resources to complete this action.

Explore cross-program air modeling project to understand PFAS air emissions and their impacts on air, groundwater, surface water, and fish tissue

Information is needed regarding the level of PFAS air emissions that could impair surface water or other media so that air emissions can be controlled to protect these sensitive endpoints. The EPA developed a model to estimate deposition of air pollutants onto surfaces (e.g. water, soil) and uptake into the food chain using chemical-specific parameters.[134] This model, called the Human Health Risk Assessment Protocol (HHRAP), is currently used by the air toxics program at MPCA to assess the fate of persistent, bioaccumulative, and toxic compounds, including potential cross-media impacts of new projects and permit amendments. This proposal is to apply the HHRAP to model PFAS movement from air to water and soil, and subsequent uptake to plants and fish.

Using the HHRAP for PFAS would involve gathering available chemical/physical fate and transport parameters for PFAS. These include parameters necessary to estimate sorption to water and soil particles, dissolution in water, uptake into biota, sorption into the organic fraction of soil and water, bioaccumulation rates, and volatility. If the model were to be refined for use at a specific site, site characteristics (including source parameters, air emissions, environmental parameters, meteorological data, topography, and surface water depth and flow near PFAS emitters), would also be collected. Such a model could be run to understand when limits on PFAS emissions would be needed to protect human and ecological health.

In order to capture PFAS exposure deriving from precursor compounds, the model could be refined to incorporate PFAS transformation and breakdown products into emission estimates and air deposition modeling. This would be accomplished by applying a PFAS precursor model to the direct emissions from a facility to estimate the products that would eventually be entrained into the air and potentially deposit onto land and water surfaces.

Work status: under consideration

Leader: MPCA Environmental Analysis and Outcomes Division**.**

Benefits: Developing this model could allow MPCA to estimate human exposure to PFAS from multiple routes, including inhalation, surface water, and fish consumption for populations living near facilities that emit PFAS such as platers, metal processers, and contaminated sites. Facilities and waste sites tend to be concentrated more heavily in environmental justice communities.[135] Using

[134] EPA. (2005). Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities. https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P10067PR.TXT

[135] Taylor, D. (2014). Toxic Communities. Environmental racism, industrial pollution, and residential mobility. New York: NYU Press. https://nyupress.org/9781479861781/toxic-communities/

the modified HHRAP model discussed in this proposal, Minnesota could determine if PFAS emissions from a facility were contributing to surface water impairments or exceedances of health-based thresholds for other media like soils. This knowledge could allow MPCA to develop annual emission reporting limits for PFAS facilities, as has been done in other states like New Hampshire.[136]

Challenges: There are several challenges to modifying the HHRAP model to predict PFAS impacts on multiple media from air emissions. Some PFAS will not have the known fate and transport parameters required to run the model, and modelers would likely have to rely on computationally estimated values like those derived by EPA's CompTox program.[137] This effort would likely have to start by focusing on PFAS with the most data available, such as PFOS, PFOA, PFHxS, and precursor PFAS that degrade to those compounds.

Resources: Applying the HHRAP for use on PFAS would require multiple staff with chemical fate transport experience, water quality criteria experience and atmospheric deposition and bioaccumulation modeling experience. This effort would not require additional authorities, but may require additional staff.

Overview of intersectional issues

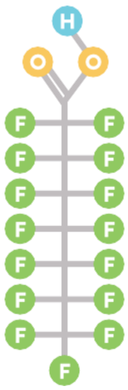
- **Fish and game consumption:** New assessments of risks posed to human health from surface water contamination indicate that low levels of bioaccumulative PFAS like PFOS can result in significant levels of exposure. Protecting fish and game for human consumption may require limits on PFAS emissions to air that result in PFAS loading to surface water.
- **Pollution prevention**: Reducing PFAS pollution at the source places the cost burden of treatment with the polluters. Requiring sources of PFAS emissions to the air to reduce overall air emissions would take the cost burden away from communities struggling with PFAS contamination of surface water, drinking water, and food like fish and game.
- **Quantifying PFAS toxicity**: Understanding of the potential health impacts of PFAS exposure is key in ensuring exposure stays below "safe" thresholds and communicating with the public. Health-based guidance values, however, require data on toxicity and exposure that are not available for the vast majority of all the PFAS found in the environment. *See* the Quantifying PFAS Risks to Human Health Issue Paper for more information on challenges stemming from PFAS toxicity data limitations.
- **Managing PFAS in waste streams**: Landfill leachate, effluent and biosolids from wastewater treatment plants, and contact water from composting facilities all contain PFAS stemming from industrial and commercial uses of PFAS-containing products. Waste management strategies like burning trash or evaporating landfill leachate could result in additional PFAS emissions to the air, where they can spread in the atmosphere and cause widespread contamination. Considerations will be needed to ensure that waste facilities are not emitting PFAS to an extent that harms human or ecological health.
- **Developing and expanding access to analytical methods**: Analytical methods for PFAS are expensive and time-intensive to run, and include only a subset of all PFAS that may be occurring in surface water and biota. There are currently no EPA-approved methods for testing PFAS at the stack, though other non-EPA approved air methods are available.

[136] Beahm, C. *Saint-Gobain Performance Plastics air permit public hearing*. [PowerPoint slides] Retrieved from: *https://www4.des.state.nh.us/nh-pfas-investigation/wp-content/uploads/SGPP-Draft-Air-Permit-Public-Hearing-Presentation_11052019.pdf*

[137] EPA. (n.d.). CompTox Chemicals Dashboard. Retrieved from: https://comptox.epa.gov/dashboard

Protecting ecosystem health

Background



- **Minnesotans value having healthy, diverse ecosystems** – protecting the environment includes protecting wildlife like birds, mammals, plants, and aquatic organisms against harmful pollution.
- Efforts related to PFAS pollution in Minnesota have **historically focused on protection of human health**, but there has been ongoing research into potential ecological impacts from PFAS contamination since the early 2000s.
- **Ecological risk assessments** establish levels of a contaminant in various ecological media that are unlikely to result in adverse impacts – the risk-based values derived in these assessments could be relevant to multiple sites.
  - EPA, Environment and Climate Change Canada (ECCC), MPCA, and other state agencies have conducted ecological risk assessments. For PFAS, ECCC has published an assessment for PFOS, and EPA has similar assessments underway for PFOA and PFOS.
  - MPCA Remediation Division programs' site investigations are conducted to determine the likelihood for adverse ecological effects. These investigations use risk-based values derived in ecological risk assessments, when available for PFAS, to compare against levels seen at the site. These risk-based values for ecological endpoints may be additionally used as clean-up values.
- MPCA also conducts ecological risk assessments as part of **standard or criteria development under the Clean Water Act** (CWA). The CWA is a federal law that allows states to protect surface waters by determining the beneficial uses of the waterbody and setting water quality standards (WQS) to protect those uses. Beneficial uses for waterbodies include sustaining aquatic life (**fish, aquatic insects, and aquatic-dependent wildlife**).
  - Deriving WQS protective of aquatic life and aquatic-dependent wildlife is generally not prioritized if values protective of other endpoints, like human health, would likely result in more protective WQS than those for aquatic life.
  - Should EPA publish the ecological risk assessment and corresponding recommended aquatic life criteria for PFOA and PFOS, MPCA would consider adopting those recommended criteria into Minnesota's WQSs.
- There are many **challenges** to conducting ecological risk assessments for PFAS.
  - With over 5,000 known structures in the PFAS family, **there are not ecological toxicity data for the vast majority of PFAS** that may be found in the environment.
  - For PFAS with ecological data available, conducting risk assessments using CWA methodologies requires **significant time from skilled staff**.
  - Outside of the CWA methodologies for conducing risk assessment for aquatic life, there are **not MPCA methods available** for risk assessments that derive risk-based values protective of **mammals or other non-aquatic wildlife** that could be impacted by PFAS releases to land or water.
- **New methods for ecological risk assessment** that rely on computational models or other predictive tools designed for the unique physical and chemical properties of PFAS are in development. These new computational methods could be an important resource for PFAS ecological risk assessment moving forward.

What is Minnesota doing now?

- MPCA has developed **site-specific WQC protective of aquatic life** under the CWA for PFOA and PFOS in Pool 2 of the Mississippi River.
- Minnesota has completed or provided funding for **multiple monitoring efforts** for PFAS in various ecological receptors.
  - MPCA monitored for PFAS in benthic invertebrates, which are important components of the aquatic food chain, along with fish, water, and sediment in Pool 2 of the Mississippi River. This data informed knowledge of **PFAS transfer from sediment and water into biota**.
  - MPCA provided funding for two separate studies monitoring **PFAS in birds**. One study measured PFAS levels in eggs of tree swallows nesting in Minnesota and Wisconsin and found that **increased PFAS levels were associated with decreases in reproductive success**. Another study monitored for PFAS in the blood of **Bald Eagle nestlings** in Minnesota.
  - MPCA is currently conducting analysis of **PFAS levels in aquatic animals, sediment, and surface water** as part of the work in the East Metro Area.

What are remaining gaps and opportunities for action?

- **Gap**: There is a lack of completed risk assessments for ecological health endpoints. The existing risk assessments that derived risk-based values for PFOA and PFOS protective of aquatic life in the Mississippi River were completed before new ecological toxicity data became available from federal agencies and academic researchers. Other PFAS do not have risk-based values available for use in WQS, Water Quality Criteria (WQC), or site assessment under the Superfund program.
  - **Opportunity**: The Aquatic Toxicity Profile (ATP) is a tool developed by MPCA to understand potential impacts of contaminants of emerging concern in the environment. MPCA could complete ATPs for as many PFAS as possible to prioritize complete risk assessment using CWA methodologies.
  - **Opportunity**: PFAS data collected by MPCA, MDNR, other state agencies, the EPA and international agencies like ECCC could be used to develop ecological risk screening values relevant to all local wildlife, not just aquatic organisms. These values would help guide clean-up efforts and inform the need for standards under the CWA.
  - **Opportunity**: Recent studies of what appeared to be naturally-occurring foams on surface water have revealed they contain high concentrations of PFAS. MPCA could investigate if PFAS-containing foam is causing acute ecological toxicity.

How does this work benefit human health and the environment?

- Conducting ecological risk assessment and site investigations provide the information needed to determine if there is potential for PFAS releases to cause adverse effects in wildlife, and react appropriately to protect those species.
- Healthy ecosystems improve the mental health and wellbeing of all Minnesotans.

How does this work benefit Minnesota's economy?

- Healthy ecosystems provide opportunities for tourism and provide a strong basis for industries that rely on ecosystem services like abundant fish and wildlife.

Background

Minnesotans value having healthy, diverse ecosystems – protecting the environment includes protecting wildlife like birds, mammals, plants, and aquatic organisms against harmful pollution. Though initial research on PFAS pollution in Minnesota focused on protection of human health, there has been ongoing research and risk assessment related to ecological health since the early 2000s. This issue paper aims to introduce the science behind ecological risk assessment and the regulatory tools and structures available to protect wildlife, outline the past and ongoing work to study ecological impacts of PFAS in the state, and finally discuss the gaps and opportunities remaining in the area of PFAS ecological risk assessment.

Ecological risk assessment

Ecological risk assessments determine levels of contaminants in various media (such as water, soil, sediment) that are unlikely to result in adverse ecological effects in aquatic life or aquatic-dependent wildlife. These values are used to develop WQS, which prevent discharges to surface water at concentrations that would pose risks to ecological health. Under the Superfund program, site assessments estimate the likelihood that adverse ecological effects are occurring at the site. These site assessments are used to identify and characterize the current or potential threats to the environment, to evaluate the ecological impacts of various remediation strategies, and to establish clean-up levels in the selected strategy that will protect wildlife at risk. Ecological site assessments often rely on risk assessments that have derived risk-based values for comparison to levels seen in samples collected from the contaminated site.

Ecological risk assessments consider several potential avenues for disruption to ecosystems. One mechanism for ecosystem harm is direct toxicity to wildlife or plants from exposure to the compound. Direct toxic effects are generally determined by conducting laboratory toxicity studies where various organisms are exposed to controlled concentrations of the substance to determine lethal concentrations or concentrations likely to produce other toxic effects. However, ecological risk assessments can also include consideration of toxic effects associated with bioaccumulation of the substance in an organism over time, which could potentially lead to effects not observed in direct toxicity studies. Bioaccumulation factors – which are a numeric value for how much a pollutant accumulates from the environment into biological tissues -- can be determined by measuring concentrations in environmental media (like water or soil) and concentrations in biological samples (like fish or mammals). Finally, ecological risk assessments can also consider trophic transfer through food chains to capture scenarios when concentrations accumulate in predator organisms, which is called food chain biomagnification. Trophic transfer factors can be calculated by comparing biological samples from various trophic levels. After considering direct toxicity, bioaccumulation, and biomagnification, assessments will determine which concentrations of the substance should not result in adverse ecosystem effects when observed in various media like surface water, sediment, fish tissue, blood of predator species, or eggs of birds.

There are several databases and tools that are frequently used to help develop ecological risk assessments. The ECOTOXicology knowledgebase (ECOTOX) is a tool developed and maintained by the EPA that provides a searchable database for environmental toxicity data on aquatic life, terrestrial plants and wildlife. There has been a concerted effort by EPA to regularly conduct literature searches for PFAS, extract the reported data, and upload that data into ECOTOX. EPA researchers are also producing data from conducting their own studies on ecological toxicity due to PFAS exposure, which are also being loaded into ECOTOX. In all, this database is useful for identifying susceptible species, understanding bioaccumulation, and supporting decisions to protect ecosystems. MPCA and DNR have also collected biological samples for analysis, contributing to a local database of PFAS data in wildlife. In addition to ECOTOX and state-collected data, EPA is continuing to develop predictive models for determining toxicity, bioaccumulation, and various physical and chemical properties for PFAS. The results of some of these models are available on the EPA's Chemistry Dashboard, where the results of the predictive model OPERA can be downloaded.[138,139] These predictive models are especially useful for screening level assessments in scenarios where ecological data for the PFAS in question are not available.

Though data limitations have hindered efforts to conduct ecological risk assessments for most PFAS, Minnesota has conducted past site-specific aquatic life risk assessments for PFOA and PFOS for Bde Maka Ska (formerly, Lake Calhoun) and Pool 2 of the Mississippi River,[140] and is currently conducting a site-specific ecological risk assessment for PFAS in the East Metro (the Project 1007 Corridor). In addition, Environment and Climate Change Canada has published an ecological risk assessment deriving Federal Wildlife Dietary Guidelines, which include health-protective levels designed to protect mammalian and avian consumers of aquatic biota, for PFOS.[141] Currently, there are not risk assessments available for terrestrial ecosystem health; however, some state agencies, like Michigan EGLE, are starting field investigations including risks of PFAS to muskrats in Clark's Marsh.[142] Finally, in 2019, the National Wildlife Foundation published a report on the existing research related to PFAS occurrence and effects on wildlife in the Great Lakes Region, which includes a summary of potential policy actions available for protecting wildlife moving forward.[143]

Regulatory structures for protection of ecological health

The DNR and MPCA both participate in monitoring wildlife, but the regulatory authority for protecting ecological health against chemical contamination health rests with the MPCA. The CWA is a federal law that allows states to protect surface waters by determining the "beneficial uses" of the waterbody and setting WQS to protect those uses. States monitor waterbodies to compare levels of pollution to the applicable standards and list waterbodies as "impaired" if they exceed the WQS and therefore do not meet their beneficial uses. States also permit facilities that discharge into surface waters in order to ensure that their discharges do not have the reasonable potential to cause or contribute to an exceedance of any WQS.

Beneficial uses for waterbodies include aquatic life, which means protecting the health of aquatic communities (such as fish and aquatic insects) and aquatic-dependent wildlife. In the context of CWA implementation, MPCA has conducted site-specific risk assessments for PFOA and PFOS protective of aquatic life, but has not generated a state-wide standard protective of aquatic life or aquatic-dependent wildlife. Deriving new standards protective of aquatic life and aquatic-dependent wildlife for a given contaminant is generally not prioritized if standards protective of other endpoints, like human health due to consuming fish or drinking water, would likely result in more protective standards than those protective of wildlife.

In addition to MPCA's regulatory authorities over aquatic life protections in surface waters, the agency also has regulatory authority to require clean-ups of terrestrial sites that may have contamination

---

[138] EPA. (n.d.) CompTox Chemicals Dashboard. https://comptox.epa.gov/dashboard/

[139] Lampic, A. & Parnic, M.J. (2020). Property estimation of per- and polyfluoroalkyl substances: a comparative assessment of estimation methods. *Environmental Chemistry, 39*, 4, 775-786. DOI: 10.1002/etc.4681

[140] MPCA. (2007). Surface Water Quality Criterion for Perfluorooctane Sulfonic Acid. Retrieved from: https://www.pca.state.mn.us/sites/default/files/pfos-report.pdf; MPCA. (2007).Surface Water Quality Criterion for Perfluorooctanic Acid. Retrieved from: https://www.pca.state.mn.us/sites/default/files/pfoa-report.pdf

[141] ECCC. (2019). Canadian Environmental Protection Act, 1999 Federal Environmental Quality Guidelines Perfluorooctane Sulfonate. https://www.canada.ca/en/environment-climate-change/services/evaluating-existing-substances/federal-environmental-quality-guidelines-perfluorooctane-sulfonate.html#toc11

[142] MI Department of Health and Human Services. (2019). Public Health Advisory for Wildlife from Clark's Marsh. [Memo]. Retrieved from: https://www.dhd2.org/wp-content/uploads/2019/12/APPROVED-Clarks-Marsh-Memo_Do-Not-Eat-Wildlife.pdf

[143] Murray, M.W., & Salim, O. (2019). The Science and Policy of PFAS in the Great Lakes Region: A Roadmap for Local, State and Federal Action, National Wildlife Federation, Great Lakes Regional Center, Ann Arbor, MI. National Wildlife Federation. Retrieved from: www.nwf.org/-/media/Documents/PDFs/NWF-Reports/2019/NWF-PFAS-Great-Lakes-Region.ashx

impacting human health and aquatic or terrestrial ecosystems. These authorities fall under the federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly referred to as "Superfund," and the state Minnesota Environmental Response and Liability Act (MERLA) laws. CERCLA is the federal law that governs how locations with released hazardous substances are identified, prioritized, and ultimately cleaned up. MERLA, found in Minn. Stat. 115B, establishes the state Superfund Program. This law provides broad state authority to respond to releases or threatened releases of hazardous substances that may endanger public health, welfare, or the environment. Sites with significant contamination warranting placement on the National Priorities List under CERCLA are managed in partnership with the federal EPA, but many other sites are managed by MPCA under the state version of the Superfund law.

Though there are several available documented methodologies for conducting ecological risk assessments in aquatic ecosystems, methodologies for conducting ecological risk assessments for terrestrial ecosystems are limited. This is partially because environmental regulations like the CWA allows for regulation of discharges of chemicals to water that may cause harm to aquatic life, but similar regulations investigating and remediating discharges of chemicals to land, like CERCLA and MERLA, are more focused on assessing risks to humans than to wildlife. For example, when new sites are being investigated for possible remediation under Superfund, visual inspections for dead vegetation or animals are conducted, but generally not detailed risk assessments considering ecological endpoints – clean-up standards derived for human health protection are often assumed to also be protective of terrestrial ecological health. Progress towards filling the gap in terrestrial risk assessment could be made by establishing terrestrial risk assessment methodologies appropriate for conducting these assessments for PFAS.

Challenges to conducting ecological risk assessment for PFAS

There are many challenges to conducting ecological risk assessments for PFAS. Firstly, with over 5,000 known structures in the PFAS family, there simply is not toxicity, bioaccumulation, or biomagnification data for the vast majority of PFAS that may be found in the environment. Data collection and risk assessment for these compounds are generally prioritized first towards human health rather than ecological health. There are available analytical methods to quantify levels of PFAS in biological specimens, water, soil and sediments for about 40 PFAS, but there may be other PFAS present in the environment at levels of concern that are not included in regular analysis. When PFAS can be measured, sample analysis is expensive, ranging from $300-$400 per sample. Because many ecological risk assessments are inherently site-specific – they consider food chains and species that are relevant to the potentially contaminated site – site-specific data collection is sometimes warranted. This results in added costs. Finally, many traditional risk assessments consider effects that are obvious to researchers without need for additional investigation (frank effects), like lethality, decreases in reproduction, or clear changes in animal behavior. These effects may not be the most sensitive toxic effects for the organisms. More sophisticated toxicity studies that consider sensitive effects would result in more protective risk assessment results.

Despite these challenges, there are ecological risk assessments for PFOS published by the Canadian agency ECCC that demonstrate what levels of PFOS must be met to protect aquatic life and aquatic-dependent wildlife, and similar risk assessments are underway at the EPA. There are additionally new methods for risk assessment that rely on computational models or other predictive tools designed specifically for the unique physical and chemical properties of PFAS. These new computational methods could be an important resource for PFAS risk ecological risk assessment moving forward.

Past and ongoing efforts

The following sections describe the work that has already been completed to better understand and quantify risks to aquatic life and other ecological systems from PFAS stressors. These sections also highlight projects that are currently underway at the agency.

Monitoring and site assessment

Monitored for PFAS in benthic invertebrates in Pool 2 of the Mississippi River

Benthic invertebrates – organisms that live in the sediment of waterbodies – are a foundation of aquatic ecosystem food webs. They are also especially vulnerable to contaminants that accumulate in aquatic sediments. Mississippi River Pool 2 is the 32.5-mile reach of the Mississippi between Lock & Dam No. 1 (Ford Dam) and Lock & Dam No. 2 (Hastings Dam) that runs through Minneapolis, St. Paul, and communities south of St. Paul to Hastings. The 3M Cottage Grove Center has produced and discharged PFAS into the lower reach of Pool 2 since the 1950s. An extensive collection of fish and water throughout Pool 2 was completed in 2009, and the sampling was repeated in 2012 and expanded to include sediment and zoobenthos (also called benthic macroinvertebrates).

The results of the sediment and zoobenthos monitoring in Pool 2 of the Mississippi were variable. The zoobenthos were sufficiently abundant at 39 of the 50 sediment stations where PFAS analysis was conducted. PFOS concentrations in the zoobenthos ranged from 2 ng/g-wet weight (ww) to 684 ng/g-ww, with a median of 12 ng/g-ww. The two samples with the highest PFOS concentrations were both collected immediately downstream of the 3M Cottage Grove Center. The sediment and invertebrate PFOS concentrations corroborated previous data of PFAS in fish and water, which showed that highest concentrations of PFOS were near and downstream of the wastewater discharge outlet of the 3M Cottage Grove Center. Longer-chain PFAS (nine carbon and greater), which are typically not measurable in water due to their low solubility, were detected in fish and in sediment. Overall, the flow of PFAS from sediment to zoobenthos to fish is an important pathway for fish exposure and deserves additional attention. This indicates that even if a given PFAS is not very soluble in water and not measured in most ambient water samples, it is still a source of concern in the ecosystem if discharged via effluent to waterbodies.

Work status: completed, additional studies would be valuable

Leaders: MPCA Water Assessment Section, MPCA Environmental Analysis and Outcomes Division and the Interagency Fish Contaminant Monitoring Program (includes staff from MPCA, DNR, and MDH). **Partners:** DNR Fish and Wildlife Division.

Benefits: Before this study was conducted, there had been limited data available on exposure pathways to PFAS in aquatic ecosystems. By understanding the pathways of exposure of fish and other aquatic organisms to various PFAS, MPCA can target our regulatory and research work to successfully reduce PFAS exposure to fish and other wildlife. The increased understanding about which PFAS are most likely to stay in sediment is especially interesting and motivates additional studies on this topic.

Challenges: Collecting zoobenthos is time intensive and unpredictable. Multiple sediments samples were collected at each site and the zoobenthos had to be sorted from the sediment immediately. This study observed only one reach of the Mississippi at one period of time – additional studies of lakes and rivers in Minnesota would be beneficial and continue to add to our understanding of PFAS impacts on aquatic food webs.

Resources: This project required funding for analytical sampling (~$50,000) and a field crew (four people for one week). Additional efforts to pair zoobenthos and sediment PFAS sampling would help inform ecological risk assessments, especially for PFAS likely to occur in sediment rather than water.

Providing funding to research partners for monitoring and effects analysis for PFAS in birds

Concerns over the health of birds who may be exposed to PFAS from either fish consumption or aquatic insect consumption led to MPCA contributing funding for others to conduct research on PFAS levels in birds and their eggs. In 2008 and 2009, MPCA contributed to funding for a National Park Service study on levels of persistent compounds, including PFAS, in bald eagle nestlings at three national parks in the Upper Midwest. This study found that PFAS were detectable in all eaglet plasma samples, with PFOS contributing the most to the total PFAS concentrations.[144] PFOS was found in high levels in eagles in the lower St. Croix River and in Mississippi National River and Recreation Area (1,580 µg/L and 1,250 µg/L, respectively). The second most prevalent PFAS was PFDS (perfluorodecane sulfonic acid), which contributed significantly to the total PFAS concentration in the Mississippi National River and Recreation Area eaglets (representing 26% of total PFAS measured), but not in the Lake Superior eaglets (represented <1% of total PFAS measured). These studies were not designed to assess the correspondence between PFAS levels and health outcomes in the birds.

A separate study conducted from 2007 to 2011, funded in part by MPCA, focused on PFAS levels and effects on tree swallows, which gather a large portion of their diet from feeding on insects. The results of this study were published in the peer-reviewed journal Archives of Environmental Contamination and Toxicology.[145] This study measured PFAS levels in one egg from tree swallow nests collected from eight locations in Minnesota and Wisconsin. The study tracked the success of the remaining eggs in the nests to determine if PFAS levels in the eggs were associated with decreased success in reproduction. The study found that when PFOS levels in eggs were higher, there was a significant decreased likelihood of hatchling success.

Work status: completed

Leaders: National Park Service and Academic Partners, with funding from MPCA.

Benefits: This research is beneficial because it could provide part of the basis for ecological risk assessments and potentially water quality standards protective of aquatic-dependent organisms. Field-based data for PFAS effects analysis is limited, and these studies being conducted in Minnesota and other Great Lakes States ensures that they are relevant to local ecological conditions.

Challenges: As MPCA was able to provide funding for this research rather than conducting the research in the agency, challenges for MPCA were limited.

Resources: The MPCA contributed $50,000 for research on PFAS in swallows and significant funding for the National Park Service Bald Eagle study.

