DEPARTMENT OF AGRICULTURE

PFAS in Pesticides

Final Report to the Legislature

02/01/2025

Legislative Charge

Sec. 138. REPORTS REQUIRED; PFAS IN PESTICIDES.

The commissioner of agriculture must conduct a review of existing published literature and other available information on the presence of PFAS in pesticides used in Minnesota. The review must consider the presence of intentionally added PFAS in pesticide active and inert ingredients; the potential for PFAS that are not intentionally added in pesticides; an assessment of the use and necessity of pesticides containing PFAS in Minnesota; potential alternative products; and other considerations necessary to determine the risks of, and need for, PFAS in pesticide products used in Minnesota. The commissioner must submit an interim report to the chairs and ranking minority members of the legislative committees with jurisdiction over agriculture no later than February 1, 2024, and a final report no later than February 1, 2025.

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As requested by MINN. STAT. 3.197: Projected costs to prepare this report by the end of fiscal year 2025 are $250,000 including staff time.

Executive Summary

Laws regulating perfluoroalkyl and polyfluoroalkyl substances (PFAS) in consumer products were passed in Minnesota in 2023. The laws outline the process for gathering information on and prohibiting the sale and distribution of products, including pesticide products, containing intentionally added PFAS. Additionally, [SF 1955 Sec. 138] directs the Minnesota Department of Agriculture (MDA) to submit an interim report on PFAS in pesticides to the Minnesota Legislature no later than February 1, 2024, and a final report no later than February 1, 2025.

PFAS, commonly known as "forever chemicals," are a large and diverse group of manufactured chemicals with a wide array of industrial and consumer product uses. PFAS are often defined based on their chemical structure; however, there is not one universal definition of PFAS. While precise definitions may vary, one characteristic that all PFAS share is the presence of a carbon-fluorine bond. The carbon-fluorine bond, which is very strong and difficult to break, imparts many of the properties (e.g., high stability and persistence) that PFAS are known for. PFAS can be found in a long list of products including non-stick cookware, waterproof outdoor gear, lubricants, greases, and pesticides.

Pesticides are substances used to manage pests such as insects, weeds, and pathogens. They are important tools for growing food, fuel, and fiber, preventing disease, controlling invasive species, and managing nuisance pests. Pesticides are regulated by the Environmental Protection Agency (EPA) at the federal level and by the MDA at the state level. Prior to use in the United States (U.S.), all pesticides must go through a rigorous scientific review as part of the EPA's registration process which involves evaluating potential risks to human health and the environment. Once pesticide products are registered federally by the EPA, each pesticide product must also be registered by the MDA to be used in Minnesota. The MDA may conduct additional reviews as part of its registration process.

PFAS can be intentionally added to pesticide products as either active or inert ingredients. The MDA screened pesticide active ingredients registered for use in Minnesota and identified 97 that meet the Minnesota definition of PFAS (MINN. STAT. 18B.01 subd. 15(c)), based on their chemical structure. Pesticide products containing active ingredients considered to be PFAS made up approximately 15% (2,078 products) of all the pesticide products registered in Minnesota in 2023 and accounted for approximately 1.3% of statewide sales (active ingredient by weight) in that year. Inert ingredients are not disclosed to the MDA during registration and may be considered trade secret information (MINN. STAT. 18B.38); therefore, it is not known how many additional pesticide products may contain intentionally added PFAS as inert ingredients at this time. The MDA has, however, reviewed the EPA's list of approved inert ingredients and identified 12 that meet Minnesota's definition of PFAS. Pesticide registrants will also be required to provide information about all intentionally added PFAS in their products to the MDA by the applicable statutory deadlines. While PFAS may also be present in pesticide as contaminants (e.g., from fluorinated high-density polyethylene [HDPE] containers), these PFAS are not considered intentionally added and are therefore not regulated by the MDA.

Key information is available on the toxicological effects and potential exposure to pesticide active ingredients categorized as PFAS; however, similar data is not readily available for most non-pesticidal PFAS. As part of the EPA's pesticide registration process, registrants are required to submit extensive data on physical and chemical properties of pesticide active ingredients and their degradation products. Toxicity data for pesticide active ingredients to plants, animals, and humans are also required by the EPA and are used to conduct human health and ecological risk assessments prior to registration. Much of the data submitted to the EPA is published in publicly available documents along with the full risk assessments. Unlike pesticides, EPA's regulations and accompanying data reporting requirements for non-pesticidal PFAS are not uniform and may only apply to a subset of PFAS. Furthermore, available risk assessments for non-pesticidal PFAS are more varied and have only been conducted for a small fraction of these chemicals.

A great deal of variability exists among chemicals classified as PFAS with respect to the potential risks they pose to humans and the environment. For example, the toxicity of PFAS to humans can drastically differ, as shown through comparisons of [human health-based water guidance values] developed by the Minnesota Department of Health. The health-based values for perfluorooctonoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) are set at 0.0000079 (cancer) and 0.0023 (chronic) parts per billion (ppb), respectively, while the health risk limit for the pesticide active ingredient fomesafen (a PFAS under the Minnesota definition) is orders of magnitude higher (20 ppb, chronic). The variable risk from PFAS chemicals also relates to differences in potential exposure and presence in the environment which can be evaluated, in part, through monitoring.

While some PFAS have a well-established history of monitoring, many others do not. Pesticides, including those that are considered PFAS, have been routinely monitored for in food and water by multiple federal and state agencies. For example, in Minnesota, the MDA monitors for more than 180 pesticide-related chemicals in groundwater and surface waters (e.g., rivers, streams), 31 of which are PFAS under Minnesota's definition. Monitoring data for non-pesticidal PFAS is generally more limited at both the state and federal level, with the exception of select PFAS such as PFOA and PFOS. Limited monitoring for many non-pesticidal PFAS is due, in part, to analytical limitations. In order to monitor for a chemical, analytical methods must exist.

The overall contribution of pesticides to total PFAS pollution in the environment is unclear. PFAS in agricultural lands, for example, can originate from multiple sources, including the application of contaminated biosolids (a byproduct of wastewater treatment) as fertilizer, use of PFAS-contaminated water for irrigation, and deposition of airborne PFAS, in addition to pesticides. The EPA regulates the total amount of pesticide active ingredients that can be applied per acre on an annual basis, which can help to estimate the amount entering the environment; however, the breakdown or degradation of pesticides following application can complicate the identification of specific sources. For example, some pesticides may break down in the environment to form different PFAS such as trifluoroacetic acid, which can also originate from non-pesticidal PFAS chemicals.

When regulating PFAS as a class, how PFAS are defined will impact which chemicals are subject to regulations. In Minnesota, PFAS are defined as, "a class of fluorinated organic chemicals containing at least one fully fluorinated carbon atom" (MINN. STAT. 18B.01 subd. 15(c)). Minnesota's PFAS definition is the broadest definition in regulatory use. It categorizes more chemicals as PFAS than the definitions used by EPA, the European Chemicals Agency, and the Organization for Economic Co-operation and Development. For example, of the 97 pesticide active ingredients considered PFAS under the Minnesota definition, only six active ingredients registered in Minnesota would be PFAS under the EPA Office of Pollution Prevention and Toxics definition. The European Union and European Economic Area are proposing to prohibit the use of a broad suite of PFAS in products; however, as of November 2024, a proposal from five countries recommends excluding pesticides from the proposed prohibitions due to the extensive evaluations and approval processes that are already in place for pesticides.

According to new regulations under the Minnesota Pesticide Control Law (MINN. STAT. 18B), the commissioner of agriculture may not register a pesticide product that contains intentionally added PFAS beginning January 1, 2032; and beginning January 1, 2026, the commissioner may not register a cleaning product if the product contains intentionally added PFAS. However, the Pesticide Control Law (MINN. STAT. 18B.26) provides an exemption for “currently unavoidable use” (CUU) of PFAS in pesticide products. Factors such as the need to prevent or minimize potential pest resistance and the potential human health and environmental impacts of alternative products will be considered in CUU exemption decisions for pesticides. Pesticide registrants with products containing intentionally added PFAS may request a CUU exemption that could allow the product to be registered and sold in Minnesota beyond the prohibition deadlines.

There are a number of important factors and challenges to consider in implementing PFAS regulations in pesticides. With respect to CUU, the MDA will need to collect information to determine exemptions and assess the necessity of pesticides containing intentionally added PFAS and the risks of alternative products. The PFAS laws will also likely require the MDA to handle confidential/trade secret information; therefore, the MDA is in the process of developing a reporting process to ensure the security of such information. Another challenge relates to testing pesticide products for PFAS for the purposes of enforcement, as validated analytical methods for PFAS in pesticide products remain limited. Considering these and other factors, the MDA is continuing its work preparing to implement the PFAS regulations related to pesticides.

The full impacts of Minnesota laws regulating intentionally added PFAS in pesticides are uncertain. It is anticipated that the pesticide products available for sale in Minnesota will change because of the PFAS laws. Determining how the loss of pesticide products could impact agriculture and other industries would require extensive data and study. Revenue losses from a reduction in pesticide product annual registration fees and gross sales fees will likely occur. There are also pesticide-related products that may contain intentionally added PFAS and be affected by Minnesota’s PFAS laws such as pesticide-treated seed, personal protective equipment, and fluorinated pesticide storage containers that would be regulated by the Minnesota Pollution Control Agency. The MDA is committed to ensuring that pesticide use in Minnesota will not endanger humans, damage agricultural products, food, livestock, fish, or wildlife, or cause unreasonable adverse effects on the environment.

Scientific understanding of PFAS is growing, but many uncertainties remain. This report summarizes regulation of pesticides, regulation of PFAS, what is known about PFAS in pesticides, pesticide and PFAS risk assessment, sources of PFAS in agricultural lands, monitoring for PFAS, and analytical methods for PFAS in pesticides. The report also addresses the MDA’s implementation of PFAS in pesticides laws and key considerations and challenges related to the implementation.

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Abbreviations

AFFF: Aqueous film forming foam
CAS: Chemical Abstracts Service
CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act
CUU: Currently unavoidable use
ECHA: European Chemicals Agency
EEA: European Economic Area
EPA: Environmental Protection Agency
EPCRA: Emergency Planning and Community Right-to-Know Act
ETAP: EPA Transcriptomic Assessment Product
EU: European Union
FDA: Food and Drug Administration
FIFRA: Federal Insecticide Fungicide and Rodenticide Act
GenX: Chemicals that replace perfluorooctanoic acid such as hexafluoropropylene oxide (HFPO)
HBV: Health-based value
HDPE: High density polyethylene
HFPO-DA: Hexafluoropropylene oxide dimer acid
HRL: Health risk limit
IRIS: Integrated Risk Information System
LC-PFCAs: Long chain perfluorocarboxylic acids
MCL: Maximum contaminant level
MCTF: Mosquito Control for the Twenty-First Century Task Force
MDA: Minnesota Department of Agriculture
MDH: Minnesota Department of Health
MPCA: Minnesota Pollution Control Agency
NTA: Non-targeted analysis
OPP: Office of Pesticide Programs
OPPT: Office of Pollution Prevention and Toxics
OECD: Organization for Economic Co-operation and Development
ORD: Office of Research and Development
PFAS: Perfluoroalkyl and polyfluoroalkyl substances
PFBA: Perfluorobutanoic acid
PFDA: Perfluorodecanoic acid
PFHxA: Perfluorohexanoate
PFHxS: Perfluorohexanesulfonic acid
PFOA: Perfluorooctanoic acid
PFOS: Perfluorooctane sulfonic acid
PPB: Parts per billion
PPM: Parts per million
PPT: Parts per trillion

PPE: Personal protective equipment
PTFE: Polytetrafluoroethylene
REACH: Registration, Evaluation, Authorization and Restriction of Chemicals
SDWA: Safe Drinking Water Act
TFA: Trifluoroacetic acid
TOF: Total organic fluorine
TSCA: Toxic Substance Control Act
UCMP: Unregulated Contaminants Monitoring Project
USDA: United States Department of Agriculture
USGS: United States Geological Survey

Introduction

New laws regulating perfluoroalkyl and polyfluoroalkyl substances (PFAS) in consumer products were passed in Minnesota in 2023. These laws outline the process for gathering information on the intentional addition of PFAS in consumer products and prohibiting the sale and distribution of products containing intentionally added PFAS, including pesticide products (See Appendix A). Additionally, SF 1955 Sec. 138 directs the MDA to prepare two legislative reports on PFAS in pesticides. The PFAS in Pesticides: Interim Report to the Legislature (PDF) was submitted to the legislature in February of 2024.

This final legislative report on PFAS in pesticides summarizes the science and regulation of PFAS in pesticides, describes areas of uncertainty, and outlines key considerations and challenges in the implementation of PFAS in pesticides legislation in Minnesota.

Introduction to Pesticides

According to federal law, a pesticide is a substance or mixture of substances intended to prevent, destroy, repel, or mitigate a pest. Substances or mixtures of substances used as a plant growth regulator, defoliant, or desiccant, or as a nitrogen stabilizer are also considered pesticides (U.S. Code Title 7, Chapter 6, Subchapter II, § 136 (u)). Pesticides can be chemical substances or biological agents and have many uses. For example, pesticides can be used to control weeds (herbicides), insects (insecticides), and plant diseases (fungicides). Pesticides can also be used to sanitize surfaces (e.g., antimicrobial sprays) and treat wood, among other uses. Certain substances, such as cleaning agents, may be considered pesticides if pesticidal claims are made.

Pesticide Components

Pesticide products are made up of active and inert ingredients. Active ingredients are the chemicals that control pests while inert ingredients are included in the pesticide formulation but do not act directly to control the pest (40 CFR 158.300). Inert ingredients are added to pesticide products to improve the product performance and usability; for instance, inert ingredients may extend a product's shelf-life or help the pesticide penetrate leaf surfaces. Examples of inert ingredients include solvents, carriers, emulsifiers, and dyes.

One category of chemicals that may be included in pesticide products as inert ingredients is adjuvants. Adjuvants are chemicals that are used to improve pesticide product efficacy such as surfactants, oils, and defoaming agents. Adjuvants that are added by the manufacturer to a pesticide product's formulation as inert ingredients are known as formulation adjuvants. Adjuvants can also be sold separately and later mixed with the pesticide product by the applicator; these are known as spray adjuvants.

All active and inert ingredients must be approved by the EPA before they can be included in a pesticide product. Federal law requires that all active ingredients be listed by name and percentage on the pesticide product label; however, for inert ingredients, only the total percentage of inert ingredients is required on the label.

Pesticide Regulatory Framework

In the U.S., pesticide active and inert ingredients are regulated at the state and federal levels. Sale, distribution, and use of pesticides at the federal level are governed by the Federal Insecticide Fungicide and Rodenticide Act (FIFRA). The EPA is the lead agency for regulating pesticides at the federal level and is responsible for administering FIFRA. Under FIFRA, the EPA is required to register all pesticides sold or distributed in the United States except for minimum risk 25(b) pesticides (pesticides that the EPA has determined pose little to no risk to human health or the environment) which are exempt from federal registration (40 CFR 152.25(f)). When the EPA registers a pesticide product, the product receives an EPA registration number that must appear on the label.

Before registering a pesticide for use in the U.S., the EPA is required to conduct an independent, rigorous scientific assessment to ensure a pesticide product will not cause unreasonable risk to humans or the environment. As part of the pesticide registration process, the EPA evaluates the product ingredients (both active and inert), the target site or crop, the amount, frequency, and timing of use, and storage and disposal practices. For products containing a new active ingredient, the extensive review process can take years to complete. Once registered, pesticides must undergo a reregistration review at least once every 15 years to ensure that new information and data are considered in the EPA's registration decision and to determine if any new risk assessments are needed. For more on pesticide risk see the "Assessing Risk and Developing Guidance" section.

In addition to FIFRA, some of the other EPA laws regulating pesticides at the federal level include:

- The Food Quality Protection Act, which requires the EPA to review each pesticide registration at least once every 15 years;
- The Federal Food, Drug and Cosmetic Act, which requires the EPA to establish tolerances for registered pesticides used in or on food and feed;
- The Endangered Species Act, which requires the EPA to ensure that any action they authorize, fund, or carry out, such as registering pesticides, will not likely jeopardize the continued existence of any listed species, or destroy or adversely modify any critical habitat for those species; and
- The Resource Conservation and Recovery Act, which regulates pesticides after they are disposed.

At the state level, the primary statute regulating pesticide registration, sale, distribution, and use is the Pesticide Control Law (MINN. STAT. 18B), and the MDA is the lead state agency responsible for implementing the Pesticide Control Law (MINN. STAT. 18B.03, subd. 1). The MDA is responsible for regulating the registration of pesticides for distribution and use in Minnesota (MINN. STAT. 18B.26, subd. 1), as well as the application of pesticides and enforcement of pesticide label requirements (MINN. STAT. 18B.03, subd. 1). With the exception of minimum risk pesticides, all pesticide products must be registered by the MDA to be legally sold, distributed, and used in the state, and registrations must be renewed annually (MINN. STAT. 18B.26, subd. 1). While the MDA does not register minimum risk pesticides, these pesticides are still regulated by the MDA to ensure that all conditions of minimum risk exemptions are met, and they are used according to label directions. The MDA does not register or regulate spray adjuvants sold as standalone products.

Pesticides are regulated by the EPA at the federal level and by the MDA at the state level.

