BUREAU OF WATER QUALITY
PROGRAM GUIDANCE

WASTEWATER POLICY AND MANAGEMENT TEAM

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PFOS and PFOA Minimization Plans

10/22/2024

EGAD Number: 3400-2024-07

Edition Number: 1

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APPROVED:

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11/18/2024 | 8:53 AM CST

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Summary

The intent of this document is to provide guidance as to what the expectations are for minimization plans developed in accordance with s. NR 106.99, Wis. Adm. Code. Permittees required to develop these plans are those which, after an initial two-year period spent monitoring their effluent for PFOS and PFOA, are shown to have reasonable potential to cause or contribute to an exceedance of the PFOS and/or PFOA water quality standards in s. NR 102.04(8)(d)1., Wis. Adm. Code.

Table of Contents

Table of Figures

Acronyms

AFFF – Aqueous Film-Forming Foam

AOF – Adsorbable Organic Fluorine

BRRTS - Bureau of Remediation and Redevelopment Tracking System

IU – Industrial User

NAICS – North American Industry Classification System

PFAS – Per-and-Polyfluoroalkyl Substances

PFOA – Perfluorooctanoic Acid

PFOS – Perfluorooctane Sulfonic Acid

POTW – Publicly-Owned Treatment Work

PPT – parts per trillion

TOP Assay – Total Oxidizable Precursor Assay

TSCA – Toxic Substances Control Act

USEPA – United States Environmental Protection Agency

WDNR – Wisconsin Department of Natural Resources

WQBEL – Water Quality-Based Effluent Limitation

WQS – Water Quality Standards

Chapter 1 – Background

Per-and-polyfluoroalkyl substances (PFAS) are a group of several thousand manmade chemicals used in a large number of consumer and industrial products since the 1950s. They are often referred to as “forever chemicals,” because many of them do not break down under naturally occurring conditions. They contain strong carbon-fluorine bonds that allow them to accumulate over time in the environment and in the bodies of animals and people, posing health risks. PFOS and PFOA are just two of several thousand PFAS but are the focus of this document because Wisconsin has promulgated surface water quality standards for PFOS and PFOA.

PFOS and PFOA

“Perfluorooctane Sulfonic Acid” (PFOS) – an 8-carbon perfluoroalkyl sulfonic acid (PFSA). This compound has historically been used in the production of aqueous film-forming foam (AFFF) and household products such as Scotchgard. In 2002, the domestic manufacturing of PFOS was phased out.

“Perfluorooctanoic Acid” (PFOA) – an 8-carbon perfluoroalkyl carboxylic acid (PFCA). This compound has historically been used in the synthesis of polytetrafluoroethylene (PTFE), also known by its trade name, Teflon®. PFOA’s historical applications have been for nonstick oil-and-water-repellent coatings in products such as food packaging, cookware, personal care, waterproof apparel, and electronic cables.

In 2006, the United States’ Environmental Protection Agency (USEPA) initiated the PFOA Stewardship Program, in which eight major manufacturing/processing companies committed to reducing the manufacture/usage of PFOA. By 2015, PFOA manufacturing had completely ceased in the United States. However, this led to the increased international production of PFAS. In January 2024, USEPA issued a final Significant New Use Rule to prevent companies from starting or resuming the manufacture (including import) or processing of 329 PFAS compounds that are designated as inactive on the Toxic Substances Control Act (TSCA) Chemical Substance Inventory, including both PFOA and PFOS.

In 2019, the Wisconsin Department of Natural Resources (WDNR or department) began rule development for surface water criteria for both PFOS and PFOA. Section NR 102.04(8)(d)1., Wis. Adm. Code, became effective on August 1, 2022, establishing numeric surface water quality standards (WQS) of 8 ng/L for PFOS, 20 ng/L in surface waters used as a source of public drinking water for PFOA, and 95 ng/L in surface waters not used as a source of drinking water for PFOA. The implementation procedures for these standards, including Wisconsin Pollutant Discharge Elimination System (WPDES) permit requirements, are in subch. VIII of ch. NR 106, Wis. Adm. Code. Section NR 106.98, Wis. Adm. Code, specifies steps to generate data in order to determine the need for reducing PFOS and PFOA in the discharge. Data generated per the effluent monitoring requirements will be used to determine the need for developing a PFOS and PFOA minimization plan. For a visual timeline of this implementation process, see Appendix A.