Conducting site-specific investigation of aquatic life and aquatic-dependent wildlife exposure to PFAS in the Project 1007 remediation corridor

Project 1007 is a stormwater conveyance system that was constructed by the Valley Branch Watershed District in the eastern Twin Cities Metro Area (the East Metro). The system was designed to mitigate flooding in the Tri-Lakes area by lowering water levels in several lakes, but the system also drained the

[144] Route, B., Rasmussen, P., Key, R., Meyer, M., & Martell, M. (2011). Spatial Patterns of Persistent Contaminants in Bald Eagle Nestlings at Three National Parks in the Upper Midwest. *Natural Resource Technical Report.* Retrieved from: https://www.nps.gov/miss/learn/nature/upload/BaldEagleContaminants_Route_2011.pdf

[145] Custer, C.M., Custer, T.W., Dummer, P.M., Etterson, M.A., Thogmartin, W.E., Wu, Q., Kannan, K., Trowbridge, A., & McKann, P.C. (2014). Exposure and Effects of Perfluoroalkyl Substances in Tree Swallows Nesting in Minnesota and Wisconsin, USA. *Environmental Contamination and Toxicology*, *66,* 120-138. DOI 10.1007/s00244-013-9934-0

wetlands immediately around a disposal site in Oakdale where 3M historically disposed of PFAS waste (*see* Remediating PFAS-contaminated Sites Issue Paper). Due to the potential risks to wildlife in this region posed by elevated PFAS concentrations, MPCA is currently conducting a baseline ecological site investigation. The goal of the site investigation was to identify risks to wildlife receptors (i.e., fish and invertebrates) due to exposure to 33 PFAS, including PFOS and PFOA, in surface water and sediment. Part of this risk assessment includes updating bioaccumulation factors for PFAS from water, soil, and sediment into wildlife. These uptake factors could be used to inform clean-up values protective of ecological health in the future. This assessment also includes sampling of PFAS-containing surface water foam, which may be an important exposure pathway of PFAS to wildlife. A parallel wildlife monitoring effort near the Project 1007 Corridor for deer is being conducted by the Minnesota Department of Natural Resources (DNR) (*see* the Reducing PFAS exposure from Fish and Game Consumption Issue Paper).

Work status: ongoing

Leaders: MPCA Remediation Division. **Partners**: MPCA Environmental Analysis and Outcomes Division, state contractors.

Benefits: Establishing the risks to ecological receptors is an important step towards remediating PFAS pollution and protecting potentially-impacted wildlife. The data collected as part of the ecological risk assessment for this site may be relevant to other areas in the state and could possibly contribute to the development of water quality standards protective of aquatic life or aquatic-dependent wildlife in the future.

Challenges: Despite much progress in understanding the impacts of PFAS to wildlife, funding for studies of wildlife health have been more limited than studies of PFAS impacts on human health. As a result, there are still many data gaps remaining on how PFAS may be impacting ecological systems.

Resources: This risk assessment has been primarily conducted by state contractors, overseen by MPCA staff. Though this project is ongoing, it is estimated that the sample collection, sample analysis, and risk assessment effort will cost ~$500,000.

Regulation

Derived site-specific PFOA and PFOS Water Quality Criteria protective of aquatic life for Pool 2 of the Mississippi River

Site-specific (WQC) are values derived for contaminants present in select waterbodies to protect the specific Class 2 beneficial uses of that waterbody. These WQC are different from WQS in that they are derived using authorities already in state rule, not promulgated through a state rulemaking process. They are applied to specific waterbodies. WQC are developed based on methods and authorities in state statute and the federal CWA.[146] WQC can be derived to protect human health, aquatic life, aquatic plants, and aquatic-dependent wildlife.

In 2007, after a discovery of significant PFAS releases into the Mississippi River, staff from MPCA's Water Quality Standards unit worked with consultants to derive a site-specific WQC protective of aquatic life for Pool 2 of the Mississippi River. This effort coincided with similar efforts to derive WQC protective of human health for the same stretch of the river. Though multiple PFAS were measured in river water, data limitations for most PFAS resulted in prioritizing development of WQC for PFOS, PFOA, and PFBS. After initial data review and derivations of preliminary criteria, it was determined that, despite some

[146]Minnesota Administrative rules. CHAPTER 7050, WATERS OF THE STATE. Retrieved from: https://www.revisor.mn.gov/rules/7050/?view=chapter

data limitations, PFBS did not appear toxic enough to aquatic life to warrant derivation of an aquatic life WQC. Therefore, MPCA and consultant staff focused on developing aquatic life WQC for PFOA and PFOS.

Minnesota rules outline two methods for developing aquatic life criteria, called Tier 1 and Tier 2 methods, that differ in the amount of data required for each approach. Tier 1 methods are the preferred approach, but require a larger number of toxicity studies than Tier 2 methods. If the compound does not meet the minimum data requirements for Tier 2 methods, there is too much uncertainty in the understanding of toxicity to develop aquatic life criteria. After reviewing the data available, it was determined that neither PFOA nor PFOS had enough toxicity studies available to qualify for Tier 1 methods, but both qualified for Tier 2 methods. The final chronic criteria (protecting longer-term exposure) for PFOS and PFOA were calculated as 19 µg/L (1.9×10^4 ng/L) and 1,700 µg/L (1.7×10^6 ng/L), respectively.[147,148] This assessment also derived acute criteria, protecting short-term exposure, for PFOS and PFOA of 85 µg/L (8.5×10^4 ng/L) and 15,000 µg/L (1.5×10^7 ng/L), respectively. Because these chronic and acute values were significantly higher than the respective WQC derived to protect human health consumption of fish, any clean-up levels or permit limits for this waterbody would have to meet the human health WQC and subsequently also protect aquatic life. However, the reports that detail the derivation of these values note that these criteria were derived based on a very limited dataset – as more data become available, these values should be reassessed to ensure that they can still be considered protective. This effort did not consider potential toxicity to aquatic-dependent wildlife.

Work status: completed, consideration of new data may warrant updates to existing criteria

Leader: MPCA Environmental Analysis and Outcomes Division.

Benefits: There were several benefits to conducting a risk assessment for aquatic life exposed to PFOA and PFOS. This effort indicated that risks to aquatic life were less sensitive to PFOA and PFOS pollution than humans, meaning that cleaning up PFOA and PFOS pollution to levels safe for humans would also benefit and protect aquatic organisms.

Challenges: At the time that these risk assessments were conducted, there were a very limited amount of data available regarding aquatic toxicity to PFAS and potential toxicity to aquatic-dependent wildlife like birds. Because of these limitations, it is not possible to determine with certainty that the criteria developed are protective of Minnesota wildlife. Additionally, research into potential impacts to wildlife from PFAS-containing foams that can form on contaminated waterways continues to evolve. Revisiting ecological risk assessment periodically as more information becomes available will be important to ensure that these values continue to reflect the best current science.

Resources: The initial effort to develop site-specific water quality criteria for aquatic life in Pool 2 of the Mississippi involved several MPCA staff and consultant support. The site-specific criteria for Pool 2 of the Mississippi could be updated leveraging ongoing work in the Project 1007 Corridor.

Gaps and opportunities

There are many gaps in data availability and risk assessment, which impact the development of policy and regulation to protect ecological health from PFAS. PFAS are all either persistent themselves, or transform to other PFAS that are environmentally persistent. This means that if there continues to be use and release of PFAS into the environment, levels in environmental media will increase over time, perhaps reaching levels that are harmful to humans or wildlife. Reducing PFAS loading into the

[147] MPCA. (2007).Surface Water Quality Criterion for Perfluorooctane Sulfonic Acid. Retrieved from: https://www.pca.state.mn.us/sites/default/files/pfos-report.pdf
[148] MPCA. (2007).Surface Water Quality Criterion for Perfluorooctanic Acid. Retrieved from: https://www.pca.state.mn.us/sites/default/files/pfoa-report.pdf

environment would be the most protective and effective approach to protecting wildlife (*See* the Preventing PFAS Pollution Issue Paper).

To date, most monitoring and risk assessment related to PFAS has been conducted with an eye towards human health protections. For example, many studies of PFAS in fish tissue focused on measuring fish fillets – the part of the fish usually eaten by people – rather than the whole fish as it is consumed by wildlife. However, despite the prioritization of human health research, there have been significant gains in understanding toxicity to wildlife, bioaccumulation, trophic transfer, and overall contaminant presence in a large number of species for some PFAS. Combined with advances in computational toxicity estimation tools from efforts like EPA's CompTox program,[149] these new PFAS wildlife toxicity and monitoring data provide a sufficient basis to conduct preliminary ecological risk assessments for the better-studied PFAS like PFOA and PFOS.

For aquatic life, MPCA already has a methodology in place to conduct preliminary toxicity reviews called ATPs. Conducting ATPs for as many PFAS as possible given data restrictions would help prioritize development of CWA standards protective of these ecological endpoints. Additionally, ATP completion could identify scenarios where site-specific ecological risk assessments for clean-up of PFAS contaminated sites under MERLA or CERLA are warranted.

Though there are methodologies in place at MPCA to conduct reviews of toxicants and impacts on aquatic ecosystem health, no such methods currently exist for developing risk-based values applicable to terrestrial ecosystems. Developing these methodologies and implementing them for the data-rich PFAS could additionally inform the need for site-specific risk assessments at contaminated sites in the Superfund program or to motivate the development of CWA standards designed to protect aquatic-dependent wildlife like waterfowl. Currently, DNR is conducting a pilot study of PFAS in deer and working with MDH and MPCA to determine if surface water impacts are resulting in deer tissue levels that are of concern for human consumption (*see* the Reducing PFAS exposure from Fish and Game Consumption Issue Paper). In collaboration with DNR, MPCA could leverage the PFAS data collected in these studies to conduct preliminary risk assessments for PFAS accumulation in terrestrial ecosystems.

In addition to opportunities to conduct risk assessment for ecosystem impacts due to PFAS contamination in soil, sediment and water, there is an additional gap in understanding of a new PFAS phenomenon observed on surface water – PFAS-enriched foams. Recent monitoring of PFAS-rich foams in Minnesota and other states in the Upper Midwest have revealed that these foams preferentially accumulate PFAS that are designed to act as surfactants (like PFOA, PFOS, PFHxS, and many others). Concentrations of PFAS in these foams have proven to be exceptionally high -- upwards of 20 ppm (20,000,000 ng PFOS per liter of foam). MPCA and MDH have issued guidance for people not to touch surface water foams while recreating.[150] The potential risks of these PFAS-enriched foams to wildlife are unknown. The Great Lakes PFAS Taskforce, an interagency taskforce of governments from the US and Canada in states and provinces bordering the Great Lakes, has created a specialized sub-team of experts to share data on PFAS-enriched surface water foams. In order to continue advancing our understanding of potential risks posed by these foams, MPCA could compile the existing information and assess the ability to conduct acute-risk assessments for wildlife exposure to PFAS-rich foam.

[149] EPA. CompTox Chemistry Dashboard. https://comptox.epa.gov/dashboard/

[150] MPCA. (n.d.). PFAS foam on surface water. Retrieved from: https://www.pca.state.mn.us/waste/pfas-foam-surface-water

Risk assessment

Conduct Aquatic Toxicity Profiles for PFAS to assess the need to update aquatic life criteria or develop statewide aquatic life standards

In 2017, MPCA developed new methods —Aquatic Toxicity Profiles (ATPs) — to help understand how various contaminants of emerging concern in the environment might be impacting wildlife. ATPs use a weight-of-evidence approach to gain a broad understanding of the potential impacts of specific contaminants in the environment. ATPs help MPCA prioritize contaminants for further toxicity or occurrence research. Some ATPs have been completed for PFAS. Each ATP consists of two parts, a worksheet containing all the technical information used to determine the level of concern of each contaminant and a summary profile that gives a brief overview of the concerns related to each contaminant. This proposal is to conduct ATPs for as many PFAS as there are data (modeled or empirical) available.

Work status: under consideration

Leader: MPCA Environmental Analysis and Outcomes Division, Water Quality Standards Unit.

Benefits: This effort would be beneficial for several reasons. Firstly, the results of ATP screening would prioritize which PFAS observed in the environment have data available for developing aquatic life standards and which PFAS may have high toxicity risk and would be good candidates for further research.

Challenges: Data generated by governments are often published in reports rather than peer-reviewed academic journals. As a result, they are often not included in databases used for literature reviews for an ATP, such as ECOTOX. Modeled data can be used if the model was designed to reflect the unique physical and chemical traits of the PFAS class of compounds.

Resources: This effort would not require additional funding, but may benefit from contractor support. Staff time would be needed to compile data and complete ATPs. Collaboration with partners within Minnesota, in the EPA, and in the Great Lakes PFAS Taskforce might be beneficial.

Leverage data from existing studies to develop state-wide wildlife risk values for PFAS

Various studies of PFAS accumulation in deer, waterfowl and other wildlife have been undertaken by state governments in the US and internationally. In Minnesota, the DNR is currently collecting deer samples for PFAS analysis in regions of the state with known surface water PFAS contamination. Though the main goal of this study is to ensure that game harvested for consumption by humans is safe to eat, the data collected will also help inform ecological risk assessments for terrestrial wildlife. Other agencies, including Environment and Climate Change Canada, have developed environmental quality guidelines that are designed to provide thresholds for concern of PFAS in various wildlife, including PFAS levels in bird eggs. Additionally, an effort to assess wildlife impacts at the Project 1007 Corridor PFAS remediation site is underway, and this effort includes sampling for PFAS in various samples from aquatic and aquatic-dependent organisms.

The goal of any wildlife screening levels project would be to develop a methods document for terrestrial risk assessment and derive toxicity values that apply in fish or wildlife tissues to more accurately determine if internal burdens of toxic pollutants exceed concentrations that raise concern for that organism's health. These values would be screening levels to assess ecosystem health and guide clean-up efforts, not regulatory values. For bioaccumulative pollutants, like PFOS, having tissue-based toxicity values would be more accurate than translating a water or sediment concentration to an expected internal concentration of concern. This project proposes to aggregate the available wildlife data collected by MPCA, DNR, other state agencies, the EPA and agencies like Environment and Climate Change Canada to develop wildlife ecologic risk screening values relevant to Minnesota wildlife.

Work status: under consideration

Leaders: MPCA Environmental Analysis and Outcomes Division. **Partners**: DNR Wildlife Health; MPCA Remediation Division.

Benefits: Developing wildlife screening values for PFAS will benefit wildlife management by providing information about the impact that toxic pollutant stressors are having on a wildlife's health and population parameters. Because the DNR and other organizations are either actively gathering PFAS wildlife data for other purposes or have already compiled relevant datasets, this project provides added value to ongoing and completed data collection efforts.

Challenges: Though there are sufficient data to develop wildlife risk screening levels, especially after DNR and MPCA Remediation complete sample collection of PFAS in various wildlife, additional data will reduce uncertainties in the results.

Resources: This effort would require staff time to synthesize data, write a risk assessment document, and review the resulting values.

Assess the need for acute wildlife risk assessment from exposure to PFAS-containing foam

Many PFAS are designed to be compounds that readily foam when agitated. Recent studies of what appears to be naturally-occurring foams on surface waters have revealed to have concentrated PFAS, sometimes at very high levels. In fact, PFOS concentrations in these foams have sometimes exceeded 20 ppm (or 20,000,000 ng PFOS per liter of foam). In contrast, site-specific WQC for PFOS concentrations in surface water are 0.05 ng/L in water. Though this discovery of PFAS-enriched foam has led to the realization that intentionally causing PFAS to foam in surface waters and collecting that foam may be an effective and economical way to remediate PFAS, there are concerns about humans and wildlife being exposed to this PFAS-enriched foam in uncontrolled settings. In past evaluations in 2007 of aquatic life toxicity for site-specific WQC development of PFOS and PFOA (see above), MPCA developed acute criteria to protect aquatic life. Recent monitoring of PFAS-containing foam found PFOS concentrations greater than these acute toxicity criteria. The potential exposure of ecological species to PFAS from foam or PFAS concentrating at the air-water interface is unclear, but may be more significant than recreational exposure to people (where risk is expected to be low). This route of exposure may also be contributing to the high levels of PFAS found in Michigan and Wisconsin deer harvested near contaminated surface water sites. In this proposal, MPCA would evaluate information relevant to determine if PFAS contaminated sites are contributing to acute toxicity in ecological species.

Work status: under consideration

Leader: MPCA's Water Quality Standards Unit. **Partners**: MPCA Water Assessment Section, DNR Wildlife Health, and the "Foamy Friends" subgroup of the Great Lakes PFAS Taskforce.

Benefits: Conducting this review would inform remediation actions associated with PFAS-containing foams being observed on surface waters impacted by PFAS contamination and any future water quality criteria or standards for protection of aquatic life.

Challenges: Conducting risk assessment for PFAS-containing foams on surface water is challenging for several reasons. First, sampling of various surface water foams for PFAS has revealed that concentrations of PFAS in foam can vary significantly across samples, even samples collected in the same waterbody. It is also unknown how wildlife interacts with PFAS-containing foams – it is possible that, like humans, wildlife tend to avoid the foam whenever possible. In addition, because foams on surface water are ephemeral, it could be difficult to estimate how much exposure may be occurring between wildlife and foams.

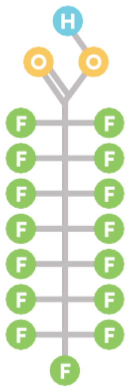
Resources: This effort would require staff time from MPCA Water Quality Standards unit and support from other MPCA and DNR partners. The effort would also likely be strengthened by collaborating with the inter-state Great Lakes PFAS Taskforce subgroup called "Foamy Friends," which includes scientists from many partner states who are also investigating the topic of PFAS-contaminated foam on surface waters.

Overview of intersectional issues

- **Pollution prevention**: Reducing PFAS pollution at the source places the cost burden of treatment with the polluters. Conducting ecological risk assessment for all PFAS found in the environment is not likely tenable. *See* the Preventing PFAS Pollution Issue Paper for actions related to reducing the overall production and emission of PFAS products.
- **Developing and expanding access to analytical methods**: Analytical methods for PFAS are expensive and time-intensive to run, and include only a subset of all PFAS that may be occurring in surface water and biota – *see* the Measuring PFAS Effectively and Consistently Issue Paper for more information on the costs and challenges associated with measuring PFAS in various matrixes.
- **Managing PFAS in waste streams**: Landfill leachate, effluent and biosolids from wastewater treatment plants, and contact water from composting facilities all contain PFAS stemming from industrial and commercial uses of PFAS-containing products. Considerations will be needed to ensure that waste facilities are not aggregating PFAS to an extent that harms ecological health.

Remediating PFAS contaminated sites

Background



- There are several state and federal programs that work together to identify sites with contamination, set remediation goals, and ensure that clean-up results in health-protective outcomes. These programs include the **federal Superfund** program, the **state Superfund** program, and the **state Brownfields** program.
- When it comes to PFAS investigation and remediation, **federal regulation is lacking**.
  - There has been **no action on the proposed EPA rule that would designate PFOA and PFOS as "hazardous substances"** under the federal Superfund law (CERCLA). Federal legislation designating all PFAS as "hazardous substances" has not advanced.
  - Though limited emission reporting requirements for PFAS went into effect for 2020 under the federal TTRI program, several exemptions allow **unreported PFAS emissions to continue**.
  - The **DoD would likely not accept Minnesota's health-based clean-up values for PFAS** as "applicable or relevant and appropriate requirements" (ARARs) at Department of Defense (DoD) sites in Minnesota unless they are promulgated in state rule – most of Minnesota's health-based clean-up values would not be considered as ARARs by the DoD.
- Under MERLA, PFAS meets the definition of a hazardous substance based on its properties – Minnesota currently has PFAS sites under investigation or in remediation and believes that there are **likely additional sites with PFAS contamination** due to historic or ongoing uses of PFAS.
- **Clean-ups are expensive and time consuming**. Efforts that stem PFAS pollution at the source can be expensive, but are essential for cost-effective management of PFAS in the environment.

What is Minnesota doing now?

- MPCA and MDH have **established health-based clean-up values** for several PFAS in multiple media.
  - MDH developed values for five PFAS that are protective of human health through groundwater exposure via **drinking water**.
  - MPCA developed site-specific water quality criteria for PFOS protective of human health through surface water exposure via **consumption of freshwater fish**.
  - MPCA developed values for five PFAS that are protective of human health through soil exposure via incidental **soil ingestion**.
- MPCA is **remediating sites associated with 3M disposal of PFAS**, including the widespread area of surface water and groundwater contamination in East Metro.
- MPCA is investigating and remediating sites associated with PFAS releases from **metal plating industries** and from uses of **PFAS-containing firefighting foam**.
- MPCA is collaborating with MDH on the **Pilot PFAS Inventory Project**.
  - This initiative aims to leverage existing monitoring data for PFAS, data on types of industrial activity occurring in Minnesota, and data on geologic susceptibility of aquifers to **prioritize sites for PFAS investigation**.

What are remaining gaps and opportunities for action?

- **Gap**: PFAS are not listed directly as hazardous substances under either CERCLA or MERLA.
  - **Opportunity**: Hazardous substance designation under CERCLA or MERLA would solidify existing authorities regarding PFAS to require responsible parties to clean up PFAS contamination and improve the state's ability to recover costs from responsible parties when they fail to act.
- **Gap**: There is incomplete data listing which entities use or produce PFAS that could be released to the environment.
  - **Opportunity**: Authority to allow the state to request information on environmental contaminants could help fill gaps in federal emission reporting requirements for PFAS.
  - **Opportunity**: Continuing to expand the Pilot PFAS Inventory Project would help identify the likelihood of finding PFAS contamination at existing sites and currently unknown sites.
- **Gap**: Though there are some existing health-based clean-up values for PFAS, additional guidance values would help ensure protective clean-up goals and prioritize sites for investigation.
  - **Opportunity**: MPCA could develop soil leaching to groundwater values and additional surface water values for PFAS with health-based values available.
- **Gap**: Some industries, like car washes and metal platers, may have widespread historic and ongoing uses of PFAS, and Minnesota may not have the resources to clean-up each impacted site.
  - **Opportunity**: Minnesota could explore options for ways to supplement the Remediation Fund should it be strained by an increase in PFAS sites without responsible parties.

How does this work benefit human health and the environment?

- Cleaning-up PFAS contaminated sites has the direct benefit of **reducing PFAS concentrations** in the water, soil, and sediments to safe levels for humans and wildlife.

How does this work benefit Minnesota's economy?

- Conducting site investigations to determine responsible parties for contamination **places the cost burden of PFAS controls with polluters** rather than drinking water utilities and the general public, who would otherwise fund drinking water treatment or other remedial actions.
- Remediation and redevelopment of contaminated properties encourages **new businesses**, creates **jobs**, and results in an **improved tax base**.
- Drawing attention to the potential liabilities associated with PFAS release **encourages responsible use and management of PFAS,** which decreases the likelihood of continued environmental contamination and costly remediation efforts.
- **Preventing adverse physical health outcomes** associated with PFAS exposure and **preventing negative mental health outcomes** associated with concern over exposure to these compounds is financially beneficial for families and individuals.

MINNESOTA

Background

Remediation is the process of cleaning up soil, water, sediment, and air after it has been contaminated with pollutants, some of which may be hazardous substances. This work has two main goals: reducing risks to human health and the environment, and ensuring properties are safe for reuse and redevelopment. Site investigations and clean-up actions are often complex, involving multiple types of contaminated media, receptors of concern, and potential routes of exposure. Identification, investigation, and oversight of these sites is also complex; there can be involvement from federal authorities, state authorities, those responsible for the contamination, and the impacted community. Though there have been many success stories of redeveloping once-contaminated sites in Minnesota, these projects often require large investments of money and time – the most strategic management of environmental contaminants, including those in the PFAS family, is to prevent the need for remediation actions in the first place.

MPCA first addressed PFAS contamination in 2002, when the Remediation Program traced PFAS to four 3M disposal sites in the East Metro. Over the past 18 years, investigations by MPCA and MDH into the 3M disposal sites have identified an area of groundwater contamination covering over 150 square miles and impacting over 174,000 Minnesotans. Over this period, scientists discovered that PFAS contamination is more widespread than originally believed, with many potential sources of PFAS releases that are not tied to historic 3M disposal practices or chemical production companies. Currently, MPCA is investigating a wide variety of sites with PFAS contamination and is collaborating with MDH's Drinking Water Protection program to identify potential PFAS sources to contaminated drinking water.

Remediation overview and regulatory authorities

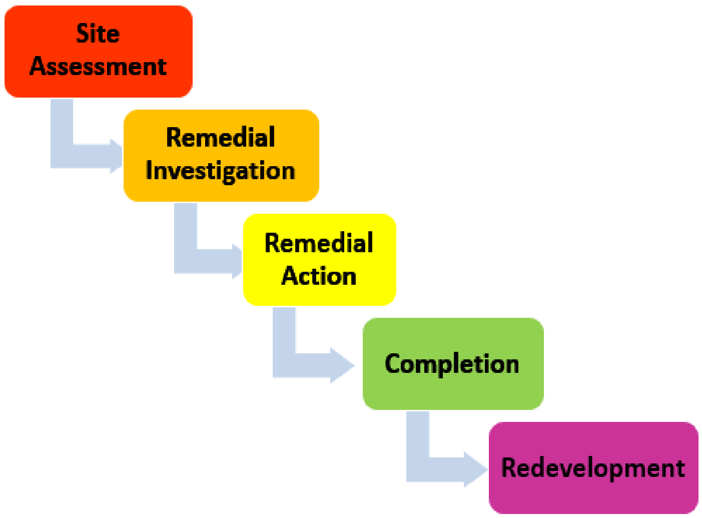
The MPCA's Remediation Division has authority to investigate and remediate sites to protect human health, welfare, and the environment. This Division is broadly separated into the Brownfields Program, which provides oversight to voluntary parties electing to address the investigation and clean-up of contaminated properties, the Site Assessment and Site Remediation (Superfund) program, which oversees the investigation and clean-up of sites of hazardous substances, or pollutants and contaminants by responsible parties and at state-led sites, and the Petroleum Remediation program, which oversees the investigation and clean-up of sites with petroleum releases by responsible parties and at state-led sites.

Brownfields are abandoned, idled, or underused industrial and commercial properties where redevelopment is complicated by actual or suspected environmental contamination. By overseeing voluntary investigation and clean-up of brownfield sites, volunteer parties can proceed with redeveloping contaminated properties in a safe manner that is protective to human health and the environment. This benefits Minnesota communities by enhancing the livability of neighborhoods and creating new businesses, jobs, and an improved tax base.

The CERCLA, commonly referred to as "Superfund," is the federal law that governs how locations with released hazardous substances are identified, prioritized, and ultimately cleaned up. The law includes a list of substances that, if released, trigger legal responsibility and require the party responsible for that release to investigate and, if necessary, remediate the release site. If there is no viable responsible party, CERCLA provides authority for the EPA to conduct the investigation and remediation using funding in the federal Superfund account. Under CERCLA, EPA produces the Superfund National Priorities List

(NPL), which lists "sites of national priority among the known releases or threatened releases of hazardous substances, pollutants, or contaminants."[151]

Figure 6. Process of progressive risk reduction as sites move through the Superfund process



Similarly, MERLA, Minn. Stat. ch. 115B, establishes broad state authority to respond to releases or threatened releases of hazardous substances or pollutants and contaminants. Minn. Stat. §116.155 establishes a State Remediation Fund from which the MPCA and the Minnesota Department of Agriculture (MDA) can spend money to investigate and remediate releases or threatened releases of hazardous substances, pollutants or contaminants, and agricultural chemicals. The state lists its Superfund sites on the Minnesota Permanent List of Priorities (PLP).