Introduction to PFAS

PFAS Classification and Uses

PFAS, commonly known as "forever chemicals," are a large and diverse group of manufactured chemicals with a wide array of industrial and consumer product uses. PFAS can be resistant to extreme temperatures and repel water and oil, which leads manufacturers to use them for applications such as non-stick cookware and waterproof outdoor apparel. Lubricants and greases, gaskets, electronics, textiles, ammunition, paper and packaging, musical instruments, leather, pharmaceuticals, and pesticides are just some of the many products that may contain PFAS (Glüge et al., 2020). While PFAS have been widely used since the 1940s, there has been growing interest in the potential health and environmental risks associated with these chemicals in recent years.

PFAS are often discussed and are now being regulated as a class due in part to structural similarities and shared properties. As a class, PFAS encompass over 10,000 unique chemicals and potentially many more depending on the definition used (Gaines et al., 2023). For example, the 2021 Organization for Economic Co-operation and Development (OECD) definition of PFAS encompasses over 7 million chemicals in the PubChem database (Schymanski et al., 2023). Because there is not one universal definition of PFAS, chemicals classified as PFAS can vary greatly. One key characteristic that all PFAS share, however, is the presence of a carbon-fluorine bond. The carbon-fluorine bond is extremely strong and difficult to break; therefore, PFAS are often very stable and persistent (i.e., slow to break down). While this stability is often favorable in commercial and industrial applications, it has also led to PFAS becoming ubiquitous in the environment and in humans.

PFAS Regulatory Framework

Compared to pesticides, a regulatory framework for PFAS chemicals has not been well-established, and uniform regulations for the entire class of PFAS do not exist at the federal level. PFAS represent a large number of chemicals with a wide range of functions, which adds to the complexity of regulating PFAS as a class.

At the federal level, PFAS regulation has primarily been carried out by the EPA; however, the United States Department of Agriculture (USDA) and the United States Food and Drug Administration (FDA) have also implemented PFAS-related laws. Several federal laws address PFAS use and contamination, some of which are summarized below.

- Emergency Planning Community Right-to-Know Act (EPCRA) – Section 7321 of the National Defense Authorization Act for Fiscal Year 2020 added select PFAS to the list of chemicals covered by the Toxic Release Inventory (TRI) under the EPCRA. As of January 2024, there are 196 PFAS on the TRI, none of which are pesticide active ingredients. Inclusion on the TRI list requires facilities to annually report the amount of each listed PFAS that is released into the environment and/or managed through recycling or recovery. In October 2024, the EPA proposed adding 15 PFAS categories and 16 individual PFAS to the TRI list, four of which are pesticides (broflanilide, hexaflumuron, pyrifluquinazon, tetraconazole).
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) also known as "Superfund" – The EPA designated two PFAS, perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS), as hazardous substances under CERCLA. CERCLA designation addresses liability and cleanup costs related to the release of hazardous chemicals in the environment.

- Toxic Substances Control Act (TSCA) – The EPA finalized reporting and recordkeeping requirements for PFAS under TSCA Section 8(a)(7). All entities that have manufactured (including imported) PFAS (as defined in TSCA) in any year since January 1, 2011, will have until July 2025 to report data on PFAS uses, production volumes, disposal, exposures, and hazards to the EPA. The reporting/recordkeeping rule is limited to PFAS that are considered a "chemical substance" under TSCA Section 3(2) and notably does not include pesticides, which are excluded from the definition of "chemical substance." The EPA also finalized a significant new use rule under TSCA preventing anyone from resuming manufacture or processing of PFAS listed as "inactive" on the TSCA Inventory without EPA review of the significant new use.
- Safe Drinking Water Act (SDWA) – In April 2024, the EPA announced final National Primary Drinking Water Regulation (NPDWR) for select PFAS under the SDWA. The NPDWR established legally enforceable levels (Maximum Contaminant Levels [MCLs]) for six PFAS in drinking water.

The EPA has taken legal actions on PFAS based on laws such as TSCA; however, some actions have been challenged and continue to be contested. One pertinent example relates to PFAS contamination from fluorinated high-density polyethylene (HDPE) containers. In December 2023, the EPA issued orders to Inhance Technologies LLC, a major producer of fluorinated HDPE containers, directing them not to produce PFAS under the authority of TSCA. Inhance sued the EPA. In March 2024, the 5th U.S. Circuit Court of Appeals vacated the orders issued by the EPA (PDF) after ruling that the agency had overstepped its statutory authority. In April 2024, several environmental groups submitted a petition requesting that the EPA establish regulations under TSCA Section 6 (PDF) prohibiting the manufacturing, processing, use, distribution in commerce, and disposal of three PFAS found in fluorinated containers (PFOA, perfluorononanoic acid [PFNA], and perfluorodecanoic acid [PFDA]). The EPA granted this petition in July 2024 and sought public comment to inform regulations under TSCA.

In addition to implementing PFAS-related laws, the EPA has also published a centralized document titled the PFAS Strategic Roadmap which lays out a whole-of-agency approach to address PFAS (USEPA, 2021). The National Science and Technology Council published a "Per- and Polyfluoroalkyl Substances (PFAS) Federal Research and Development Strategic Plan" to outline goals, objectives, and tasks that, through interagency coordination, would further the federal government's actions to protect Americans from the harmful effects of PFAS (NSTC, 2024).

In Minnesota, multiple state agencies, including the Minnesota Department of Health (MDH), the Minnesota Pollution Control Agency (MPCA), and the MDA, are involved in implementing PFAS regulation. The MDA is the lead state agency for PFAS regulations pertaining to pesticides, fertilizers, and soil and plant amendments.

A number of state statutes regulate PFAS in Minnesota, some of which are listed below.

- Chapter 116: Pollution Control Agency – Amara's Law MINN. STAT. 116.943
- Chapter 18B: Pesticide Control Law – MINN. STAT. 18B.26
- Chapter 18C: Fertilizer, Soil Amendment, and Plant Amendment – MINN. STAT. 18C.202
- Chapter 325F: Consumer Protection Law – Food Packaging (MINN. STAT. 325F.075) and Firefighting Foam (MINN. STAT. 325F.072)

Similar to the EPA's PFAS Strategic Roadmap, Minnesota state agencies published Minnesota's PFAS Blueprint in 2021 (MPCA, 2021). The Blueprint describes Minnesota's strategy to prevent, manage, and clean up PFAS pollution in the state, identifies key priorities to protect communities and families, and outlines both short- and long-term opportunities for action.

Defining PFAS for Regulation

To regulate PFAS as a class, this large and complex group of chemicals must be clearly defined. PFAS are typically defined and grouped based on their chemical structures; however, there is not a single, universal definition of PFAS (Gaines et al., 2023). Various agencies, organizations, and groups have adopted differing definitions of PFAS (See Table 1 for examples), and many of these definitions continue to evolve over time.

Table 1. Definitions of PFAS by select organizations.

Organization	Definition of PFAS	Notes
Minnesota (2023)	"…means a class of fluorinated organic chemicals containing at least one fully fluorinated carbon atom."	• Defined in Minnesota Statute (e.g., MINN. STAT. 18B.01 subd. 15(c) and MINN. STAT. 116.943 subd. 1(p))
Connecticut (2024)	"…means all members of the class of fluorinated organic chemicals containing at least one fully fluorinated carbon atom."	• Defined in Public Act 24-59 (PDF)
Maine (2021) Rhode Island (2024)	"…means substances that include any member of the class of fluorinated organic chemicals containing at least one fully fluorinated carbon atom."	• Maine: Defined in Public Law 2021, c. 477 (PDF) • Rhode Island: Defined in Public Law 457 Section 23-18.18-3
EPA – Office of Pollution Prevention and Toxics (OPPT) (2023)	"PFAS is defined as including at least one of these three structures: • R-(CF2)-CF(R')R'', where both the CF2 and CF moieties are saturated carbons; • R-CF2OCF2-R', where R and R' can either be F, O, or saturated carbons; and • CF3C(CF3)R'R'', where R' and R'' can either be F or saturated carbons."	• Defined in TSCA Section 8(a)(7) reporting and recordkeeping requirements for PFAS final rule • Modifications were made to the PFAS definition in the proposed rule following public comment

Organization	Definition of PFAS	Notes
European Chemicals Agency (ECHA) (2023)	"Any substance that contains at least one fully fluorinated methyl (CF3-) or methylene (-CF2-) carbon atom (without any H/Cl/Br/I attached to it). A substance that only contains the following structural elements is excluded from the scope of the proposed restriction: CF3-X or X-CF2-X', where X = -OR or -NRR' and X' = methyl (-CH3), methylene (-CH2-), an aromatic group, a carbonyl group (-C(O)-), -OR'', -SR'' or –NR''R''', and where R/R'/R''/R''' is a hydrogen (-H), methyl (-CH3), methylene (-CH2-), an aromatic group or a carbonyl group (-C(O)-)."	• Defined in ECHA proposed restriction of PFAS • Plant protection products and biocides are exempt from the proposed restriction
Organization for Economic Co-operation and Development (OECD) (2021)	"… fluorinated substances that contain at least one fully fluorinated methyl or methylene carbon atom (without any H/Cl/Br/I atom attached to it), i.e., with a few noted exceptions, any chemical with at least a perfluorinated methyl group (–CF3) or a perfluorinated methylene group (–CF2–) is a PFAS."	• Defined in OECD 2021 report (OECD, 2021)

When regulating PFAS as a class, how PFAS are defined will impact which chemicals are subject to regulations. Therefore, the words or specific structural elements chosen to define PFAS can have important regulatory implications. Seemingly subtle differences among definitions can represent an increase or decrease in the number of regulated chemicals by orders of magnitude. For example, Hammel et al. (2022) explored the implications of PFAS definitions with respect to fluorinated pharmaceuticals and found that depending on the definition of PFAS used, between 1% and 100% of the 360 pharmaceuticals screened would be included. Furthermore, while PFAS are often described as a class of over 10,000 chemicals, Schymanski et al. (2023) found that as many as 7 million chemicals in the PubChem database would be considered PFAS under the OECD 2021 definition.

Minnesota Statute defines PFAS as "a class of fluorinated chemicals containing at least one fully fluorinated carbon atom" (MINN. STAT. 18B.01 subd. 15(c)). While the language in Minnesota's definition largely parallels that of the OECD 2021 definition (See Table 1), it notably does not specify that the fully fluorinated carbon atom must be a methyl (-CH3) or methylene (-CH2-) carbon. Similarly, while the term "per/poly-fluoroalkyl substances" itself has scientific meaning with respect to chemical structure, the Minnesota definition does not explicitly state that the chemical be an alkyl substance or contain a minimum number of fluorine atoms. The MDA looked to 15 U.S.C. § 8931(2)(B) to define "fully fluorinated carbon," which offered the following: "The term 'fully fluorinated carbon atom' means a carbon atom on which all the hydrogen substituents have been replaced by fluorine." As noted by Hammel et al. (2022), the U.S. Code definition does not specify that the fully fluorinated carbon must be saturated (contains only single bonds) or part of an alkyl chain. Therefore, as written, Minnesota's definition of PFAS includes chemicals such as beta-cyfluthrin, which contains a single fluorine atom on a benzene ring (**Figure 1**).

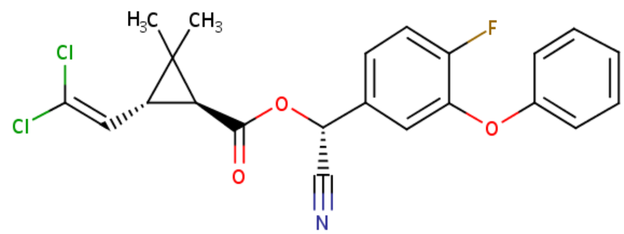

Figure 1. Chemical structure for the pesticide active ingredient beta-cyfluthrin (source: EPA Comptox Chemicals Dashboard).

The definition of PFAS adopted by the state of Minnesota is broader than the EPA Office of Pollution Prevention and Toxics (OPPT), ECHA, and OECD definitions. As a result, chemicals that would not be considered PFAS by EPA OPPT, ECHA, or OECD may be classified and regulated as PFAS in Minnesota (e.g., beta-cyfluthrin, **Figure 1**). For example, of the 97 pesticide active ingredients registered in Minnesota that are classified as PFAS under Minnesota's definition, only around 65 of those active ingredients would be classified as PFAS under the OECD 2021 definition, and only six would be PFAS under the EPA OPPT definition. The number of active ingredients that would be considered PFAS under different definitions is provided strictly for comparison to demonstrate the variability among definitions. The MDA is bound to the definition of PFAS in Minnesota Statute and is working closely with the MPCA to ensure a clear and consistent interpretation across agencies.

Of the 875 pesticide active ingredients registered for use in Minnesota, as of October 2024, 97 are considered PFAS under Minnesota's definition. Of those 97, only six are considered PFAS by the EPA under their Office of Pollution Prevention and Toxics definition.

PFAS in Pesticides

PFAS can be present in pesticide products as both an intentionally added ingredient as well as a contaminant (**Figure 2**). The MDA has been carefully tracking the presence of PFAS in pesticides for many years and is continuing to gather information to carry out PFAS laws in Minnesota. This section reviews the known uses of PFAS in pesticides and potential sources of PFAS in pesticide products.

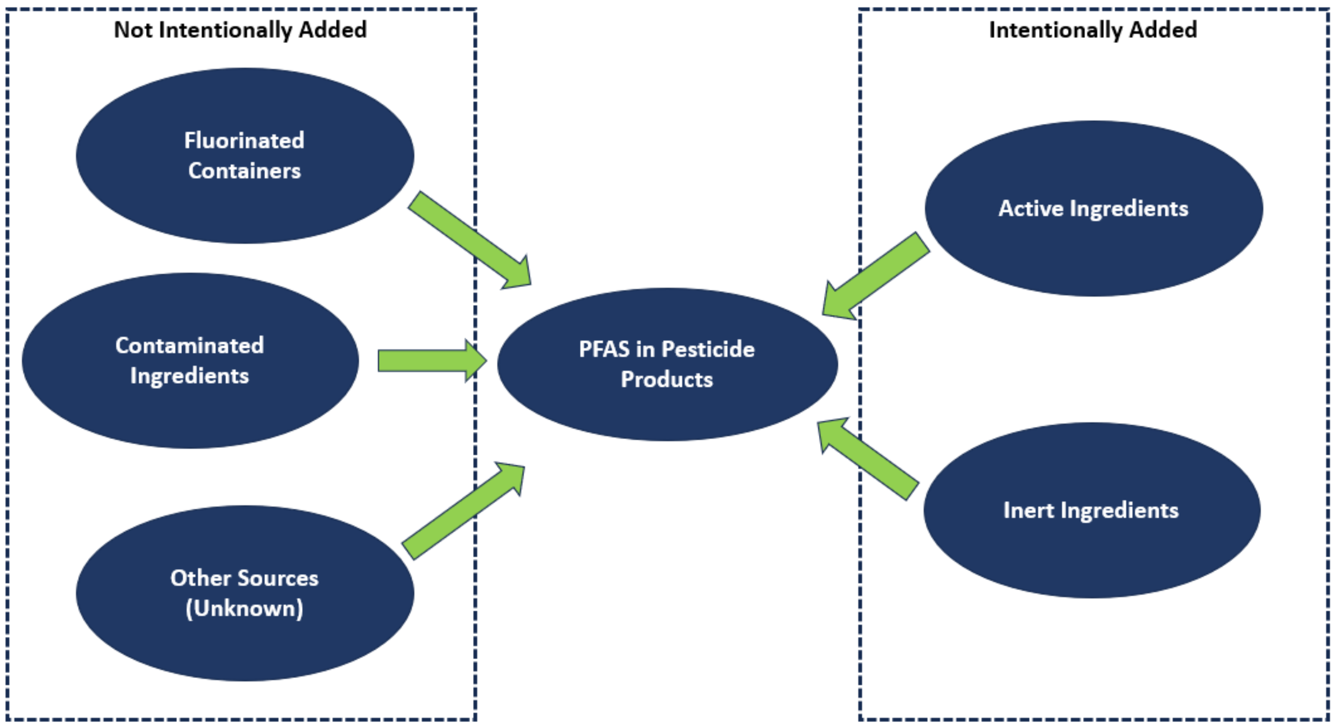

Figure 2. Potential sources of PFAS in pesticide products.

Intentionally added PFAS

Active Ingredients

Many pesticide active ingredients contain fluorine, which can favorably alter the properties of a chemical and improve its efficacy as a pesticide. For example, fluorine can be used to provide additional selectivity, specificity, and improved stability of pesticides in the field (Alexandrino et al., 2022). The manufacturing and use of fluorinated pesticides have increased worldwide over the last 30 years (Burriss et al., 2018). Between 2016 and 2020, 28 out of 42, or two-thirds of, new active ingredients were fluorinated molecules (Ogawa et al., 2020). A recent publication reviewed a list of 1,157 pesticide active ingredients registered for use in the U.S. and found that 14% of them would be considered PFAS under the OECD definition (Donley et al., 2024).