Chapter 2 - PFOS and PFOA Minimization Plans

Once the department has determined that a discharge has shown reasonable potential to cause or contribute to an exceedance of a water quality standard for PFOS or PFOA (henceforth referred to as "reasonable potential"), the facility is notified they need to begin development of a minimization plan pursuant to s. NR 106.985(1), Wis. Adm. Code. Procedures for determining reasonable potential can be found in s. NR 106.98(4), Wis. Adm. Code. More information related to water quality based effluent limits (WQBELs) and reasonable potential can be found in the department's "Calculating Water Quality - Based Effluent Limitations for Surface Water Discharges" guidance document.

The overall goal of minimization plans is to improve effluent quality, reduce any adverse impact of the discharge on uses of the receiving waters, ensure reasonable progress towards attainment of the WQS, and, ultimately, reduce the effluent discharge below calculated effluent limits in a cost-effective manner. This is meant to be an iterative process, with the components of the minimization plan changing as new information becomes available through the methodology outlined in this document. This is accomplished through identifying sources, assessing the controllability of the sources, implementing strategies to reduce or eliminate the sources to the extent feasible, and monitoring the resulting impacts on influent and effluent quality. Minimization plans can include many different actions (but are not limited to): financial incentives, outreach and education, technical support, replacement of additives, and measures mandated by the department or other entities.

If reasonable potential is triggered for only one PFAS compound (e.g., PFOS and not PFOA), the facility may choose to target its minimization plan's efforts toward just the compound of concern, both PFOS and PFOA, or all PFAS. Throughout the remainder of the document, both compounds will be referenced together as PFOS and PFOA, though site-specific actions may be targeted towards a certain compound due to source identification.

Section NR 106.99, Wis. Adm. Code, outlines the components of a PFOS and PFOA Minimization Plan, requiring that the plan "*be implemented in a manner that reduces PFOS and PFOA concentrations to the maximum extent practicable[.]*"

GENERAL COMPONENTS OF A MINIMIZATION PLAN

Pursuant to ss. NR 106.99(1)(a)-(d), Wis. Adm. Code

- *Identification of specific PFOS and PFOA source reduction activities to be undertaken.*
- *A list of PFOS and PFOA source reduction activities that have been implemented prior to submission of the plan, if any, and a description of how effective those activities were in reducing potential and actual PFOS or PFOA discharges, concentrations, or sources.*
- *An explanation of how implementation of the PFOS and PFOA minimization plan will be documented.*
- *Steps to measure the effectiveness of the PFOS and PFOA minimization plan elements in reducing potential and actual PFOS and PFOA discharges.*

Though minimization plan actions will be site-specific depending on the general characteristics of the discharge, s. NR 106.99(2) – (3), Wis. Adm. Code, outlines the expectations for municipal dischargers

(Section 2.01) and primary/secondary industrial direct dischargers (Section 2.02). The minimization plan is meant to be an iterative process. Results from annual reports will be used to make necessary revisions to the plan and implementation activities in subsequent years. At a minimum, the department anticipates updates to these plans will occur at permit reissuance, though a permit modification may be required in some cases to include plan revisions made before or after permit reissuance. These revisions will address problems discovered and investigate new areas where the pollutant might be found. The goal of the minimization plan is to improve the effluent quality and to achieve compliance with the calculated WQBEL as soon as is practicable. If the minimization plan is successful and the discharger can be reasonably expected to comply with the WQBEL, then effluent limits will not become effective. However, the permittee will still be required to maintain effluent quality below the PFOS and PFOA standards (pursuant to s. NR 106.985(3), Wis. Adm. Code) and monitoring may still be included. Where a facility believes it has identified all known sources of PFOS and PFOA and has fully implemented control strategies with respect to those sources, yet remains unable to meet the WQBEL, it should document those findings in its annual reports, and revise subsequent versions of the plan accordingly.

Section 2.01: Municipal Discharger Plans

In addition to the general components of a minimization plan, s. NR 106.99(2), Wis. Adm. Code, outlines the components of a PFOS and PFOA Minimization Plan specific for municipal dischargers.