Whether a site is managed by the state under the MPCA Superfund program or by the EPA under the federal Superfund program, properties will go through a series of steps that result in progressive risk reduction (*See* Figure 6). Any direct exposure risks to human health are addressed as they are found and do not need to wait until later stages in the process, which can take years to reach. Sites are first assessed to determine the potential risks to human health or the environment and to identify the party responsible for the release or threatened release. Once this initial site assessment is completed, a detailed remedial investigation is taken to determine the scope of the pollution. The goal of this remedial investigation is to answer questions like: In what media is the pollution found? How far has the pollution spread? What are the relevant clean-up goals for the site? What are the options for responses that could be taken to best fix this problem? After consideration of the potential response options available, remedial action begins. This involves designing the clean-up process and taking the required actions to reduce risks. Finally, the site enters the closing phases of the process, where administrative steps are taken to finalize the project, prepare for long-term monitoring, and remove the site from the priorities list. At this point, the property is ready for redevelopment or reuse. Altogether, this process can take many years and require millions of dollars to complete.

Lack of federal regulations on PFAS

Although the regulatory structure for remediation is generally well-established, federal regulation establishing liability for PFAS contaminated sites is not. Currently, federal law does not include PFAS as a "hazardous substance" under CERCLA; EPA in 2019 proposed federal rulemaking to list two PFAS, PFOA and PFOS, as CERCLA hazardous substances, but this rule has not been finalized.[152] Congress has

[151] EPA. (n.d.) Superfund: National Priorities List (NPL). Retrieved from: https://www.epa.gov/superfund/superfund-national-priorities-list-npl

[152] Office of Information and Regulatory Affairs, Office of Management and Budget. (2019). Designating PFOA and PFOS as CERCLA Hazardous Substances. https://www.reginfo.gov/public/do/eAgendaViewRule?pubId=201910&RIN=2050-AH09

proposed including PFAS as hazardous substance, but these proposals have not become law.[153] Despite the fact that no PFAS are currently listed as hazardous substances, EPA has tested for PFAS at the sites on the National Priorities List "where there is a reason to believe PFAS might be present."[154] Additionally, theDoD has acknowledged widespread contamination of groundwater near bases and other facilities with historic use of PFAS-containing firefighting foam and Congress required DoD to submit a remediation plan for cleanup of all water at or adjacent to a military installation that is impacted with PFOA or PFOS.[155]

At federally managed contaminated sites in Minnesota, the federal government is committed to clean up to state and federal standards established by ARARs include cleanup standards and substantive environmental protection requirements that are promulgated in rule under federal or state law. Currently, the only federally-managed PFAS clean-up sites in Minnesota are managed by the DoD. Because several of the health-based groundwater values (HBVs) derived by MDH for PFAS are not promulgated in rule, EPA and DoD would not consider them to be ARARs and will not use them as clean-up levels. However, EPA and DoD consider MDH's Health Risk Limits (HRLs), which are promulgated in rule, to be ARARs and would likely use them as clean-up values. (*See* the Quantifying PFAS Risks to Human Health Issue Paper for more information about the guidance values derived by MPCA and MDH). In all, the current status of the CERCLA hazardous substance definition not specifically including PFAS, the lack of federally promulgated health-protective clean-up values, and the unwillingness of the DoD to honor health-based guidance values derived in Minnesota as ARARs limit the effective remediation of federal PFAS contaminated sites and federal response actions related to contaminated water supply wells.

Federal regulation regarding mandatory reporting of PFAS use, discharge, and emissions is also lacking, hindering the ability of cleanup programs to investigate potential releases of PFAS. The TRI program, authorized under the Emergency Planning and Community Right to Know Act, requires entities to report environmental releases of listed substances to air, water, or land. (The list of substances generated for the TRI is different from, but generally inclusive of, hazardous substances listed under CERCLA.)[156] Until 2020, when Congress added an amendment to the National Defense Authorization Act that required EPA to add some PFAS to the TRI list, there were no PFAS with reporting requirements. This meant that Minnesota agencies had limited ability to determine which facilities were producing PFAS, importing PFAS, or releasing PFAS to the environment. Though entities are currently tracking PFAS environmental release data during 2020 (this data will be released by EPA in summer 2021), the new TRI reporting requirements for PFAS include several exemptions. First, emission reporting will only be required for the PFAS listed in the federal rulemaking, which does not constitute the full range of PFAS currently used in industry and commerce. Second, reporting is only required if more than 100 pounds of PFAS-containing products are released in a year and if that product, regardless of the quantity released, contains more than 0.1% PFOA or greater than 1% other PFAS. Finally, some PFAS, like PFOS, have very low health-based guidance values in drinking water. A facility releasing enough PFAS to cause exceedances in health-based guidance values could still be below the mandatory reporting threshold.

---

[153] NYU School of Law. (2020, December 16). PFAS Federal Legislation. Retrieved from: https://www.law.nyu.edu/centers/state-impact/press-publications/research/pfas-federal-legislation#

[154] US Senate Committee on Environment and Public Works. (2020). Carper, DPW Democrats As EPA to Share its Plan to Address PFAS Contamination at Superfund Sites. Retrieved from: https://www.epw.senate.gov/public/index.cfm/2020/5/carper-epw-democrats-ask-epa-to-share-its-plan-to-address-pfas-contamination-at-superfund-sites

[155] DoD. (2020). Department of Defense Remediation Plan for Cleanup of Water Impacted with Perfluorooctane Sulfonate or Perfluorooctanoic Acid. Retrieved from: https://media.defense.gov/2020/Jul/10/2002451983/-1/-1/1/DOD_REMEDIATION_PLAN_FOR_CLEANUP_OF_WATER_IMPACTED_WITH_PFOS_OR_PFO.PDF

[156]EPA (2020) Consolidated List of Lists under EPCRA/CERCLA/CAA §112(r) (August 2020 Version). https://www.epa.gov/epcra/consolidated-list-lists-under-epcracerclacaa-ss112r-august-2020-version

Minnesota actions on PFAS investigation and clean-up

Minnesota has taken action to clean-up PFAS contamination under authorities provided by MERLA. Minnesota's investigation into PFAS contamination began in 2002, when PFAS contamination was traced to four 3M disposal sites in the east metropolitan area of the Twin Cities. A consent order and a settlement with 3M have resulted in funding for remediation of dump sites, development and implementation of drinking water supply plans, natural resources preservation, and research into other potential PFAS contamination not associated with 3M disposal sites. Over time, it has become clear that widespread use of PFAS in many products, from firefighting foams to industrial mist suppressants, has resulted in the potential for PFAS contamination to be far more widespread than originally believed. Currently, MPCA is investigating a wide variety of sites with PFAS contamination and is collaborating with MDH's Drinking Water Protection program to identify additional potential PFAS sources of contaminated drinking water.

Establishing health-protective clean-up goals

Many PFAS cause adverse health effects in humans and wildlife when exposure exceeds toxic thresholds. Currently, Minnesota established health-based drinking water guidance values for five PFAS, incidental ingestion guidance values for the same five PFAS, and site-specific WQC for one of those PFAS (PFOS). However, Minnesota has not developed soil leaching values that would protect against PFAS leaching to groundwater, air values, or sediment quality target values. There are currently no federal or state drinking water standards (MCLs) for PFAS.

The lack of publicly available toxicity data for most PFAS hampers the development of health-based guidance (*see* the Quantifying PFAS Risks to Human Health Issue Paper). Similarly, there are limited data available for most PFAS to calculate risk-based values protective of aquatic life and other wildlife (*see* the Protecting Ecosystem Health Issue paper).

Challenges in PFAS site remediation

There are several technical challenges associated with remediation of PFAS-contaminated sites. First, it can be challenging to identify which PFAS are present when many novel PFAS do not have analytical methods or standards available. Non-targeted approaches to identifying PFAS are available, but access to the required laboratory equipment and staff expertise are limited. Using only standard analytical methods does not detect if new or less-commonly studied PFAS were present at the site (*see* the Measuring PFAS Effectively and Consistently Issue Paper). Once PFAS are identified, risk-based guidance values are needed to set clean-up goals. MPCA and MDH may need to develop new clean-up goals if existing values are not available. Then, the MPCA needs to determine an appropriate course of action to reduce concentrations below those risk-based thresholds. For many PFAS, these risk-based values for protecting human health or ecological health are currently unavailable. Finally, there are limited options available for treating PFAS contaminated media and disposing of or destroying PFAS waste generated as part of remediation, and these options are often quite expensive (*see* the Managing PFAS in Waste Issue Paper). Significant work is needed to fill these gaps. Overall, clean-ups for PFAS-contaminated sites are expensive and time consuming. Therefore, preventing PFAS contamination should be a high priority.

Past and ongoing efforts

The following sections describe completed and ongoing work related to identifying and remediating sites with PFAS contamination. While every contaminated site is unique, the projects described below give a sense of where PFAS contamination may be found and what remedial actions would be needed to clean it up. Several projects are related to the investigation and remediation of historic 3M disposal sites for PFAS waste. Other projects address remediation of PFAS contamination stemming from industries or activities outside of PFAS manufacturing, such as emissions from PFAS products used in metal plating and use of PFAS-containing firefighting foam. Challenges that arise in undertaking remediation projects include establishing clean-up values for relevant media, determining the extent PFAS disperses in the environment, and evaluating how to safely manage and dispose of contaminated materials. In addition to work related to known PFAS sites, MPCA is actively identifying new sites that, due to historic industrial activity, are likely to contain PFAS contamination. This initiative is currently in the pilot phase.

Activities related to PFAS investigation and remediation at 3M PFAS-contaminated sites

Implementation of the 2007 Consent Order

In May 2007, 3M and the MPCA entered into a Settlement Agreement and Consent Order (2007 Consent Order), which outlined requirements for 3M to address PFAS releases from three 3M disposal sites in Washington County: the Oakdale Site,[157] the Woodbury Site,[158] and the Cottage Grove Site.[159] The 2007 Consent Order required 3M to complete investigations at each site to determine the extent and magnitude of PFAS contamination and to undertake the appropriate remedial actions to address releases. To meet the terms of the 2007 Consent Order, 3M proposed the excavation and removal of PFAS impacted soil and sediment, installation of an enhanced groundwater control and treatment system, and long-term groundwater and surface water monitoring at each site, as appropriate. 3M is also required to file Environmental Covenants (which place restrictions on future land uses) for each site with the appropriate County Office. The 2007 Consent Order additionally required that 3M provide alternative drinking water sources to those public and private drinking water supplies with levels of PFAS contamination above MDH drinking water criteria. MPCA requested that 3M conduct additional evaluation of the surface water controls at the Oakdale site including additional surface water, sediment, and ground water sampling to help determine if more surface water remedies to control PFAS releases through Raleigh Creek are needed. 3M completed the additional work in fall of 2020. The MPCA and MDH continue to monitor both public and private drinking water supplies in the East Metro to ensure compliance with the 2007 Consent Order.

Work status: ongoing

Leader: MPCA East Metro Unit, MPCA Remediation Division. **Partners**: MDH Site Assessment and Consultation, MPCA Legal Services Unit, MPCA contractors.

Benefits: The 2007 Consent Order prevented further PFAS contamination from the subject disposal sites, and provided funding for interventions to reduce PFAS in impacted drinking water systems. Biomonitoring of individuals exposed to 3M contaminated drinking water showed significantly reduced levels of PFAS in blood serum after implementation of the drinking water intervention (*See* the Limiting PFAS Exposure from Drinking Water Issue Paper).

Challenges: Geologic conditions in the region surrounding the Oakdale disposal site and Washington County Landfill resulted in PFAS contamination spreading through interconnected surface water and groundwater systems. A series of pipes and man-made water conveyances (called the Project 1007 Corridor) designed to more efficiently drain water from the region to the St. Croix River contributed to the surface water transport of PFAS. There continues to be significant levels of PFAS in surface water and groundwater in the region. Remedial investigations of the Project 1007 Corridor are currently underway.

---

[157] MPCA (2008). 3M Oakdale Disposal Site Proposed cleanup plan for PFCs. [fact sheet]. Retrieved from: https://www.pca.state.mn.us/sites/default/files/Fc-s3-06.pdf

[158] MPCA. (2008). 3M Woodbury Disposal Site Proposed cleanup plan for PFCs. [fact sheet]. Retrieved from: https://www.pca.state.mn.us/sites/default/files/c-pfc3-02.pdf

[159] MPCA. (2009). 3M Cottage Grove Site Proposed cleanup plan for PFCs. [fact sheet]. Retrieved from: https://www.pca.state.mn.us/sites/default/files/pfc3-04.pdf

Resources required: Oversite of 3M activities involved many staff at MPCA and MDH, including risk assessors, hydrologists, engineers, legal staff, and others. Monitoring at these sites is ongoing.

Washington County Landfill triple liner installation (2009-2011)

The Washington County Landfill was used by 3M for disposal of PFAS containing wastes generated at the 3M Cottage Grove facility. This landfill falls under the authority of the MPCA's Closed Landfill Program (CLP), which means that Minnesota is financially responsible for long-term obligations related to releases of hazardous substances from the landfill. MPCA, under direction from the Legislature, determined that the most appropriate action to address the PFAS contamination at the site was to consolidate the waste material at the landfill onto a triple-liner system. Under the terms of the 2007 Consent Order, 3M contributed $8 million towards the implementation of the triple-liner system at the landfill. 3M also entered into an agreement with the City of Lake Elmo to pay for the connection of approximately 200 homes near the landfill to the city's public water supply system. Overall, 1.89 million cubic yards of waste were moved in order to add a lining to the landfill. The MPCA continues to monitor private drinking water wells that were not connected to the city drinking water system.

Work status: completed

Leaders: MPCA Closed Landfill Program. **Partners**: MPCA East Metro Unit.

Benefits: The lining of the Washington County Landfill significantly reduced the discharge of PFAS from this site. Continuous monitoring of wells surrounding the landfill ensures that drinking water wells will be protected into the future.

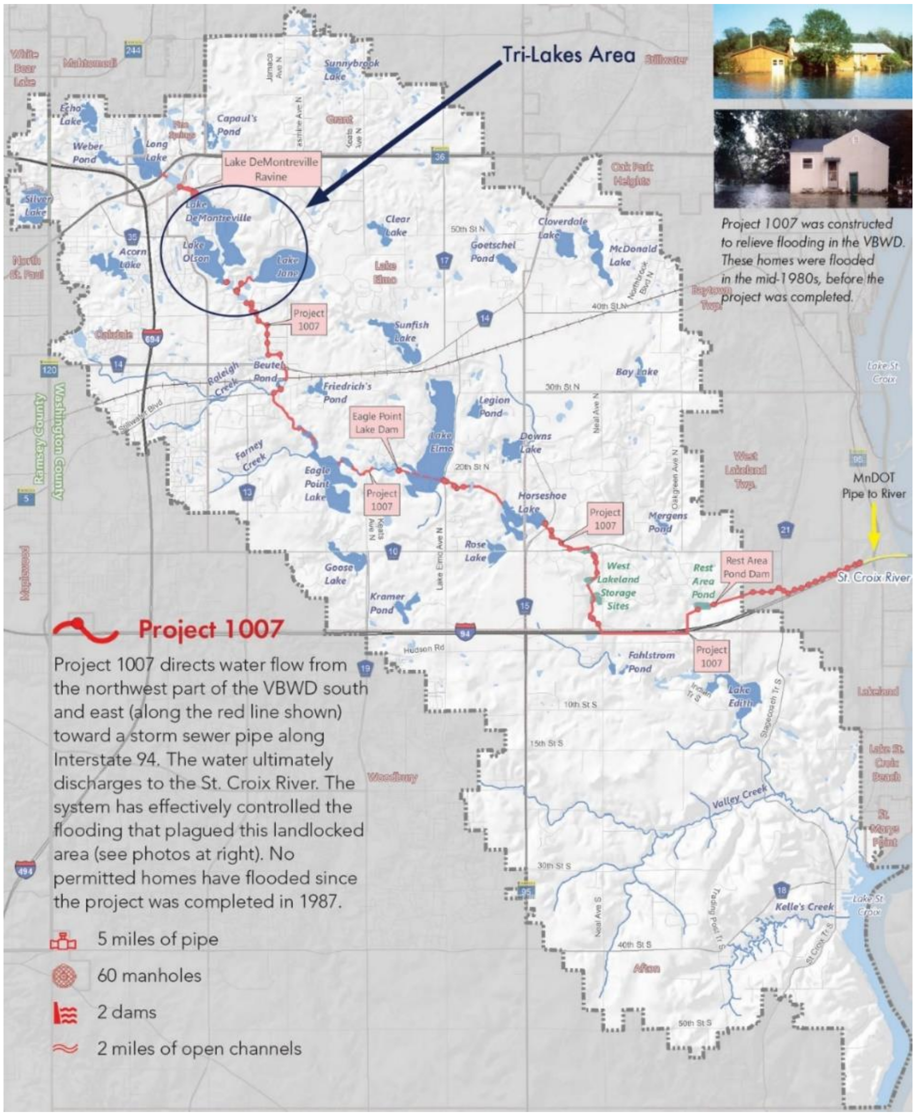
Challenges: This project faced several logistical challenges. The entire landfill needed to be dug out in order to install liners, so the materials were temporarily moved to the surface. This resulted in concerns from the community over the exposed waste being in contact with rainwater and generating leachate. Although there was a desire to build a leachate recirculation system within the landfill to reduce the overall volume of waste and leachate, compaction of materials in the landfill made this not possible.

Resources: This project was extensive and took over two years to complete. 3M contributed $8 million to the project, but the total cost was approximately $24 million.

Remediating the Project 1007 Corridor

The Project 1007 Corridor is a system of storm water pipes, open channels, catch basins, and dams constructed in 1987 that direct the flow of water from the Tri-Lakes area (lakes Jane, Olson, and DeMontreville) to the St. Croix River in an effort to reduce flooding. The engineered systems capitalized on existing creeks and lakes to facilitate the desired flow path – one of those creeks, Raleigh Creek, also flows through the former 3M Oakdale disposal site where PFAS discharged into the creek (and continues to do so). Additionally, from the late 1980s to the early 1990s, untreated water from the Washington County Landfill was discharged into the Project 1007 Corridor. Crucially, these additions of PFAS to the man-made drainage system allowed PFAS to spread past the natural hydrological basin where they were discharged and PFAS moved into the St. Croix drainage basin. The karstic geology in this watershed has also allowed for PFAS to flow from groundwater to surface water and back to groundwater in complex patterns. Figure 7 illustrates the geographic extent of hydrologic systems influenced by Project 1007.

Figure 7. Map of Project 1007 Corridor.



The 2018 3M Natural Resources Settlement (2018 Settlement) with MPCA states that "the MPCA shall conduct a source assessment and feasibility study regarding the role of the Valley Branch Water District's project known as Project 1007 in the conveyance of Perfluorochemical (PFCs) in the environment." The goal of the assessment is to understand how Project 1007 is contributing to PFAS contamination in the East Metro Area. The data collected during this assessment is being used to conduct feasibility studies for potential mitigation efforts.

Work status: ongoing

Leader: MPCA East Metro Unit, Remediation Division. **Partner**: State contractors, MDH Site Assessment and Consultation, Valley Branch Watershed District, MnDOT.

Benefits: Human and ecological receptors will benefit from removal of PFAS from multiple media (sediment, surface water, groundwater) in this region. Positive health outcomes are anticipated for human and ecological receptors from improved water quality and the associated reduction of bioaccumulation of PFAS through the food chain. A long-term approach to gradient control and treatment of the regional subsurface PFAS plumes will result in improved groundwater quality. A similar set of benefits will be realized for impacted surface water that is hydrologically connected to the regional drinking water resources.

Challenges: There are many technical challenges that will need to be overcome to successfully remediate PFAS plumes impacting the groundwater and surface water in this region. PFAS-impacted surface water and sediments pose challenges. Considerations are underway regarding disposal of impacted sediments, potential surface water treatment systems, and the amount of time treatment systems would need to be operational to address the contamination. Treatment, disposal, and destruction technologies for PFAS are evolving quickly. In many ways, the scale of PFAS remediation in this project is unprecedented – Minnesota is learning and evolving to new information as the project proceeds.

Resources: Significant resources from the 2018 Settlement funding are necessary to continue investigation and remediation of this region. This project has involved partnerships from many experts across Minnesota agencies, including various media specialists, hydrologists, geologists, engineers, risk assessors and toxicologists. The project has contractor support to lead well-drilling, sample collection, risk assessment, and many other elements of the project. External stakeholder groups have also supported the project by participating in the development of regional, long-term remedial options for groundwater resources. Through fiscal year 2021, over $4 million will have been spent on this effort.

Activities related to PFAS use in other industries

Remediating metal plating sites

Following the initial discovery of elevated PFOS concentrations in Bde Maka Ska, a Minneapolis lake, MPCA conducted extensive stormwater monitoring to find the PFOS source. This monitoring revealed that PFOS was released to air by a metal plating-on-plastic facility. Some of the emitted PFOS landed on the roof of the facility, where it traveled via stormwater to a wetland and lake a mile away. In the lake, MPCA found that the PFOS built up in fish tissue to levels of concern for human consumption, leading to development and application of a site-specific water quality criteria, fish consumption advice from MDH, and the waterbody being included on the Impaired Waters List. This discovery sparked general concern over PFAS emissions from metal plating facilitates, especially facilities that plate metal onto plastic, where PFOS-containing mist suppressant and wetting agent products are often used.

Since the discovery of metal platers as potential point sources of PFAS, especially PFOS, MPCA's Remediation and Compliance and Enforcement programs have engaged in actions to reduce PFOS emissions from some of these metal plating facilities and clean-up the resulting contamination in drinking water, surface water, and fish. For example, a metal plating facility in Brainerd was discovered as a source of PFAS to the city's wastewater treatment plant, and voluntary actions were taken to end the use of PFOS products in the plant and to further manage the PFOS released.[160] Enforcement and remediation activities related to several of these metal plating facilities are ongoing.

Work status: *ongoing*

Leaders: MPCA Remediation, Environmental Analysis and Outcomes, and Industrial Divisions.
Partner: DNR

Benefits: Minnesota was at the forefront of discovering that chrome plating facilities potentially act as major source of PFOS to surface water, drinking water, wastewater effluent, and biosolids. The research and communication around the initial plating facility investigation has led to many states and federal agencies being involved in researching and reducing PFOS emissions from plating. Many plating facilities switched to non-PFOS containing mist suppressants shortly after the discovery that PFOS-based mist suppressants were the source of elevated PFOS concentrations in some surface water, wastewater, effluent, and biosolids. However, it is not clear that the replacement mist suppressant and wetting agent products are fully PFAS-free.

Eliminating the use of PFOS-based mist suppressants and wetting agents at chrome plating facilities significantly reduced PFOS concentrations in wastewater and stormwater, which led to reductions in surface water and fish tissue concentrations at impacted waterbodies. The improvement in water

[160] MDH (2008). Health Consultation, PFOS detections in the city of Brainerd, Minnesota. Retrieved from: https://www.health.state.mn.us/communities/environment/hazardous/docs/pfas/pfosdetectbrainerd.pdf

quality from actions at metal plating sites is directly benefiting Minnesotans who eat fish from those waterbodies, some of whom rely on fishing as a healthy protein source, by reducing their exposure to PFOS. Remediation activities at these sites also ensures that drinking water sources potentially impacted by these sites are tested, and treatment is provided as needed. Ecological receptors also benefit from reduced exposure to PFOS and other PFAS in surface water surrounding metal plating facilities.

Challenges: Though extensive remediation and mitigation at one facility did reduce the concentration of PFOS leaving the facility in wastewater and stormwater, the residual amounts of PFOS in this facility continue to be a meaningful source of PFOS to the environment. It is not clear how to go about removing the PFOS residuals, and collaboration among Minnesota, other states, and EPA on this topic is ongoing.

Anticipated resource needs: Remediation sites associated with metal plating may be active for years and require a number of staff from different programs to manage. For example, one such site has been active for thirteen years and will likely need staff time and monitoring funds for years to come.

Statewide survey of PFAS-containing firefighting foam usage

PFAS, including PFOA and PFOS, used in firefighting foam products are especially effective in extinguishing liquid fires, such as fires of fuel, solvents, or other chemicals. For this reason, federal regulations require firefighting products containing foam (aqueous film-forming foam, or AFFF) to be present at petroleum refineries, all FAA regulated airports, and other facilities. From 2008-2011, MPCA reviewed and evaluated every fire department and agency in Minnesota to determine which may have used firefighting foam containing PFAS. This effort was funded by 3M under the terms of the 2007 Consent Order, which required that 3M provide $5 million to the MPCA for research activities that would help determine the extent of PFAS contamination in Minnesota outside of the 3M PFAS disposal sites.

Firefighting training sites and fire sites where PFAS-containing Class B firefighting foam is or was used were ranked for their potential to release PFAS to the environment. The ranking included a number of criteria such as the types and amounts of foam used, the frequency of the training events, the environmental setting, and nearby receptors. MPCA and MDH then followed-up by conducting soil, groundwater, and public drinking water system sampling at high priority locations with reported PFAS-containing foam. Data collected at these sites were documented in several reports.[161, 162] Site-specific investigations identified PFAS in soil, groundwater, surface water, or sediment at many of the high priority sites. PFAS were found in surface water or groundwater at concentrations above HRLs for drinking water at the following sites:

- Former firefighting training area behind the Richfield Ice Arena, Richfield
- Former firefighting training areas at Minneapolis-St. Paul International (MSP) Airport
- Firefighting training area at the Marathon Refinery, St. Paul Park
- Apple Valley-Burnsville-Lakeville-Eagan (ABLE) Training Center in Burnsville
- Firefighting training area at the Bemidji Regional Airport
- Firefighting training area at the Lake Superior College Emergency Response Training Center (ERTC), Duluth
- Former firefighting training area at the Duluth International Airport
- Western Area Fire Training Academy (WAFTA) in St. Bonifacius

[161] MPCA. (2010). Perfluorocarbon (PFC)-Containing Firefighting Foams and their use in Minnesota. Retrieved from: https://www.pca.state.mn.us/sites/default/files/c-pfc1-19.pdf

[162] MPCA (2010). Report of Investigation Activities at select Firefighting Foam Training Areas and Foam Discharge Sites in Minnesota. Retrieved from: https://www.pca.state.mn.us/sites/default/files/c-pfc1-09.pdf

In response to groundwater exceedances of HRLs, MDH began in 2011 to identify and sample water supply wells potentially at risk. Sampling water supply wells near several AFFF use sites has continued to the present and has been re-initiated near several sites as PFAS drinking water HRLs have continued to decrease and method detection levels have improved. Response actions to replace supply or treat water with PFAS concentrations above current drinking water advisory levels have been implemented at several sites, including two private wells near the Duluth Air Force base and municipal wells near the Bemidji airport.

Work status: completed

Leaders: MPCA Remediation Division and MDH Site Assessment and Consultation**. Partners:** Participating firefighting departments and agencies, the State Fire Marshal's office.