Not all pesticides registered federally are registered for use in Minnesota. As previously stated, the MDA has identified 97 active ingredients that are considered PFAS under Minnesota's definition based on a screening of all pesticide active ingredients registered in Minnesota in September 2024 (See Appendix B). In its review, the MDA applied the 15 U.S.C. § 8931(2)(B) definition of "fully fluorinated carbon" (a carbon atom on which all the hydrogen substituents have been replaced by fluorine). Because the definition does not specify whether the fully fluorinated carbon must be saturated, chemicals containing a single fluorine atom attached to a benzene ring, a common structural element among fluorinated pesticides (e.g., flumetsulam), were considered PFAS. This approach is consistent with Hammel et al. (2022). Most of the pesticide active ingredients considered to be PFAS in Minnesota do not meet the EPA's current OPPT definition of PFAS. In 2022, sales of individual PFAS pesticide active ingredients in Minnesota ranged from zero to approximately 200,000 pounds. However, sales data do not necessarily correlate with pesticide use in the state on an annual basis (See Appendix B).

Inert Ingredients and Adjuvants

Compared to pesticide active ingredients, little information is available about inert ingredients at the state level. Inert ingredients may be considered trade secrets or confidential business information (MINN. STAT. 18B.38), and pesticide registrants are not required to disclose inert ingredients in pesticide products by name or percentage on the product label or to the MDA as a part of the registration process. There is, however, a list of all approved inert ingredients maintained by the EPA that is available through the EPA's InertFinder database. Currently, there are more than 5,000 inert ingredients on this list that may be present in pesticide products.

The EPA Office of Pesticide Programs (OPP) conducted a review of chemical substances approved for use as inert ingredients in pesticide products to determine whether any of these ingredients are PFAS. The EPA identified 12 ingredients as PFAS and removed them from the list of inert ingredients approved for use in pesticides in December 2022 (USEPA, 2022b). It is important to note that the EPA's review would have been conducted using the EPA OPPT 2021 working definition of PFAS (i.e., "a structure that contains the unit R-CF2-CF(R')(R''), where R, R', and R'' do not equal "H" and the carbon-carbon bond is saturated"), which is narrower than Minnesota's definition.

In February 2024, the MDA conducted a screening of approved inert ingredients in the EPA's InertFinder Database applying the Minnesota PFAS definition. The MDA identified 12 inert ingredients that are classified as PFAS under Minnesota's definition (See Appendix B); however, there were some ingredients for which a clear determination of PFAS status could not be made due to insufficient information provided. For example, the inert ingredient identified only as "dog or cat collar" (presumably for use in flea and tick collar products) was insufficiently detailed to determine if it contained PFAS. In February 2024, the EPA proposed removing Teflon, one of the 12 inert ingredients the MDA identified as PFAS, from its list of approved pesticide inert ingredients.

The MDA and MPCA are collaboratively discussing the relevant PFAS statute language that applies to both agencies. Formulation adjuvants included in pesticide products as inert ingredients were screened under the umbrella of inert ingredients, as regulated under Minnesota's Pesticide Control Law (MINN. STAT. Chapter 18B). Spray adjuvants, sold as standalone products, will be regulated by the MPCA (MINN. STAT. Chapter 116.943). The MDA does not have a list of spray adjuvants that are sold, distributed, or used in Minnesota.

Minimum Risk Pesticides

The EPA maintains a list of active and inert ingredients that can be used in minimum risk pesticide products (40 CFR 152.25(f)). The MDA reviewed all active ingredients and inert ingredients permitted for use in minimum risk 25(b) pesticide products by the EPA in September 2024. No ingredients on either the active or inert 25(b) lists were identified as PFAS based on Minnesota's definition.

Other Sources of PFAS in Pesticides

While PFAS may be intentionally added to a pesticide product as either an active or inert ingredient, there is also potential for PFAS to be present in products from other sources. For example, PFAS may appear in the product as a byproduct or impurity. Recently, it was discovered that fluorinated HDPE containers can act as an unintentional source of PFAS in pesticide products.

Fluorinated HDPE containers are commonly used in the manufacturing, transport, storage, and packaging of pesticides. Fluorination creates a barrier on plastic containers that can improve the containers' stability and make them less chemically reactive and permeable. The EPA began investigating fluorinated HDPE containers as a potential source of PFAS in pesticides in 2020 after PFAS were detected in the mosquito control product Anvil 10+10 (PEER, 2020). Through its investigation, the EPA found that fluorinated HDPE containers can have certain PFAS on/in their walls that can leach into the liquid pesticide stored inside. In its 2021 study, "Rinses from Selected Fluorinated and Non-Fluorinated HDPE Containers," the EPA detected eight different PFAS leached from the tested fluorinated HDPE containers at levels ranging from 20 to 50 parts per billion (ppb) (USEPA, 2021c). Further studies by the EPA demonstrated the ability of PFAS from containers to leach into both water and organic solvent-based products and found that the total amount of PFAS leached into the products can gradually increase over storage time (USEPA, 2022b). The EPA also noted variability in PFAS leaching from different fluorinated containers tested and suggested this may be due to different degrees of fluorination and the technology used. A study by Vitale et al. (2022) similarly found that the manufacturing and fluorination technologies used to produce fluorinated HDPE containers resulted in differences in PFAS leaching. Under FIFRA Section 6(a)(2), pesticide registrants are required to inform the EPA about any unreasonable adverse effects of their product, including metabolites, degradates and impurities, such as PFAS. According to the EPA's website, "EPA considers any level of PFAS to be potentially toxicologically significant" and may trigger reporting under 40 C.F.R. 159.179(b) (PFAS here refers to chemicals meeting the EPA OPPT definition [See Table 1]). Therefore, PFAS in pesticides from fluorinated containers or other sources may need to be reported to the EPA.

Another potential route of PFAS contamination in pesticide products is by contaminated ingredients. The widespread use of PFAS in industry and their ubiquity in the environment provides opportunities for contamination of ingredients. For example, various plant-derived ingredients are included on the EPA's list of approved inert ingredients, and studies have shown that plants can take up PFAS from contaminated water and soil (Mei et al., 2021). Inclusion of ingredients such as these could lead to the unintentional inclusion of PFAS in the final pesticide products.

The new Minnesota PFAS laws apply only to intentionally added PFAS in products. Minnesota's PFAS laws define "intentionally added PFAS" as PFAS deliberately added during the manufacture of a product where the continued presence of PFAS is desired in the final product or one of the product's components to perform a specific function. Given that PFAS appearing in pesticide products from fluorination of containers are not intentionally added, they do not fall under the purview of the Pesticide Control Law (MINN. STAT. Chapter 18B). Fluorinated HPDE containers are instead regulated by the MPCA (MINN. STAT. Chapter 116.943).

Unlike many other products, all ingredients in pesticide products are reported to the EPA. Active ingredients must be publicly disclosed on the product label, while inert ingredients are reported directly to the EPA. Additionally, the MDA tracks the sale of pesticides in Minnesota.

Risk Assessment

Risk is the chance of harmful effects resulting from exposure to an environmental stressor, such as a pesticide or PFAS chemical. Information on toxicity and exposure is used to calculate estimates of risk and characterize the nature and magnitude of risks to human health and the environment (e.g., plants, birds, aquatic life). Guidance such as regulatory limits, benchmarks, and advisories are developed through the risk assessment process and can be used by regulators, the public, or others to help make informed decisions around risk.

If and how full risk assessments are conducted for chemicals often depends on how the chemical is used and regulated as well as the data available. The following sections detail aspects of risk assessment for both pesticides and PFAS and key guidance that has been developed at the federal and state levels.

Pesticide Risk Assessment

At the federal level, risk assessments for individual pesticide active ingredients are required as part of the EPA's pesticide registration process and follow a set protocol using data provided by registrants, published literature, or other sources. At the state level, the MDA may further assess risk for newly registered pesticide active ingredients, pesticides with a significant new use, or other pesticides of interest through special registration reviews. Generally, pesticide registration reviews and risk assessments are carried out on a chemical-specific basis, though similar chemicals may be combined and reviewed as a class in some instances (e.g., organophosphate insecticides).

Federal

When applying for EPA registration, companies are required to submit a suite of data on product chemistry, efficacy, how the pesticide moves and breaks down in the environment, and its toxicity to humans and other non-target organisms (40 CFR Part 158). The EPA uses the submitted data along with a variety of other risk assessment tools (e.g., databases, models) to evaluate the potential health and ecological effects of a pesticide product. Typically, the pesticide active ingredient is the focus of risk assessments; however, the EPA also requires sufficient data to make a safety determination for the approval of new inert ingredients (USEPA, 2015).

As part of the pesticide registration review, the EPA conducts both human health and ecological risk assessments following standardized protocols. Human health risk assessments, for example, consider pesticide exposure from various sources (e.g., food, drinking water, contact/inhalation during application) and potential short-term and long-term health effects (e.g., acute toxicity, carcinogenicity, developmental effects). Degradates (i.e., breakdown products) of the pesticide are also considered in the risk assessment along with whether the pesticide shares a common mechanism of toxicity or common degradate with other chemicals. Ecological risk assessments evaluate risk to various taxa, including birds, mammals, fish, terrestrial and aquatic invertebrates, and plants, and similarly consider multiple exposure pathways, acute and chronic toxicity data, and pesticide degradates. For listed species (i.e., threatened and endangered species), the EPA consults with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service to evaluate the potential risk. The EPA ultimately makes a registration decision based on risk assessment outcomes and may require actions to mitigate identified risks and ensure use does not result in unreasonable adverse effects.

The EPA also uses risk assessments to set limits for pesticides and/or their degradates in food and water. For example, the EPA develops tolerances, also known as maximum pesticide residue limits, for each food and feed commodity on which a pesticide is labeled for use. Tolerances consider aggregate exposure to pesticide active ingredients from multiple sources and the potential increased susceptibility of sensitive subpopulations (e.g., infants and children), among other factors. Tolerances may also be required for some inert ingredients. While labeled uses of pesticides are unlikely to result in tolerance exceedances, the FDA regularly tests commodities intended for sale in the U.S. to ensure tolerances are not exceeded. In drinking water, the EPA may set MCLs or Health Advisories for pesticides or develop non-enforceable Human Health Benchmarks for Pesticides. For water bodies such as rivers and streams, the EPA often develops Aquatic Life Benchmarks for pesticides and/or their degradates based on toxicity data for various taxa including fish, aquatic invertebrates, and aquatic plants (See examples in Table 3). The EPA may also develop water quality criteria (also known as 304(a) criteria) for pesticides in surface water that states and authorized Tribes may adopt as water quality standards.

While PFAS are often described as a group of chemicals we know little about, a substantial amount of information is available on PFAS that are used as active ingredients in pesticide products. The EPA routinely conducts risk assessments for pesticides, which are required as part of the registration process, and toxicology and exposure data on pesticides is readily available.

Minnesota

The MDA tracks and reviews the EPA's pesticide risk assessments for potential state-specific impacts and works closely with other state agencies to evaluate the risks of pesticides in Minnesota. For new active ingredients, significant new uses of existing active ingredients, and major pesticide label changes, the MDA may conduct brief registration reviews to assess the potential impacts in Minnesota. Larger, more in-depth reviews evaluating the risk may also be conducted to determine the potential exposure and risks. Additionally, the MDA may also add a pesticide and/or its breakdown products to the agency's water quality monitoring program to assess potential exposure.

Minnesota develops and uses a variety of state-specific guidance for pesticides in conjunction with the federal guidance available. While the MDA does not independently develop any guidance for pesticides, the agency often requests state-specific guidance from the MDH and MPCA to evaluate concentrations of pesticides detected in water. For example, the MDH develops human health-based guidance values to evaluate potential human health risks from exposure to chemicals in groundwater. Health risk limits (HRLs) and health-based values (HBVs) from the MDH are available for a number of pesticides and their degradates, including some that meet the Minnesota definition of PFAS (See examples in Table 2). For pesticides without HRLs or HBVs, the MDH develops Rapid Assessments to use as guidance for pesticides in drinking water, and these values are often developed at the request of the MDA. The MDH has developed Rapid Assessments for over 200 pesticides and pesticide transformation products, including many categorized as PFAS. The MPCA can adopt water quality standards for chemicals in surface waters such as rivers, streams, and lakes (MINN. R. Chapters 7050 and 7052). Minnesota water quality standards are available for approximately 32 pesticides.

PFAS Risk Assessment

Unlike the EPA risk assessments for pesticides, which are required under FIFRA and conducted in a consistent manner, risk assessments for PFAS are more varied and have only been conducted for a small fraction of non-pesticidal PFAS chemicals. One key challenge in assessing risk for PFAS is the lack of toxicity and exposure data available for many chemicals. Despite data limitations, however, new regulatory requirements and assessment tools are continuing to make risk assessments for individual PFAS and larger PFAS categories more feasible.

Federal

At the federal level, risk assessments for non-pesticide PFAS are primarily conducted by the EPA. Risk assessments may be required by law for some PFAS and can be conducted under multiple EPA programs including the Biosolids Program and Superfund Program. Another program that may require risk assessments for select PFAS is the EPA's New Chemicals Program under TSCA which evaluates the potential risk new chemicals pose to human health and the environment, taking into consideration their persistence, bioaccumulation, toxicity, expected degradation products, and potential exposure pathways. In 2023, the EPA developed a framework for addressing new PFAS and new uses of PFAS through the New Chemicals Program. While most PFAS risk assessments to date have focused on individual chemicals, the EPA is also working toward improving its ability to evaluate multiple PFAS at once by grouping them based on similar characteristics to identify candidates for tiered toxicological testing (Patlewicz et al., 2024) and more efficiently address this very large class of chemicals (USEPA, 2021b).

As previously described, data on toxicity and exposure is needed to assess the potential risk of a chemical. While pesticide registrants are required to submit much of this data as part of the registration process, for many PFAS, chemical-specific toxicity data and data to estimate exposure is not routinely generated or readily available. Toxicity data for PFAS can come from required data submissions (e.g., Significant New Use Notices), published literature, or other sources/databases. For example, ECOTOX is an EPA database that compiles ecological toxicity data from published literature and includes data for 360 chemicals flagged as PFAS. Data on potential exposure for PFAS can also come from a variety of sources including published studies, monitoring programs, and required reporting (e.g., PFAS on the EPA's TRI list). While data on various non-pesticidal PFAS is becoming increasingly available, it is worth noting that many of the published toxicity and exposure studies to date have focused only on a small number of PFAS (De Silva et al., 2021; Fenton et al., 2021; Gkika et al., 2023) and the PFAS data available in databases such as ECOTOX can be dominated by these widely-researched PFAS (e.g., PFOA and PFOS).

The EPA has developed a variety of tools and approaches to assess the potential risk chemicals such as PFAS pose to human health and the environment, some of which are designed to assess chemicals lacking traditional toxicity testing data. For example, the EPA Transcriptomic Assessment Product (ETAP) can be used to evaluate the potential effects of a chemical on human health based on changes in gene activity. Transcriptomic-based reference values, which estimate the daily dose of a chemical where there is likely no appreciable human health risk, can also be derived from ETAP and are available for select PFAS including Perfluoro-3-methoxypropanoic acid (Brennan et al., 2024). The EPA's Integrated Risk Information System (IRIS) Program is another important source of toxicity values (e.g., reference doses) based on assessments of a single chemical, a group of chemicals, or a complex mixture of chemicals. The EPA has completed draft IRIS assessments for several PFAS, and final assessments are available for select PFAS including PFBA and PFHxA.

Based on available toxicity data, exposure data, and risk assessments, a variety of regulatory values or guidance values have been developed for non-pesticidal PFAS to protect both human and environmental health. Many of the types of guidance values available for non-pesticidal PFAS are the same as for pesticides. For example, the EPA has set MCLs for select PFAS in drinking water (See "PFAS Regulatory Framework" section). The EPA has also published final national recommended water quality criteria for PFOA and PFOS and developed acute Aquatic Life Benchmarks for eight individual PFAS to protect aquatic ecosystems (Table 3). Specific regulatory limits for non-pesticidal PFAS in food have not been set in the U.S.; however, the EPA has issued guidance for developing fish advisories to address fish consumption from water known to be contaminated with PFAS.

Minnesota

At the state-level, risk associated with non-pesticidal PFAS is primarily assessed by the MDH for human health and by the MPCA for environmental health, though all state agencies work together on issues related to PFAS. As with pesticides, Minnesota state agencies carefully track and review the available data, risk assessments, and guidance on PFAS from federal agencies, other states, and published research. Monitoring in the environment and drinking water for PFAS in Minnesota is ongoing (See "Monitoring for PFAS" section).

Minnesota has developed state-specific guidance for select non-pesticidal PFAS based on independent risk assessments conducted by state agencies. For example, the MDH has developed HRLs and/or HBVs for several PFAS to protect public health from these contaminants in drinking water (Table 2). The MDH has also developed air guidance values for several PFAS as well as fish consumption guidance. The MPCA currently has site-specific water quality criteria for six PFAS in select surface waters, including portions of the Mississippi River and St. Croix River and is planning to amend MINN. Rules Chapter 7050 to establish water quality standards for six PFAS. Additionally, Minnesota has soil reference values (spreadsheet) available for select non-pesticidal PFAS.

While different types of guidance values are available for non-pesticidal PFAS in various matrices, it is worth noting these values are typically only available for a small fraction of the thousands of chemicals classified as PFAS. Given the size and diversity of the PFAS class of chemicals, the potential risks posed by individual chemicals can vary greatly. For example, the MDH's HRLs/HBVs (Table 2) and the EPA's Aquatic Life Benchmarks and Aquatic Life Water Quality Criteria (Table 3) for chemicals classified as PFAS by Minnesota's definition can vary by orders of magnitude.