COMPONENTS OF A MUNICIPAL MINIMIZATION PLAN

Pursuant ss. NR 106.99(2)(a)-(f), Wis. Adm. Code

- *Source identification. The permittee shall establish an inventory of treatment system users to identify dischargers to the municipal treatment system that may be significant sources of PFOS and PFOA.*
- *Source monitoring. Once sources have been identified, the permittee shall develop a monitoring plan to sample all probable sources of PFOS and PFOA, the sampling protocol that will be followed, and the timeline for completion.*
- *Perform source monitoring. The permittee shall provide sample results from each probable source identified in the monitoring plan for PFOS and PFOA.*
- *Actions to reduce or eliminate PFOS and PFOA in permitted discharges.*
- *Education and outreach. The plan shall include activities to educate about the ways to reduce the use of PFAS-containing products, proper disposal of PFAS-containing products, and other mitigation efforts.*
- *Other activities. The plan may include activities that the department, in consultation with the permittee, determines to be appropriate for the individual permittee's circumstances.*

One of the most powerful tools for PFAS source identification is chemical fingerprinting. "Fingerprinting" is based on the idea that various products which contain PFAS compounds, or various industrial users of PFAS have unique chemical signatures. Because analytical methods allow for sampling and analysis of many different PFAS compounds that are commonly present in the effluent of publicly owned treatment works (POTWs), permittees can analyze the ratios of concentrations of various PFAS to establish a PFAS "fingerprint" associated with their facility's influent, and then compare that to the domestic baseline concentrations that are documented in this guidance. Literature indicates that wastewater sources belonging to certain industrial sectors can exhibit relatively consistent fingerprints within their sector, allowing source identification through fingerprinting analysis (Charbonnet et al. 2021, He et al. 2018, Qi et al. 2016, Ruyle et al. 2021, Zhang et al. 2021). These distinct fingerprints may result in detectable deviations from the typical domestic wastewater fingerprint, aiding in source identification efforts.

Though Wisconsin Administrative Code does not specifically require influent monitoring of PFOS and PFOA, the department recommends monitoring influent as part of developing the minimization plan to maximize potential for successful fingerprinting. Sampling of both influent and effluent of POTWs has consistently shown that effluent concentrations of PFOS and PFOA can be higher than the influent concentrations. This is because the treatment process itself will often transform precursor PFAS compounds in the influent into terminal compounds in the effluent. Perfluoroalkyl substances have a fully fluorinated tail, meaning all carbon atoms in the tail are bonded with fluorine atoms. Given that the C-F bond is one of the strongest known bonds in organic chemistry, perfluoroalkyl substances do not typically break down under naturally occurring conditions. Polyfluoroalkyl substances, on the other hand, have only a partially fluorinated tail, meaning that one of the carbon atoms on the tail is not bonded with fluorine. This introduces a weaker point in the molecular structure. Consequently, polyfluoroalkyl substances may break down during treatment into perfluoroalkyl substances. PFOS and PFOA are both perfluoroalkyl substances, so the mass load of PFOS and PFOA measured in the influent is typically far lower than the mass load of PFOS and PFOA measured in the effluent and biosolids due to transformation of precursor PFAS into PFOS and PFOA during treatment.

Additionally, research has shown that long chain PFAS tend to partition to solids more readily than short chain PFAS. Perfluoroalkyl sulfonates, such as PFOS, partition to solids more readily than perfluoroalkyl carboxylates, such as PFOA. This means that long chain PFAS and perfluoroalkyl sulfonates are more likely to be removed from the effluent in the treatment process (i.e., partition to biosolids) than short chain PFAS and perfluoroalkyl carboxylates.

Together, the potential for precursor transformation and preferential partitioning of certain PFAS to solids during treatment mean that concentrations and fingerprints of PFAS in effluent are expected to be different than concentrations and fingerprints in influent and less representative of fingerprints at industrial sources. Therefore, while effluent sampling is important to demonstrate compliance with water quality standards, the department's recommendation to facilities undertaking source identification is to compare *influent* concentrations (or concentrations in the sewerage system) with those of the various sources to the sewerage system.