Benefits: The firefighting foam survey effort led to the identification of several PFAS-impacted sites that continue to be actively monitored by MPCA and MDH. Actions were taken at drinking water wells that had exceedances of HRLs to reduce exposure. Additionally, the survey led to collaboration between MPCA, MDH, and the State Fire Marshal's office, which led to local fire departments having greater awareness of the health and environmental risks of PFAS. Minnesota recently passed a law banning PFAS-containing firefighting foams for training and testing purposes under most circumstances, but this early outreach to fire departments led to a reduction in PFAS-containing firefighting foam use in training before that ban went into effect, reducing the amount of PFAS released into the environment.

Challenges: Early monitoring for PFAS was difficult due to high detection limits, a limited number of PFAS analytes, and a lack of health-based guidance values that could be used for comparison. Since beginning this effort in 2008, MDH has developed health-based guidance for five PFAS and analytical methods have improved.

Resources required: This work involved several staff overseeing outreach to firefighting facilities, sampling of various media at high-priority sites, and interventions at private drinking water wells with exceedances of HRLs. This work was funded by money from the 3M settlement.

Remediating sites impacted by PFAS-containing firefighting foam

MPCA is currently overseeing several site investigations and remedial actions at sites that have been impacted by PFAS-containing firefighting foam usage. Some of these sites are associated with DoD activities. The National Guard Bureau, on behalf of the Minnesota Air and Army National Guard and the US Air Force, began conducting preliminary assessments and site inspection investigations at active operational areas where PFAS-containing firefighting foams have been used or stored. These investigations were completed for the Minnesota Army National Guard installations at Camp Ripley and St. Cloud, for the Minnesota Air National Guard 148th Fighter Wing installation at the Defense Logistics Agency, and for the US Air Force and the Minnesota Air National Guard 133rd Airlift Wing installations at the MSP Airport. The initial investigations at these sites revealed that potentially significant releases of PFAS and PFAS-containing firefighting foam have occurred at each of these facilities. The respective military components are in the process of evaluating the risk and priority for funding remedial investigation and response actions at these sites in Minnesota given the hundreds of other military installations around the US also in need of remediation. Currently, MPCA is investigating potential impacts to groundwater, drinking water, surface water, and biota in the areas around these sites as funding allows.

Work status: ongoing

Leader: MPCA Remediation Division. **Partners**: Responsible military departments in the DoD.

Benefits: PFAS-containing firefighting foams have proven to be a major source of PFAS to the environment. Cleaning up these sites will reduce risks to human health and the environment. Requiring that the DoD pay for remediation at sites where the agency released PFAS-containing foams will reduce cost burdens on municipalities and individuals with impacted drinking water.

Challenges: Given the magnitude of PFAS pollution caused by DoD activities in the US (which is estimated to produce potential cleanup liabilities that exceed $2 billion), DoD sites in Minnesota are on a long queue of sites requiring clean-up action. Additionally, given that there are currently no federal standards for PFAS (no MCLs or hazardous substance designation under CERCLA), it is not fully clear which requirements DoD is subject to for clean-up. The federal government is unlikely to accept Minnesota's HBVs as ARARs for any contaminants, but would accept HRLs, which are promulgated by MDH.

Resources: Investigating and managing sites impacted by PFAS-containing foam has required multiple staff and many years of effort. Continued investigation and oversite of DoD activities will require additional staff time and funding for the foreseeable future.

Deriving health-based clean-up levels

Established and updated site-specific PFOS criteria to support clean-ups

Water Quality Criteria (WQC) are site-specific surface water values that are applied to address pollution in areas of known surface water contamination. These WQC are different than WQS in that they do not apply to the entire state, only to waterbodies explicitly included in the criteria. WQC are developed based on methods and authorities in state statute and the federal CWA (*See* Minn. R. ch. 7050). The MPCA Remediation Program is managing sites with PFAS surface water contamination and requested WQCs for PFAS be derived for impacted waters to inform clean-up efforts.

In October 2020, MPCA released a new PFOS WQC that applied to targeted waterbodies including Lake Elmo and connected waterbodies in the Project 1007 corridor in Washington County. When deriving WQC for those sites, MPCA also took the opportunity to update existing WQC for PFOS elsewhere in the State (Bde Maka Ska, and Pool 2 of the Mississippi River). MPCA prioritized deriving a PFOS WQC because PFOS has the highest bioaccumulation potential in fish compared to the other PFAS with health-based guidance values available. This high propensity of PFOS to accumulate in fish means that the largest pathway of exposure for those interacting with PFOS-contaminated water could be through consuming fish caught in that waterbody. MPCA is in the process of developing WQC for other PFAS found in surface waters in these impacted waterbodies.

PFOS is known to accumulate to levels of concern in fish and is transferred to humans when consumed, potentially causing adverse health effects. The site-specific WQC for PFOS in fish tissue and water incorporate a toxicological and exposure approach that is similar to that used by the MDH to develop drinking water values. This approach protects the most vulnerable populations to PFOS toxicity, which are developing fetuses and newborn infants being exposed to PFOS through the placenta during pregnancy and through breastmilk in early life. In developing this new WQC for PFOS, MPCA reviewed new fish consumption survey datasets from the MDH, Great Lakes Consortium for Fish Consumption Advisories, and other regional and national studies relevant to the amount and types of freshwater-caught fish consumed by women of childbearing age (ages 15 to 50). Because PFOS and other PFAS are developmental toxicants, characterizing potential exposure to this subgroup of fish consumers from PFOS is very important. The interim fish consumption rate for women of childbearing age used in this

PFOS WQC is over twice the default rate for adults who eat freshwater-caught fish and is based on a study lead by MDH called, *Fish are Important for Superior Health* (FISH).

The new WQC for PFOS can be expressed either as a fish tissue concentration or as a water concentration. For fish tissue, the WQC is 0.37 nanograms PFOS per gram (ng/g). The corresponding WQC for water is 0.05 nanograms per liter (ng/L). The goal of these WQC is to reduce the levels of PFOS in water, which should eliminate the need for additional protections like fish consumption advisories.

Work status: ongoing

Leader: MPCA Water Quality Standards Unit. **Partners**: MPCA Water Assessment and MDH Health Environmental Surveillance and Assessment.

Benefits: PFOS WQC are based on protecting people's health from the presence of this toxic pollutant in Minnesota's surface waters and fish. The criteria provide numeric targets for MPCA programs to use in remediation cleanup, wastewater permitting, and other environmental protection authorities. Reductions of PFOS in fish tissue have already been documented in some surface waters due to national restrictions of some PFAS, including PFOS, and ongoing remediation activities. Any efforts to reduce PFOS pollution also benefit wildlife.

Challenges: The PFOS WQC consist of an applicable fish-tissue concentration and surface water concentration. These values are very low and require the use of the most recently developed analytical methods to assess. The fish-tissue WQC of 0.37 ng/g can be accurately quantified by MPCA contract labs, but the water concentration of 0.05 ng/L cannot. The MPCA's Effluent Limit Unit is working with the Environmental Data Quality Unit to develop guidance related to these analytical issues.

Resources: The development of the PFOS WQC took an MCPA staff person approximately one year and involved the support of several other technical staff at MPCA and MDH. This effort was possible because MDH had already conducted a human health assessment for PFOS, containing toxicity values and a serum model for understanding PFOS transfer to infants. Currently, the Water Quality Standards Unit is developing new site-specific WQC for PFOA (which would allow for additional updates to existing WQC for Bde Maka Ska and Pool 2), PFBA, PFHxS, and PFBS – primarily based on the potential for recreational risk. These PFAS also have MDH toxicological values and health-based guidance for drinking water that are relevant for this work. This work is anticipated for completion in 2021.

Derived PFAS soil ingestion values to support clean-ups

Children are especially likely to have exposure to contaminants in soil, and studies have quantified the amount of soil children incidentally ingest while playing outdoors. However, adults can also be exposed to contaminants in soil. Site-specific soil screening values protective of human health for both residential exposure (focused on protecting children's soil exposure) and industrial or commercial exposure (focused on adult soil exposure) were derived to support remediation activities in the East Metro.[163] These values are also relevant to sites with soil PFAS contamination in Minnesota. SRVs are used to determine potential public health risks resulting from direct exposure to impacted soil, but are not used as clean-up values. The SRVs for PFAS were last revised in November 2019.

Work status: completed, with additional future work possible

Leaders: MPCA Environmental Analysis and Outcomes Division**.**

[163]MPCA. (2017). *Revised per- and polyfluoroalkyl substances human health soil reference values*. https://www.pca.state.mn.us/waste/what-minnesota-doing-about-pfas

Benefits: Guidance values for soil ingestion are used to determine if there are potential public health risks posed by soil exposure in various settings.

Challenges: Soil guidance values for additional PFAS would be helpful, but toxicological assessments are needed before such values could be derived. The lack of oral toxicity data has so far prevented risk assessments for several of the long-chain PFAS that are most likely to remain sorbed to soils or sediments. Additionally, risk-based values derived to protect against leaching of PFAS from soils to groundwater may need to be more stringent than values protecting against incidental ingestion of soil.

Resources required: This effort to derive soil risk values involved a small team of human health risk assessors in the MPCA, with support from toxicologists in the environmental health team at MDH. The MPCA has lost human health risk assessment expertise in 2020 and is working to fill a position to help support this work. Additional effort will be required to update soil risk values as the underlying toxicity information for PFAS is updated.

Identifying new PFAS sites

Continue developing the Pilot PFAS Inventory

The goal of the Pilot PFAS Inventory is to develop a comprehensive database of known and potential PFAS-contaminated sites and tools to prioritize investigations into those sites. In 2017, a multi-phase protocol was developed to identify and prioritize locations where PFAS may be present. The protocol maps potential PFAS-generating businesses and receptors, such as drinking water sources, to determine potential risk to human health and the environment. A four-county pilot study (including Dakota, Olmsted, St. Louis, and Stearns counties) was launched to validate the protocol by testing for PFAS in groundwater, surface water, air, soil, and sediment at high priority sites. MPCA is partnering with MDH to incorporate results of ongoing drinking water monitoring into the site prioritization tools.

Work Status: ongoing

Leader: MPCA Remediation Division. **Partner:** MDH Drinking Water Protection.

Benefits: PFAS data is collected over many programs in multiple agencies, making it difficult to synthesize information, analyze trends, and prioritize future actions. The PFAS Inventory is compiling information about industrial activities that may have resulted in PFAS releases and PFAS data from multiple monitoring programs in a format that can be easily mapped and analyzed, facilitating more timely investigations into sites with the highest likelihood of impacting human health and the environment. The prioritization tools developed as part of the Pilot PFAS Inventory will be validated by conducting site investigations for PFAS in multiple media at high-priority sites.

Challenges: The assessment of PFAS contamination requires data on the presence of current and historic potential PFAS-generating businesses. To identify sites with industrial activities that may have resulted in PFAS releases, industry codes associated with PFAS use were collected from the National American Industrial Classification System. However, not all businesses in industries identified as having potential PFAS use will actually have had PFAS on site. For example, airports are listed as a potential major source of PFAS release, but small airstrips at farms, for example, are unlikely to have firefighting foam usage that resulted in PFAS release. Data about facilities associated with current industries types were collected using the Made in Minnesota database, which is hosted by the Minnesota Department of Employment and Economic Development. However, a facility's inclusion in the Made in Minnesota database is voluntary and the database is therefore not comprehensive. Data on historic businesses that may have potentially generated or used PFAS were collected from the state's PLP, which includes Superfund sites in Minnesota. Together these databases provide some information on facilities that have past or present potential PFAS uses, but do not capture all potential facilities with PFAS uses and environmental releases in the state. The inclusion of some PFAS in the TRI starting in calendar year 2020 will provide more detailed data on current PFAS emissions, but there are limitations in the reporting requirements that will allow some PFAS releases to go unreported.

Resources: This project is currently in a pilot stage that includes gathering data and prioritizing sites in four counties. The cumulative costs for the development of the protocol, identification of priority sites, evaluation of data, and launch of the pilot study is approximately $125k for years 2016-2021. This includes funding made available through an EPA MPG. The methods developed in this project, after their verification, could be applied in multiple areas.

Gaps and opportunities

There are several opportunities that could help fill ongoing gaps in areas related to remediation of PFAS-containing sites. These opportunities include refining legal authorities related to PFAS investigation and clean-ups, developing additional guidance for PFAS site remediation, and exploring options for ways to supplement the state Remediation Fund should it be strained by an increase in PFAS sites without responsible parties.

There are several areas where additional legislative action would enhance the agency's ability to respond to PFAS pollution. Despite prior legal and regulatory actions in Minnesota, there remain challenges to state authorities to regulate PFAS. Legislative changes to the hazardous substance designation under MERLA would solidify existing authorities regarding PFAS in Minnesota. Similarly, congressional changes to the designation of PFAS under CERCLA would clarify federal authorities. Additionally, there is a lack of data identifying which entities use or produce PFAS that could be released to the environment. Using the Pilot PFAS Inventory to identify unknown sites could be a step to fill this data gap; however, this effort is restricted by limitations in publicly available information about PFAS use and release. Additional statutory authority that would allow MPCA to request information on environmental contaminants could also fill gaps in the available information. This would benefit the many initiatives where additional information held by private parties would inform risk assessment or site investigation.

In addition to gaps related to environmental release of PFAS, there are also gaps in guidance related to determining risk-based clean-up values and monitoring needed to prioritize sites. Though there are some existing clean-up values for PFAS, additional guidance values would help ensure protective clean-ups and prioritize sites for investigation. MPCA could develop soil leaching to groundwater values and additional surface water values using the existing health-based values from MDH for five PFAS. Additional risk assessments for PFAS from MDH would allow for corresponding surface water and soil values to be derived. Finally, there is a gap in guidance for when investigations of sites should include monitoring for PFAS. Filling these gaps would ensure that clean-ups are health-protective and that actions at sites are consistent.

There is work underway to remediate many PFAS-containing sites in Minnesota, but there are likely many more businesses and industries with PFAS releases than could be addressed in the remediation program. Some common industries, like car washes or metal platers, may have widespread historic and ongoing uses of PFAS, and the state may not have the resources to clean-up each impacted site in the near-term should the responsible party be unable to do so. Minnesota could consider options for ways to supplement the state Remediation Fund should an increase in PFAS remediation sites without responsible parties strain that fund. The following sections describe these possible opportunities to fill existing gaps in more detail.

Request additional legal authorities associated with PFAS Remediation

Formally define PFAS as a hazardous substance under MERLA

The Legislature should specifically include PFAS in its definition of hazardous substances under the Minnesota Environmental Response and Liability Act, or MERLA. Under MERLA, compounds are considered hazardous substances if they meet one of several criteria, including if they are a hazardous waste. Hazardous waste is defined as any hazardous waste in Minn. Stat. 116.06, subd. 11, any substance identified as a hazardous waste under rules adopted by the agency, and any hazardous waste as defined in the Resource Conservation and Recovery Act (RCRA), which is listed or has certain identified characteristics. PFAS are currently considered hazardous substances based on their properties as hazardous waste under Minn. Stat. 116.06, subd. 11; but, specifically designating PFAS as a hazardous substance in statute would clarify MPCA's authority to respond to releases of PFAS under MERLA. It would reduce legal challenges over whether PFAS is a hazardous substance or not. Including PFAS in the definition of hazardous substances would also provide greater clarity for the state to require responsible parties to investigate or clean-up releases under Minn. Stat. 115B.17 and recover costs from responsible parties that fail to take all appropriate and necessary actions to investigate or clean-up releases of PFAS as provided in Minn. Stat. 115B.04.

Work status: requires legislative action

Leaders: MPCA Remediation Division.

Benefits: There are several benefits to proposing that the Legislature amend MERLA to specifically include PFAS in its definition of hazardous substances. Legal challenges can delay the agency's ability to quickly respond to PFAS related releases, including those in environmental justice areas. Additionally, if the Legislature were to amend MERLA's definition of hazardous substances to specifically include PFAS, it would expedite MPCA's actions to require responsible parties to take remedial actions or recover costs from responsible parties that are reluctant to investigate or clean-up PFAS contamination that may be threatening human or ecological health. Finally, specifically identifying PFAS in the definition of a hazardous substance would alert PFAS users of the hazardous nature of the chemical and encourage entities that use or produce PFAS to invest in safer alternative chemistries.

Challenges: The family of PFAS is large and diverse, with different PFAS causing different problems in human biological functioning, wildlife biological functioning, and overall ecological health. The persistence of PFAS as a class combined with the known toxic effects of many individual PFAS is sufficiently troubling to warrant designating the entire class as hazardous substances. If a chemical is highly persistent, continued release leads to ever increasing concentrations in the environment, corresponding to increased likelihood that that once adverse effects are identified, clean-ups will be necessary. When extremely persistent compounds are released to the environment, it takes considerable time, effort, and money to remediate the pollution. The best management approach to highly-persistent compounds in the environment is to prevent their use and release whenever possible.

Resources: This effort requires legislative action but would require no additional resources to propose or implement; implementation may even result in resource efficiencies.

Establish authority to request data regarding contaminants of potential environmental concern

Data gaps in PFAS research limit the ability to understand exposure levels in the environment, quantify toxic levels for humans or wildlife, and identify parties responsible for contamination. Authority to request information from entities on compounds in products would aid the MPCA and other agencies in closing the data gaps. The agency could collect information (documents, testimony, written responses to questions) related to the facilities' activities or activities of the entities in the facilities' supply chain. This authority would not require any additional regular reporting by industries or entities, but it would allow MPCA to collect information in a timely manner when concerning levels of environmental pollution are found, including information that would identify sources of PFAS contamination. *See* the Quantifying PFAS Risks to Human Health Issue Paper for discussion of how this authority would also be relevant to conducting future toxicity assessments.

Work status: requires legislative action

Leaders: MPCA Safer Chemicals Unit. **Partners**: MDH Health Risk Assessment Unit.

Benefits: The authority, would help MPCA identify sources of these contaminants faster, reduce or prevent contamination including contamination of drinking water, and improve the overall health of Minnesotans and the environment.

Challenges: This authority would allow MPCA to request information from entities, but some crucial data gaps, such as gaps in toxicity information, may not be filled by requesting data from entities using or producing PFAS. Additionally, this authority would help MPCA respond to PFAS contamination.

Resources: Enacting this authority would not require significant resources. It may save MPCA and other agencies future efforts if they could acquire desired information directly from companies, instead of having MPCA and other agencies recreate studies, techniques, etc.

Develop additional tools for PFAS clean-ups

Develop soil to groundwater leaching values for PFAS to be used in clean-ups and disposal guidance

PFAS have been shown to be highly mobile in soil and in groundwater once they have been released into the environment. Investigations of PFAS groundwater contamination have demonstrated that uncontrolled soil releases of PFAS can result in impacts on groundwater. The leaching potential of toxic chemicals to groundwater is an important factor when evaluating risks posed by releases at remediation sites. Soil leaching values (SLVs) are risk-based values developed to estimate risk to groundwater via the soil-to-groundwater leaching pathway. A SLV estimates the concentration of a chemical in soil that will not result in leaching of that chemical to groundwater at concentrations greater than the compound's groundwater risk criteria. In Minnesota, risks posed by ingestion of drinking water are evaluated using promulgated Health Risk Limits (HRLs) or Heath Based Values (HBVs), developed by the MDH. The MDH has developed HBVs or HRLs for five PFAS: PFBS, PFBA, PFHxS, PFOA, and PFOS. These values are available on the MDH's Human Health-Based Water Guidance Table.[164]

Currently, no SLVs have been developed for any of the PFAS often found at environmental release sites. Reasons that SLVs have not been developed for PFAS include 1) the lack of guidance for developing leaching PFAS values by the EPA or other national organizations; 2) the rapidly evolving understanding of PFAS fate and transport chemistry; 3) the limited number of PFAS with groundwater risk criteria due to a lack of oral toxicity data. Appropriate chemical and physical information would need to be collected to develop SLVs for the five PFAS for which HBVs are available and be prepared to develop additional PFAS SLVs as additional drinking water criteria or standards are developed. The data required to develop SLVs are reliable published estimates of soil adsorption coefficients (K_{oc}, defined as the amount of a substance that is absorbed onto soil per volume of water) and drinking water criteria.

Work status: under consideration

Leaders: MPCA Remediation Division. **Partners:** MPCA Environmental Outcomes and Analysis, MDH Drinking Water Protection.

[164] MDH. (n.d.) Human Health-Based Water Guidance Table. Retrieved from: https://www.health.state.mn.us/communities/environment/risk/guidance/gw/table.html

Benefits: There are many scenarios where SLVs would be helpful tools for making decisions. The application of SLVs at PFAS release sites would provide risk-based tools to estimate what concentrations of PFAS soil contamination should be remediated and what potentially could remain in the soil without posing a risk to surrounding groundwater. Similarly, SLVs could be used to help make decisions about options for disposing of impacted soils. The use of SLVs can provide justification for soil response actions intended to prevent additional groundwater contamination. SLVs can provide an additional risk-based tool to require necessary soil cleanups to minimize future PFAS groundwater contamination.

Challenges: The unique physical and chemical properties associated with the PFAS family of compounds makes developing of SLVs more difficult. SLVs are generally calculated using K_{oc} constants, but K_{oc} for PFAS can vary widely depending on the conditions of the measurements. Though many K_{oc} values are available for PFAS, expert consideration is needed to determine representative K_{oc} values for soil types and conditions common in Minnesota or present at a given site. Additionally, several states and the EPA are developing models for PFAS that estimate leaching from soils and biosolids, and these models should be considered for development of PFAS SLVs in Minnesota. Collaboration with these groups (EPA, partner states, Interstate Technology and Regulatory Council [ITRC]) will be helpful in assessing the state of the science regarding PFAS fate and transport in soils. Risk-based values for drinking water are also needed for any pollutant to support derivation of an SLV.

Anticipated resource needs: This effort will require staff time to develop SLVs.

Update guidance for recommended analyte sampling at clean-up sites to include PFAS

MPCA has existing guidance for investigations at Brownfields sites that includes recommendations for analytes to measure given various activities that may have occurred at the site.[165] This guidance document, last revised in April 2001, does not include guidance on when it is advisable to sample soil, water, or air for PFAS. At a price of $300-$400 per sample, PFAS sampling is expensive, and voluntary participants in the Brownfields program or responsible parties in the Superfund program are hesitant to sample for PFAS when PFAS may not be present at levels of concern. An ongoing initiative at MPCA is the Pilot PFAS Inventory, which has gathered data on which industries are known or likely to use PFAS. Revising the site investigation methodology to leverage the information gathered by the Pilot PFAS Inventory will inform MPCA and partners about when it is strategic to sample for various PFAS and in which media (water, soil, biota, air). This project proposes initiating a workgroup of scientists and project managers from MPCA to update the existing guidance document to include both recommendations of when to sample for PFAS and other emerging contaminants as well as recommended sampling strategies. This guidance might take the form of a flow chart or other decision-making tool to ensure that consistent, science-based decisions about PFAS sampling at potential remediation sites (whether for the Brownfield or Superfund program) are being made across sites and programs.

Work status: under consideration

Leaders: MPCA Remediation Division. **Partners**: MPCA Environmental Analysis and Outcomes.

Benefits: This project would help ensure that potential PFAS contamination is not overlooked at clean-up sites and appropriate health-protective actions are taken.

[165] MPCA. (2001). Minnesota Pollution Control Agency Voluntary Investigation and Cleanup, Guidance Document #11. Retrieved from: https://www.pca.state.mn.us/sites/default/files/vic-gd11.pdf

Challenges: The lack of requirements mandating reporting of PFAS releases, labeling PFAS in products, and handling or disposing of PFAS waste means that there is much unknown about which industries use PFAS, which PFAS they use, and how much PFAS they are likely to discharge to soil, water, and air. The guidance may have to be regularly updated to incorporate new knowledge of likely PFAS sources.

Resources: Updating this guidance would likely require effort by a team of staff from MPCA.

Explore opportunities to supplement the state Remediation Fund

There are many businesses across Minnesota that have historically used PFAS products and may have discharged PFAS at levels that are now identified as harmful to human health and the environment. Car washes using PFAS in waxes and polishes, textile companies using PFAS coatings, paper production companies, and firefighting training centers using PFAS-containing foams are just some examples of facilities that may have significant liability stemming from PFAS releases. There are potentially thousands of industrial and commercial sites around Minnesota with ongoing or historic PFAS releases that may be impacting drinking water and aquatic ecosystems. In some number of PFAS-contaminated sites, there may not be a responsible party available to pay for remediation and the costs associated with remediation would instead be borne by the state's Remediation Fund. It is unknown how many PFAS-contaminated sites are present in Minnesota that do not have responsible parties available to pay for site's remediation. This project would investigate the potential costs and benefits of various strategies for supplementing the state's Remediation Fund to account for increased financial stress from PFAS sites without responsible parties available to pay for investigation and clean-up.

Work status: under consideration

Leaders: MPCA Remediation Division.

Benefits: Planning for potential strains on the Remediation Fund stemming will allow MPCA to respond in a timely manner to PFAS-contaminated sites into the future.

Challenges: It is currently difficult to determine how many sites are likely to be discovered in Minnesota without responsible party's available to fund remediation activities. This may challenge the planning process.

Resources: Investigating the potential to develop a PFAS fund program would require staff resources from MPCA and likely also the Minnesota Department of Commerce.

Overview of intersectional issues

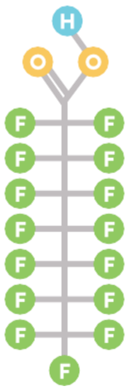
- **Quantifying PFAS toxicity**: Communication with the public and understanding the potential health impacts of PFAS exposure are key to ensuring protection of human health, welfare, and the environment. Health-based guidance values, however, require data on toxicity and exposure that are not available for the vast majority of all the PFAS found in the environment. (*See* the Quantifying PFAS Risks to Human Health Issue Paper for more information on challenges stemming from PFAS toxicity data limitations.)
- **Managing PFAS in waste streams**: Remediating PFAS sites results in PFAS contaminated media that requires disposal. Guidance is needed on when waste from clean-up sites, like soils with detectable PFAS, can be passed to landfills and when these materials should be further treated or disposed of in a hazardous waste landfill or hazardous waste incinerator. Even without acceptance of waste generated from remediation sites, landfill leachate, effluent and biosolids from wastewater treatment plants, and contact water from composting facilities all contain

PFAS stemming from industrial and commercial uses of PFAS-containing products and need to be addressed appropriately. Additional considerations will be needed to ensure appropriate regulations are in place to address safe handling and disposal of PFAS-containing products.

- **Protecting Minnesota wildlife**: The limited data available for a limited number of PFAS currently indicate that health-based values protecting humans from PFAS exposure in drinking water and from fish consumption are more stringent than benchmarks that are protective of wildlife; therefore, remediating PFAS-contaminated sites to protect against adverse effects in humans likely also results in protective concentrations for wildlife for those PFAS. However, ongoing review of wildlife research is needed to ensure that continuing research supports that conclusion and that these conclusions are also valid for currently unstudied PFAS.
- **Developing and expanding access to analytical methods**: Analytical methods for PFAS are expensive and time-intensive to run, and include only a subset of all PFAS that may be occurring in drinking water – *see* the Measuring PFAS Effectively and Consistently issue paper for more information on the costs and challenges associated with measuring PFAS in various matrices.