The potential risk (i.e., chance of harmful effects from exposure to a chemical) from different PFAS varies greatly. PFAS can drastically differ in their toxicity to humans and other organisms and in how they move and break down in the environment, which impacts the potential for exposure.

Table 2. Minnesota Department of Health human health-based water guidance for select PFAS and pesticide active ingredients that are considered PFAS under Minnesota Statute (MINN. STAT. 18B.01 subd. 15c). Value types include health risk limits (HRLs) and health based values (HBVs) with subscripts indicating the year of development.

Chemical	Value (ppb)	Value Type	Approved for Use in Pesticides
Perfluorobutane Sulfonate (PFBS)	0.1	HRL_{23}, short-term, chronic, and sub-chronic	No
Perfluorobutanoate (PFBA)	7	HRL_{18}, short-term, chronic, and sub-chronic	No
Perfluorohexane sulfonate (PFHxS)	0.047	HRL_{23}, short-term, chronic, and sub-chronic	No
Perfluorohexanoate (PFHxA)	0.2	HRL_{23}, short-term, chronic, and sub-chronic	No
Perfluoroctanoic acid (PFOA)	0.0000079	HBV_{24}, cancer	No
Perfluorooctane sulfonate (PFOS)	0.0023	HBV_{24}, short-term, chronic, and sub-chronic	No
Fomesafen	20	HRL_{23}, chronic	Yes
Isoxaflutole	7	HBV_{24}, chronic	Yes

Table 3. The U.S. Environmental Protection Agency Aquatic Life Benchmarks (ALB) and aquatic life water quality criteria (ALWQC) for select PFAS and pesticide active ingredients that are considered PFAS under Minnesota Statute (MINN. STAT. 18B.01 subd. 15c).

Chemical	Value (ppm)	Value Type	Approved for Use in Pesticides
Perfluorobutane Sulfonate (PFBS)	5.0	ALB (Acute Freshwater)	No
Perfluorobutanoate (PFBA)	5.3	ALB (Acute Freshwater)	No
Perfluorohexane sulfonate (PFHxS)	0.21	ALB (Acute Freshwater)	No
Perfluorohexanoate (PFHxA)	4.8	ALB (Acute Freshwater)	No
Perfluoroctanoic acid (PFOA)	3.1	ALWQC (Acute Water Column)	No
Perfluorooctane sulfonate (PFOS)	0.071	ALWQC (Acute Water Column)	No
Fomesafen	63 188	ALB (Acute Freshwater Fish) ALB (Acute Freshwater Invertebrates)	Yes
Isoxaflutole	>0.85 >0.75	ALB (Acute Freshwater Fish) ALB (Acute Freshwater Invertebrates)	Yes

PFAS Regulations and Actions

Regulations to limit PFAS use are being passed in other countries and states. While select PFAS are being regulated as individual chemicals (e.g., PFOA), a growing number of jurisdictions, including Canada, the European Union (EU), and several U.S. states, are regulating or proposing regulations to address PFAS as a class. This section provides an overview of regulations that limit the manufacture, import, sale, use, and disposal of PFAS as it may relate to pesticides.

Federal and International

The Stockholm Convention on Persistent Organic Pollutants is an international treaty seeking to protect human health and the environment from persistent organic pollutants. The Stockholm Convention includes regulation to eliminate use of the PFAS chemicals PFOS and its derivatives; PFOA, its salts, and PFOA-related compounds; and PFHxS, its salts, and related compounds. Currently, long-chain perfluorocarboxylic acids (LC-PFCAs) (C9-21) are being considered for inclusion in the Stockholm Convention. Notably, the U.S. signed the Stockholm Convention in 2001 but has yet to ratify the treaty.

European Union

The European Chemicals Agency (ECHA) uses Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) to protect human health and the environment from risks posed by chemicals including PFAS. From February 2023 onwards, REACH restricted PFCAs (C9-14), along with their salts and precursors, in the European Union (EU) and European Economic Area (EEA) following a decision by the European Commission. ECHA continues to assess the potential risk to human health and the environment from the manufacturing or use of additional PFAS.

In January 2023, five European authorities (Denmark, Germany, the Netherlands, Norway, and Sweden) submitted a proposal to ECHA to limit the use of PFAS in the EU. The proposal seeks restrictions on both the use and production of around 10,000 PFAS to reduce negative effects on humans and the environment. The five European authorities and ECHA are currently reviewing more than 5,600 scientific and technical comments received in response to the proposal.

Notably, "plant protection products" and "biocidal products," (i.e., pesticide products), are recommended to be excluded from restrictions in the proposal. The authors acknowledge that pesticide ingredients are sometimes PFAS but that they are "already regulated in the EU with extensive evaluations and approval processes by designated bodies with specific expertise and experience." The authors also note that limiting the number of available pesticides generally aggravates resistance management. Thus, they proposed that pesticide active ingredients be exempt from restrictions under this proposal, but still recommend pesticides be required to report on the PFAS chemicals to the European Commission.

Canada

In Canada, the manufacture, use, sale, offer for sale, or import of PFOS, PFOA, LC-PFCAs, and products that contain them have been prohibited since 2016. Recognizing that the PFAS used to replace PFOS, PFOA, and LCPFCAs may also be associated with environmental and/or human health effects, the Government of Canada published a notice of intent to address concerns related to PFAS in April 2021. The Government of Canada published in May 2023 a draft state of PFAS report and a Risk Management Scope for PFAS for public comment. The reports and proposed conclusion are intended to inform decision-making on PFAS as a class in Canada. However, the draft reports do not categorize agricultural chemicals or pesticides as a separate subgroup.

Australia

The Australian government has taken a precautionary approach to managing existing PFAS contamination, working to prevent or reduce environmental and human PFAS exposure wherever possible. Efforts have mainly been directed at contamination created by historical use of PFAS. Investigations are conducted across Australia to establish a greater understanding of the contamination extent and likely impacts on surrounding communities and, when necessary, developing management strategies tailored to the unique site conditions.

Longstanding regulation of pesticides exists around the world with extensive evaluations and approval processes. While there is a proposed ban of products with PFAS in the EU and the European Economic Area, five countries have proposed that pesticides be excluded from the ban.

Other U.S. States

May states in recent years, including California, Colorado, Connecticut, Hawaii, Illinois, Indiana, Maryland, Michigan, New Hampshire, New York, Oregon, Rhode Island, Vermont, Washington, and Wisconsin, have passed laws prohibiting PFAS use in non-pesticidal product categories such as food packaging, firefighting foam, ski wax, and rugs and carpets. As of November 2024, three states besides Minnesota have enacted major laws related to PFAS and pesticides. They are Maine, Maryland, and Massachusetts. The California Legislature passed a bill in 2022 requiring registration of all products containing intentionally added PFAS by 2026, but it was vetoed.

In 2021, Maine passed the first extensive ban and information collection requirement law (Public Law 2021, c. 477) for PFAS in all products and product components, which includes pesticide products. While sales prohibitions on products containing intentionally added PFAS remain, the law was amended in April 2024 to eliminate the information collection requirement (Public Law 2023, c. 630 [PDF]). The prohibitions applicable to pesticides and fluorinated containers start January 1, 2032 and include “any products containing intentionally added PFAS sold in Maine unless the use of PFAS in the product is a currently unavoidable use,” and “products that do not contain intentionally added PFAS but that are sold, offered for sale, or distributed for sale in a fluorinated container or in a container that otherwise contains intentionally added PFAS” (Maine Department of Environmental Protection, n.d., para. 2).

Maryland passed the “Pesticides – PFAS Testing – Study” law in 2023 (SB 158/HB 319), requiring the Maryland Department of Agriculture, in consultation with the Departments of Environment and Health and the EPA, to prepare a report on the use of PFAS in pesticides in the state, including: assessing human and environmental risks of PFAS in pesticides, identifying methods to test for PFAS in pesticides, and summarizing federal efforts to test for or regulate and ban PFAS in pesticides. The report was presented to the governor of Maryland in October 2023 (MDA, 2023).

In Massachusetts, the Mosquito Control for the Twenty-First Century Task Force (MCTF) was created in 2020 (Chapter 120 of the Acts of 2020). One of the topics the task force was directed to review and make recommendations on was "promoting the use of the safest or minimum risk pesticides feasible and employing methods, including product disclosures or implementation of testing protocols and procedures, to avoid the use of pesticides containing per- and polyfluoroalkyl substances." In April 2022, the MCTF submitted its recommendations (Mosquito Control for the Twenty-First Century Task Force, 2022) to avoid the use of pesticides containing PFAS and other contaminants which included:

- Using available analytical methods to ensure pesticides registered in Massachusetts are not contaminated with PFAS or emerging contaminants of concern;
- Identifying pesticides that might have unintended properties possibly through bioassay screening;
- Preventing the sale or use of mosquito pesticides contaminated with PFAS or emerging contaminants of concern;
- Defining or categorizing "persistence," as it relates to pesticides; and
- Making appropriate registration decisions based on new information from the EPA, including evaluating whether substances should be added to the Groundwater Protection List.

In 2024, Connecticut (PA 24-49 [PDF]) and Colorado (SB 24-081[PDF]) passed laws banning the sale of cleaning products with intentionally added PFAS. Cleaning products that make pesticidal claims and have an EPA pesticide registration number may be impacted by these laws.

Sources of PFAS Pollution

PFAS are used globally in many consumer and industrial products. With the large number of chemicals that may be considered PFAS and their wide range of uses, it can be challenging to identify specific sources of PFAS pollution. Additionally, PFAS are known to be persistent, highly mobile, and found in inhabited and uninhabited areas worldwide (Rankin et al., 2016). Therefore, it is expected that some amount of PFAS will be found in all environments. Detections of PFAS in the environment at high concentrations have typically been associated with industrial sites, facilities where aqueous film forming foam (AFFF) has been used (e.g., military complexes), landfills, and sites where biosolids/municipal wastewater treatment sludge have been applied (Brunn et al. 2023; Ghisi et al. 2019).

Sources of PFAS in Agricultural Lands

Because agricultural lands are directly linked to our food source, PFAS pollution is of great interest and concern. PFAS in agricultural lands can originate from various sources, including biosolids applied as fertilizer (Cousins et al., 2022), atmospheric deposition from fluoropolymer manufacturing and use (Prevedouros et al., 2006), irrigation supplied from PFAS-contaminated water (Kwiatkowski et al., 2020), and/or pesticides (Ogawa et al., 2020). Overall, the contribution of pesticides to total PFAS pollution in agricultural lands or other sites is unclear; however, the EPA regulates the total amount of pesticide active ingredients allowed per acre to be applied on an annual basis.

To date, regulation of PFAS in agricultural lands has largely focused on biosolids. Biosolids, sometimes referred to as sewage sludge, are a product of wastewater treatment. It is worth mentioning that animal manures are not the same as biosolids, though both can be applied as fertilizer. Land application of biosolids can offer a number of benefits including nutrient addition and improved soil structure and, in addition to landfilling and incineration, is a means of disposal for this common wastewater treatment product. However, contaminated biosolids can introduce PFAS to agricultural lands. PFAS can enter wastewater treatment facilities from various sources including industrial waste streams and personal care products containing PFAS that are washed down the drain and then end up in biosolids (Saliu & Sauvé, 2024). While biosolids may undergo treatment to remove or destroy specific pollutants, such as heavy metals, they are not required to be treated for PFAS as PFAS are not listed as pollutants under the Minnesota Sewage Sludge Management Rule (PDF). As of December 2024, the EPA has not set regulatory limits for PFAS in land applied biosolids; however, the MPCA has published a proposed PFAS in Biosolids Strategy (PDF) outlining limits for PFAS in land applied biosolids that will be finalized in early 2025. The proposed strategy applies to all wastewater treatment facilities that intend to apply biosolids to land and includes sampling and response actions based on sample results. According to the National Biosolids Data Project, biosolids are applied to <1% of farmland in Minnesota (National Biosolids Data Project, n.d.). The EPA publishes biennial biosolids reviews, as required by the Clean Water Act. In the most recent report from 2020-2021, the EPA reported that a total of 26 different PFAS have been found in biosolids across all the studies they reviewed (USEPA, 2022a).

In response to concerns over PFAS in biosolids, several states have developed programs and guidance to mitigate the land application of contaminated biosolids. Maine, Connecticut, and Michigan have each taken distinct approaches. Maine passed a law in 2021 (LD 1600) requiring the evaluation of soil and groundwater for PFAS at locations licensed to apply sludge or septage to land. Then, in 2022, Maine passed another law (LD 1911) restricting the application of sludge and sludge-derived compost that contain levels of PFAS above the state determined safe levels (≥2.5 ppb, depending on the specific PFAS). Michigan has been working on PFAS in biosolids for many years. The Michigan Department of Environment, Great Lakes, and Energy began a statewide study in 2018 evaluating the presence of PFAS in land applied biosolids. Michigan implemented an Interim PFAS Strategy in 2021 focused on biosolid sampling, PFAS source identification and reduction, and landowner and farmer communication. In the most recent update to the Interim PFAS Strategy released in 2024, it was stated that biosolids/sludge with PFOS or PFOA concentrations above 100 ppb would be considered “industrially impacted” and may not be land applied. In addition to the “industrially impacted” category biosolids/sludge with a concentration of PFOS or PFOA over 20 ppb are considered “elevated” and must be applied at a reduced rate. There were no additional requirements added to biosolids/sludge with a PFOS or PFOA concentration less than 20 ppb (Department of Environment, Great Lakes, and Energy, n.d., para. 2). Connecticut passed Public Act 24-59 in 2024 which bans the sale or use of any biosolids or wastewater sludge as a soil amendment if it contains PFAS.

Other states have begun to implement testing for PFAS in biosolids. New Hampshire, for example, amended its Sludge Quality Certificate Program Requirements to include PFAS testing. The Massachusetts Department of Environmental Protection has required that residuals approved for land application (which includes biosolids) must be monitored for PFAS on a quarterly basis (Massachusetts Department of Environmental Protection, n.d., para. 1). Michigan also requires testing for PFAS in all land-applied biosolids (Department of Environment, Great Lakes, and Energy, n.d., para. 6).

A less studied path by which PFAS can enter agricultural lands is through aerial deposition. Aerial deposition can occur when PFAS chemicals from industrial processes (Prevedouros et al., 2006) or waste management (e.g., incineration (Longendyke et al., 2022)) move through the air and are deposited on agricultural lands. For example, in North Carolina, fluorotelomer manufacturing activities were found to release PFAS into the air via stack emissions. The North Carolina Department of Environmental Quality Air Quality Division performed weekly deposition sampling that detected hexafluoropropylene dimer acid (also called HFPO-DA or “Gen X”) in samples from the area surrounding a manufacturing facility which had produced Gen X for manufacturing purposes. Research has also shown that when PFAS-impacted wastes are incinerated, the heat is not necessarily sufficient to break down PFAS completely, leading to incomplete combustion where larger PFAS are broken down into smaller molecules that would still be considered PFAS (USEPA, 2020).

The use of PFAS-contaminated water in agriculture represents another potential source of PFAS. Use of PFAS-contaminated water can lead to the accumulation of PFAS in crops (Bao et al., 2020) and products of livestock such as meat and dairy (Jha et al., 2021). A notable example comes from New Mexico, where PFAS contamination of agricultural land has been linked to the U.S. Department of Defense’s use of fire-suppressing aqueous film-forming foams (AFFF) at Holloman and Cannon Air Force Bases. Contamination of shared water resources has impacted neighboring dairy operations, resulting in unsafe PFAS levels in milk and substantial financial losses, with millions of dollars in milk production lost (New Mexico Petition to the USEPA). In 2023, the New Mexico Environment Department began testing private domestic wells for PFAS across the state and the FDA reported extremely high levels of PFAS in milk from cows that were given AFFF contaminated water (47-169 parts per trillion [ppt] PFOA and 881–5680 ppt PFOS) (FDA, 2021).

While the EPA limits the maximum amount of an active ingredient that can be applied to an area in a given year, there are no federal regulatory limits for the amount of PFAS that can be applied via contaminated biosolids.

Pesticide Degradates

Despite being called “forever chemicals,” PFAS can break down or degrade in the environment. Degradation is beneficial in that it reduces the concentration of the parent PFAS; however, it can also lead to the production of new, different PFAS. For example, fluorinated chemicals that contain a trifluoromethyl group can potentially degrade to form trifluoroacetic acid (TFA), a PFAS chemical according to Minnesota Statute (Solomon et al., 2016). TFA can potentially form from numerous PFAS chemicals including several pesticide active ingredients registered in Minnesota that contain a trifluoromethyl group (e.g. tefluthrin, trifluralin, and tau-fluvalinate). Pesticide degradation studies typically focus on initial degradates; as such, there have been few published studies that follow the entire pathway of degradation to determine the formation of TFA or other fluorinated terminal degradates (Solomon et al., 2016). The EPA determines degradates of concern by taking into account the chemical structure of the degradates, their prevalence, and their toxicity.

Monitoring for PFAS

Monitoring PFAS is critical to evaluating contamination in the environment, environmental sources of PFAS, and potential exposure to PFAS. While some PFAS, such as those that are pesticides, have a well-established history of monitoring, many others do not. Monitoring efforts focused on non-pesticidal PFAS have increased in recent years largely due to increased concerns over widespread contamination and the potential health effects of PFAS; however, efforts have focused on only a fraction of the thousands of chemicals that fall within the PFAS class. Which PFAS are monitored can depend on the known or predicted risk of the chemicals, the location, and the analytical methods available.