Finally, to maximize potential for successful source identification via fingerprinting, the department believes it is important to collect data on as many PFAS parameters as possible. Cost for analysis of a suite of 40 PFAS compounds under EPA Method 1633 are often the same as or only slightly more than the cost for just analysis of PFOS and PFOA, so the department recommends (note this is not a plan requirement) that facilities undertaking source identification request labs to analyze for as many PFAS compounds as possible to facilitate source identification efforts (note this is not a plan requirement). If permittees have concerns about sampling specific additional compounds for which there are no promulgated water quality criteria, another option would be taking Total Oxidizable Precursor (TOP) assays or adsorbable organic fluorine (AOF) as screening tools. These other tests, however, would not provide the necessary information to attempt robust fingerprinting analysis.

Additionally, in situations where the permittee has limited resources and thus has low sample sizes, the department recommends (not requires) that permittees take composite samples as part of the minimization plan rather than grab to capture variability in effluent concentrations, as at least one study has demonstrated that effluent PFAS concentrations can vary widely at POTWs, even across the duration of a single day (Szabo et al. 2023). Permittees are not required to take a composite over a grab sample. Rather, the department strongly recommends composites over grab in order to capture effluent variability throughout the day.

Municipalities – Source Identification

There may be multiple sources of PFOS and PFOA to a sewerage system. Publicly owned treatment works (POTWs) are encouraged to make an inventory of all treatment system users and begin evaluating the likelihood of PFAS contributions based on a site-specific literature review.

Notwithstanding the aforementioned benefits of influent sampling, POTWs may elect to begin source identification efforts using already-collected effluent data to avoid unnecessary sampling expenses. POTWs may compare their effluent fingerprints to documented fingerprints of municipalities without inputs from significant industrial users (SIUs) belonging to sectors known or suspected to be PFAS sources. Figure 1 below shows box and whisker plots of Wisconsin POTWs' fingerprints, sorted into two pools: (1) "baseline" refers to POTWs without SIUs known or suspected to be PFAS sources, and (2) "SIU" refers to POTWs with SIUs known or suspected to be PFAS sources. Further description and visualization of this data is available for reference in Appendix B. A facility undertaking source identification should examine how their effluent fingerprint deviates from the baseline fingerprint for their sector.