Managing PFAS in waste

Background



- The term "waste" encompasses the things that we "throw out" or "wash down the drain" after they are no longer useful. Facilities collecting this waste, like composters, landfills, and wastewater treatment plants (WWTP), **also produce end products from treatment or disposal operations that must be managed**, such as leachate from landfills or biosolids from a WWTP.
- State and federal regulatory programs -- including the RCRA, the **Clean Water Act** (CWA), the **Clean Air Act** (CAA), and **Minnesota Solid Waste Rules** -- ensure that all waste is handled in a manner that minimizes damage to human health and the environment.
- Per- and polyfluoroalkyl substances (PFAS) pose challenges to our existing waste management systems. PFAS are **persistent** in the environment, **ubiquitous** in commercial and industrial products, **resistant to destruction**, and often **harmful to people** at low doses. There is not guidance regarding disposal of PFAS-containing waste.
- **Monitoring of PFAS** in leachate, ash, effluent, and biosolids shows that though these facilities do not use or produce PFAS, they can serve as a **conduit** for waste streams containing **high concentrations** of a **diversity of PFAS.** PFAS are often passed through to effluent, leachate, ash, and biosolids – the management of these pass-through end products can result in PFAS releases to the environment.
- Managing waste with PFAS is challenging because PFAS are resistant to degradation, causing them to **cycle between environmental media** and **waste management facilities**.
  - **Treatment technologies** used to remove PFAS **create new, concentrated PFAS end products**, which then need to be destroyed or landfilled. If PFAS are not completely destroyed, some PFAS will be released into the environment.
  - Treatment or destruction is more **difficult and expensive** when pollution is diffuse or combined with other co-contaminants -- treating leachate or effluent is generally more costly than treating concentrated PFAS waste from an industrial facility.
  - Manufacturers are not required to disclose if or how much PFAS are present in products, making it **difficult to track down sources** of PFAS in waste streams.
- Due to the propensity for PFAS to cycle through waste management facilities and the environment, the most strategic approach is to **prevent PFAS from entering waste streams** (*see* the Preventing PFAS Pollution issue paper).

What is Minnesota doing now?

- **Monitoring**: MPCA partnered with landfills, composting facilities, and WWTPs to conduct voluntary, one-time monitoring for PFAS (funded by MPCA). MPCA has also monitored for PFAS in the landfills managed by the CLP. If drinking water impacts are discovered during monitoring, MPCA takes remedial actions to reduce PFAS concentrations in drinking water to below the health-based values determined by MDH.
- **Research**: MPCA has approved a demonstration research project on landfill leachate treatment that is designed to remove PFAS before discharging treated leachate to a stormwater pond.
- **Regulation**: MPCA has required landfills and composting facilities land-applying leachate to monitor for PFAS. MPCA has issued site-specific Water Quality Criteria (WQC) for PFOS protective of fish consumers applicable to waterbodies with known PFOS surface water contamination – this will affect permittees discharging effluent to those waters.

What are remaining gaps and opportunities for action?

- **Gap**: Research is needed to understand the fate and transport of PFAS in land-applied biosolids and define the extent of known PFAS groundwater plumes at CLP sites.
  - **Opportunity**: MPCA could conduct a study to evaluate the fate and transport of PFAS contained in land-applied biosolids, which could provide the data needed to develop tools for making reasonable and responsible decisions regarding land-application of biosolids with detectable levels of PFAS.
  - **Opportunity**: Initial investigation of groundwater at closed landfills in the CLP showed PFAS levels exceeding health-based values at 55 locations – sometimes by a large margin. Access to funding sources would allow MPCA to fully investigate PFAS plumes to determine if remedial actions are needed.
- **Gap**: WWTPs, landfills, and composting facilities have struggled to identify and reduce PFAS sources to their facilities.
  - **Opportunity**: Identifying and reducing PFAS inputs to waste management facilities is a challenge. To address industrial sources, MPCA could support monitoring and discussions between WWTPs and their industrial PFAS sources, leveraging data from the industrial pre-treatment program in Michigan. To address PFAS loading to facilities from consumer products, pollution prevention policies are needed (*see* the Preventing PFAS Pollution issue paper).
- **Gap**: The science and regulatory status of PFAS is complex and rapidly evolving – there is limited guidance for facilities making management, treatment, and disposal decisions for products containing PFAS.
  - **Opportunity**: MPCA could develop guidance on options available for disposing of unused PFAS-containing firefighting foam and options for collecting and disposing PFAS-containing wastewater produced in an emergency.
- **Gap**: There is a lack of regulation regarding management of PFAS-containing waste.
  - **Opportunity**: Waste management facilities fall under various regulatory programs, and the "first step" in a process to begin assessment of and reductions in PFAS releases through permit conditions would also vary. MPCA could consider taking coordinated regulatory actions on PFAS in waste facilities, including:
    - Mandating monitoring of PFAS in groundwater at all permitted solid waste facilities, which would inform next steps to minimize PFAS in groundwater and surface waters.
    - Rulemaking to define PFAS as "hazardous waste" under RCRA, resulting in requirements on handling, storage, and disposal of concentrated PFAS.
    - Mandating monitoring of PFAS in effluent from WWTPs and conducting rulemaking to develop statewide WQS for PFAS, which would trigger the regular regulatory processes for development of effluent limits. MPCA would develop a path forward to assess, list, and address PFAS impairments.

How does this work benefit human health and the environment?

- Reducing PFAS discharges to surface water, groundwater, and soil from waste facilities **prevents harmful exposure** to humans and wildlife.

How does this work benefit Minnesota's economy?

- **Treating PFAS at the source** rather than in the outputs from (often publicly-owned) waste facilities places the financial burden with PFAS generators, encouraging innovative pollution prevention approaches and saving tax-payer money. These actions to limit PFAS releases from the source also **reduce Superfund liability** for businesses **and the likelihood of costly cleanups.**

Background

The term "waste" generally refers to products and materials at the end of their life – the things that we "throw out" after they are no longer useful. Most people are familiar with the municipal solid waste stream. When products we have in our homes are "thrown out," they leave our homes and are sent to recycling, composting, a waste to energy facility, or a landfill. Water and sewage from our homes goes down the drain and ends up at a municipal WWTP or at a soil-based treatment system. Industries also have both wastewater and solid waste streams. People and businesses rely on private and public waste facilities to manage and dispose of our waste. Though it can appear that waste simply "disappears," the reality is more complicated. Waste treatment systems – including those that deal with solid waste (e.g. composting, incineration, and landfills) and wastewater – create various end products. Some end products, such as biosolids or landfill gas, may be beneficially re-used; other end products, such as landfill leachate, wastewater effluent, or incineration ash, may need to be managed. All end products could be conduits of pollutants to the environment. Complex systems are at play to ensure that waste is managed in a way that results in the least possible disturbance to our communities, our environment, and our health.

PFAS pose challenges to our existing waste management systems – PFAS are ubiquitous in the economy and the environment, and therefore also in our waste streams. Extensive monitoring in Minnesota and around the country has found that PFAS can concentrate to high levels at waste facilities, including those accepting only municipal solid waste (waste from businesses and homes). PFAS are persistent, meaning that they do not break down in the environment or in traditional treatment systems that may be applied at waste facilities. Many PFAS will not break down during combustion unless high temperatures are achieved under optimal conditions – incomplete PFAS combustion products can be released back to the environment at waste burning facilities. Finally, many PFAS cause adverse health effects at low doses, and can pose a risk if they are consumed through drinking water, food, or incidental ingestion of dust and soil. Little is known regarding health risks associated with inhalation of PFAS.

Regulatory structures for waste management

There are several state and federal regulatory programs that intersect to ensure that waste is handled in a manner that minimizes damage to human health or the environment.

Resource Conservation and Recovery Act and Minnesota Waste Statutes and Rules

The main federal law for the regulation, handling, treatment, transport, storage, and disposal of waste is the RCRA, passed in 1976. Minnesota's parallel waste management statutes, under Minn. Stat. ch. 116 and 115A, establish similar goals. RCRA has provisions relevant to municipal solid waste, hazardous waste, materials from construction or demolition projects, and underground storage tanks. There are multiple goals of RCRA, including protecting human health and the environment from the hazards posed by waste handling and disposal, encouraging recycling and recovery, and reducing the amount of waste generated. The regulated community that complies with RCRA and its regulations is large and diverse. It includes facilities typically thought of as hazardous waste generators, such as industrial manufacturers and laboratories, but also government agencies and small businesses, such as a dry cleaners generating small amounts of hazardous solvents, or a gas station with underground petroleum tanks.[166]

RCRA is related to, but distinct from, another law called the Comprehensive Environmental Response, Compensation, and Liability Act (known as Superfund or CERCLA), which regulates the cleaning-up of contaminated sites. RCRA regulates materials that are currently destined for disposal or recycling. Both

[166] EPA. (2014). RCRA Orientation Manual. Retrieved from: https://www.epa.gov/hwgenerators/resource-conservation-and-recovery-act-rcra-orientation-manual

programs have enforcement capabilities that allow regulators to assess if a site or facility contains a hazardous substance that is posing a risk to human health or the environment, investigate the nature of a violation or spill, evaluate clean-up options, and implement the preferred method of clean-up.

Minnesota has broader hazardous waste rules and regulations. Any business generating waste in Minnesota is potentially regulated under the Minnesota Hazardous Waste Rules; Minnesota has received state authorization from EPA that delegates to MPCA the primary responsibility of implementing the RCRA hazardous waste program. Currently PFAS are not *listed* as a "hazardous wastes" under RCRA or the Minnesota Hazardous Waste Rules, but some PFAS-containing materials can have characteristics of hazardous waste.

Non-hazardous solid waste facilities, including municipal solid waste (MSW) landfills, industrial landfills, construction and demolition (C&D) landfills, combustor ash landfills, and yard waste or composting facilities, are also regulated. For example, MSW landfills are required to be located in a suitable geological area (away from wetlands, flood plains, or other restricted areas), must be lined to protect underlying soil and groundwater, must collect the water filtrating through the landfill (called leachate) and properly treat or dispose of it, must be covered with soil, must test surrounding groundwater to make sure that waste is not leaking through the liner, and landfill operators must maintain the landfill for an extended period after it has closed.[167] At MSW and industrial landfills, leachate is most frequently disposed of by being sent to a municipal WWTP, but a limited number of MSW facilities land-apply leachate by spray irrigation to fields owned and operated by the facility. In Minnesota, C&D landfills have fewer restrictions than MSW and industrial landfills and are not required to be lined. Construction and demolition debris includes concrete, brick, bituminous concrete, untreated wood, masonry, glass, trees, rock and plastic building parts, and similar materials. Large-scale composting facilities that accept food waste and possibly other compostable products are also required to operate on an impermeable surface and collect water infiltrating the compost, which is called "compost contact water." MPCA and local governments are the primary planning, regulating, and implementing entities for the management of nonhazardous solid waste, such as household garbage and nonhazardous industrial solid waste.

Closed Landfill Program

The Legislature created the CLP to provide resources to manage closed landfills without using the complex legal-liability framework of the Superfund process. Superfund laws use a "polluter pays" model to manage and clean-up contaminated sites, but this process is ineffective at dealing with closed municipal landfills, where the "responsible parties" may be hundreds of businesses and waste haulers and thousands of residents. Because virtually all Minnesotans create trash, the CLP uses mostly tax dollars to manage closed landfills and funding from insurance settlements. The CLP was established to maintain certain mixed municipal waste landfills in the state over the long term. Closed landfills must be monitored and managed in perpetuity to protect the environment and human health; they produce leachate and gases that must be managed properly to avoid polluting groundwater or affecting nearby structures. There are 114 closed landfills eligible for the CLP. Once landfills are enrolled in the CLP, the MPCA is responsible for their long-term care. The agency contracts with businesses to perform many services, including mowing, sampling and analysis, operating gas and groundwater treatment systems, and leachate collection and disposal.

Clean Water Act

The CWA is a federal law passed in 1972 that regulates pollution to surface waters from discharges of waste. While RCRA frequency regulates solid waste facilities, the CWA tends to focus on management of treated wastewater called effluent. MPCA regulates entities discharging contaminants to the environment based on Water Quality Standards (WQS), which are the rules promulgated by Minnesota

[167] Title 40 of the Code of Federal Regulations (CFR) part 258

under the CWA framework. Effluent discharge limits for permittees are set to ensure that WQS are not exceeded. In some cases, site-specific WQC can be developed to address areas of known contamination or to account for site-specific water quality considerations. Many waste facilities, including WWTPs, have National Pollutant Discharge Elimination System (NPDES) permits that allow them to discharge effluent to surface waters in the state or State Disposal System (SDS) permits that allow them to discharge to land or soil. These permits are renewed every five years to consider new monitoring requirements or new effluent limits based on applicable WQS or WQC.

WWTPs, the facilities that collect wastewater and sewage from municipal, commercial, or industrial sources for treatment and disposal, are regulated under the CWA and with NPDES permits. Frequently these WWTPs are publicly owned. WWTPs act as funnels for all the of pollutants used in commercial, household, and industrial products that end up flushed down a drain – some of these pollutants can be treated by the WWTP and removed before effluent or sludge is released from the facility. However, many pollutants (including PFAS) are not removed through the standard treatment operations at the WWTP. The CWA allows WWTPs to require commercial facilities and other non-domestic wastewater sources to remove harmful pollutants before the wastewater is discharged to a municipal sewer system.[168] This "pretreatment program" prevents the introduction of pollutants to public systems that may pass through public treatment to rivers, lakes, and streams. Pretreatment also prevents discharges to publicly owned treatment facilities of pollutants that would interfere with facilities' operations, including their use and disposal of biosolids or sludge. Generally, WWTPs can enforce pretreatment requirements of wastewater sources whether or not the WWTP has effluent limits for that contaminant.

In addition to regulating the level of pollutants in the wastewater leaving a WWTP, the CWA also can regulate the biosolids or sewage sludge produced by the WWTP. Biosolids are the solids that emerge from a WWTP after treatment – they are beneficial products that, if high-enough quality, can be applied to fields for use as a soil amendment. Biosolids that are not land-applied to fields are often either landfilled at a solid waste facility or burned at a sewage sludge combustion site. EPA has regulations on the levels of various toxics that are acceptable in biosolids that will be land-applied. EPA reviews federal biosolids standards every two years to identify additional toxic pollutants that occur in biosolids and set regulations for those pollutants if sufficient scientific evidence shows they may harm human health or the environment. Currently, there are no limits for PFAS in biosolids. PFAS have been shown to concentrate in this product; therefore, EPA is currently conducting a risk assessment for PFOA and PFOS in biosolids and may publish new standards for these contaminants.

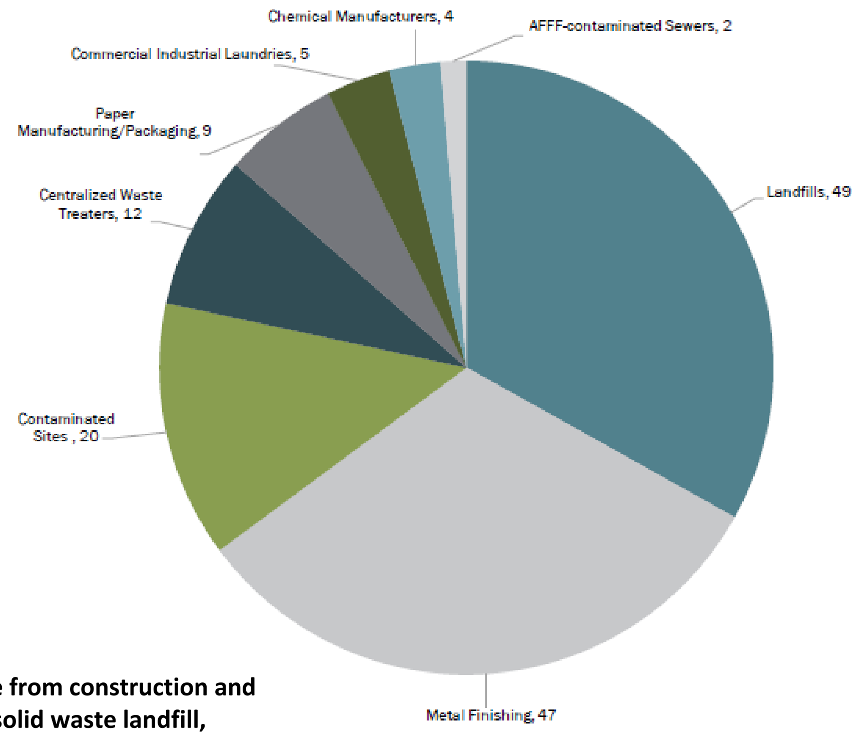
Clean Air Act

Confined and controlled burning, known as combustion, can decrease the volume of solid waste destined for landfills and recover resources and energy from the waste-burning process. Some waste-to-energy facilities use energy recovered from combustion of solid waste to produce steam and electricity. While Minnesota emphasizes reuse and recycling, roughly one-fifth of Minnesota's garbage is used for energy production. Minnesota currently has seven waste-to-energy plants. Ash left over from incineration can be used as top cover for landfills or be disposed of inside the landfill. Emissions also occur from pollutants that volatilize from the landfill. The CAA regulates emissions from MSW landfills and waste incinerators. However, despite the fact that PFAS has been measured in air emissions from landfills, because PFAS is not a "hazardous air pollutant" (HAP) under the CAA, there are currently no requirements for monitoring or controlling PFAS emissions to the air from combustion or volatilization. Currently there are no air health benchmarks from MDH or from the EPA related to PFAS inhalation risks, but there are benchmarks developed by Michigan. Air emissions of PFAS may also pose a risk to

[168]MPCA. (n.d.). Wastewater pretreatment. Retrieved to: https://www.pca.state.mn.us/water/wastewater-pretreatment

surrounding surface water and soils due to PFAS's ability to fall back to earth's surface through rain and dry deposition. *See* the Understanding Risks from PFAS Air Emissions Issue Paper for more information.

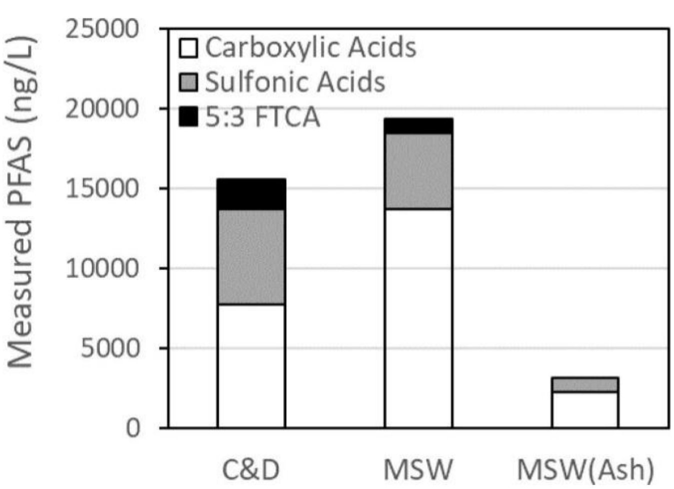
Figure 8. Summary of industrial sources of PFOS to Municipal WWTPs (Michigan).



Occurrence of PFAS at various entry points to the environment

The past and ongoing activities section of this paper discusses the PFAS monitoring that has already been conducted in Minnesota at various waste facilities, but PFAS monitoring is also ongoing at waste facilities across the US For example, a recent study of influent, effluent, and biosolids in WWTPs in Michigan found that many facilities had elevated levels of PFAS.[169] Michigan summarized the industrial sources of PFOS to municipal WWTPs, which were identified through the Industrial Pre-Treatment Program PFAS Initiative (see Figure 8). Sources were defined as those industrial users with discharges to WWTPs above a screening level of 12 ng/L (this is not a risk-based level). The majority of significant PFOS sources were metal finishers, contaminated sites associated with industries or activities with PFOS usage, and landfills that accepted industrial wastes containing PFOS. Michigan has developed a Municipal NPDES Permitting Strategy for PFOS and PFOA, with the goal of continuing to identify, reduce, and remove PFOS and PFOA at WWTPs.

Figure 9. PFAS levels in leachate from construction and demolition landfills, municipal solid waste landfill, and municipal solid waste ash landfills in Florida. From Solo-Gabriele et al. 2020.



Various studies have also measured levels of PFAS in landfill leachate. For example, the USGS recently published a survey of PFAS releases from municipal landfills across the country.[170] This study measured

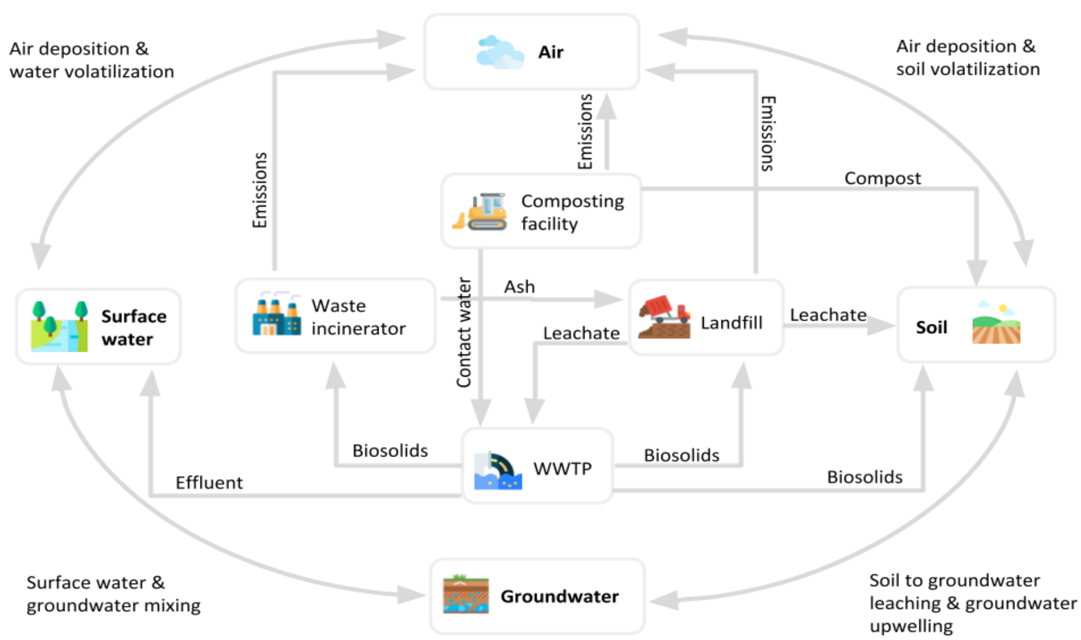
[169] MPART. (2020). Wastewater Treatment Plants / Industrial Pretreatment Program. https://www.michigan.gov/pfasresponse/0,9038,7-365-88059_91299---,00.html

[170] Lang, J.R., Allred, B.K., Field, J.A., Levis, J.W., & Barlaz, M.A. (2017). National estimate of per- and polyfluoroalkyl substances (PFAS) release to US municipal landfill leachate. *Environmental Science and Technology, 41,* (4), 2197-2205. https://doi.org/10.1021/acs.est.6b05005

70 PFAS in 95 leachate samples, estimating that the total mass of PFAS moving from landfill leachate to WWTPs in the US was between 562 and 638 kg (5.62×10^5 g – 6.38×10^5 g) in the year 2013. For context, MPCA estimated that 0.4 - 1 g/year of PFOS emissions associated with a metal plating facility in Minnesota caused exceedances of site-specific surface water criteria for PFOS and resulted in a "do not eat" fish advisory in a nearby lake.[171] This study also found that the PFAS 5:3 fluorotelomer carboxylic acid (5:3 FTCA) was the dominant structure present in leachate. 5:3 FTCA is a PFAS degradate of polyfluroalkyl phosphates, which are used as commercial surfactants, often in the context of food contact paper and textile coatings. 5:3 Fluorotelomer carboxylic acid (FTCA) in turn further degrades to PFHpA, PFHxA, and PFPeA.[172] In Minnesota, PFHxA has been commonly detected in ambient groundwater, drinking water, and human biomonitoring studies – MDH has begun a toxicity review of this compound.[173] Another study measured PFAS in leachate from five landfills in Florida, including C&D landfills, MSW landfills, and landfills containing only MSW ash from combusting municipal waste.[174] This study found that found that C&D landfills had lower levels of PFAS than municipal solid waste facilities, but still had quite high PFAS levels overall (see Figure 9). This study also found that while leachate from landfills containing ash associated with waste combustion at municipal facilities had measurable PFAS, the levels were considerably lower than leachate levels in municipal solid waste facilities.

Breaking the PFAS waste cycle

Figure 10. Schematic diagram of how PFAS could cycle through waste facilities and environmental media.



[171] MPCA. (2020, Jan 30). Minnesota Pollution Control Agency's (MPCA's) comments on the Addition of Certain Per- and Polyfuoroalkyl Substances; Community Right-to-Know Toxic Chemical Release Reporting (EPA-HQ-TRI-2019-0375). Available upon request.

[172] Lee, H., D'Eon, J., & Mabury, S. (2010). Biodegradation of Polyfuoroalkyl Phosphates as a Source of Perfluorinated Acids to the Environment. *Environmental Science and Technology*, *44*, 3505-3310. https://doi.org/10.1021/es9028183

[173] MDH. (2020). Nominated Contaminants Status and Information, MDH Drinking Water Contaminants of Emerging Concern Initiative. Retrieved from: https://www.health.state.mn.us/communities/environment/risk/guidance/dwec/index.html#cecnom

[174] Solo-Gabriele, H.M., Jones, A.S., Lindstrom, A.B., Lang, & J.R. Waste type, incineration, and aeration are associated with per- and polyfluoroalkyl levels in landfill leachates. (2020). *Waste Management, 107,* 191-200. https://doi.org/10.1016/j.wasman.2020.03.034

One of the major challenges posed by managing PFAS in waste is how resistant PFAS are to degradation, causing them to cycle between media and from one waste product to another. PFAS are common in both wastewater and solid waste. The standard options for handling or treating these wastes do not remove PFAS. Because of the way these wastes are handled, PFAS may move in between landfills and WWTPs. Figure 10 illustrates schematically how PFAS may transfer between waste facilities and environmental media. For instance, municipal wastewater treatment creates effluent and sludge or biosolids. If there are PFAS in what is coming into the WWTP, there is going to be PFAS in what is leaving the wastewater treatment plant (unless special treatment is undertaken). Some PFAS will be in the effluent, but others are known to partition to the biosolids. Biosolids are often used as a beneficial source of nutrients to soil, so PFAS may travel with land-applied biosolids, potentially resulting in soil, surface water, groundwater, and crop contamination. If the biosolids are not land-applied, they are likely to be taken to a landfill or an incineration facility. Incineration of PFAS-containing wastes can emit harmful air pollutants, such as fluorinated greenhouse gases and products of incomplete combustion, and some PFAS may remain in the incinerator ash, which is often landfilled. If the landfill has PFAS-containing materials in it, that leachate will likely contain PFAS. In some cases, that leachate is spray irrigated onto fields, which can again lead to problematic soil, surface water, and groundwater contamination. If the leachate is not spray irrigated, it may be sent to a wastewater treatment plan – and the cycle starts over again.