A laboratory requires analytical methods to test for the presence and/or concentration of a chemical. Analytical methods to test water, plants, soil, and other matrices are commonly available for pesticides, including those that are classified as PFAS. Analytical methods for non-pesticidal PFAS, including a number of EPA validated methods, have been published and are commercially available; however, these methods typically only identify and quantify less than 50 non-pesticidal PFAS analytes. Alternative approaches to monitoring for individual PFAS also exist (e.g., total organic fluorine analysis and non-targeted analysis [See "Testing for PFAS in Pesticide Products" section]), but the majority of PFAS monitoring data available is based on chemical-specific analysis.

PFAS in Minnesota's Environment

In Minnesota, PFAS have been detected in soil (Rankin et al., 2016; Scher et al., 2018), groundwater (MPCA, 2021), surface water (Simcik & Dorweiler, 2005), rain (Gewurtz et al., 2019), and air (MPCA, 2021); however, detected concentrations range widely depending on the specific PFAS and sampling location. The MPCA has published reports on a number of PFAS monitoring efforts and also summarized ambient PFAS levels in environmental matrices (i.e., PFAS levels not directly associated with industry, commercial, or agricultural environmental inputs), which are needed to understand baseline levels of contamination in the environment (MPCA, 2024a). In 2022, the MPCA launched its PFAS Monitoring Plan aimed at identifying possible sources or conduits of PFAS entering the environment (e.g., wastewater, hazardous waste landfills, Superfund sites) (MPCA, 2022); initial findings and next steps were published in April 2024 (MPCA, 2024b).

It is important to note that much of what is considered "PFAS monitoring" focuses on select non-pesticidal PFAS, such as PFOS and PFOA. Monitoring data for many of the pesticide active ingredients categorized as PFAS under MINN. STAT. 18B.01 subd. 15c are available through various "pesticide monitoring" programs and studies. In Minnesota, the MDA monitors for over 180 pesticide-related chemicals in groundwater and surface water through its water quality monitoring program. Chemicals are carefully selected for monitoring based on a number of factors including a chemical's persistence, toxicity, and sales in Minnesota. Thirty-one of the monitored analytes are, or are associated with, currently registered pesticide active ingredients that are categorized as PFAS in Minnesota (Table 3). Details regarding the number of detections, concentrations, and method reporting limits for the monitored analytes are available on the MDA's website, the MDA's annual water quality monitoring reports, and through the Water Quality Portal. Concentrations of PFAS pesticide active ingredients detected in 2023, as well as applicable reference values, can be found in Appendix C. Data on pesticide active ingredients in water is also available through the United States Geological Survey (USGS) and other published studies (e.g.,[Chow et al., 2020; De Souza et al., 2020]).

Table 4. The Minnesota Department of Agriculture's water monitoring detections (2018-2023) for pesticide active ingredients categorized as PFAS under Minnesota Statute (MINN. STAT. 18B.01 subd. 15c).

EPA PC Code	CAS Number	Analyte Name	Detected in Groundwater 2018-2023	Detected in Rivers/Streams 2018-2023
114402	62476-59-9	Acifluorfen	Yes	Yes
084301	1861-40-1	Benfluralin	No	No
118831	68359-37-5	Cyfluthrin	No	No
018986	352010-68-5	Bicyclopyrone	Yes	Yes
128825	82657-04-3	Bifenthrin	No	Yes
128400	581809-46-3	Bixafen	No	No
129116	147150-35-4	Cloransulam-methyl	No	Yes
128994	97886-45-8	Dithiopyr	No	No
113101	55283-68-6	Ethalfluralin	No	No
129121	120068-37-3	Fipronil	No	Yes
NA	201668-31-7	Flufenacet OXA	No	No
129016	98967-40-9	Flumetsulam	Yes	Yes
128940	76674-21-0	Flutriafol	No	Yes
138009	907204-31-3	Fluxapyroxad	Yes	Yes
123803	72178-02-0	Fomesafen	Yes	Yes
117501	943831-98-9	Halauxifen-methyl	No	No
123000	141112-29-0	Isoxaflutole	No	Yes
128897	91465-08-6	lambda-Cyhalothrin	No	No
122000	1417782-03-6	Mefentrifluconazole	No	Yes
090088	403640-27-7	Methiozolin	No	No
016331	609346-29-4	Momfluorothrin	No	No
105801	27314-13-2	Norflurazon	No	Yes
128111	1003318-67-9	Oxathiapiprolin	No	No
129200	117428-22-5	Picoxystrobin	No	No
090099	447399-55-5	Pyroxasulfone	No	Yes
118203	372137-35-4	Saflufenacil	Yes	Yes
012801	335104-84-2	Tembotrione	Yes	Yes
120603	112281-77-3	Tetraconazole	Yes	Yes
090097	1229654-66-3	Tetraniliprole	No	No
129112	141517-21-7	Trifloxystrobin	No	No
036101	1582-09-8	Trifluralin	No	Yes

PFAS in Agricultural Commodities and Drinking Water

In addition to monitoring for PFAS in the environment, monitoring efforts can focus on potential sources of dietary exposure in humans (i.e., food and drinking water). As with environmental monitoring, data available through "PFAS monitoring" studies typically relate to a subset of non-pesticidal PFAS and data on pesticidal active ingredients considered to be PFAS comes from other pesticide monitoring studies or programs.

In 2019, the FDA began testing for PFAS in foods to estimate dietary exposure to PFAS from the general food supply. The FDA's Total Diet Study and Pesticide Residue Monitoring Reports are key sources of PFAS monitoring data in U.S. food. Compared to non-pesticidal PFAS monitoring in food, pesticide monitoring has a long history and a more extensive data set is available. Because pesticide active ingredients used on food and feed crops must not exceed tolerances set by the EPA (40 CFR Part 180), the FDA and USDA regularly monitor pesticide residues in and on food. The FDA publishes annual reports summarizing results from its pesticide residue monitoring program, and data on detections of active ingredients (including those considered PFAS) in different agricultural commodities is also available through the USDA's Pesticide Data Program Database. The MDA reviewed the USDA data from 2014 to 2022 and found that during that period, there were 471 exceedances of tolerances related to 28 pesticide active ingredients that would be considered PFAS.

Drinking water systems throughout the U.S. have been monitored for a number of PFAS, and monitoring is now required at all public water systems for six PFAS for which the EPA has set MCLs. In Minnesota, the MDH tested community water systems throughout the state and developed an Interactive Dashboard for PFAS Testing in Drinking Water to display the results and provide information on detected concentrations in relation to available standards and guidance. The MDH has also monitored a number of non-pesticidal PFAS and PFAS pesticide active ingredients through its Unregulated Contaminants Monitoring Project (UCMP) (MDH, 2023). The PFAS pesticide active ingredients monitored for through the UCMP and detections in drinking water are summarized in Table 4. The MDA, through its Private Well Pesticide Sampling Project, has also monitored drinking water for pesticides, including some of which that are considered PFAS (See Appendix D). Monitoring data for PFAS active ingredients in drinking water can also be gleaned from a variety of other pesticide studies by the MDA, MDH, and other entities (e.g., 2015 Reconnaissance Study of Pesticide Compounds in Community Public Water Supply Wells (MDA, 2016)).

Table 5. The Minnesota Department of Health's Unregulated Contaminants Monitoring Project detections of pesticide active ingredients categorized as PFAS under Minnesota Statute (MINN. STAT. 18B.01 subd. 15c) in finished drinking water from community water systems (2019-2021).

EPA PC Code	CAS Number	Analyte Name	Detected in Finished Drinking Water from Community Water Systems 2019-2021
128825	82657-04-3	Bifenthrin	No
108201	35367-38-5	Diflubenzuron	No
005107	109293-97-2	Diflufenzopyr	No
107091	153233-91-1	Etoxazole	No
129121	120068-37-3	Fipronil	No
129016	98967-40-9	Flumetsulam	Yes
067710	173584-44-6	Indoxacarb	No
123000	141112-29-0	Isoxaflutole	No
105801	27314-13-2	Norflurazon	No
124002	116714-46-6	Novaluron	No
120603	112281-77-3	Tetraconazole	Yes
129112	141517-21-7	Trifloxystrobin	No

Food, drinking water, and the environment have routinely been monitored for pesticides, including many of those considered PFAS in Minnesota.

PFAS Remediation

Despite being called forever chemicals, there are methods that have been developed that can effectively remove or immobilize PFAS in the environment. Remedial techniques have been developed for a variety of matrices including soil, surface water, and groundwater (ITRC, n.d., para. 6). There are three main strategies for PFAS treatment which include stabilization/immobilization, removal, and destruction.

Stabilization/immobilization of PFAS compounds is typically the most cost-effective strategy for PFAS remediation as it can be performed in situ. In situ or “in place” remediation can be completed without moving contaminated media which can significantly reduce the overall cost of treatment. Methods such as these do not remove or destroy PFAS, but they prevent horizontal or vertical migration of a PFAS plume in soil or groundwater. Examples of immobilization techniques include injecting colloidal activated carbon into aquifers (Niarchos et al., 2023) and using soil amendments such as biochar and activated carbon (Navarro et al., 2023).

PFAS removal has been executed at a large scale with many different technologies. One of the most commonly employed removal methods is granular activated carbon, also known as GAC. GAC can be utilized on a small scale in in-home treatment designs, but it has also been effectively scaled to remove PFAS in full-scale drinking water treatment plants (Belkouteb et al., 2020). In addition to GAC, there are various other removal methods for contaminated water including reverse osmosis, ion exchange resin, and foam fractionation (Amen et al., 2023). Removal methods for contaminated soil include soil washing and thermal treatment (Bolan et al., 2021). Removal methods are usually more costly than stabilization/immobilization treatments as they require pumping or excavating the contaminated media.

The most energy intensive and technically challenging strategy to remediate PFAS is destruction. The strength of the carbon-fluorine bond makes PFAS very difficult to destroy completely. Incineration was previously viewed as a viable method for PFAS destruction; however, subsequent research has found that incineration can lead to the the production of shorter chain PFAS that have not been sufficiently broken down. These shorter chain PFAS are also called products of incomplete combustion (USEPA, 2020). There are very few available methods that have achieved complete PFAS destruction. Some of the more promising technologies that have demonstrated mineralization of PFAS are plasma treatments, sonolysis, supercritical water oxidation, and thermal degradation (Meegoda et al., 2022). It is important to note that these technologies are largely still in the developmental stage.

MDA's Previous and Ongoing Work on PFAS in Pesticides

The MDA recognized potential concerns with select PFAS in pesticides over 15 years ago and has since been working to track and understand their presence in pesticide products used in Minnesota. The MDA carefully tracks EPA actions and other published literature related to pesticides and PFAS and is committed to ensuring that the use of pesticides in Minnesota will not endanger humans, damage agricultural products, food, livestock, fish, or wildlife, or cause unreasonable adverse effects on the environment.

The MDA first examined pesticide active and inert ingredients as a potential source of PFAS in the environment in 2007. Through its review, the MDA identified one active ingredient (sulfluramid) and one inert ingredient (Fluowet PL-80) that may contribute to PFAS in the environment. The MDA determined that neither ingredient was likely a significant source of PFAS at the time. Fluowet PL-80 has since been cancelled, and sulfluramid has not been registered for use by the EPA for over a decade. It is important to note that the MDA did not have a set structural definition of PFAS to apply at the time, and instead reviewed ingredients for structures that resembled well-known PFAS like PFOS and PFOA.

More recently, the MDA reviewed the mosquito control product Anvil 10+10 as a potential source of PFAS in the environment after the EPA announced that PFAS had been detected in the product. In 2020, the EPA began investigating the potential source of PFAS in Anvil 10+10 and determined that the detected PFAS had leached from the product packaging (See the "Other Sources of PFAS in Pesticides" section). Based on Minnesota sales data for the active ingredient in Anvil 10+10 (phenothrin), the MDA concluded this product was not likely a significant source of PFAS in the state. However, it is unclear at this time how widespread of an issue PFAS leaching from fluorinated containers into pesticide products is and if it could be a significant source of PFAS in the environment. There is an ongoing effort by the EPA to regulate the fluorination procedures for HDPE containers to address the potential leaching of PFAS into products (See "PFAS Regulatory Framework" section).

The MDA's previous and ongoing work also involves tracking articles related to PFAS and pesticides in scientific literature. While the number of papers published specifically on PFAS in pesticides is limited, one example of a recent article on the topic is by Lasee et al. (2022). The study by Lasee et al. (2022) reported detections of PFAS, specifically PFOS, in six out of 10 pesticide products tested; however, the EPA was unable to confirm the results using their own analytical laboratory tests (USEPA, 2023b). Another notable paper exploring the topic of PFAS and pesticides was published in 2024 by Donley et al. (2024). In addition, the MDA is reviewing literature related to fluorinated pesticides (e.g., Ogawa et al., 2020), as many fluorinated pesticides meet the Minnesota's definition of PFAS, along with various reports, webinars, and other sources of information shared by different states and organizations.

The MDA is continuing to track changes to the PFAS definitions being used by the EPA. In 2021, the EPA OPP began applying the EPA OPPT's 2021 "working definition" of PFAS to identify pesticide active or inert ingredients that would be considered PFAS. The EPA OPPT's 2021 working definition defined PFAS as "a structure that contains the unit R-CF2-CF(R')(R''), where R, R', and R'' do not equal "H" and the carbon-carbon bond is saturated." This definition included branching, heteroatoms, and cyclic structures (USEPA, n.d., para. 14). Previously, EPA had determined that there were no pesticide active or inert ingredients with structures similar to prominent PFAS (e.g., PFOS, PFOA, GenX). The EPA is in the process of evaluating all pesticide active ingredients to determine which would be considered PFAS; however, EPA has not yet published the results of their evaluation. The EPA also conducted a review of chemical substances approved for use as inert ingredients based on the EPA OPPT 2021 working definition. In December 2022, the EPA removed 12 PFAS inert ingredients from its list of approved inert ingredients, none of which were being used in registered pesticide products at that time (EPA-HQ-OPP-2022-0542). The EPA also proposed the removal of Teflon, also known as polytetrafluoroethylene or PTFE, from the list of approved ingredients in February of 2024.

The MDA independently conducted a preliminary review of pesticide active ingredient structures based on the EPA OPPT's 2021 working definition and identified at least two active ingredients (broflanilide and pyrifluquinzon) that meet the structural criteria to be PFAS. As previously described, the MDA also reviewed pesticide active ingredients registered in Minnesota and identified 97 active ingredients that meet Minnesota's definition of PFAS (See "Active Ingredients" section and Appendix B). From this list of 97 active ingredients, the identified six that would be considered PFAS based on the EPA OPPT's updated 2023 definition (See Table 1). The MDA has also independently reviewed EPA's inert ingredient list to determine which are considered PFAS by Minnesota's definition and has identified 12 additional inert ingredients (See "Inert Ingredients and Adjuvants" section and Appendix B.)

Implementation of PFAS Regulation for Minnesota Pesticide Products

The MDA will collect information on, implement prohibitions for, and make evaluations of "currently unavoidable use" (CUU) for pesticide products regulated under Minnesota law (MINN. STAT. 18B), which includes pesticide products with an EPA registration number. Details on the information required, determining CUU exemptions, assessing the necessity of pesticides containing intentionally added PFAS, and the risks of alternative products are discussed below. Information about how the MDA is implementing the PFAS laws for pesticides is also on the MDA's "Products with Added PFAS" website. In addition, the MDA hosted a webinar titled "Regulation of Pesticide Products Containing Intentionally Added PFAS".

Required Information

Reporting

Beginning in 2026, new pesticide registration applications and renewal forms will require verification that no intentionally added PFAS exists in each product. Registrants or agents will have to certify the accuracy of the PFAS information with a signature annually. If a product contains intentionally added PFAS, the MDA will send a follow-up letter requesting additional information about the PFAS. The letter will include directions for what to submit and how to access a secure portal to upload information (MINN. STAT. 18B.26 Subd. 7).

Data Privacy

Data submitted to the MDA is considered public data unless the pesticide registrant requests the data be considered trade secret (MINN. STAT. 18B.38) and the commissioner of agriculture determines the data qualifies for Trade Secret protection or other state or federal laws apply. During the information reporting process, registrants may note information they believe is trade secret that merits privacy protection at MDA. The MDA will review requests and make the determination whether information meets criteria for protection. Examples of information the commissioner may consider as confidential: identity or quantity of intentionally added inert ingredients, production, or other commercial/financial information.

Product Ban

Consequences of the Potential Loss of Pesticide Products

Given the breadth of chemicals considered PFAS under the Minnesota definition, many pesticide products may be classified as containing intentionally added PFAS as active or inert ingredients. The consequences of not registering pesticides with intentionally added PFAS are uncertain. Pesticide registrants can request a CUU exemption for their product; however, it is not known how many pesticide products contain intentionally added PFAS, how many pesticide registrants will request CUU exemptions, or how many CUU exemptions will be granted. Thus, determining the potential impact of pesticide product loss on agricultural production and other industries is difficult.

Resources and Potential Revenue Loss

No money has been allocated for the MDA to gather information on the intentional addition of PFAS in pesticide products, make CUU determinations, or to prohibit the sale and distribution of pesticide products containing intentionally added PFAS.