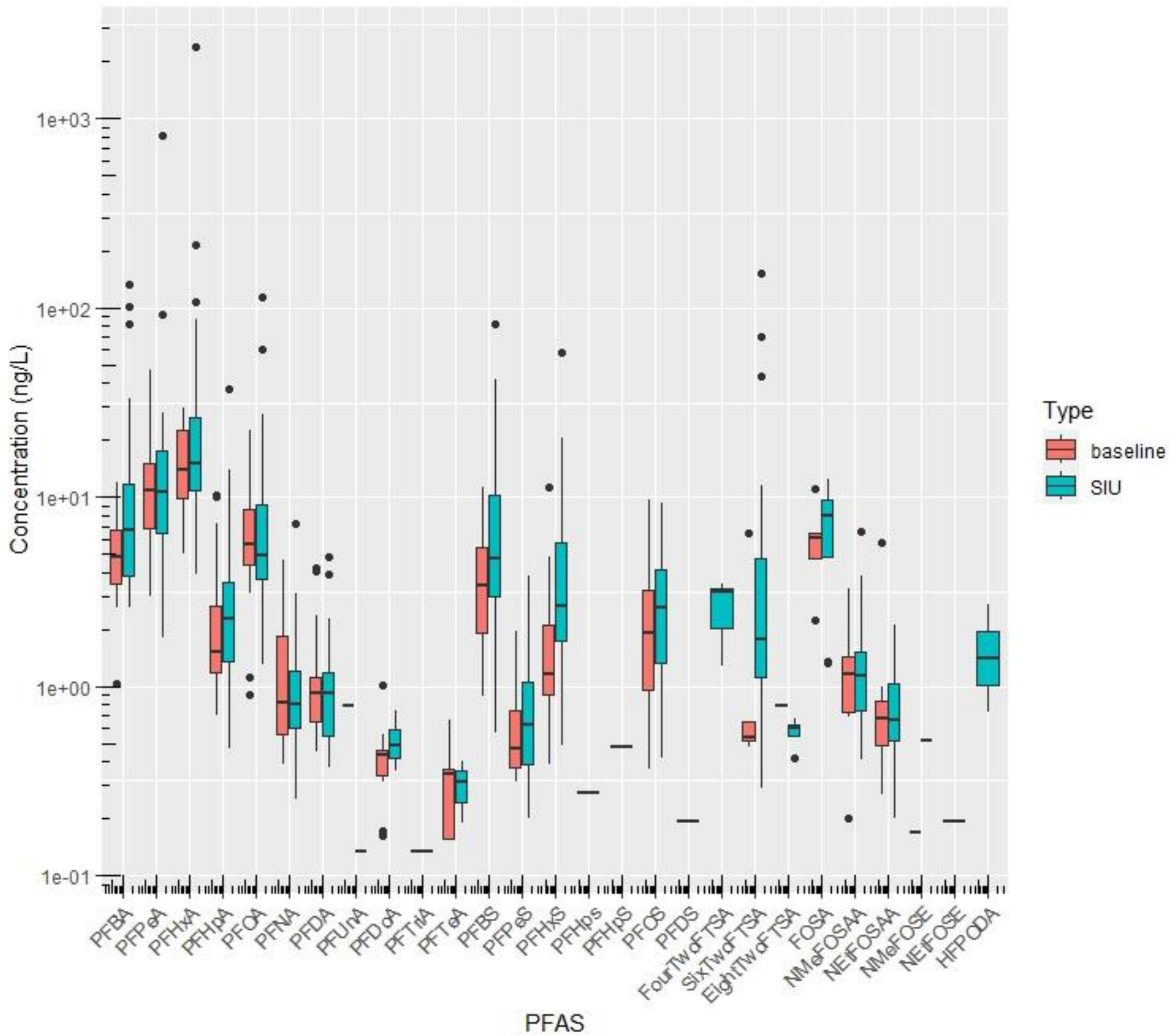

Figure 1 - Baseline vs SIU Trends in Wisconsin POTWs

Principal component analysis, radar graphs, and bar charts can be helpful in visualizing fingerprints and identifying discrepancies between typical baseline POTW fingerprints and a given POTW's fingerprint (example R code provided in Appendix C). These deviations can then be compared to fingerprints of potential PFAS sources. For municipalities, this may include fingerprints from industrial sectors that discharge to the POTW (see Appendix D: Potential Sources of PFAS to POTWs), sites with legacy contamination that may enter the sewers through inflow/infiltration, and the public water supply.

In cases where source identification is not feasible based upon a comparison of a POTW's effluent fingerprint to the established baseline domestic effluent fingerprint and literature on fingerprints of industrial sectors, POTWs must conduct further sampling and evaluation to identify sources. The next recommended course of action is to sample POTW influent and review the influent fingerprint against literature on fingerprints from industrial sectors. EPA's POTW Influent Study of PFAS (https://www.epa.gov/eg/study-pfas-influent-potws), once published, will provide a comprehensive dataset on fingerprints of industrial users, POTW influent, and POTW effluent. Review of influent data removes two confounding factors implicit in the effluent data – degradation of precursor PFAS during the treatment processes and preferential partitioning of certain PFAS to sludges (Link 2023, Pancras et al.

2016, Houtz et al. 2016). Influent fingerprints are expected to more clearly reflect the fingerprints from industries discharging to the sanitary sewer.

Where this still fails to identify likely sources, a POTW may sample some or all industrial users' (IUs') discharges to the sanitary sewer or require by local ordinance that all IUs submit a sample. Where the number of industrial users is too large to require this universally, a POTW may sample a subset of industrial users, such as those belonging to the sectors mentioned in Appendix D: Potential Sources of PFAS to POTWs. Permittees will have the flexibility to prioritize which IUs will be sampled, and sampling may be an iterative process until one or more sources are identified.

If sampling of industrial users fails to reveal a clear source, it is possible that the contamination may be caused by a commercial discharge, inflow and infiltration of contaminated groundwater into the sanitary sewer, or legacy contamination from industrial sources that no longer discharge to the sanitary sewer. POTWs should review available geodatabases on the location of known contamination sites and historical pretreatment records to evaluate the possibility of such sources within the system. In Wisconsin, the WDNR's Interactive PFAS Data Viewer or Bureau of Remediation and Redevelopment's Tracking System on the Web (BRRTS on the Web) may be used to evaluate the presence of known contaminated groundwater or soil in a community. The sewer system may be sampled downgradient and upgradient of any potential sources mentioned in this paragraph to evaluate whether they are a source of PFAS.