Another complicating factor is the nature of PFAS treatment. The types of treatments that are used to remove PFAS from environmental media – air, water, soil – do not destroy the PFAS. Standard treatments like granular activated carbon (GAC), reverse osmosis, ion exchange resins, or foam fractionation, create a waste product with a high concentration of PFAS. These PFAS-containing wastes then need to be disposed of or destroyed. If they are landfilled, leachate may reintroduce some PFAS back into the environment. While some options to destroy PFAS – such as high temperature incineration – may be available, they may not destroy all PFAS and some emissions of PFAS may still occur.

Research on the most efficient and cost-effective mechanisms to destroy PFAS is ongoing.[175, 176] Effective treatment and destruction of PFAS is currently technologically challenging and costly. The stability and other physical and chemical traits of PFAS make many treatment technologies ineffective. Even aggressive technologies such as thermal treatment and chemical oxidation require extreme conditions beyond typical in those practices.[177] For example, PFAS destruction may require extremely high temperatures, high chemical doses, or extreme pH to be effective or even partially effective in destroying PFAS. Though the emerging realization that there will be money to be made in inventing effective PFAS treatment and destruction technologies has resulted in a boom in research, many new technologies are bench scale and have not been confirmed to be effective. The standard PFAS treatment and destruction options available are expensive to set up and maintain. Leachate and other complex matrixes often require multiple pre-treatment steps before PFAS removal steps, which adds to cost and time. Many treatment technologies are designed to work most effectively for specific types of PFAS – for example, GAC filtration is more effective for long-chain PFAS and less effective for short-chain PFAS. There is a concern that if a treatment regime is installed, it may need to be augmented or replaced if new PFAS toxicity information indicates that a different PFAS compound should be targeted for treatment and destruction.

---

175 EPA, Office of the Administrator. (2020, August 25) EPA, US Department of Defense, and State Partners Launch Technical Challenge Seeking Innovative Ways to Destroy PFAS in Firefighting Foam. [Press release]. Retrieved from: https://www.epa.gov/newsreleases/epa-us-department-defense-and-state-partners-launch-technical-challenge-seeking

176 SERDP-ESTCP. (n.d.). DoD-Funded Research on PFAS. Retrieved from: https://serdp-estcp.org/Featured-Initiatives/Per-and-Polyfluoroalkyl-Substances-PFASs/DoD-PFAS-Page/DoD-PFAS-Page

177 ITRC. (2020). PFAS Treatment Technologies. Retrieved from: https://pfas-1.itrcweb.org/12-treatment-technologies/

Treatment can occur at multiple points in the waste process. Waste can be treated for PFAS before it is sent to a WWTP or landfill. For example, liquid waste from an industrial facility can be treated before it is sent to a WWTP, or contaminated soils can be thermally treated before they are landfilled. Outputs from WWTPs (effluent, biosolids), landfills (leachate), composting facilities (contact water), or incinerators (air emissions, ash) can also be treated before they are released to the environment. Generally, treatment or destruction is most difficult and expensive when the pollution is diffuse (less concentrated) and combined with other co-contaminants. For this reason, treating complex matrixes like landfill leachate or WWTP effluent are generally more costly than treating concentrated PFAS waste from an industrial facility.

As this section describes, it is difficult to break the cycle of PFAS moving between media and between waste products. The more strategic approach is to prevent PFAS from entering waste streams as much as possible. *See* the Preventing PFAS Pollution Issue Paper for more information on steps MPCA and others can take to prevent continued PFAS loading to waste facilities and to the environment.

Distinguishing PFAS sources and PFAS conduits

When talking about PFAS in waste streams, it can be helpful to distinguish between "sources" of PFAS and "conduits" of PFAS. Sources are those where PFAS are produced or manufactured, or industries that intentionally use PFAS-containing products as part of their processes. These kinds of sources would generally be industrial-type sources and result in industrial waste streams that carry PFAS. Conduits are locations where PFAS are not produced or intentionally used, but are released to the environment. PFAS can be present at conduits because of the occurrence of PFAS in consumer products (perhaps including those used for some general purposes at the facility) industrial products, or the environment. Waste facilities – such as WWTPs and or municipal solid waste facilities – are conduits of PFAS. As wastes travel from our households to final disposal, PFAS travel with the waste stream and are concentrated and passed through to the environment through wastewater effluent discharge, wastewater biosolids disposal, landfill leachate, and compost contact water.

In the early 2000s, when PFAS were first discovered in Minnesota, concern was focused on PFAS sources – areas where PFAS or PFAS-containing products had been manufactured and the resulting waste streams had high levels of PFAS. However, increased understanding of PFAS toxicity over time has led to the realization that lower levels of PFAS, especially more bioaccumulative PFAS, can also have adverse health impacts. That understanding means that levels of PFAS in materials emitted or discharged from waste facilities – as conduits of PFAS to the environment – are now considered levels of concern.

Responsible environmental stewardship of PFAS will require management of PFAS in waste streams. While PFAS impacts from both sources and conduits will likely need to be considered, the approaches will need to be different at sources than at conduits. Differences between PFAS at sources and conduits include differences in the concentrations of PFAS in waste and differences in the diversity of PFAS present. Pollution prevention approaches, potentially including phasing-out PFAS in certain non-essential uses for commercial products and industry, would reduce sources of PFAS into the facilities that are conduits of PFAS to the environment in the future. However, the quantity of PFAS-containing products already in circulation in households, businesses, and factories around the state may require additional source reduction actions at waste facilities.

Past and ongoing efforts

The MPCA has compiled monitoring data from many types of waste systems, including some WWTPs, landfills, large subsurface treatment systems, and composting facilities. The data collected include samples of influent, effluent, sludge, leachate, groundwater, and air. MPCA has also worked with one landfill to research and pilot a potential leachate treatment system for PFAS. Finally, MPCA has taken some regulatory actions with respect to PFAS in waste: MPCA has required PFAS monitoring in groundwater and leachate at active landfills that land-apply leachate and MPCA has issued a site-specific WQC for PFOS, which will correspond to the regular regulatory steps associated with NPDES and SDS permits. The following sections describe these efforts in more detail.

Voluntary monitoring

Monitored for PFAS at all major municipal WWTPs

From 2007 to 2010, PFAS monitoring was completed at all major WWTPs (meaning any plant with treatment design flows greater than 1 million gallons per day) throughout the state. The first set of sampling at WWTPs occurred from 2007-2008. This sampling included measurements of 13 PFAS in influent, effluent, and sludge at 28 municipal and industrial WWTPs. The data from this sampling effort were published in an appendix to the document "PFC's in Minnesota's Ambient Environment: 2008 Progress report."[178] This was a voluntary effort and was carried out at no cost to the WWTPs.

The results of this monitoring showed elevated levels of multiple PFAS at multiple WWTPs. At the time that this effort was undertaken, there were no available screening levels for PFAS in sludge, and health-based benchmarks for human toxicity were higher than they are today. However, levels of PFAS in influent, effluent, and sludge at the Brainerd facility drew concerns that there was an unknown significant industrial source of PFAS to the facility. Further investigation led to the discovery that a chrome plating facility was contributing to PFAS loading at the WWTP. In 2007, the industrial facility switched to use non-PFOS products. Further investigations into PFAS levels in the Mississippi River downstream of the WWTP discharge location found that while PFAS levels at the discharge location in the Mississippi were elevated, concentrations downstream of the discharge were below detection for all PFAS except PFNA, which was detected one time. MPCA also investigated PFAS levels in fish caught in the Brainerd area on the Mississippi River, and found PFOS in bluegill, smallmouth bass, walleye, and northern pike. The average concentrations in those species ranged from 7-13 ng/g.

A second round of PFAS influent, effluent, and sludge monitoring at WWTPs was conducted from 2009-2010. This sampling included 22 locations in the Metro Area and 67 locations in Greater Minnesota. The results of this study have not been published but are available upon request. Overall, PFOS levels in effluent ranged from non-detect (ND) to 153 ng/L, PFOA levels ranged from ND to 667 ng/L, PFHxS levels ranged from ND to 365 ng/L, PFNA ranged from ND to 70 ng/L, and PFBA ranged from ND to 48,100 ng/L. PFAS were detected in influent, effluent, and sludge at high rates in both Metro region WWTPs and WWTPs located in Greater Minnesota.

Work status: completed

Leader: MPCA Municipal Division. **Partners**: Participating WWTPs.

Benefits: This monitoring effort identified the baseline levels of PFAS in influent, effluent and biosolids at a sample of municipal WWTPs. Having this information will be important in measuring improvements in PFAS levels over time, as source reduction and other efforts are undertaken. As a result of this study, some source identification and reduction steps were taken immediately, which lead to a decrease in PFAS releases.

Challenges: With many facilities participating in this monitoring effort, it was challenging to coordinate times for staff to collect samples. It was also challenging to train the many MPCA staff sample collectors to ensure that there was no PFAS contamination. Some facilities were hesitant to participate in the monitoring effort due to concerns over future regulatory actions. When facilities tried to identify sources of PFAS into their plants, some described the experience as "like chasing a ghost" due to the difficulties associated with finding information on which products contained PFAS

[178] MPCA. (n.d.) PFAS studies and reports. https://www.pca.state.mn.us/waste/pfas-studies-and-reports

and at what levels. These facilities were discouraged that despite significant effort to find and reduce PFAS sources, they were not seeing meaningful reductions in PFAS levels in influent or effluent.

Resources: The MPCA covered the costs of all sampling analysis (over $250,000) as well as the staff time to collect samples and process the information that was collected.

Monitoring for PFAS at six Large Subsurface Treatment Systems

Large Subsurface Treatment Systems (LSTS) are subsurface disposal treatment systems designed to treat more than 10,000 gallons of wastewater per day and discharge to groundwater through soil – these facilities are permitted using the SDS. The MPCA has permitted over 100 LSTS systems. In this PFAS sampling effort, grab samples were collected at six LSTS facilities: Lake Shore WWTP, Marine on St. Croix WWTP, Whispering Ridge, Clearwater Harbor Sewage Treatment Plant, Backus WWTP, and Rockwood Estates WWTP. The facilities sampled were chosen based on record of operation, flow, and treatment type. Wastewater flow at the sampled LSTS facilities consisted mainly of residential waste. Some of these facilities received commercial flow, but little, if any, from any industry. Samples were collected in spring 2011 and analyzed for 13 PFAS -- influent wastewater, effluent wastewater, up-gradient groundwater, and down-gradient groundwater were sampled at each facility. Samples of the solids accumulated in the tanks were not taken. The results of this study were not published, but are available upon request.[179]

The study found that PFAS were detectable in influent and effluent at all facilities. PFAS were detected in down-gradient groundwater wells at three locations. PFAS were detected in up-gradient wells at two locations. The highest PFOS concentration in groundwater was 5 ng/L, and the highest PFOA concentration in groundwater was 10 ng/L. PFBA, PFPeA, PFHxA, PFHpA, and PFBS were also detected in down-gradient groundwater. These values do not exceed MDH’s current health-based guidance values.

Work status: completed

Leader: MPCA Municipal Wastewater Division. **Partners**: Participating LSTS.

Benefits: Although this was a relatively small sampling effort (capturing six of the over 100 LSTS facilities in Minnesota), the results help provide context for the range of PFAS levels in largely residential LSTS systems. Overall, the lower PFAS levels observed in LSTS systems compared to major WWTPs accepting municipal and industrial waste helped prioritize efforts to understand PFAS levels in WWTPs.

Challenges: This effort had similar challenges to the WWTP monitoring effort described above – it was important to train samplers to ensure that there were no opportunities for PFAS contamination. Gaining access to groundwater wells was challenging in a few instances due to snow.

Resources: This effort was funded with grant money ($10,000) for analysis of samples. MPCA staff collected the samples.

Monitored PFAS in leachate, groundwater, and gas at active landfills

From 2006 through 2009, MPCA’s Solid Waste Section conducted an investigation to evaluate the nature of PFAS in various waste streams generated at 41 solid waste facilities in Minnesota. This investigation included MSWs, waste combustion facilities, industrial landfills, and construction and demolition landfills. Sampling included leachate (when the facility was lined, including leachate from combustor ash landfills), down-gradient groundwater, up-gradient groundwater, and landfill gas condensate (at gas-energy facility). Sixteen PFAS were included for analysis.

[179] Office memo: FINAL REPORT: PFC Sampling at LSTS Systems

The results of this study showed that all sampled facilities had detections of PFAS in leachate. The maximum concentration in leachate for PFOA was 84,000 ng/L, for PFOS was 31,000 ng/L, for PFBA was 25,000 ng/L, for PFBS was 15,000 ng/L, and for PFHxS was 12,000 ng/L. Facilities with the highest concentrations tended to be those that accepted PFAS waste from 3M. While many groundwater monitoring samples resulted in non-detectable PFAS, several samples had PFAS levels above intervention limits and above current health-based values from MDH. Detection limits for PFAS have decreased since this effort was undertaken in the 2000s. The maximum concentration in groundwater for PFOA was 840 ng/L, for PFOS was 71 ng/L, for PFBA was 26,000 ng/L, for PFBS was 58 ng/L, and for PFHxS was 140 ng/L. For facilities with multiple up-gradient and down-gradient measurements of PFAS, statistical analysis was completed to determine if the concentrations down-gradient were higher in a statistically significant manner than PFAS found in up-gradient monitoring wells at the landfill – in most instances, PFAS levels in down-gradient monitoring wells showed a statistically significant higher concentration than up-gradient monitoring wells at the facility. This statistical analysis is available upon request.[180] Landfill gas resulted in detectable PFAS at every sampling location. After this study was undertaken, MPCA began requiring landfills that land-apply leachate to annually monitor for PFAS in leachate and in down-gradient groundwater.

Work status: ongoing, initial monitoring completed

Leader: MPCA Solid Waste Section. **Partners**: Solid waste landfill operators.

Benefits: The result of the investigation led to an understanding of the nature of PFAS in landfill leachate from various landfill systems (MSW, industrial, C&D, and combustor ash), and the impacts these facilities may be having on groundwater quality.

Challenges: At the time of this effort, limited information was available for measuring PFAS in gas condensate. MPCA partnered with SGS AXYS Laboratories to develop a method for this measurement and conduct analyses.

Resources: The MPCA Solid Waste Section funded the investigation through internal funds (over $250,000) at the MPCA.

Monitored PFAS in composting contact water and investigated potential upstream sources

This project aimed to better understand PFAS composition and concentrations in contact water collected at composting facilities – both those that collect source-separate organic material (SSOM) from household waste and those that collect only yard waste. Composters that accept food scraps and compostable products are required to collect and treat contact water (water that has come in contact with organic material during the early stages of composting). Most SSOM compost facilities manage their contact water by collecting it in a pond and then sending it to a WWTP. In some cases, the contact water can be land applied through spray irrigation. If contact water is land applied, the levels of pollutants must meet solid waste intervention limits, defined as a quarter of the health risk limit or health based value. MPCA worked with seven facilities (five of those facilities collected food and yard waste and two collected only yard waste) from fall 2018 to spring 2019. Contractors conducted three contact water pond sampling events at each site. A total of 88 samples were collected, including 59 primary environmental samples and 29 quality assurance/quality control samples. These samples were analyzed for 29 PFAS.

[180] MPCA. (2009). Statistical Analysis of PFC data collected by the Open Landfills program. [Memo].

The results of the study have been published in a report, available on MPCA's website.[181] The study confirmed the presence of one or more PFAS in contact water at concentrations above intervention limits at all SSOM and yard waste sites sampled. At every compost site in the study, at least one sampling event revealed a PFAS that was over the applicable solid waste intervention limit. At the SSOM facilities, the detected PFAS included PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFNA, PFDA, PFBS, PFHxS and PFOS. For the yard waste sites, the detected PFAS included PFBA, PFPeA, PFHxA, PFOA, PFBS, PFHxS, and PFOS.

Based on these conclusions, an additional literature review was conducted by a contractor, aiming to find major feedstock contributors to PFAS at compost facilities and identify data gaps. The review suggests that food contact materials (including compostable products) could be a significant contributor to PFAS at compost sites. The study notes there is a lack of research on PFAS in yard waste and recommends that evaluating potential ambient sources near compost sites or feedstock sources should be a priority. The full literature review will be published on MPCA's website in early 2021.

Work status: completed

Leader: MPCA Solid Waste Section. **Partners**: Participating composting facilities, Wood Environment & Infrastructure Solutions, Inc., SGS AXYS Laboratories

Benefits: The MPCA requires compost facilities test for PFAS in contact water in order to land apply that contact water, which is a more affordable operational strategy than sending the contact water to a WWTP. MPCA suspected that PFAS concentrations would be low or non-detect in contact water. The results of this investigation were surprising and helped identify areas for further research. Compost sites have environmental benefits and the MPCA is committed to helping sites succeed. Mitigating PFAS from entering sites and treating contact water for PFAS will help preserve the operational viability of compost sites. Partnerships with compost facilities will continue to help the agency facilitate creative and collaborative efforts to reduce PFAS discharges in the future. Policy and research recommendations are discussed in both the contact water study and the subsequent literature review.

Challenges: SGS AXYS Lab encountered difficulties in analyzing the samples due to the presence of very fine suspended particulate matter within the aqueous portion of most samples received. The suspended particulate matter could not be sufficiently removed prior to analysis using centrifugation or allowing the samples to settle out prior to filtration. All data was still validated with qualifiers noted in the report. Subsequent sample sizes were adjusted and lab methods were updated to ensure better results.

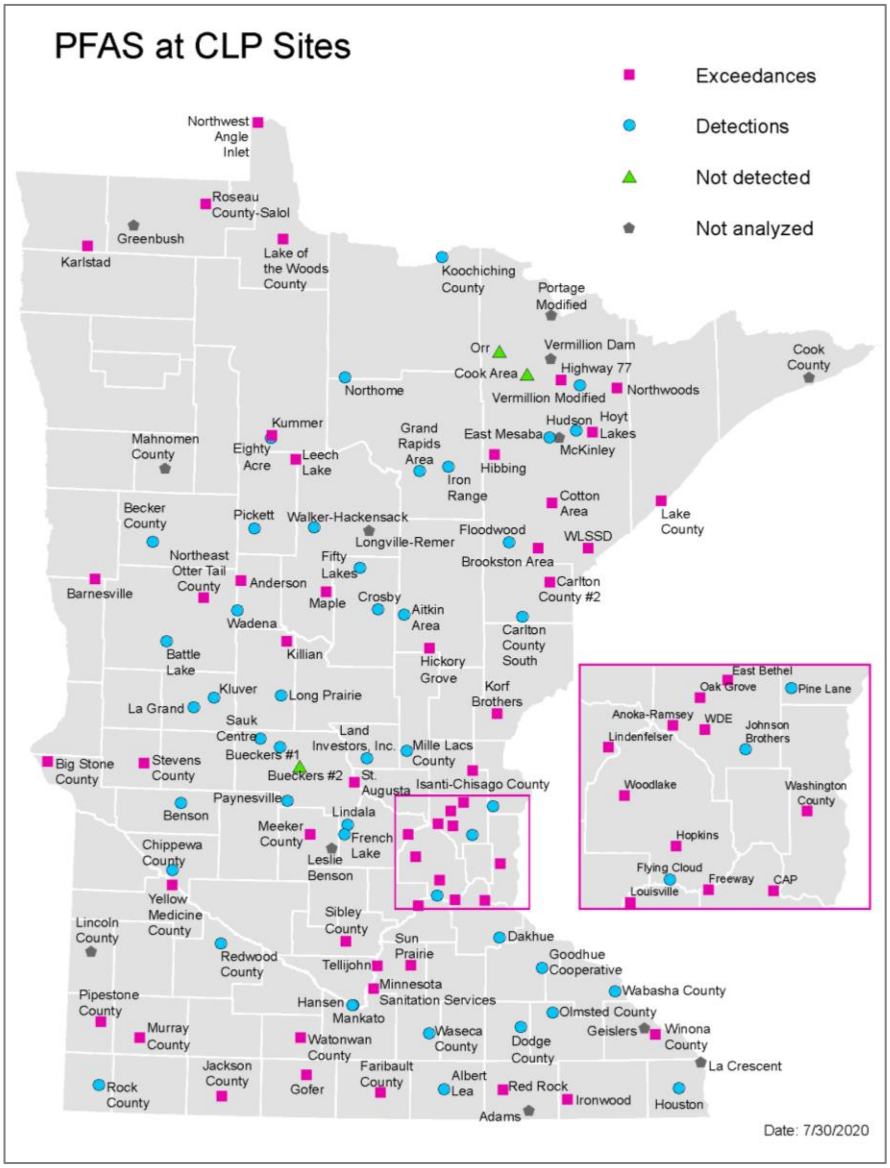
Resources: This study involved two MPCA staff directly overseeing the project, and two additional staff providing technical expertise. The contact water study cost approximately $35,000 in lab analytical fees and an additional $42,000 for contractor support (Quality Assurance Project Plan development, collecting/processing samples and reporting). It took approximately one year to complete both sampling and report publication.

Monitored for PFAS in groundwater down-gradient of closed landfills

The MPCA owns or oversees 110 closed landfill sites through the CLP. Many of these sites were established before regulations on landfills related to lining -- landfills in the CLP include landfills that are unlined, lined in one of the cells, or fully lined. In 2006, MPCA conducted sampling for PFAS in groundwater down-gradient of the landfills and in leachate in a small number of closed landfills.

[181] MPCA. (n.d.). Composting and PFAS. Retrieved from: https://www.pca.state.mn.us/waste/composting-and-pfas#:~:text=MPCA%20recommendations&text=For%20consumers%3A%20Continue%20composting!,composting%20has%20many%20environmental%20benefits

Figure 11. PFAS levels in down-gradient groundwater wells at CLP sites.



Early results of this sampling were included in a 2006 report to the Senate Environment Committee,[182] but the bulk of the initial PFAS sampling at CLP sites began in 2009, when the agency investigated groundwater and leachate at roughly 30 CLP sites. From 2009 to 2018, PFAS sampling of groundwater and leachate was conducted at a small set of sites each year, as funding allowed. In 2018, CLP created a goal to sample all 110 CLP sites for PFAS at least one time. Currently, PFAS testing has been completed at 101 of the 110 CLP sites. A summary of the analytical results for emerging contaminant monitoring at landfills, published in May 2020, is available on MPCA's website.[183] To date, PFAS has been detected in groundwater at 98 of the 101 tested sites. Groundwater levels exceeded MDH's HBVs in groundwater at 55 of those sites. Levels of PFOA and PFOS as high as 30,000 ng/L and 20,000 ng/L respectively have been detected in shallow groundwater wells.

The CLP has taken several remedial actions at sites due to detected PFAS levels. At the Washington County Landfill, a triple liner system was installed, along with other work (*see* Remediating PFAS Contaminated Sites Issue Paper). At several other sites, drinking water wells located down gradient of the site were tested to determine if PFAS plumes were impacting private drinking water wells at levels exceeding health-based values. In several instances, drinking water was found at levels above HBVs, and the CLP purchased and maintains point-of-use water filters for those homes. In other instances, the CLP provided funds to dig a new drinking water well into a deeper aquifer without PFAS contamination. At this time, CLP has focused on sampling drinking water wells and not wells used for agriculture. Ongoing

[182]MPCA. (2006). Investigation of perfluorochemical (PFC) contamination in Minnesota, phase one.
[183] MPCA. (2020). Evaluation of Emerging Contaminant Data at Solid Waste Facilities. Retrieved from: https://www.pca.state.mn.us/sites/default/files/Evaluation-of-Emerging-Contaminant-Data-at-Solid-Waste-Facilities_02132020.pdf

sampling of groundwater around these facilities would help determine the extent and location of PFAS plumes and determine the need for additional remedial actions.

Work status: ongoing, additional funding needed to investigate sites with high PFAS levels

Leaders: MPCA Closed Landfill Program.

Benefits: CLP has collected a large amount of PFAS data that can aid in different types of research. Due to CLP sampling, more is known about closed landfills as a potential source of PFAS contamination. CLP is tracking the PFAS contamination around the landfills and alerting residents of the potential risk. CLP reduces risks of PFAS exposure by testing domestic wells around landfills for PFAS and providing treatment systems as needed.

Challenges: PFAS are present in the leachate and groundwater at most of the closed landfills in the CLP. Most of the sites in the CLP do not have any type of liner beneath the waste and waste is often in direct contact with the groundwater below. Digging up the waste and placing it on top of an engineered liner is an expensive, large scale project. Although remedial action has taken place at several sites with high PFAS concentrations, PFAS is still present in the groundwater at those sites. Funding has not been available to fully investigate all sites with high PFAS levels. Remedial action, increased sampling, and plume delineation is needed at most of the sites with PFAS exceedances in order to help minimize PFAS exposure. Funding has been reduced during fiscal year 2021 and many PFAS investigations are on hold.

Resources: CLP sites will need to be managed long into the future. As more new contaminants are identified at the closed landfills, such as 1,4-dioxane and PFAS, there will be a need for site investigations, sampling, and remedial actions for many years to come. Adequate staffing and funding are essential to allow the CLP to effectively manage sites. The cost of sampling monitoring wells and drinking water wells for PFAS is a large yearly expense; it can range anywhere from $100,000 to $300,000.

Research

Approved Demonstration Research Project for a PFAS leachate management system

Demonstration Research Project (DRP) refers to a limited-scale project designed to promote new methods of solid waste management. It is designed to obtain new scientific or other information about a specific method for managing solid waste. In 2015, the Kandiyohi County Landfill was issued a DRP agreement from MPCA to pilot the application of a proprietary landfill leachate treatment system developed by Clark's Technology called LEACHBUSTER. This technology includes multiple filter systems to remove PFAS and other constituents from leachate – it discharges 90% of the leachate volume as "clean water" and 10% as "dirty water." In this pilot, the "clean water" is further passed through a "boron finishing" treatment system to remove excess boron and discharged to a stormwater pond that infiltrates to groundwater. The "dirty water" is introduced into the landfill. Kandiyohi County has collected samples at the influent and effluent of the pilot system and used EPA Method 537 to monitor for PFBS, PFHpA, PFHxA, PFNA, PFOS, and PFOA. After leachate moved through the treatment system, PFAS levels were non-detectable for all PFAS except PFOA, which was detected at 3.7 ng/L (below the intervention limit of 8.75 ng/L) in one sample. Currently Kandiyohi County Landfill sends its leachate to a WWTP and is testing this leachate system on a subset of the leachate at the plant. The landfill will continue sampling for many analytes, including PFAS, in the effluent from the LEACHBUSTER system on a quarterly basis and reporting that data to the MPCA.