Revenue is generated through the registration and sale of pesticide products. There is an annual registration fee and a gross sales fee for pesticide products that are registered and sold in Minnesota. To illustrate potential revenue loss, fees from all pesticide products containing a PFAS-considered active ingredient were calculated. In total, these products provided approximately $1.7 million from registration and gross sales fees in 2022 ($757,000 in registration fees and $903,000 in gross sales fees). The actual total revenue loss expected from the PFAS in pesticides laws is uncertain because it is unknown how many additional pesticide products contain PFAS as inert ingredients, how many pesticide registrants will request and be granted CUU exemptions, or whether other pesticide products will replace those that are not registered.

Determining Currently Unavoidable Use

Registrations for pesticide products with intentionally added PFAS ingredients will be cancelled on January 1, 2026 (pesticidal cleaning products) or January 1, 2032 (all other pesticide products) unless the commissioner determines that the use of PFAS is a currently unavoidable use (CUU) (MINN. STAT. 18B.26 Subd. 8). Pesticide registrants will have the opportunity to apply for a CUU exemption prior to the cancellation of their product's registration. The MDA will assess exemption applications using the statutory definition of CUU, "a use of a PFAS that is essential for the health, safety, or functioning of society and for which alternatives are not reasonably available. Currently, unavoidable use may include consideration of the need to prevent or minimize potential pest resistance and the potential human health and environmental impacts of alternative products" (MINN. STAT. 18B.01 Subd. 6c).

A CUU application must be submitted individually for each product with an unique Minnesota pesticide registration number seeking an exemption and cover all intentionally added PFAS ingredients within the product. To be eligible for a CUU exemption, registrants should demonstrate why the PFAS ingredient is essential for the health, safety, or functioning of society and why alternatives are not reasonably available. If pertinent, registrants can demonstrate the need for the PFAS to prevent or minimize pest resistance or the potential human health and environmental impacts of alternative, non-PFAS products (MINN. STAT. 18B.26 Subd. 8). Data and information to support arguments will need to be submitted and should come from reputable sources such as peer-reviewed articles, EPA or government-authored documents, EPA accepted data or documents submitted as part of the federal pesticide registration process, and expert letters of support. Internal or external product performance data generated from laboratories inspected under the EPA's Good Laboratory Practice Standards Monitoring Program may also be accepted with a detailed explanation of methods and results. For more information on CUU exemption guidelines see the MDA's PFAS website.

Testing for PFAS in Pesticide Products

As regulations regarding PFAS are passed, the ability to test for PFAS in pesticides is critical. Reliable, robust analytical methods are necessary to enforce laws. The ability to test pesticide products for PFAS is also important for manufacturers/registrants to identify and quantify PFAS in their products, whether added intentionally or present as an impurity or byproduct. Under Minnesota's new law, the MDA may request analytical methods for intentionally added PFAS in pesticide products during the registration process.

With respect to pesticide active ingredients, which are intentionally added, analytical methods are generally widely available; therefore, a variety of methods are expected to exist for the active ingredients categorized as PFAS under the Minnesota definition. When available, the MDA can request analytical standards and methods for active ingredients and their degradates, or breakdown products, from pesticide registrants. The department has historically done this. Requests occur often for new active ingredients in Minnesota, particularly when there is interest in environmental monitoring. Inert ingredients, however, often do not have established analytical methods.

Analytical methods are also available for certain non-pesticidal PFAS; however, methods are not readily available for all PFAS chemicals. Targeted analysis is used to test a product for a specific, pre-determined list of known chemicals. Most targeted analytical methods focus on a small subset of PFAS, often widely used PFAS or those with known adverse human health or environmental effects (e.g., PFOS, PFOA, GenX). Currently, the EPA has validated methods to analyze for a limited number of PFAS in (e.g., Method 1633, 533, 537.1). In September

2021, the EPA released a method to detect 28 PFAS compounds in oily matrices that can be used for pesticide products formulated in oil, petroleum distillates, or mineral oils (USEPA, 2021a). The EPA released another method in May 2023 for analysis of PFAS in pesticide formulations containing non-ionic surfactants and non-volatile oils, which can be used to detect 29 PFAS compounds (USEPA, 2023a).

Given the quantity and diversity of PFAS compounds, interest is growing in using non-targeted analysis (NTA) to test for PFAS. NTA is a relatively new, developing approach to identifying unknown chemicals in a sample. While NTA could screen for a larger number of PFAS in pesticides compared to traditional targeted analyses, several challenges and limitations to its application exist at this stage (e.g., data-processing can be time consuming; follow-up analysis requiring standards is typically needed for quantification). The EPA Office of Research and Development (ORD) is working to provide guidance on NTA workflows and data libraries for PFAS identification and has been working on projects in collaboration with state agencies in California, Maryland, and Minnesota.

Total organic fluorine (TOF) is another type of analysis being employed by major commercial labs as a PFAS screening tool. TOF is a proxy measurement for total PFAS concentration in a sample and is thus not as informative as targeted analysis or NTA because it does not provide data on the types of PFAS present in a sample. There are also issues with accuracy in some cases as some organofluorine compounds could be detected by this method that would not be considered PFAS under even the broadest regulatory definitions.

The MDA has a laboratory that tests for chemicals in various matrices such as water, soil, plants, and food. Currently, the lab has capabilities to analyze for some PFAS chemicals in some matrices; however, without additional funding to cover new instruments, supplies, and staff time, it would be difficult to test for PFAS in pesticides or other matrices. Furthermore, the MDA laboratory's capacity to analyze for PFAS may be limited by the analytical methods and standards available for the large number of chemicals classified as PFAS. PFAS analysis is also available through some commercial laboratories, though not all testing laboratories are accredited by the EPA.

Necessity of and Alternatives for Pesticide Products Containing PFAS

Pesticides are an important tool for safe and adequate food production, prevention of human and animal diseases, protection of structures and human dwellings, and maintenance of natural environments. Pesticides are used globally to increase crop yields, manage microorganisms and their vectors that cause disease, prevent structural and nuisance pests, and stop invasive species from spreading. Safe and judicious use of pesticides is crucial to the protection of human health, the environment, and the food supply.

The MDA will collect information about pesticides containing intentionally added PFAS in Minnesota according to statute. However, at this time, much is still unknown about the extent to which registered pesticide products contain intentionally added PFAS inert ingredients. In 2024, most registrants did not voluntarily report if their products contain intentionally added PFAS, so a comprehensive summary was not able to be completed.

Until the MDA has received information from pesticide registrants about intentionally added PFAS in pesticide products, it will not be possible to fully understand and assess the use and necessity of pesticides containing PFAS in Minnesota. At this time, pesticide active ingredients have been screened to determine which meet the definition of PFAS; however, it is not known how many products contain PFAS inert ingredients. It is also unknown whether registrants will reformulate products to remove PFAS ingredients. Pesticide products containing active ingredients considered to be PFAS under the Minnesota definition make up approximately 15% (2,078 products) of all the pesticide products registered in the state in 2023 and accounted for approximately

1.3% of pesticide active ingredient sales (by weight) in Minnesota in 2023. Likewise, determining reasonable alternatives to pesticides with intentionally added PFAS will be difficult until the MDA has received information from pesticide registrants about intentionally added PFAS in all pesticide products.

Pesticide-related Products

While the following products are not under the MDA's authority to regulate for intentionally added PFAS, they are products that relate to pesticides.

Fluorinated Containers

It has been established that PFAS can leach from some fluorinated HDPE containers and enter liquid pesticide products; however, the fluorination technique used in the manufacturing of the container can impact its potential to leach PFAS along with the type of liquid stored in the container (e.g., water vs. organic solvent-based pesticides). Therefore, it is not possible to accurately predict which PFAS and how much of each may be present in pesticide products due to leaching from containers. Furthermore, the types of containers used to store pesticide products during manufacture, transport, and sale is not reported to the MDA. In general, the use of fluorinated containers for pesticides registered in Minnesota is expected to be extensive. Fluorinated pesticide containers fall under the purview of MINN. STAT. 116 and will be regulated by the MPCA.

Pesticide-treated Articles

Pesticide-treated articles are items treated with a pesticide to protect the item itself from pests (e.g., fungus, microbes, insects). "Treated articles" are exempt from FIFRA registration requirements. The pesticide may be added during or after manufacture, but it is always added before use of the article. Some examples of items that may be pesticide-treated articles include paint, wood, and seeds. Since pesticide-treated articles are exempt from pesticide registration requirements, there is limited information on their sale and use, the pesticide active ingredients used, and any other materials included in the product (e.g., dyes, lubricants, and polymers). Pesticides used for treating articles fall under the purview of the Pesticide Control Law (MINN. STAT. 18B), regulated by the MDA, but pesticide-treated articles fall under the purview of MINN. STAT. 116 and will be regulated by the MPCA. The MDA and the MPCA are working together to implement PFAS laws as they relate to pesticide-treated articles.

Personal Protective Equipment for Pesticide Application

Pesticide personal protective equipment (PPE) is garments or other equipment deemed necessary to ensure the safe handling and use of pesticides before, during, and after a pesticide application. PPE is used in many fields, such as medical settings, and some PPE are known to contain PFAS (e.g., anti-fog goggles, waterproof coveralls) (Cousins et al., 2019). However, PFAS use in some pesticide PPE is considered essential because it is required for human health and safety, and, in many cases, no safer alternatives exist (Bălan et al., 2023; Cousins et al., 2019). The EPA determines what PPE is required for a specific pesticide application during the pesticide registration process, and using the PPE listed on the label is legally required. In the near term, PPE intentionally treated with PFAS for the purpose of repelling substances will not be banned under Minnesota law (MINN. STAT. 116.943). Under that law, the MPCA will, in the future, determine whether PPE containing intentionally added PFAS will be exempted from the 2032 ban as a "currently unavoidable use."

References

Alexandrino, D. A. M., Almeida, C. M. R., Mucha, A. P., & Carvalho, M. F. (2022). Revisiting pesticide pollution: The case of fluorinated pesticides. *Environmental Pollution*, *292*, 118315. https://doi.org/10.1016/j.envpol.2021.118315

Amen, R., Ibrahim, A., Shafqat, W., & Hassan, E. B. (2023). A Critical Review on PFAS Removal from Water: Removal Mechanism and Future Challenges. *Sustainability*, *15*(23), 16173. https://doi.org/10.3390/su152316173

Bălan, S. A., Andrews, D. Q., Blum, A., Diamond, M. L., Fernández, S. R., Harriman, E., Lindstrom, A. B., Reade, A., Richter, L., Sutton, R., Wang, Z., & Kwiatkowski, C. F. (2023). Optimizing Chemicals Management in the United States and Canada through the Essential-Use Approach. *Environmental Science & Technology*, *57*(4), 1568–1575. https://doi.org/10.1021/acs.est.2c05932

Bao, J., Li, C.-L., Liu, Y., Wang, X., Yu, W.-J., Liu, Z.-Q., Shao, L.-X., & Jin, Y.-H. (2020). Bioaccumulation of perfluoroalkyl substances in greenhouse vegetables with long-term groundwater irrigation near fluorochemical plants in Fuxin, China. *Environmental Research*, *188*, 109751. https://doi.org/10.1016/j.envres.2020.109751

Belkouteb, N., Franke, V., McCleaf, P., Köhler, S., & Ahrens, L. (2020). Removal of per- and polyfluoroalkyl substances (PFASs) in a full-scale drinking water treatment plant: Long-term performance of granular activated carbon (GAC) and influence of flow-rate. *Water Research*, *182*, 115913. https://doi.org/10.1016/j.watres.2020.115913

Bolan, N., Sarkar, B., Yan, Y., Li, Q., Wijesekara, H., Kannan, K., Tsang, D. C. W., Schauerte, M., Bosch, J., Noll, H., Ok, Y. S., Scheckel, K., Kumpiene, J., Gobindlal, K., Kah, M., Sperry, J., Kirkham, M. B., Wang, H., Tsang, Y. F., … Rinklebe, J. (2021). Remediation of poly- and perfluoroalkyl substances (PFAS) contaminated soils – To mobilize or to immobilize or to degrade? *Journal of Hazardous Materials*, *401*, 123892. https://doi.org/10.1016/j.jhazmat.2020.123892

Brennan, A., Chang, D., Cowden, J., Davidson-Fritz, S., Dean, J., Devito, M., Ford, J., Everett, L., Harrill, A., Hester, S., Hughes, M., Lambert, J., Lizarraga, L., Mezencev, R., MacMillan, D., Patlewicz, G., Thayer, K., Thomas, R., Vitense, K., … Zhao, J. (2024). *Standard Methods for Development of EPA Transcriptomic Assessment Products (ETAPs)* (p. 0 Bytes). The United States Environmental Protection Agency's Center for Computational Toxicology and Exposure. https://doi.org/10.23645/EPACOMPTOX.25365496

Burriss, A., Edmunds, A. J., Emery, D., Hall, R. G., Jacob, O., & Schaetzer, J. (2018). The importance of trifluoromethyl pyridines in crop protection. *Pest Management Science*, *74*(6), 1228–1238. https://doi.org/10.1002/ps.4806

Chow, R., Scheidegger, R., Doppler, T., Dietzel, A., Fenicia, F., & Stamm, C. (2020). A review of long-term pesticide monitoring studies to assess surface water quality trends. *Water Research X*, *9*, 100064. https://doi.org/10.1016/j.wroa.2020.100064

Cousins, I. T., Goldenman, G., Herzke, D., Lohmann, R., Miller, M., Ng, C. A., Patton, S., Scheringer, M., Trier, X., Vierke, L., Wang, Z., & DeWitt, J. C. (2019). The concept of essential use for determining when uses of PFASs can be phased out. *Environmental Science: Processes & Impacts*, *21*(11), 1803–1815. https://doi.org/10.1039/C9EM00163H

Cousins, I. T., Johansson, J. H., Salter, M. E., Sha, B., & Scheringer, M. (2022). Outside the Safe Operating Space of a New Planetary Boundary for Per- and Polyfluoroalkyl Substances (PFAS). *Environmental Science & Technology*, *56*(16), 11172–11179. https://doi.org/10.1021/acs.est.2c02765

De Silva, A. O., Armitage, J. M., Bruton, T. A., Dassuncao, C., Heiger-Bernays, W., Hu, X. C., Kärrman, A., Kelly, B., Ng, C., Robuck, A., Sun, M., Webster, T. F., & Sunderland, E. M. (2021). PFAS Exposure Pathways for Humans and Wildlife: A Synthesis of Current Knowledge and Key Gaps in Understanding. *Environmental Toxicology and Chemistry*, *40*(3), 631–657. https://doi.org/10.1002/etc.4935

De Souza, R. M., Seibert, D., Quesada, H. B., De Jesus Bassetti, F., Fagundes-Klen, M. R., & Bergamasco, R. (2020). Occurrence, impacts and general aspects of pesticides in surface water: A review. *Process Safety and Environmental Protection*, *135*, 22–37. https://doi.org/10.1016/j.psep.2019.12.035

Donley, N., Cox, C., Bennett, K., Temkin, A. M., Andrews, D. Q., & Naidenko, O. V. (2024). Forever Pesticides: A Growing Source of PFAS Contamination in the Environment. *Environmental Health Perspectives*, *132*(7), 075003. https://doi.org/10.1289/EHP13954

EGLE. (n.d.). *Interim Strategy – Land Application of Biosolids Containing PFAS (2024)*. Retrieved October 15, 2024, from https://www.michigan.gov/egle/about/organization/water-resources/biosolids/pfas-related

FDA. (2021). *Analytical Results for PFAS in 2018-2021 Dairy Farm Sampling (Parts Per Trillion)*. https://www.fda.gov/media/127850/download?attachment

Fenton, S. E., Ducatman, A., Boobis, A., DeWitt, J. C., Lau, C., Ng, C., Smith, J. S., & Roberts, S. M. (2021). Per- and Polyfluoroalkyl Substance Toxicity and Human Health Review: Current State of Knowledge and Strategies for Informing Future Research. *Environmental Toxicology and Chemistry*, *40*(3), 606–630. https://doi.org/10.1002/etc.4890

Gaines, L. G. T. (2023). Historical and current usage of per- and polyfluoroalkyl substances (PFAS): A literature review. *American Journal of Industrial Medicine*, *66*(5), 353–378. https://doi.org/10.1002/ajim.23362

Gaines, L. G. T., Sinclair, G., & Williams, A. J. (2023). A proposed approach to defining per- and polyfluoroalkyl substances (PFAS) based on molecular structure and formula. *Integrated Environmental Assessment and Management*, *19*(5), 1333–1347. https://doi.org/10.1002/ieam.4735

Gewurtz, S. B., Bradley, L. E., Backus, S., Dove, A., McGoldrick, D., Hung, H., & Dryfhout-Clark, H. (2019). Perfluoroalkyl Acids in Great Lakes Precipitation and Surface Water (2006–2018) Indicate Response to Phase-outs, Regulatory Action, and Variability in Fate and Transport Processes. *Environmental Science & Technology*, *53*(15), 8543–8552. https://doi.org/10.1021/acs.est.9b01337

Gkika, I. S., Xie, G., Van Gestel, C. A. M., Ter Laak, T. L., Vonk, J. A., Van Wezel, A. P., & Kraak, M. H. S. (2023). Research Priorities for the Environmental Risk Assessment of Per- and Polyfluorinated Substances. *Environmental Toxicology and Chemistry*, *42*(11), 2302–2316. https://doi.org/10.1002/etc.5729