Finally, if this does not reveal responsible sources, the POTW may need to conduct a systematic sampling of their collection system. As a first attempt in this sampling effort, POTWs might choose to sample only in interceptors at the pour points of various sub-sewersheds throughout their service area. Any areas with high results could then be targeted for further sampling with a higher resolution. This can serve as an iterative process until certain city blocks have been identified as potential sources. The entities in that area can then be reviewed to determine which are potential PFAS sources, and/or the groundwater can be sampled for PFAS and the sewer lines televised to determine whether inflow/infiltration of contaminated groundwater is a source. For more information about potential sources of PFAS to POTWs, see Appendix D.

Municipalities – Source Monitoring

Once the permittee has identified potential or confirmed sources of PFOS and PFOA, they are required to develop a plan to monitor these sources. Section NR 106.99(2)(b), Wis. Adm. Code, requires the source monitoring to be completed within 24 months of when the permit is modified to include the minimization plan. This monitoring plan should include the timeline for completion and the protocol that will be followed. These initial timelines should be based on what the facility can reasonably implement in the two-and-a-half-year period to implement the approved minimization plan after the permit has been modified prior to the next permit reissuance. This is to ensure that information is available to both the department and the permittee at the time the permit is next reissued. The department anticipates that this initial two-and-a-half-year period of minimization plan implementation will be important for establishing baseline PFOS and PFOA loading to the sewerage system, along with identifying potential sources.

In situations where resources are limited, it's important to note that s. NR 106.99(2)(b), Wis. Adm. Code, does specify that the source monitoring plan may be implemented jointly with other entities, so one option available to POTWs is to update their sewer use ordinances to require that indirect dischargers submit sampling results for PFOS and/or PFOA. This could potentially free up resources for smaller POTWs affected to focus on other sampling efforts within the sewerage system.

As noted in ch. NR 106, Wis. Adm. Code, the department recommends that facilities follow sampling protocols developed by Michigan's Department of Environment, Great Lakes, and Energy to ensure cross-contamination of samples does not occur. All samples should be analyzed by a laboratory certified in Wisconsin for such testing. A list of certified laboratories is available here: https://dnr.wisconsin.gov/topic/PFAS/Labs.html. If permittees suspect cross-contamination could be occurring with samples, the department recommends collecting a sampling equipment blank to ensure this is not the case.

Municipalities – Source Reduction Actions for Permitted Discharges

The department anticipates that POTWs will rely on local means of controlling PFOS and/or PFOA discharges from industries through sewer use ordinances. POTWs could set local limits, either calculated using the water quality standards in s. NR 102.04(8)(d)1., Wis. Adm. Code, or set by way of best management practices. This creates a situation where the responsibility is on the indirect dischargers to the sewerage system to perform their own source reduction measures to comply with the local regulations. The intent of this source-reduction approach is for POTWs to act as the gatekeepers to their own sewerage system, not for POTWs to install their own tertiary treatment for PFAS. For industries which are looking to develop their own minimization plans in response to a local POTW's updated sewer use ordinance, see Section 2.02 below.

In setting local limits for PFOS and/or PFOA, POTWs may consider requiring the collection of Total Oxidizable Precursor (TOP) assays rather than targeted analysis of PFAS. TOP assays involve oxidation of the sample prior to analysis, which causes precursors to degrade prior to analysis. This assay would account for the presence of any precursors to PFOS and/or PFOA that may not be detected as such in samples of the industrial user's effluent but that may break down to PFOS or PFOA in the collection system or treatment system. It is important to note that TOP assays are a conservative approach and may result in an overestimation of PFOA and/or PFOS loadings to a sewerage system.

The department stresses that local limits are only one tool available to municipalities in controlling the discharge of PFOS and/or PFOA to their sewerage system. In instances where going through the process of calculating and then setting the local limit is not desirable, POTWs are encouraged to work directly with their local industries to see if they can reduce PFOS and/or PFOA loadings voluntarily.