Work status: ongoing

Leaders: MPCA Solid Waste Division and Kandiyohi County Landfill.

Benefits: Managing elevated PFAS levels in leachate is a challenge that will only grow more complex if WWTPs reduce upstream sources of PFAS by limiting the leachate they are willing to accept from landfills. By conducting DRPs, landfills like Kandiyohi County gain an understanding of the efficacy of various leachate treatment systems that could be leaned on in the future to control PFAS levels in leachate.

Challenges: Operating and maintaining the equipment used in the DRP is costly. At between $300-$400 per sample, PFAS monitoring to ensure the treatment system is effectively removing PFAS is also costly.

Resources: DRPs are paid for by the facility looking to investigate the new technology or management strategy – MPCA provides some technical assistance and oversight.

Regulation

Developed site specific Water Quality Criteria for PFOS

WQC are site-specific surface water values that are applied to address pollution in areas of known surface water contamination. These WQC are different than WQS in that they do not apply to the entire state, only to waterbodies explicitly included in the criteria. WQC are developed based on methods and authorities in state statute and the federal CWA (see Minn. R. ch. 7050). Once a WQC is in place, permits that are being renewed or newly issued will be evaluated to determine what monitoring requirements are appropriate. Based on the discharges reported through monitoring, MPCA would determine if there is a reasonable potential that the facility can cause or contribute to an exceedance of the WQC. If so, effluent limits would be established and variances may be considered.

In October 2020, MPCA released a new PFOS WQC that applied to targeted waterbodies including Lake Elmo and connected waterbodies in the Project 1007 corridor in Washington County. When deriving WQC for those sites, MPCA also took the opportunity to update existing WQC for PFOS elsewhere in the state (Bde Maka Ska, and Pool 2 of the Mississippi River). MPCA prioritized deriving a PFOS WQC because PFOS has the highest bioaccumulation potential in fish compared to the other PFAS with health-based guidance values available. This high propensity of PFOS to accumulate in fish means that the largest pathway of exposure for those interacting with PFOS-contaminated surface water is through consuming fish caught in that waterbody. MPCA is in the process of developing WQC for other PFAS found in surface waters in these impacted waterbodies.

The site-specific WQC for PFOS required an assessment of PFOS toxicity and exposure from fish tissue. The criteria incorporate a model-based toxicological and exposure approach that is similar to that used by the Minnesota Department of Health (MDH) to develop drinking water guidance. The criteria are based on protecting the most vulnerable populations to PFOS toxicity, which are the developing fetuses and newborn infants being exposed to PFOS through the placenta during pregnancy and through breastmilk in early life. The new WQC for PFOS can be expressed either as a fish tissue concentration or as a water concentration. For fish tissue, the WQC is 0.37 nanograms PFOS per gram (ng/g). The corresponding WQC for water is 0.05 nanograms per liter (ng/L). The goal of these WQC is to reduce the levels of PFOS in water so that freshwater fish consumption does not result in body burdens greater than those associated with health effects.

Completed for PFOS, ongoing for other PFAS

Leader: MPCA Water Quality Standards Unit. **Partners**: MPCA Water Assessment and MDH Health Environmental Surveillance and Assessment.

Benefits: PFOS WQC are based on protecting people's health from the presence of this toxic pollutant in Minnesota's surface waters and fish. Reductions of PFOS have already been documented in some surface waters due to national restrictions by EPA on some PFAS, including

PFOS, and ongoing remediation activities. Any efforts to reduce PFOS pollution also benefit fish and wildlife.

Challenges: The PFOS WQC consist of an applicable fish-tissue concentration and surface water concentration. These values are very low and require the use of the most recently developed analytical methods to assess. The MPCA has a contract with SGS AXYS Analytical, which recently lowered reporting limits for PFOS and other PFAS. The fish-tissue WQC of 0.37 ng/g can be accurately quantified by SGS AXYS, but the water concentration of 0.05 ng/L cannot. The MPCA's Effluent Limit Unit is working with the Environmental Data Quality Unit to develop guidance related to these analytical issues.

Minnesota's impaired waters or 303(d) list contains 10 existing impairments for PFAS. These include impairments based on MDH's fish consumption advice (an approach MPCA no longer uses for listing waters that are impaired for consumption of fish tissue) and on exceedances of site-specific WQC. There are a large number of new surface water and fish-tissue PFOS datasets available since the last time PFAS was assessed statewide, and the new site-specific WQC is more stringent than prior values. The MPCA is continuing to work on identifying the best path forward in assessing and listing impaired waters for PFAS. MPCA is considering the long-term need for a statewide PFOS WQS, which would result in statewide assessment for impaired waters listing wherever PFOS fish tissue data were available.

Resources: The development of the PFOS WQC took an MPCA staff person approximately two years and involved the support of several other technical staff at MPCA and MDH. This effort was possible because MDH had already conducted a human health risk assessment for PFOS, containing a reference dose and a serum model for understanding PFOS transfer to infants. Currently, the Water Quality Standards Unit is developing new site-specific WQC for PFOA (which would allow for additional updates to existing WQC for Bde Maka Ska and Pool 2), PFBA, PFHxS, and PFBS. These PFAS also have MDH toxicological assessments and health based guidance for drinking water that are relevant for this work. The development of the new interim fish consumption rate for women of childbearing age took almost a year to obtain and review survey datasets; this rate needs further review and consultation with Tribes and other subsistence fishing communities before adopting into a statewide rule.

Required monitoring for PFAS at active landfills that land-apply leachate

Most active landfills dispose of leachate by sending it to WWTPs, but nine MSWs land-apply their leachate at on-site fields or discharge it to a stormwater pond. In the past five years, MPCA has begun incorporating PFAS monitoring requirements in the permits for these facilities. As of 2020, all facilities land-applying leachate are required to monitor for PFAS in down-gradient groundwater wells and in leachate. This data is reported to MPCA and included in annual reports. Intervention limits are ¼ the lowest available HBV, HRL, RAA, or MCL. For PFAS, there are five intervention limits (PFOS = 3.75 ng/L, PFOA = 8.75 ng/L, PFBS = 500 ng/L, PFHxS = 11.75 ng/L, and PFBA = 1750 ng/L). At least four facilities have reported concentrations in down-gradient groundwater wells that exceed the intervention limit – the concentrations in these wells also exceed the MDH guidance values. Next steps for management plans are being considered. Options include tightening waste acceptance rules, installing treatment systems, and taking actions to ensure that down-gradient drinking water receptors are not impacted by PFAS plumes emanating from the facility. If down-gradient drinking water wells are found to have PFAS contamination stemming from the facility, the facility would need to install and maintain a point of use drinking water treatment system (such as GAC filter), as is done when PFAS contamination is found through the down-gradient monitoring wells in the CLP.

Work status: ongoing

Leader: MPCA Solid Waste Permitting Section. **Partners**: Solid waste landfill operators.

Benefits: Landfill Permittees have established an understanding that PFAS are a component of their leachate and have become aware of the potential long-term impacts that the practice of land applying leachate may have on the environment.

Challenges: There are no easy solutions for the problem of high PFAS levels in landfill leachate. PFAS are especially persistent compounds – traditional methods to reduce the volume of leachate (like evaporation) will not decrease the concentration of PFAS in the leachate; in fact, these approaches will either concentrate PFAS in the leachate or diffuse the PFAS through the air in a way that may cause widespread contamination. Treatment of leachate to remove PFAS is effective, but costly (as seen in the DRP results from Kandiyohi County Landfill described in the section above). Reducing PFAS sources to landfills moving forward (as described in the pollution prevention issue paper) will be an important element to the overall PFAS management approach. Improvements to treatment and destruction technology for PFAS over time will hopefully reduce the costs associated with installing and maintaining PFAS treatment systems.

Resources: The permitted facilities are responsible for paying for PFAS monitoring. MPCA staff oversee results.

Gaps and opportunities

There are several gaps remaining on issues related to PFAS waste, which can be categorized as gaps in research or knowledge, gaps in state assistance, and gaps in regulation.

Research

One of the most significant gaps in knowledge when it comes to PFAS waste is related to the potential risks posed by land-applying biosolids from WWTPs that may have elevated levels of bioaccumulative and persistent PFAS like PFOS. Land-application of biosolids has many beneficial outcomes and alternative disposal options for PFAS-containing biosolids also pose potential risks. The proposed research project described below would help understand the relative risks of biosolids management strategies so that land-application of biosolids can continue whenever it is responsible and feasible.

Another gap in PFAS research relates to PFAS groundwater plumes emanating from landfills currently managed by MPCA's closed landfill program. Initial investigation of down gradient groundwater at these landfills indicated that PFAS levels exceeded health-based values in 55 locations – sometimes by a large margin. Investigations into these PFAS plumes will help define the extent and movement of them so that appropriate remedial actions can be taken to protect drinking water consumers and farmers whose property may be impacted by PFAS pollution. Currently there are not funds available to conduct these research projects. These opportunities are described in more detail below.

Conduct study of biosolids fate and transport following land-application

While land application of biosolids has benefits for farming, land application of contaminated biosolids is a known source of PFAS to groundwater, soil, surface water, crops, and, in some cases, livestock. There are many unknowns regarding how PFAS moves out of biosolids and into the environment and food supplies. These gaps in knowledge about PFAS fate and transport make it difficult to proactively manage biosolids without potentially causing groundwater or surface water contamination. The goal of this study is to collect data that would inform tools used to evaluate PFAS risks in land-applied biosolids and manage biosolids appropriately. Specifically, this project proposes to 1) evaluate and characterize PFAS concentrations in land-applied biosolids; leaching from those biosolids; and subsequent movement of PFAS into water and food; and 2) analyze alternative disposal and treatment options and develop tools for managing PFAS-contaminated waste streams. The study would analyze 40 PFAS compounds and their breakdown products in biosolids, ash, landfill leachate, compost, soil, water, and crops, to understand occurrence of PFAS in these mediums and allow characterization of the risk associated with land application. Total oxidizable precursor (TOP) analysis would be performed to determine whether longer chain PFAS compounds that are present in these wastes can break down to PFOS, PFOA, and other long-chain PFAS compounds of concern. Non-targeted analytical techniques would be used to identify the presence of additional PFAS compounds that cannot be detected with available standard analytical methods. This project was recommended for funding under the LCCMR process, but funding for all LCCMR projects was not secured for the entire 2020 set of proposals. Nevertheless, a full description of the project, as proposed to LCCMR, is available online.[184] This project is also discussed in the Limiting PFAS Exposure from Food Issue Paper.

Work status: proposed

Leader: MPCA Environmental Analysis and Outcomes Division. **Partners**: Participating wastewater treatment plants and academic partners at University of Minnesota and Texas Tech University.

Benefits: This project will develop pollution prevention, treatment, and disposal options that can be applied statewide. Data from field and lab-based leaching and uptake studies could be used to develop screening values for biosolids. Long-term implementation of these strategies will safeguard drinking water and food supplies for current and future needs.

Challenges: Understanding the fate and transport of PFAS after land-application requires sampling in multiple media, including surrounding surface water, porewater in soils, down-gradient groundwater, crops planted on the biosolids amended fields, and the soil itself. Extra care must be taken during application to avoid cross-contamination between controlled plots, including cleaning of tractors and other equipment between and away from plots. Using the results of the Minnesota study (and similar studies currently being undertaken by Wisconsin and Michigan) to develop a tool to determine risk levels and application strategies for biosolids would require significant time and effort.

Resources: This project proposal is complex, and would likely require about $1.4 million to complete in full. However, some aspects of the project proposal could be completed as standalone projects that require less funding.

Conduct additional investigations of PFAS groundwater plumes down-gradient of closed landfills

Prior monitoring of PFAS in groundwater down-gradient of landfills in the CLP has revealed that many facilities, especially those that have historically accepted PFAS-rich waste from industrial facilities including 3M, have very high levels of PFAS in groundwater. Though there has been some work conducted to test drinking water wells in residencies that may be impacted, the extent of these PFAS plumes is not yet well understood. Many PFAS are highly mobile in groundwater and could have moved far from the original closed landfill location. Additional funding would allow the CLP to conduct additional groundwater investigations surrounding the facilities with the highest PFAS groundwater concentrations.

Work status: proposed, funding required

Leaders: MPCA Closed Landfill Program.

Benefits: Existing work has confirmed that PFAS levels in groundwater surrounding some unlined closed landfills far exceed health-based concentrations established by MDH. Additional investigation will ensure that MPCA is supplying treatment or other remedial actions to any impacted private or public drinking water systems. This effort would also allow MPCA to monitor for other contaminants of concern, like 1,4-dioxane, that may be co-occurring at the same sites. Finally, some closed landfills are present in parts of the state used for agriculture. Identifying and stemming PFAS plumes

[184] Legislative-Citizen Commission on Minnesota Resources. (2020). 2020 Environment and Natural Resources Trust Fund Recommendations. Retrieved from: https://www.lccmr.leg.mn/projects/2020/2020_recommendations_by_subdivision.html

in these agricultural regions would help prevent or remediate contamination of farmland that could lead to uptake of PFAS into crops or livestock.

Challenges: The CLP has a limited number of staff available to complete PFAS investigations. Hiring a consultant would increase project costs, but would allow CLP to complete more investigations in a shorter amount of time. Understanding the extent of PFAS plumes may require digging additional temporary or permanent monitoring wells, which can be costly.

Resources: The costs of these investigations would depend on if contractors were required to lead investigations and install new monitoring wells and the number of closed landfills with PFAS concentrations in groundwater that would warrant further investigation. The Closed Landfill Investment Fund could be used to entirely or partially fund these investigations. Drilling wells and sampling could occur in one season.

Assistance

Additional improvements in PFAS management of waste could come from increased guidance and non-regulatory assistance. There are opportunities to investigate and identify PFAS-containing inputs to multiple types of waste streams. Better identification and efforts in this area would help waste treatment facilities understand which PFAS sources are driving the levels of PFAS seen in their end products like biosolids, effluent and leachate. Trying to identify PFAS-containing inputs to waste facilities involves two related but distinct efforts. One is PFAS pollution prevention. As described in the issue paper on pollution prevention, current chemical regulation practices in the US allow many PFAS to be used in industry and commerce without consideration of how those uses may impact waste facilities once the materials are disposed of. Widespread use of PFAS in products and lack information about PFAS content in products make it difficult, if not impossible, for consumers and businesses to entirely avoid PFAS. More regulation of PFAS-containing products is needed so that the burden of researching and identifying PFAS-containing products does not fall on businesses and individuals. The second type of effort involves identifying the most significant PFAS inputs to the waste facility, which are often industrial in origin, and take action to reduce those inputs. This paper addresses primarily the second area of work. Currently, there is not a robust industrial pretreatment program for PFAS at WWTPs. MPCA could support WWTPs in identifying upstream sources and requiring source reduction strategies from significant contributors of PFAS.

One known significant source of PFAS to waste facilities is PFAS-containing firefighting foam and the PFAS-enriched wastewater produced when these foams are used. Many facilities are storing PFAS-containing firefighting foam that is now illegal to use for testing and training purposes.[185] These facilities would like to dispose of the foams but are lacking information on how to do so responsibly. MPCA is developing guidance on this topic and could also develop guidance on the topic of how to manage disposal of PFAS-containing runoff collected after these foams are used in an emergency. More detail on opportunities for increased assistance and guidance are described below.

Issue guidance on the collection and disposal of PFAS-containing firefighting foam concentrate and wastewater

Releases of PFAS-containing firefighting foam (sometimes called aqueous film-forming foam, or AFFF) are known to be major sources of PFAS to the environment. In 2020, Minnesota banned the use of PFAS-containing firefighting foams for testing and training purposes. Additionally, MPCA has conducted outreach with relevant stakeholders to encourage the use of PFAS-free foams in the event of an emergency. Due to the added restrictions on using PFAS-containing firefighting foams and the increased knowledge about the potential risks these firefighting foams pose to human health, many entities

[185] MPCA. (n.d.). PFAS in firefighting foam. Retrieved from: https://www.pca.state.mn.us/waste/pfas-firefighting-foam

(including municipal firefighting agencies) are looking to dispose of their stocks of unused PFAS-containing firefighting foam concentrate. MPCA is currently developing a guidance document to help these groups understand the available options for disposal.

The new regulations in Minnesota on the use of PFAS-containing firefighting foam have also created some uncertainty about how spent PFAS-containing firefighting foams can be captured and disposed of after they are used in an emergency. Developing guidance for this scenario is more challenging because in an emergency setting, the PFAS containing firefighting foams are mixed with water and could be applied to a relatively large area that could not easily facilitate collection of the contaminated water after the fire has been extinguished. If contaminated water is able to be collected, there are several options available for treating or disposing of it including filtration, precipitation agents, and foam fractionation. MPCA could consider developing a guidance document to help inform groups that use Class B firefighting foams about options available for disposing of PFAS-containing water associated with firefighting and considerations for collected firefighting wastewater.

Work status: ongoing

Leader: MPCA, Industrial Division and Resource Management and Assistance Division.

Benefits: Encouraging responsible disposal of PFAS-containing firefighting foams and PFAS-containing wastewater associated with firefighting events will result in less PFAS discharged to the environment, which has the direct benefit of reducing exposures for humans and wildlife. Developing guidance also ensures that MPCA provides consistent and clear advice.

Challenges: PFAS is not currently listed as hazardous waste under RCRA, which means that there are generally not regulations of the handling, transport, and disposal of products like PFAS-containing firefighting foams. Though PFAS could be considered hazardous substances under MERLA, and parties could be held liable if they release PFAS to the environment at levels impacting human health and the environment, there are not clear waste management and disposal requirements related to these materials. This complicated regulatory status of PFAS can make communicating with stakeholders difficult.

Resources: Guidance documents require time of staff to write and review materials.

Engage with WWTPs to identify industrial PFAS sources and opportunities for source reduction

The goal of this project would be to focus on source reduction of PFAS waste streams entering municipal WWTPs. PFAS can be in both industrial and domestic waste streams that are contributing influent to the facility. Certain types of waste streams, particularly certain types of industrial waste streams, are known to often be high in PFAS. The Municipal Wastewater Program would assist and educate WWTPs on identifying PFAS inputs to their facilities and developing source reduction strategies, which WWTPs can use to develop and implement source reduction plans specific to their WWTP. Education materials could include recorded seminars, fact sheets, and other communication materials to help discuss PFAS with WWTPs and operators of industrial facilities that discharge to WWTPs. This work would be modeled off of the successful effort by Michigan's Department of Environment, Great Lakes, and Energy (EGLE) to monitor effluent at WWTP, identify industrially-impacted WWTPs, and implement industrial pre-treatment plans for PFAS.

Work status: under consideration

Leader: Municipal Wastewater Program. **Partners:** Municipal Wastewater Treatment Facilities and Industries.

Benefits: Focusing on source reduction as a major part of managing PFAS at WWTP will reduce the amount of PFAS entering the WWTPs, which in turn results in reduced PFAS in both the effluent and biosolids. This approach also helps ensure that the industrial entities generating the pollution are contributing to the costs associated with managing PFAS, and not passing these costs forward to WWTPs, which are taxpayer and user-funded facilities.

Challenges: Though EGLE's work on identifying PFAS sources to WWTPs helped identify the major common industrial sources to target for pollution reduction, there is a lack of information about some of the smaller sources of PFAS. In some cases, industries or individuals (or perhaps even the municipal WWTP itself) could be using PFAS-containing products without knowing it, especially because many PFAS-containing products do not have labels indicating that the product contains PFAS. This can make it challenging to determine what exactly is contributing to the levels of PFAS seen at wastewater plant. Another challenge will be to develop a cooperative and collaborative effort with the wastewater community. Although several groups representing cities and municipal WWTPs have indicated interest in a project like this one, it can be difficult for MPCA to enter as a trusted party due to its regulatory authority. Some WWTPs may be hesitant to participate in a PFAS study or do voluntary PFAS sampling, out of a concern that that might lead them to be regulated sooner.

Resources: Additional staff time or additional staff will be needed to help communicate, educate, develop resources, and oversee implementation of the plans for WWTPs. The MPCA has a limited number of staff with the knowledge to assist in this effort, and they currently have a full plate with their core work. Successful completion of this effort would require additional staff time from key subject matter experts, or potentially an outside contract. Funding to assist WWTPs with the cost of sampling could encourage higher rates of participation.

Regulation

There are many gaps when it comes to regulating waste containing PFAS. The goal of regulation is to ensure that harmful levels of contaminants do not reach the environment. Different waste facilities fall under different regulatory programs, and the "first step" in a process to begin mandating assessment and reductions in PFAS releases through permit conditions would be different as well.

Facilities that discharge effluent or wastewater to surface water have NPDES permits, which operate on a five-year renewal cycle. Generally speaking, permitting authorities first develop a water quality standard and then modify NPDES permits to require monitoring for the relevant pollutant (this could also happen in a specific geographic area using a site-specific water quality criteria). After reviewing the monitoring data, effluent limits may be included in the following permit cycle where facilities demonstrated a reasonable potential to cause or contribute to an exceedance of the standard. Having data on existing levels in WWTP discharges in advance of a water quality standard helps the regulatory agency develop reasonable and robust implementation procedures concurrently with the standard such that permit holders understand options they may have in advance of permit issuances. These options may include technical assistance and enhanced pretreatment work to identify and minimize sources such that when the water quality standard becomes available effluent levels may have decreased to the point that a limit is not required.

The process for instigating pollution reduction actions in landfills is different than that used for NPDES-permitted wastewater facilities. At landfills, generally MPCA would first require monitoring for the pollutant in groundwater. Then, if groundwater concentrations exceed intervention limits, a process would ensue to reduce releases and take remedial action, if needed. These differences in regulatory structures between solid waste and wastewater mean that the process of regulating PFAS is various waste facilities will follow a different of steps. Opportunities to begin these processes under the CWA and solid waste programs are described below.

Require monitoring for PFAS in NPDES permitted facilities

Facilities that discharge effluent or wastewater to surface water do so under conditions set in NPDES permits, which have a five-year permit term. Some states, such as Michigan and Alabama, have required some facilities to monitor and report the levels of PFAS in their effluent. These states' strategies to require effluent monitoring generally focus on those facilities that are most likely to have PFAS – either because they are industries that use PFAS or they receive wastewater from such industries. The EPA has also recently announced an interim strategy to address PFAS through certain EPA-issued wastewater permits, despite the fact that there are no federal surface water standards for PFAS.[186] The EPA strategy recommends a phase-in of effluent monitoring at facilities where PFAS is likely to be present, with the phase-in based on the availability of EPA-approved analytical methods. MPCA could develop a similar strategy to incorporate PFAS monitoring requirements into some or all NPDES permits. Developing and implementing the strategy would require considering which facility should monitor, frequency of monitoring and number of samples, specific PFAS compounds monitored, location of sampling (influent, effluent, both), and appropriate permit conditions.

Leader: MPCA Analysis and Outcomes Division.

Benefits: Understanding sources of PFAS (such as PFAS producing facilities and other industrial facilities that use PFAS-containing products) and levels of PFAS released conduits like WWTPs would help guide future strategic PFAS reduction strategies, including ways to reduce PFAS releases from the most meaningful sources. Effluent monitoring data would help support development of implementation procedures for any future water quality standard. This monitoring data could also be used to support future regulations of PFAS uses or restrictions on PFAS handling and disposal.

Challenges: PFAS sampling is costly. Prioritizing which permits have monitoring requirements included or updated will require analysis of existing PFAS effluent data from Minnesota and other states.

Resources: MPCA would not require significant resources to complete this action.

Develop statewide CWA Water Quality Standards for PFAS

Preliminary data from monitoring PFAS in fish indicate that several PFAS – and particularly PFOS - bioaccumulate in fish tissue at levels that are a concern for human consumption and potentially the health of the aquatic ecosystem. Implementing statewide Water Quality Standards (WQS) for bioaccumulative PFAS would provide a regulatory basis for reducing PFAS loading to aquatic ecosystems, thereby removing the need for fish consumption guidance or other restrictions on the beneficial uses of waterbodies in the state. A statewide WQS for PFOS or other PFAS would trigger the regular regulatory process for consideration of monitoring requirements and/or effluent limits for facilities that have permits to discharge to Minnesota waters. MPCA would also need to develop a path forward to assess, list, and address PFOS or other PFAS impairments.

Every three years, the CWA mandates that MPCA review existing WQS and propose revisions or additions as needed. The MPCA's Water Quality Standards Unit is currently undertaking the Triennial Standards Review process to determine MPCA's 2021 – 2024 WQS work plan. The MPCA will be asking for input on the need for additional PFAS water quality standards. If MPCA determines there is a need to develop new PFAS WQS for any beneficial uses (drinking water, aquatic consumption, etc.), the development of these numeric standards and adopting them into rule would be a multi-year process with several steps including economic analysis, outreach to partners like tribes, outreach to potentially impacted stakeholders, public comment steps (stipulated by the Administrative Procedures Act), and

[186] EPA. (2020, Nov. 30th). New Interim Strategy to Address PFAS through certain EPA-issued wastewater permits. [News release]. Retrieved from: https://www.epa.gov/newsreleases/new-interim-strategy-will-address-pfas-through-certain-epa-issued-wastewater-permits

finally EPA approval. If the EPA does not publish recommended CWA criteria for PFAS and MPCA needs to develop standards itself, the standards will also require external peer review, which adds additional time and review to the process.

Work status: under consideration

Leader: MPCA Water Quality Standards Unit. **Partners**: MPCA Water Assessment and MDH Health, Environmental Surveillance, and Assessment Section.

Benefits: Water Quality Standards are regulatory values that are important tools to prevent and abate toxic pollutants affecting the beneficial uses of water resources. PFOS and other PFAS are pollutants known to occur in Minnesota surface waters. Their presence results from many ongoing water discharges and air emissions from both sources and conduits of PFAS. The levels of PFAS in some of Minnesota's waterbodies are causing some municipalities to install treatment of drinking water for PFAS, at great expense to taxpayers. Levels of PFAS are also impacting fish, triggering the need for fish consumption guidance, up to and including "do not eat" for fish at popular fishing locations. Minnesota DNR is currently investigating potential uptake of PFAS from surface water to game people eat, like deer. These damages to natural resources hurt all Minnesotans, but especially those who rely on locally caught fish and game as a healthy source of protein for themselves and their families. Statewide WQS would provide transparent regulatory values and allow for the implementation of all related water quality programs – including effluent limits, assessment and impaired waters listings, and options to address resulting impairments. These related actions would reduce ongoing PFAS releases to the environment and support continued progress on reducing the presence and concentration of these toxic pollutants in already impacted regions.

Challenges: WQS rulemaking involves significant agency staff resources. The benefits and costs of implementing WQS into statewide permitting and impaired waters listing would need to be evaluated. Rulemaking for PFAS WQS are especially complex because PFAS is a family of compounds consisting of thousands of known structures. Given the current state of knowledge regarding PFAS toxicity, MPCA would likely only be able to adopt WQS for human health based beneficial uses (drinking water and aquatic consumption) for those PFAS with health assessments completed.