Glüge, J., Scheringer, M., Cousins, I. T., DeWitt, J. C., Goldenman, 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 & Impacts*, *22*(12), 2345–2373. https://doi.org/10.1039/D0EM00291G

Hammel, E., Webster, T. F., Gurney, R., & Heiger-Bernays, W. (2022). Implications of PFAS definitions using fluorinated pharmaceuticals. *iScience*, *25*(4), 104020. https://doi.org/10.1016/j.isci.2022.104020

ITRC. (n.d.). *PFAS: 12 Treatment Technologies*. Retrieved November 14, 2024, from https://pfas-1.itrcweb.org/12-treatment-technologies/

Jha, G., Kankarla, V., McLennon, E., Pal, S., Sihi, D., Dari, B., Diaz, D., & Nocco, M. (2021). Per- and Polyfluoroalkyl Substances (PFAS) in Integrated Crop–Livestock Systems: Environmental Exposure and Human Health Risks. *International Journal of Environmental Research and Public Health*, *18*(23), 12550. https://doi.org/10.3390/ijerph182312550

Kwiatkowski, C. F., Andrews, D. Q., Birnbaum, L. S., Bruton, T. A., DeWitt, J. C., Knappe, D. R. U., Maffini, M. V., Miller, M. F., Pelch, K. E., Reade, A., Soehl, A., Trier, X., Venier, M., Wagner, C. C., Wang, Z., & Blum, A. (2020). Scientific Basis for Managing PFAS as a Chemical Class. *Environmental Science & Technology Letters*, *7*(8), 532–543. https://doi.org/10.1021/acs.estlett.0c00255

Lasee, S., McDermett, K., Kumar, N., Guelfo, J., Payton, P., Yang, Z., & Anderson, T. A. (2022). Targeted analysis and Total Oxidizable Precursor assay of several insecticides for PFAS. *Journal of Hazardous Materials Letters*, *3*, 100067. https://doi.org/10.1016/j.hazl.2022.100067

Longendyke, G. K., Katel, S., & Wang, Y. (2022). PFAS fate and destruction mechanisms during thermal treatment: A comprehensive review. *Environmental Science: Processes & Impacts*, *24*(2), 196–208. https://doi.org/10.1039/D1EM00465D

Maine Department of Environmental Protection. (n.d.). *PFAS in Products*. Retrieved October 15, 2024, from https://www.maine.gov/dep/spills/topics/pfas/PFAS-products/

Massachusetts Department of Environmental Protection. (n.d.). *PFAS in Residuals: Information on MassDEP efforts to establish standards for Per- and Polyfluoroalkyl Substances (PFAS) in Residuals.* Retrieved October 23, 2024, from https://www.mass.gov/info-details/pfas-in-residuals

MDA. (2016). *2015 Reconnaissance Study of Pesticide Compounds in Community Public Water Supply Wells*. https://www.mda.state.mn.us/sites/default/files/inline-files/2015PesticideReconReport_0.pdf

MDA. (2023). *Report on the Use of Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) in Pesticides in Maryland 2023*. https://mda.maryland.gov/Documents/PFAS Testing Study Final Report.pdf

MDH. (2023). *Data Summary Report: Unregulated Contaminants Monitoring Project*. https://www.health.state.mn.us/communities/environment/water/docs/ucmpreport.pdf

Meegoda, J. N., Bezerra De Souza, B., Casarini, M. M., & Kewalramani, J. A. (2022). A Review of PFAS Destruction Technologies. *International Journal of Environmental Research and Public Health*, *19*(24), 16397. https://doi.org/10.3390/ijerph192416397

Mei, W., Sun, H., Song, M., Jiang, L., Li, Y., Lu, W., Ying, G.-G., Luo, C., & Zhang, G. (2021). Per- and polyfluoroalkyl substances (PFASs) in the soil–plant system: Sorption, root uptake, and translocation. *Environment International*, *156*, 106642. https://doi.org/10.1016/j.envint.2021.106642

Mosquito Control for the Twenty-First Century Task Force. (2022). *Recommendations of the Mosquito Control for the Twenty-First Century Task Force*. https://www.mass.gov/doc/recommendations-of-the-mosquito-control-for-the-twenty-first-century-task-force/download

MPCA. (2021). *Minnesota's PFAS Blueprint*. https://www.pca.state.mn.us/sites/default/files/p-gen1-22.pdf

MPCA. (2022). *PFAS Monitoring Plan*. https://www.pca.state.mn.us/sites/default/files/p-gen1-22b.pdf

MPCA. (2024a). *PFAS ambient background concentrations*. https://www.pca.state.mn.us/sites/default/files/tdr-g1-25.pdf

MPCA. (2024b). *PFAS Monitoring Plan: Initial findings and next steps*. https://www.pca.state.mn.us/sites/default/files/p-gen1-22h.pdf

National Biosolids Data Project. (2023). *National Biosolids Data Project: Minnesota Biosolids*. https://www.biosolidsdata.org/minnesota

Navarro, D. A., Kabiri, S., Ho, J., Bowles, K. C., Davis, G., McLaughlin, M. J., & Kookana, R. S. (2023). Stabilisation of PFAS in soils: Long-term effectiveness of carbon-based soil amendments. *Environmental Pollution*, *323*, 121249. https://doi.org/10.1016/j.envpol.2023.121249

NSTC. (2024). *Per- and Polyfluoroalkyl Substances (PFAS) Federal Research and Development Strategic Plan*. https://www.whitehouse.gov/wp-content/uploads/2024/09/PFAS-STRAT-PLAN-FINAL.pdf

OECD. (2021). *Reconciling Terminology of the Universe of Per- and Polyfluoroalkyl Substances: Recommendations and Practical Guidance*. https://www.oecd-ilibrary.org/reconciling-terminology-of-the-universe-of-per-and-polyfluoroalkyl-substances_e458e796-en.pdf?itemId=%2Fcontent%2Fpublication%2Fe458e796-en&mimeType=pdf

Ogawa, Y., Tokunaga, E., Kobayashi, O., Hirai, K., & Shibata, N. (2020). Current Contributions of Organofluorine Compounds to the Agrochemical Industry. *iScience*, *23*(9), 101467. https://doi.org/10.1016/j.isci.2020.101467

Patlewicz, G., Judson, R. S., Williams, A. J., Butler, T., Barone, S., Carstens, K. E., Cowden, J., Dawson, J. L., Degitz, S. J., Fay, K., Henry, T. R., Lowit, A., Padilla, S., Paul Friedman, K., Phillips, M. B., Turk, D., Wambaugh, J. F., Wetmore, B. A., & Thomas, R. S. (2024). Development of chemical categories for per- and polyfluoroalkyl substances (PFAS) and the proof-of-concept approach to the identification of potential candidates for tiered toxicological testing and human health assessment. *Computational Toxicology*, *31*, 100327. https://doi.org/10.1016/j.comtox.2024.100327

PEER. (2020). *Aerially Sprayed Pesticide Contains PFAS*. https://peer.org/aerially-sprayed-pesticide-contains-pfas/

Prevedouros, K., Cousins, I. T., Buck, R. C., & Korzeniowski, S. H. (2006). Sources, Fate and Transport of Perfluorocarboxylates. *Environmental Science & Technology*, *40*(1), 32–44. https://doi.org/10.1021/es0512475

Rankin, K., Mabury, S. A., Jenkins, T. M., & Washington, J. W. (2016). A North American and global survey of perfluoroalkyl substances in surface soils: Distribution patterns and mode of occurrence. *Chemosphere*, *161*, 333–341. https://doi.org/10.1016/j.chemosphere.2016.06.109

Saliu, T. D., & Sauvé, S. (2024). A review of per- and polyfluoroalkyl substances in biosolids: Geographical distribution and regulations. *Frontiers in Environmental Chemistry*, *5*, 1383185. https://doi.org/10.3389/fenvc.2024.1383185

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

Schymanski, E. L., Zhang, J., Thiessen, P. A., Chirsir, P., Kondic, T., & Bolton, E. E. (2023). Per- and Polyfluoroalkyl Substances (PFAS) in PubChem: 7 Million and Growing. *Environmental Science & Technology*, *57*(44), 16918–16928. https://doi.org/10.1021/acs.est.3c04855

Simcik, M. F., & Dorweiler, K. J. (2005). Ratio of Perfluorochemical Concentrations as a Tracer of Atmospheric Deposition to Surface Waters. *Environmental Science & Technology*, *39*(22), 8678–8683. https://doi.org/10.1021/es0511218

Solomon, K. R., Velders, G. J. M., Wilson, S. R., Madronich, S., Longstreth, J., Aucamp, P. J., & Bornman, J. F. (2016). Sources, fates, toxicity, and risks of trifluoroacetic acid and its salts: Relevance to substances regulated under the Montreal and Kyoto Protocols. *Journal of Toxicology and Environmental Health, Part B*, *19*(7), 289–304. https://doi.org/10.1080/10937404.2016.1175981

USEPA. (n.d.). *Per- and Polyfluoroalkyl Substances (PFAS) in Pesticide and Other Packaging*. Retrieved October 8, 2024, from https://www.epa.gov/pesticides/pfas-packaging#:~:text=EPA%20considers%20any%20level%20of,of%20Federal%20Regulations%20(CFR)

USEPA. (2015). *Inert Ingredient Frequently Asked Questions*. https://www.epa.gov/sites/default/files/2015-12/documents/faqs.pdf\

USEPA. (2020). *Per- and Polyfluoroalkyl Substances (PFAS): Incineration to Manage PFAS Waste Streams*. https://www.epa.gov/sites/default/files/2019-09/documents/technical_brief_pfas_incineration_ioaa_approved_final_july_2019.pdf

USEPA. (2021a). *EPA's Analytical Chemistry Branch Method for the Analysis of PFAS in Oily Matrix ACB Project B21-02*. https://www.epa.gov/system/files/documents/2021-09/epa-pfas-method-in-oil.pdf

USEPA. (2021b). *PFAS Strategic Roadmap: EPA's Commitments to Action 2021-2024*. https://www.epa.gov/system/files/documents/2021-10/pfas-roadmap_final-508.pdf.

USEPA. (2021c). *Rinses from Selected Fluorinated and Non-Fluorinated HDPE Containers*. https://www.epa.gov/pesticides/rinses-selected-fluorinated-and-non-fluorinated-hdpe-containers

USEPA. (2022a). *Biosolids Biennial Report No.9 (Reporting Period 2020–2021)*. https://www.epa.gov/system/files/documents/2022-12/2020-2021-biennial-report.pdf

USEPA. (2022b). *Pesticides: Removal of PFAS Chemicals from Approved Inert Ingredient List for Pesticide Products*. https://www.regulations.gov/document/EPA-HQ-OPP-2022-0542-0009

USEPA. (2023a). *Method for Analysis of PFAS in Pesticide Products Containing Non-ionic Surfactants and Non-volatile Oils*. https://www.epa.gov/system/files/documents/2023-05/0523%20EPA%20PFAS%20Pesticide%20Analytical%20Method.pdf

USEPA. (2023b). *Verification Analysis for PFAS in Pesticide Products*. https://www.epa.gov/system/files/documents/2023-05/BEAD PFAS Study Results 2023.pdf

Vitale, R. J., Acker, J. K., & Somerville, S. E. (2022). An assessment of the potential for leaching of per- and polyfluoroalkyl substances from fluorinated and non-fluorinated high-density polyethylene containers. *Environmental Advances*, *9*, 100309. https://doi.org/10.1016/j.envadv.2022.100309

Appendix A. Minnesota Statutes on PFAS in Pesticides

MINN. STAT. Chapter 18B.03

Subd. 5. Perfluoroalkyl and polyfluoroalkyl substances. The commissioner has the sole regulatory authority over the terrestrial application of pesticides containing PFAS, including but not limited to the application of pesticides to agricultural crops, structures, and other nonaquatic environments. In order to reduce duplication, a registrant is not required to provide technical data to another state agency if the registrant previously submitted the data to the commissioner and the data is available to the other state agencies.

MINN. STAT. Chapter 18B.26 Sec. 28.

Subd. 7. Notification required; waivers and extensions.

(a) Beginning January 1, 2026, a pesticide registrant must annually provide a statement that a product contains no intentionally added PFAS or, for products that contain intentionally added PFAS, a pesticide registrant must submit to the commissioner the following information:

   (1) the name and purpose for which PFAS are used in the pesticide, including in any product components;

   (2) the amount of each PFAS in the product, identified by its name, chemical structure, analytical methods, chemical abstracts service registry number, or other unique method approved by the commissioner; and

   (3) any additional information required by the commissioner.

(b) The commissioner may waive all or part of the notification requirement under paragraph (a) if the commissioner determines that substantially equivalent information is available. The commissioner may extend the deadline for the submission of the information required under paragraph (a) if the commissioner determines that more time is needed by the registrant to comply with the submission requirement.

MINN. STAT. Chapter 18B.26 Sec. 29.

Subd. 8. PFAS prohibitions.

(a) Beginning January 1, 2026, the commissioner may not register a cleaning product if the product contains intentionally added PFAS unless the commissioner determines that the use of PFAS is a currently unavoidable use.

(b) Beginning January 1, 2032, the commissioner may not register a pesticide product that contains intentionally added PFAS unless the commissioner determines that the use of PFAS is a currently unavoidable use.

Appendix B. PFAS Pesticide Active and Inert Ingredients

The tables below include all of the active ingredients registered in MN (Table B 1), as of September 2024, and all of the inert ingredients approved for use in pesticide products by the U.S. Environmental Protection Agency (EPA) (Table B 2), as of February 2024, that meet the Minnesota (MINN. STAT. 18B.01 subd. 15(c)) definition of PFAS. Data from the MDA Pesticide Sales Database is expressed as pounds of active ingredient (lbs a.i.). Sales data do not necessarily correlate with pesticide use in the state on an annual basis. Although Teflon appears in Table B2, the EPA proposed the removal of Teflon from the list of approved inert ingredients in February of 2024. The most up to date version of both tables can be found on the MDA's website.

Table B 1. Pesticide active ingredients registered in Minnesota (as of September 2024) that meet the Minnesota Statute definition of PFAS (MINN. STAT. 18B.01 subd. 15(c)) including links to chemical structures from the U.S. Environmental Protection Agency's CompTox Chemicals Dashboard and 2022 sales in Minnesota.

EPA PC Code	CAS Number	Chemical Name	Pesticide Type	Chemical Structure	2022 Sales in MN (lbs a.i.)
084301	1861-40-1	Benfluralin	Herbicide	Benfluralin	37
118831	1820573-27-0	beta-Cyfluthrin	Insecticide	beta-Cyfluthrin	8463
018986	352010-68-5	Bicyclopyrone	Herbicide	Bicyclopyrone	13,984
128825	82657-04-3	Bifenthrin	Insecticide	Bifenthrin	213,668
128400	581809-46-3	Bixafen	Fungicide	Bixafen	3,279
283200	1207727-04-5	Broflanilide	Insecticide	Broflanilide	117
112802	63333-35-7	Bromethalin	Rodenticide	Bromethalin	11
128712	128639-02-1	Carfentrazone-ethyl	Herbicide	Carfentrazone-ethyl	1,674
129093	122453-73-0	Chlorfenapyr	Insecticide	Chlorfenapyr	218
125203	105512-06-9 105511-96-4	Clodinafop-propargyl	Herbicide	Clodinafop-propargyl	7
129116	147150-35-4	Cloransulam-methyl	Herbicide	Cloransulam-methyl	36,771
555550	180409-60-3	Cyflufenamid	Fungicide	Cyflufenamid	0

EPA PC Code	CAS Number	Chemical Name	Pesticide Type	Chemical Structure	2022 Sales in MN (lbs a.i.)
138831	400882-07-7	Cyflumetofen	Miticide/ Insecticide	Cyflumetofen	17
128831	68359-37-5	Cyfluthrin	Insecticide	Cyfluthrin	5,612
108201	35367-38-5	Diflubenzuron	Insecticide	Diflubenzuron	4405
005107	109293-98-3	Diflufenzopyr-sodium	Herbicide	Diflufenzopyr-sodium	17,827
128994	97886-45-8	Dithiopyr	Herbicide	Dithiopyr	13,452
113101	55283-68-6	Ethalfluralin	Herbicide	Ethalfluralin	99,012
107091	153233-91-1	Etoxazole	Insecticide	Etoxazole	4
129121	120068-37-3	Fipronil	Insecticide	Fipronil	614
128016	158062-67-0	Flonicamid	Insecticide	Flonicamid	80
129108	145701-23-1	Florasulam	Herbicide	Florasulam	95
030093	1390661-72-9	Florpyrauxifen-benzyl	Herbicide	Florpyrauxifen-benzyl	314
129777	1254304-22-7	Fluazaindolizine	Insecticide	Fluazaindolizine	0
122809	79241-46-6	Fluazifop-P-butyl	Herbicide	Fluazifop-P-butyl	139,030
129098	79622-59-6	Fluazinam	Fungicide	Fluazinam	14,929
114009	181274-17-9	Flucarbazone-sodium	Herbicide	Flucarbazone-sodium	5,682
071503	131341-86-1	Fludioxonil	Fungicide	Fludioxonil	2,022
050410	318290-98-1	Fluensulfone	Nematicide	Fluensulfone	0
121903	142459-58-3	Flufenacet	Herbicide	Flufenacet	0