Additionally, research into appropriate fish consumption rates would be needed, including outreach to high fish consuming communities. Considerations of fish-eating wildlife and water to terrestrial organism impacts (like deer-drinking contaminated surface water) could also be considered. This effort would require a team of staff scientists and program managers with various areas of expertise.

Considering how WQS for PFAS would impact facilities like landfills, WWTPs, and composters would be important. These WQS could impact how landfill leachate, biosolids, and other waste products are managed. When considering options for implementation, significant input from partners and stakeholders would be needed.

Resources: Adopting WQS requires support from the Governor's Office and other state agencies, in addition to time dedicated by many MPCA staff including a Rule Coordinator and Legal Unit support.

Develop rules stablishing requirements for PFAS handling, storage, and disposal requirements

The unregulated disposal of PFAS waste from chemical producers, metal platers, tanneries, and many other industrial activities around the country have resulted in discharges to air and surface water that caused dangerous exposures for humans and wildlife. Unregulated handling of these persistent and mobile PFAS can result in PFAS and their toxic combustion products to spread to a wide geographic region. In many cases, these releases have resulted in expensive remediation efforts to treat drinking water, surface water, and soil. In Minnesota, improper disposal of PFAS from 3M resulted groundwater contamination that impacted at least 150 square miles. The relative lack of PFAS disposal regulations in the United States compared to Europe has resulted in instances of chemical companies importing PFAS waste from Europe to the US, where it is relatively cheap and easy to dispose of PFAS. Though there were two petitions to EPA (from 2019 and 2020) requesting the EPA regulate PFAS as hazardous wastes subject to the management and disposal requirements of Subtitle C of RCRA, EPA has taken no action on these petitions.[187]

Subsection C of RCRA includes management and disposal requirements for substances considered “hazardous wastes.” The objective of the Subtitle C program is to ensure that these wastes are handled in a manner that protects human health and the environment. To this end, there are Subtitle C regulations for the generation, transportation, treatment, storage, or disposal of hazardous waste. As an authorized program, the MPCA implements RCRA through Minnesota’s Hazardous Waste Rules. PFAS are not currently explicitly listed as hazardous wastes under the Minnesota’s Hazardous Waste Rules, which means that only some PFAS-containing wastes with extremely high concentrations are currently regulated for disposal in Minnesota.

MPCA could conduct rulemaking that would define PFAS as “hazardous wastes” under Minnesota’s Hazardous Waste Rules. This process is complex, and would first require establishing which PFAS-containing waste should be considered hazardous waste by setting threshold concentrations that delineate high enough risk to support the imposition of hazardous waste requirements – either for specific PFAS or the PFAS class as whole. Appropriate handling and disposal requirements would also need to be developed. In defining PFAS as hazardous wastes, MPCA could enforce requirements related to storage, handling, and disposal of these materials.

Work status: under consideration

Leader: MPCA Industrial Division, Hazardous Waste Program.

Benefits: Defining some PFAS-containing materials as hazardous waste and establishing storage, transport, handling and disposal requirements would result in fewer environmental releases of PFAS and reduced human exposures. The effort will likely also raise awareness about the dangers of PFAS-containing products and encourage investments in safer alternatives.

Challenges: There are thousands of PFAS in use today, many of which are unknown to the public due to their status as “confidential business information.” Because PFAS are so persistent in the environment and ubiquitous in consumer products and industrial processes, there are detectable levels of PFAS in many common waste products. Some products contain PFAS despite not having any PFAS intentionally added. Determining which PFAS-containing materials should be included as hazardous wastes in a rulemaking would require research and significant consideration. Destruction and disposal of PFAS is expensive and difficult, and much remains to be known about which destruction or disposal options will result in the least amount of environmental harm.

Resources: Rulemaking is a time-consuming effort that requires staff resources for several years.

Require monitoring for PFAS in groundwater at active landfills

Prior monitoring of leachate, groundwater, and landfill gas at solid waste facilities including municipal, industrial, and construction and demolition landfills indicated that PFAS levels in all of those media can be high. Many construction and demolition landfills are unlined. MPCA could consider adding PFAS to the list of analytes with mandatory groundwater monitoring for the duration of the landfills’ active life and post-closure care period. This would allow MPCA to determine when intervention limits for PFAS are exceeded and management actions at the landfill should be considered. This effort would also

[187] EPA. (n.d.). Petitions to the Office of Land and Emergency Management. Retrieved from: https://www.epa.gov/petitions/petitions-office-land-and-emergency-management

provide valuable groundwater data that could help inform drinking water or surface water monitoring at sites that may be impacted.

Work status: under consideration

Leaders: MPCA Resource Management and Assistance Division.

Benefits: Additional monitoring of PFAS in groundwater surrounding municipal landfills, industrial landfills, and construction and demolition landfills would inform MPCA, MDH, and landfill operators when PFAS releases could result in hazardous exposure to humans or wildlife. That would allow these agencies to proactively protect human health and the environment by requiring appropriate intervention strategies.

Challenges: PFAS analysis is expensive, running about $300-400 per sample. Many landfills would be hesitant to conduct ongoing PFAS monitoring, especially if management strategies to reduce PFAS releases or PFAS loading into the landfill continue to be ill-defined.

Resources: Landfills would be responsible for the cost of monitoring. Staff time would be needed to design and oversee the new monitoring.

Overview of intersectional issues

- **Pollution prevention**: Reducing PFAS pollution at the source places the burden with the polluters rather than conduits that do not use PFAS themselves, like landfills, WWTPs, and composting facilities. PFAS labeling could help inform landfills, WWTPs, and composting facilities about which products or upstream facilities may be sources of PFAS. *See* the Preventing PFAS Pollution Issue Paper for actions related to reducing the overall production and emission of PFAS products.
- **Quantifying PFAS toxicity**: Understanding the potential health impacts of PFAS exposure is key in ensuring exposure stays below "safe" thresholds and communicating with the public. Health-based guidance values, however, require data on toxicity and exposure that are not available for the vast majority of all the PFAS compounds found in the environment. *See* the Quantifying PFAS Risks to Human Health Issue Paper for more information on challenges stemming from PFAS toxicity data limitations.
- **Developing and expanding access to analytical methods**: Analytical methods for PFAS are expensive and time-intensive to run and include only a subset of all PFAS that may be occurring in waste facilities like landfills, composting facilities, and WWTPs. Increased access to non-targeted analysis and other screening-level PFAS methods would be beneficial identifying sources of PFAS to waste facilities – *see* the Measuring PFAS Effectively and Consistently Issue Paper for more information on the costs and challenges associated with measuring PFAS in various matrices.
- **Understanding risks from PFAS air emissions**: PFAS can be released to the air from volatilization in landfills or from waste incineration. It is currently unknown if levels of PFAS in air around these waste facilities could be associated with adverse health effects. It is also unknown if PFAS emissions to air through waste incineration results in contamination of surrounding surface water and soils. *See* the Understanding Risks from PFAS Air Emissions Issue Paper for more information.

Appendix A. List of gap-filling opportunities identified in all issue papers

Table A-1. All gap-filling initiatives described in issue papers.

Opportunity	Action type	Authority	Resources needed	Timeline	Contingencies
Require labeling of PFAS-containing products	P2; Regulation	New legislative grant	New funding (appropriation)	Medium to Long-term	Legislative action (state or federal) needed for labeling and disclosure requirements. Policy research could be completed by MPCA. There are no known federal actions pending on this subject.
Regulate PFAS using a framework of essential, substitutable, and non-essential uses	Pollution Prevention (P2)	New legislative grant	New funding (appropriation)	Medium to Long-term	Labeling and disclosure requirements would greatly improve the efficiency of this action (without them, significant research and investigation is needed to determine if a product contains PFAS). Level of funding required would depend on the scale and scope.
Limit or ban PFAS in known non-essential uses	P2; Regulation	New legislative grant	New funding (appropriation)	Medium to Long-term	Legislative action (state or federal) would be needed.
Develop public sector purchasing guidelines to end purchases of PFAS-containing products	Pollution Prevention (P2)	Agency existing	Existing funding	Medium to Long-term	Labeling and disclosure requirements would greatly improve the efficiency of this action (without them, significant research and investigation is needed to determine if a product contains PFAS). Essential uses of PFAS would need to be determined. Added funding could accelerate timelines.
Consider providing financial and technical assistance to businesses for switching from PFAS-containing products	P2; Guidance/ Assistance	Agency existing	Existing + Added funding	Medium to Long-term	Funding would be needed in some programs if financial assistance were to be extended to businesses for this purpose. Labeling and disclosure of PFAS products would improve the efficiency of this action (without them, significant research and investigation is needed to determine if a product contains PFAS).
Ensure capacity to meet demand for non-targeted PFAS analytical approaches	Research and Development (R&D)	Agency existing	Added funding (appropriation)	Medium to Long-term	Staff and funding would be needed to expand PHL analytical capacity for PFAS. Alternative funding streams (such as federal grants) could be explored to acquire instrumentation or for other purposes.

Opportunity	Action type	Authority	Resources needed	Timeline	Contingencies
Ensure capacity to meet demand for alternative PFAS methods	Research and Development (R&D)	Agency existing	Added funding (appropriation)	Medium to Long-term	Staff and funding would be needed to expand PHL analytical capacity for PFAS. EPA plans to publish total PFAS methods in 2021. Alternative funding streams (such as federal grants) could be explored to acquire instrumentation or for other purposes.
Compile information on inhalation PFAS toxicity	Guidance/Assistance	Agency existing	Existing funding	Short-term	None.
Research cutting-edge risk assessment techniques for data-poor PFAS	Research and Development (R&D)	Agency existing	Existing funding	Short-term	Currently collaborating with EPA ORD on this topic.
Develop an epidemiological study of residents exposed to PFAS through drinking water	Research and Development (R&D)	New legislative grant	New funding (appropriation)	Medium to Long-term	This effort would require significant funding. ATSDR is conducting ongoing biomonitoring studies at multiple sites in the US. Minnesota applied for the East Metro to be included in this effort, but was not selected.
Conduct drinking water monitoring under the Fifth Unregulated Contaminant Monitoring Rule (UCMR5) (2023-2025)	Monitoring; Regulation	Agency existing	Existing funding	Medium to Long-term	None.
Conduct routine PFAS monitoring in fish	Monitoring	Agency existing	Added funding (appropriation)	2021 Legislative proposal	Funding would be needed to include PFAS in regular ongoing monitoring plans.
Develop statewide water quality standards for PFAS - Class 1 drinking water	Regulation	Agency existing	Existing funding	Short-term	None.

Opportunity	Action type	Authority	Resources needed	Timeline	Contingencies
Consider developing statewide water quality standards for PFAS - Class 2 aquatic consumption, aquatic life	Regulation	Agency existing	Existing funding	Medium to Long-term	EPA is scoping the development of recommended CWA aquatic life and human health criteria for PFAS. MPCA would consider adopting federal criteria when they are published.
Inform and engage with farmers about potential upstream sources of PFAS	Guidance/Assistance	Agency existing	New funding (appropriation)	Medium to Long-term	Funding would be needed to support sampling of potential upstream sources.
Consider developing a new rule to make air toxics reporting mandatory, including PFAS	Regulation	Agency existing	Existing funding	Medium to Long-term	None.
Explore cross-program air modeling project to understand PFAS air emissions and their impacts on air, groundwater, surface water, and fish tissue	Research and Development (R&D)	Agency existing	Existing funding	Medium to Long-term	Models to estimate groundwater leaching values would be relevant to this effort -- EPA is working with some states to develop soil to groundwater transfer models for PFAS. Other states in the Upper Midwest are also conducting PFAS soil and biosolids studies that would be used to inform similar modeling. Developing soil-to-groundwater leaching values is also listed as an opportunity for action in Minnesota.
Develop Aquatic Toxicity Profiles for PFAS to assess the need to update aquatic life criteria or develop statewide aquatic life standards	Research and Development (R&D)	Agency existing	Existing funding	Medium to Long-term	None.
Develop state-wide wildlife risk values for PFAS, leveraging data from existing studies	Guidance/Assistance	Agency existing	Existing funding	Medium to Long-term	None.

Opportunity	Action type	Authority	Resources needed	Timeline	Contingencies
Assess the need for acute wildlife risk assessment from exposure to PFAS-containing foam	Guidance/Assistance	Agency existing	Existing funding	Medium to Long-term	None.
Formally define PFAS as hazardous substances under MERLA	Regulation	New legislative grant	Existing funding	2021 Legislative proposal	Would require legislative action. On the federal level, EPA could finalize proposed rulemaking to list PFOA and PFOS as hazardous substances under CERCLA. Federal legislation has also been proposed to designate all PFAS as hazardous substances under CERCLA.
Establish authority for MPCA to request data regarding contaminants of potential environmental concern	R&D; Regulation	New legislative grant	Existing funding	2021 Legislative proposal	None.
Develop soil to groundwater leaching values for PFAS to be used in clean-ups and disposal guidance	Guidance/Assistance	Agency existing	Existing funding	Medium to Long-term	EPA is working with some states to develop soil to groundwater transfer models for PFAS. Many states are conducting research to support similar values.
Update guidance for recommended analyte sampling at clean-up sites to include PFAS	Monitoring; Guidance/Assistance	Agency existing	Existing funding	Short-term	None.
Explore opportunities to supplement the state Remediation Fund to support site clean-ups	Guidance/Assistance	Agency existing	Added funding (appropriation)	Medium to Long-term	CERCLA hazardous substance listing for PFAS would increase access to federal funds for cleaning up PFAS-contaminated sites.
Conduct study of biosolids fate and transport following land-application	Research and Development (R&D)	Agency existing	New funding (appropriation)	2021 Legislative proposal	EPA is working with some states to develop soil to groundwater transfer models for PFAS. EPA is also developing a biosolids risk assessment for PFOA and PFOS, which would include models of PFAS fate and transport after land application of biosolids.

Opportunity	Action type	Authority	Resources needed	Timeline	Contingencies
Conduct additional investigations of PFAS groundwater plumes down-gradient of closed landfills	Monitoring	Agency existing	Added funding (appropriation)	2021 Legislative proposal	Access to the Closed Landfill Investment Fund would be needed to conduct these investigations.
Issue guidance on the collection and disposal of PFAS-containing firefighting foam concentrate and wastewater	P2; Guidance/Assistance	Agency existing	Existing funding	Short-term	EPA issued an interim PFAS disposal guidance document, but this document contains no information about concentration thresholds of PFAS in waste that would be considered hazardous or recommended disposal options based on those thresholds. EPA plans to update this "guidance" within three years.
Engage with WWTPs to identify industrial PFAS sources and opportunities for pretreatment	P2; Guidance/Assistance	Agency existing	Added funding (appropriation)	2021 Legislative proposal	Non-targeted monitoring would increase the understanding of which PFAS are present (including any new PFAS for which there are currently not analytical methods).
Develop hazardous waste rules establishing requirements for PFAS handling, storage, and disposal	Regulation	Agency existing	Existing funding	Medium to Long-term	Determination of concentration thresholds for PFAS in waste that would warrant various requirements on transport, management, and disposal is needed. There are no known federal actions on RCRA rulemaking -- various groups have petitioned EPA to conduct rulemaking on PFAS disposal, transport, and handling.
Develop a plan for monitoring PFAS in groundwater at active landfills	Monitoring; Regulation	Agency existing	Existing funding	Short-term	Traditional analytical methods for PFAS are available, but some non-targeted monitoring would increase the understanding of which PFAS are present (including those for which there are currently not analytical methods).
Develop a plan for monitoring PFAS at NPDES permitted facilities	Monitoring; Regulation	Agency existing	Existing funding	Short-term	Traditional analytical methods for PFAS are available, but some non-targeted monitoring would increase the understanding about which PFAS are present (including those for which there are currently not analytical methods).

Opportunity	Action type	Authority	Resources needed	Timeline	Contingencies
Evaluate options for managing risks from federally unregulated contaminants in drinking water	Regulation	Agency existing	Existing funding	Medium to Long-term	Federal rulemaking for PFAS is currently underway. Implementation of a federal drinking water rule for PFAS would likely not begin until 2025.
Develop a plan for performance testing for PFAS at permitted air sources	Regulation	Agency existing	Existing funding	Short-term	Performance tests have been limited; EPA is working on approved performance test methods.
Accelerate existing PFAS Pilot Inventory	Monitoring	Agency existing	Added funding (appropriation)	2021 Legislative proposal	None.

Table A-2. Gap-filling initiatives organized by timeframe.

2021 legislative proposal

Conduct additional investigations of PFAS groundwater plumes down-gradient of closed landfills

Conduct routine PFAS monitoring in fish

Engage with WWTPs to identify industrial PFAS sources and opportunities for pretreatment

Establish authority for MPCA to request data regarding contaminants of potential environmental concern

Conduct study of biosolids fate and transport following land-application

Formally define PFAS as hazardous substances under MERLA

Accelerate existing PFAS Pilot Inventory

Short-term

Compile information on inhalation PFAS toxicity

Issue guidance on the collection and disposal of PFAS-containing firefighting foam concentrate and wastewater

Research cutting-edge risk assessment techniques for data-poor PFAS

Update guidance for recommended analyte sampling at clean-up sites to include PFAS

Develop statewide water quality standards for PFAS - Class 1 drinking water

Develop a plan for monitoring PFAS in groundwater at active landfills

Develop a plan for monitoring PFAS at NPDES permitted facilities

Develop a plan for performance testing for PFAS at permitted air sources

Medium to long-term

Consider developing new rule to make air toxics reporting mandatory, including PFAS

Assess the need for acute wildlife risk assessment from exposure to PFAS-containing foam

Consider providing financial and technical assistance to businesses for switching from PFAS-containing products

Develop soil to groundwater leaching values for PFAS to be used in clean-ups and disposal guidance

Explore cross-program air modeling project to understand PFAS air emissions and their impacts on air, groundwater, surface water, and fish tissue

Require labeling of PFAS-containing products

Develop public sector purchasing guidelines to end purchases of PFAS-containing products

Develop an epidemiological study of residents exposed to PFAS through drinking water

Conduct drinking water monitoring under the Fifth Unregulated Contaminant Monitoring Rule (UCMR5) (2023-2025)

Inform and engage with farmers about potential upstream sources of PFAS

Develop aquatic toxicity profiles for PFAS to assess the need to update aquatic life criteria or develop statewide aquatic life standards

Develop state-wide wildlife risk values for PFAS, leveraging data from existing studies

Evaluate options for managing risks from federally unregulated contaminants in drinking water

Regulate PFAS using a framework of essential, substitutable, and non-essential uses

Ensure capacity to meet demand for non-targeted PFAS analytical approaches

Ensure capacity to meet demand for alternative PFAS methods

Explore opportunities to supplement the state Remediation Fund to support site clean-ups

Limit or ban PFAS in known non-essential uses

Consider developing statewide water quality standards for PFAS - Class 2 aquatic consumption, aquatic life

Appendix B. List of Minnesota PFAS values and selected other PFAS risk values

PFAS	Media	Description	Value	Units	Source	Notes
PFBA	groundwater	intervention limits (solid waste)	1750	ng/L	Minnesota	
PFBA	groundwater/drinking water	HRL (chronic)	7000	ng/L	Minnesota	
PFBA	soil	SRV (incidental ingestion, residential/recreational)	38000	ng/g	Minnesota	
PFBA	soil	SRV (incidental ingestion, commercial/industrial)	520000	ng/g	Minnesota	
PFBS	sludge	screening level	1900	ng/g	Maine	
PFBS	groundwater	intervention limits (solid waste)	500	ng/L	Minnesota	
PFBS	groundwater/drinking water	HRL (chronic)	7000	ng/L	Minnesota	
PFBS	groundwater/drinking water	HBV (chronic)	2000	ng/L	Minnesota	
PFBS	soil	SRV (incidental ingestion, residential/recreational)	57000	ng/g	Minnesota	
PFBS	soil	SRV (incidental ingestion, commercial/industrial)	77000	ng/g	Minnesota	
PFHxS	groundwater	intervention limit (solid waste)	11.75	ng/L	Minnesota	
PFHxS	groundwater/ drinking water	HBV (chronic)	47	ng/L	Minnesota	
PFHxS	soil	SRV (incidental ingestion, residential/recreational)	130	ng/g	Minnesota	
PFHxS	soil	SRV (incidental ingestion, commercial/ industrial)	1700	ng/g	Minnesota	
PFOA	sludge	screening level	2.5	ng/g	Maine	
PFOA	air	screening level	70	ng/m3	Michigan	Screening level applies to the concentration of PFOA and PFOS combined
PFOA	groundwater	intervention limit (solid waste)	8.75	ng/L	Minnesota	

PFAS	Media	Description	Value	Units	Source	Notes
PFOA	groundwater/ drinking water	HRL (chronic)	35	ng/L	Minnesota	
PFOA	soil	SRV (incidental ingestion, residential/recreational)	240	ng/g	Minnesota	
PFOA	soil	SRV (incidental ingestion, commercial/ industrial)	3200	ng/g	Minnesota	
PFOA	surface water	WQC (aquatic life, chronic)	1.70E+06	ng/L	Minnesota	
PFOA	surface water	WQC (aquatic life, acute)	1.50E+07	ng/L	Minnesota	
PFOA	Drinking water	Health advisory value	70	ng/L	EPA	Value applies to PFOA and PFOS concentrations combined
PFOS	surface water	Federal Environmental Quality Guideline (aquatic and terrestrial life)	6800	ng/L	ECCC	
PFOS	fish tissue	Federal Environmental Quality Guideline (aquatic and terrestrial life)	8300	ng/g	ECCC	
PFOS	wildlife diet (mammalian)	Federal Environmental Quality Guideline (aquatic and terrestrial life)	4.6	ng/g	ECCC	The wildlife diet guidelines are intended to protect either mammalian or avian species that consume aquatic biota. It is the concentration of PFOS in the aquatic biota food item, expressed on whole body, wet weight basis that could be eaten by terrestrial or semi-aquatic mammalian or avian wildlife.
PFOS	wildlife diet (avian)	Federal Environmental Quality Guideline (aquatic and terrestrial life)	8.2	ng/g	ECCC	
PFOS	bird egg	Federal Environmental Quality Guideline (aquatic and terrestrial life)	1900	ng/g	ECCC	
PFOS	milk	screening level	210	ng/L	Maine	

PFAS	Media	Description	Value	Units	Source	Notes
PFOS	sludge	screening level	5.2	ng/g	Maine	
PFOS	air	screening level	70	ng/m3	Michigan	Screening level applies to the concentration of PFOA and PFOS combined
PFOS	surface water	WQC (human health)	0.05	ng/L	Minnesota	
PFOS	fish tissue	WQC (human health)	0.35	ng/g	Minnesota	
PFOS	groundwater	intervention limits	3.75	ng/L	Minnesota	
PFOS	groundwater/ drinking water	HRL (chronic)	300	ng/L	Minnesota	
PFOS	groundwater/ drinking water	HBV (chronic)	15	ng/L	Minnesota	
PFOS	soil	SRV (incidental ingestion, residential/recreational)	41	ng/g	Minnesota	
PFOS	soil	SRV (incidental ingestion, commercial/industrial)	560	ng/g	Minnesota	
PFOS	surface water	WQC (aquatic life, chronic)	19000	ng/L	Minnesota	
PFOS	surface water	WQC (aquatic life, acute)	85000	ng/L	Minnesota	
PFOS	Drinking water	Health Advisory level	70	ng/L	EPA	Value applies to PFOA and PFOS concentrations combined

Appendix C. Relevant federal actions

Topic	Federal status	Citation
P2	EPA is continuing to register new PFAS for use; Congress has proposed a temporary moratorium on registration of new PFAS under TSCA but these proposals have not been signed into law.	https://www.congress.gov/congressional-report/116th-congress/house-report/364/1
Methods	EPA is working to publish additional validated PFAS analytical methods in 2021.	https://www.epa.gov/water-research/pfas-analytical-methods-development-and-sampling-research
Quantifying human health risks	EPA is developing five PFAS risk assessments under the IRIS program (PFBA, PFHxA, PFHxS, PFNA, and PFDA); the Office of Water is finalizing a draft risk assessment for the GenX chemicals, and the Superfund program (PPRTV) is finalizing a proposed risk assessment for PFBS. EPA and NIH researchers are working together to use new chemical testing approach methods to test 150 PFAS. The testing is quickly generating toxicity, toxicokinetic and other types of data to help inform decisions made about the potential health effects of PFAS.	https://cfpub.epa.gov/ncea/iris_drafts/recordisplay.cfm?deid=345065 https://www.epa.gov/pfas/genx-and-pfbs-draft-toxicity-assessments https://www.epa.gov/chemical-research/pfas-chemical-lists-and-tiered-testing-methods-descriptions
Drinking water	EPA has started the rulemaking process to regulate PFOA, PFOS, and potentially additional PFAS under the Safe Drinking Water Act. EPA is requiring monitoring for PFAS under the Unregulated Contaminant Monitoring Rule (UCMR).	https://www.federalregister.gov/documents/2020/03/10/2020-04145/announcement-of-preliminary-regulatory-determinations-for-contaminants-on-the-fourth-drinking-water https://www.epa.gov/dwucmr/development-fifth-proposed-unregulated-contaminant-monitoring-rule-ucmr-5-public-water
Exposure from fish and game consumption	With regards to ensuring safe consumption of fish, EPA's PFAS action plan states that the Agency will "determine if available data and research support the development of Clean Water Act Section 304(a) ambient water quality criteria for human health for PFAS" by 2021. EPA is taking no action related to ensuring the safety of game consumption.	https://www.epa.gov/pfas/epas-pfas-action-plan
Exposure from food	FDA has conducted some PFAS monitoring in food, but has not incorporated PFAS into the regular Total Diet Study monitoring program. FDA has coordinated voluntary phase-outs of some PFAS in food packaging, but continues to allow PFAS in food packaging generally.	https://www.fda.gov/food/chemicals/and-polyfluoroalkyl-substances-pfas
Risks from air emission	EPA mandated reporting of some PFAS from some facilities under TRI starting in 2021, but reporting exemptions mean that many meaningful PFAS emissions will not be reported.	https://www.epa.gov/toxics-release-inventory-tri-program/list-pfas-added-tri-ndaa

Topic	Federal status	Citation
Ecosystem health	EPA is not conducting ecological risk assessments for PFAS.	
Remediation	EPA has a proposed rulemaking to include PFOA and PFOS as "hazardous substances" under CERCLA. There has been no action to finalize this proposed rule.	https://www.reginfo.gov/public/do/eAgendaViewRule?pubId=201910&RIN=2050-AH09
Waste	EPA has issued technical briefs on PFAS incineration and other PFAS disposal options. EPA is conducting a risk assessment for PFOA and PFOS in biosolids.	https://www.epa.gov/chemical-research/technical-brief-and-polyfluoroalkyl-substances-pfas-incineration-manage-pfas-waste https://www.epa.gov/newsreleases/epa-releases-interim-guidance-destroying-and-disposing-certain-pfas-and-pfas-containing ; https://www.epa.gov/biosolids/risk-assessment-pollutants-biosolids#pfas