EPA PC Code	CAS Number	Chemical Name	Pesticide Type	Chemical Structure	2022 Sales in MN (lbs a.i.)
138008	1383809-87-7	Fluindapyr	Fungicide	Fluindapyr	18
036007	69770-45-2	Flumethrin	Insecticide	Flumethrin	112
123001	62924-70-3	Flumetralin	Plant Growth Regulator	Flumetralin	0
129016	98967-40-9	Flumetsulam	Herbicide	Flumetsulam	68,839
128724	87546-18-7	Flumiclorac	Herbicide	Flumiclorac	321
129034	103361-09-7	Flumioxazin	Herbicide	Flumioxazin	48,227
027412	239110-15-7	Fluopicolide	Fungicide	Fluopicolide	9
080302	658066-35-4	Fluopyram	Fungicide	Fluopyram	34,961
028869	361377-29-9	Fluoxastrobin	Fungicide	Fluoxastrobin	6,730
112900	59756-60-4	Fluridone	Herbicide	Fluridone	1,649
128959	69377-81-7	Fluroxypyr	Herbicide	Fluroxypyr	37,846 (fluroxypyr + fluroxypyr-meptyl)
128968	81406-37-3	Fluroxypyr-meptyl	Herbicide	Fluroxypyr-meptyl	37,846 (fluroxypyr + fluroxypyr-meptyl)
125701	56425-91-3	Flurprimidol	Plant Growth Regulator	Flurprimidol	439
108803	117337-19-6	Fluthiacet-methyl	Herbicide	Fluthiacet-methyl	369
014018	958647-10-4	Flutianil	Fungicide	Flutianil	0
128975	66332-96-5	Flutolanil	Fungicide	Flutolanil	397

EPA PC Code	CAS Number	Chemical Name	Pesticide Type	Chemical Structure	2022 Sales in MN (lbs a.i.)
128940	76674-21-0	Flutriafol	Fungicide	Flutriafol	29,214
138009	907204-31-3	Fluxapyroxad	Fungicide	Fluxapyroxad	19,845
123803	72178-02-0	Fomesafen	Herbicide	Fomesafen	198,552 (fomesafen + fomesafen, sodium)
123802	108731-70-0	Fomesafen, sodium	Herbicide	Fomesafen, sodium	198,552 (fomesafen + fomesafen, sodium)
128807	76703-62-3	gamma-Cyhalothrin	Insecticide	gamma-Cyhalothrin	828
117501	943831-98-9	Halauxifen-methyl	Herbicide	Halauxifen-methyl	274
118202	86479-06-3	Hexaflumuron	Insecticide	Hexaflumuron	0
118401	67485-29-4	Hydramethylnon	Insecticide	Hydramethylnon	3
067710	173584-44-6	Indoxacarb	Insecticide	Indoxacarb	599
129120	1314008-27-9	Ipflufenoquin	Fungicide	Ipflufenoquin	0
123000	141112-29-0	Isoxaflutole	Herbicide	Isoxaflutole	5,207
128888	77501-63-4	Lactofen	Herbicide	Lactofen	8,971
128897	91465-08-6	lambda-Cyhalothrin	Insecticide	lambda-Cyhalothrin	92,356
122000	1417782-03-6	Mefentrifluconazole	Fungicide	Mefentrifluconazole	50,849
090088	403640-27-7	Methiozolin	Herbicide	Methiozolin	27
109709	240494-70-6	Metofluthrin	Insecticide	Metofluthrin	8,982

EPA PC Code	CAS Number	Chemical Name	Pesticide Type	Chemical Structure	2022 Sales in MN (lbs a.i.)
016331	609346-29-4	Momfluorothrin	Insecticide	Momfluorothrin	0
105801	27314-13-2	Norflurazon	Herbicide	Norflurazon	16
124002	116714-46-6	Novaluron	Insecticide	Novaluron	3,652
118204	121451-02-3	Noviflumuron	Insecticide	Noviflumuron	0
128111	1003318-67-9	Oxathiapiprolin	Fungicide	Oxathiapiprolin	58
111601	42874-03-3	Oxyfluorfen	Herbicide	Oxyfluorfen	417
100249	494793-67-8	Penflufen	Fungicide	Penflufen	935
119031	219714-96-2	Penoxsulam	Herbicide	Penoxsulam	92
090112	183675-82-3	Penthiopyrad	Fungicide	Penthiopyrad	14,376
129200	117428-22-5	Picoxystrobin	Fungicide	Picoxystrobin	34,776
110201	29091-21-2	Prodiamine	Herbicide	Prodiamine	51,131
129031	94125-34-5	Prosulfuron	Herbicide	Prosulfuron	0
030090	129630-19-9	Pyraflufen-ethyl	Herbicide	Pyraflufen-ethyl	2
000692	365400-11-9	Pyrasulfotole Technical	Herbicide	Pyrasulfotole Technical	21,699
295149	179101-81-6	Pyridalyl	Insecticide	Pyridalyl	no data
555555	337458-27-2	Pyrifluquinazon	Insecticide	Pyrifluquinazon	4
090099	447399-55-5	Pyroxasulfone	Herbicide	Pyroxasulfone	110,299
108702	422556-08-9	Pyroxsulam	Herbicide	Pyroxsulam	150

EPA PC Code	CAS Number	Chemical Name	Pesticide Type	Chemical Structure	2022 Sales in MN (lbs a.i.)
055459	124495-18-7	Quinoxyfen	Fungicide	Quinoxyfen	0
118203	372137-35-4	Saflufenacil	Herbicide	Saflufenacil	47,839
114402	62476-59-9	Sodium acifluorfen	Herbicide	Sodium acifluorfen	12,502
005210	946578-00-3	Sulfoxaflor	Insecticide	Sulfoxaflor	4,955
109302	69409-94-5	Tau-Fluvalinate	Insecticide	Tau-Fluvalinate	3
128912	79538-32-2	Tefluthrin	Insecticide	Tefluthrin	16,645
012801	335104-84-2	Tembotrione	Herbicide	Tembotrione	126,134
120603	112281-77-3	Tetraconazole	Fungicide	Tetraconazole	15,041
090097	1229654-66-3	Tetraniliprole	Insecticide	Tetraniliprole	0
036201	88-30-2	TFM (3-trifluoromethyl-4-nitrophenol)	Piscicide	TFM	0
012311	1220411-29-9	Tiafenacil	Herbicide	Tiafenacil	11
119093	122454-29-9	Tralopyril	Antimicrobial	Tralopyril	24
129140	118712-89-3	Transfluthrin	Insecticide	Transfluthrin	0
129112	141517-21-7	Trifloxystrobin	Fungicide	Trifloxystrobin	61,459
128879	68694-11-1	Triflumizole	Fungicide	Triflumizole	23
036101	1582-09-8	Trifluralin	Herbicide	Trifluralin	131,755
129002	126535-15-7	Triflusulfuron-methyl	Herbicide	Triflusulfuron-methyl	206

Table B 2. Pesticide inert ingredients included in the U.S. Environmental Protection Agency's InertFinder database (as of February 2024) that meet the Minnesota Statute definition of PFAS (MINN. STAT. 18B.01 subd. 15(c)).

CAS Number	Chemical Name
63148-56-1	Siloxanes and silicones, Me 3,3,3-trifluoropropyl
88795-12-4	1-Butanol, 4-(ethenyloxy)-, polymer with chlorotrifluoroethene, (ethenyloxy) cyclohexane and ethoxyethene
24937-79-9	Ethene, 1,1-difluoro-, homopolymer
188027-78-3	5H-1,3-Dioxolo[4,5-f]benzimidazole, 6-chloro-5-[(3,5-dimethyl-4-isoxazolyl)sulfonyl]-2,2-difluoro
67786-14-5	2-Naphthalenesulfonic acid, 6-amino-4-hydroxy-5-{{2-(trifluoromethyl)phenyl}azo}-, monosodium s
52238-92-3	Pigment red 242
42557-13-1	Poly(oxy(methyl(3,3,3-trifluoropropyl)silylene)), alpha-(trimethylsilyl)-omega((trimethylsilyl)oxy)-
88485-37-4	Fluxofenim (as a safener)
98-56-6	p-Chlorobenzotrifluoride
29119-24-9	Trans-1,3,3,3-tetrafluoroprop-1-ene
9002-84-0	Teflon[1]
811-97-2	1,1,1,2-Tetrafluoroethane

Appendix C. Groundwater and Surface Water Detections of PFAS Pesticide Active Ingredients in 2023

Table C 1 and Table C 2 summarize the 2023 detection data for PFAS pesticide active ingredients that the MDA monitors for in surface and groundwater in Minnesota. The tables include detection frequencies, maximum detection concentrations and applicable reference values. Groundwater reference value types include rapid assessment (RA) values and health risk limits (HRLs) established by the Minnesota Department of Health. The numbers following the acronyms for the value type indicate the year it was established. Surface water reference values are based on the lowest available U.S. Environmental Protection Agency (USEPA) Aquatic Life Benchmark (ALB) value for each chemical. The aquatic life taxa associated with each ALB value are indicated by the letter in parentheses: fish (f), invertebrates (i), vascular plants (v) and nonvascular plants (n). Whether the ALB value is based on a chronic or acute exposure is also indicated. More information on the data in this table including sample locations and reference values is available in the MDA's 2023 Water Quality Monitoring Report.

Table C 1. Detections of PFAS pesticide active ingredients in groundwater from the Minnesota Department of Agriculture's monitoring in 2023 including detection frequency, maximum concentration detected, and reference values.

Analyte Name	Groundwater Detection Frequency (%) (n =)	Maximum Detection Concentration (Groundwater ng/L)	Groundwater Reference Value (ng/L)	Groundwater Reference Value Type
Acifluorfen	0 (224)	<25	5,000	RA20 (sodium acifluorfen)
Benfluralin	0 (224)	<25	8000	RA14
Bicyclopyrone	<1 (224)	44.6	400	RA15
Bifenthrin	0 (224)	<20	2000	RA14
Bixafen	0 (224)	<100	40000	RA19
Cloransulam-methyl	0 (224)	<100	40000	RA20
Cyfluthrin	0 (224)	<100	6000	RA14
Dithiopyr	0 (224)	<50	6000	RA21
Ethalfluralin	0 (224)	<50	1000	RA14
Fipronil	0 (224)	<10	300	RA14
Flufenacet OXA	0 (224)	<8.3	2000	RA14
Flumetsulam	2 (224)	195	400000	RA14
Flutriafol	0 (224)	<10	10000	RA14
Fluxapyroxad	0 (224)	<10	30000	RA16
Fomesafen	17 (224)	6780	20000	HRL23
Halauxifen-methyl	0 (224)	<10	40000	RA18
Isoxaflutole	0 (224)	<40	7000	RA14
lambda-Cyhalothrin	0 (224)	<75	200	RA14
Mefentrifluconazole	0 (224)	<25	30000	RA20
Methiozolin	0 (224)	<30	600000	RA21
Momfluorothrin	0 (224)	<50	100000	RA18
Norflurazon	0 (224)	<20	4000	RA14
Oxathiapiprolin	0 (224)	<100	6000000	RA18
Picoxystrobin	0 (224)	<50	10000	RA15
Pyroxasulfone	0 (224)	<50	5000	RA14
Saflufenacil	4 (224)	86.2	40000	RA14
Tembotrione	0 (224)	<50	600	RA14
Tetraconazole	0 (224)	<10	4000	RA14
Tetraniliprole	0 (224)	<50	300000	RA23
Trifloxystrobin	0 (224)	<80	50000	RA19
Trifluralin	0 (224)	<50	9000	RA14

Table C 2. Detections of PFAS pesticide active ingredients in surface water from the Minnesota Department of Agriculture's monitoring in 2023 including detection frequency, maximum concentration detected, and reference values.

Analyte Name	Surface Water Detection Frequency (%) (n =)	Maximum Detection Concentration (Surface Water ng/L)	Surface Water Reference Value (ng/L)	Surface Water Reference Value Type
Acifluorfen	0 (349)	<25	>355,000	USEPA ALB Chronic (n)
Benfluralin	0 (512)	<25	1900	USEPA ALB Chronic (f)
Bicyclopyrone	2 (349)	35	13000	USEPA ALB Chronic (v)
Bifenthrin	0 (512)	<20	0.05	USEPA ALB Chronic (i)
Bixafen	0 (349	<100	4600	USEPA ALB Chronic (f)
Cloransulam-methyl	<1 (349)	114	990	USEPA ALB Chronic (v)
Cyfluthrin	0 (512)	<100	0.12	USEPA ALB Chronic (i)
Dithiopyr	0 (512)	<50	6110	USEPA ALB Chronic (v)
Ethalfluralin	0 (512)	<50	400	USEPA ALB Chronic (f)
Fipronil	0 (349)	<10	11	USEPA ALB Chronic (i)
Flufenacet OXA	0 (349)	<8.3	-	-
Flumetsulam	5 (349)	131	3100	USEPA ALB Chronic (v)
Flutriafol	2 (349)	27.7	310000	USEPA ALB Chronic (i)
Fluxapyroxad	2 (349)	15	22000	USEPA ALB Chronic (f)
Fomesafen	17 (349)	884	92000	USEPA ALB Chronic (n)
Halauxifen-methyl	0 (349)	<10	135	USEPA ALB Chronic (v)
Isoxaflutole	0 (349)	<40	4900	USEPA ALB Chronic (v)
lambda-Cyhalothrin	0 (512)	<75	0.04	USEPA ALB Acute (i)
Mefentrifluconazole	0 (349)	<25	7400	USEPA ALB Chronic (f)
Methiozolin	0 (349)	<30	7000	USEPA ALB Chronic (v)
Momfluorothrin	0 (349)	<50	600	USEPA ALB Acute (f)
Norflurazon	0 (349)	<20	6030	USEPA ALB Chronic (n)
Oxathiapiprolin	0 (349)	<100	>140,000	USEPA ALB Chronic (n)
Picoxystrobin	0 (349)	<50	1000	USEPA ALB Chronic (i)
Pyroxasulfone	3 (349)	169	380	USEPA ALB Chronic (n)
Saflufenacil	11 (349)	122	42000	USEPA ALB Chronic (n)
Tembotrione	<1 (349)	129	5200	USEPA ALB Chronic (v)
Tetraconazole	1 (349)	16.8	80000	USEPA ALB Chronic (f)
Tetraniliprole	0 (349)	<50	12500	USEPA ALB Chronic (i)
Trifloxystrobin	0 (512)	<80	2760	USEPA ALB Chronic (i)
Trifluralin	0 (512)	<50	1900	USEPA ALB Chronic (f)

Appendix D. Private Well Pesticide Sampling Project Detections of PFAS Pesticide Active Ingredients

A private well sampling project, Phase 1 of which was conducted by the MDA from 2016 to spring 2021, also tested for select PFAS active ingredients. A summary of the PFAS active ingredients tested for, their detection frequencies, and relevant reference values are shown in Table D 1. All reference values in Table D 1 are rapid assessment (RA) values, which are established by the MDH. More information on the data in this table, including project background, sample collection areas, and a more in depth discussion of the included reference values, is available in the MDA's Private Well Pesticide Sampling Project Phase 1 Summary Report.

Table D 1. Detections of PFAS pesticide active ingredients in the Minnesota Department of Agriculture's Private Well Pesticide Sampling Project from 2016-2021, including detection frequency, maximum concentration detected, and reference values (RA = rapid assessment and year developed). The laboratory was unable to confirm the maximum detection of cyfluthrin with a verification sample.

Analyte Name	Number of Samples	Detection Frequency (%)	Maximum Detection (ng/L)	Reference Value (ng/L)	Reference Value Type
Cyfluthrin	5,700	<1	7,400	6,000	RA14
Ethalfluralin	1,166	0	<50	1,000	RA14
Flufenacet OXA	5,700	<1	35	2,000	RA14
Flumetsulam	5,700	3	650	400,000	RA14
Flutriafol	5,700	0	<10	10,000	RA14
Fluxapyroxad	5,700	0	<10	30,000	RA16
Isoxaflutole	5,700	0	<40	7,000	RA14
Picoxystrobin	5,700	0	<50	10,000	RA15
Pyroxasulfone	5,700	0	<50	5,000	RA14
Saflufenacil	5,700	1	150	40,000	RA14
Tembotrione	5,700	<1	61	600	RA14
Tetraconazole	5,700	0	<10	4,000	RA14

Appendix E. Description for Figure 2

A figure to represent the different sources of PFAS in pesticide products. At the center of the figure there is an oval that says “PFAS in Pesticide Products” on the right-hand side of the figure there are two additional ovals with arrows that point to the center oval, the top oval says, “active ingredients” and the bottom says, “inert ingredients.” Both ovals on the right-hand side are enclosed in a rectangle that is labeled “intentionally added” to specify that inert and active ingredients are both intentionally added to pesticide products. On the left-hand side of the figure there are three additional ovals with arrows that point to the center oval, the top oval says, “fluorinated containers,” the middle oval says “contaminated ingredients,” and the bottom oval says “other sources (unknown).” All three of these ovals on the left-hand side are enclosed in a rectangle that is labeled “not intentionally added” to specify that fluorinated containers, contaminated ingredients, and other sources (unknown) are not intentionally added to pesticide products.