Actions that industrial users might initiate to reduce PFAS include ceasing use of PFAS or PFAS-containing products, treating wastewater to remove PFAS, cleaning or replacing any tanks and pipes containing legacy contamination (and containerizing the wash water for proper disposal as appropriate), and/or ceasing discharge to the sewerage system.

Municipalities – Education and Outreach

POTWs, per s. NR 106.99(2)(e), Wis. Adm. Code, are also required to include activities which educate the public, commercial sewer users, or other professionals about ways to reduce the usage of PFAS-containing products, disposal of PFAS-containing products, and other mitigation efforts. Consumer products which contain PFAS where communities may discourage them being flushed include (but are not limited to): textile finishing agents (i.e. waterproofing spray), pesticides, lubricants, paints, waxes/polishes, household chemicals (e.g. carpet/fabric care products, cleaning chemicals, and impregnating agents), and cosmetics (Dewapriya 2023). While POTWs may choose to create their own resources based on information they acquire, POTWs are not expected or required to create these resources. Rather, facilities may provide members of the community with resources that are already publicly available. See Figure 2 below for a graphical abstract from the cited report, which shows the various household products which are most likely to contain PFAS. Resources such as these are publicly available and may be incorporated as part of the 'Education and Outreach' component of a facility's minimization plan Since the WQS for PFOS and PFOA are at the parts-per-trillion (ppt) or nanogram-per-liter (ng/L) level, any amount of source reduction which can take place at the community level would potentially have a measurable effect on effluent concentrations. POTWs are encouraged to provide resources such as the department's PFAS webpage, Interstate Technology Regulatory Council (ITRC's) PFAS fact sheets, and EPA's PFAS webpage as part of this education effort.

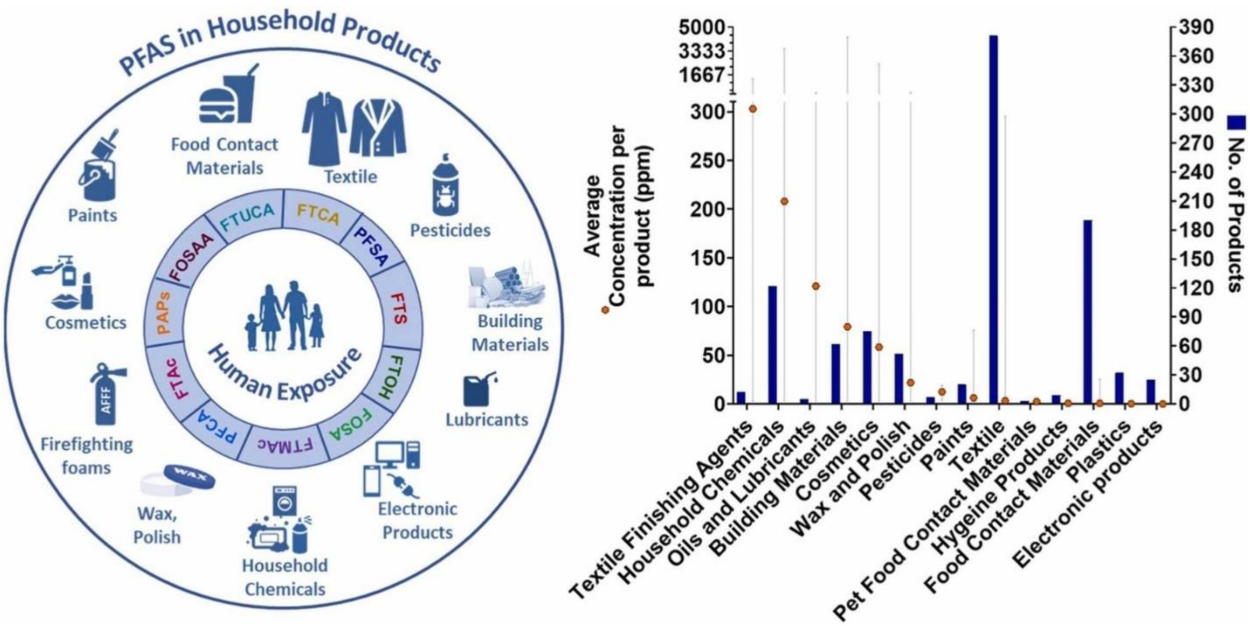

Figure 2 - Household Products Which May Contain PFAS

Municipalities – Other Actions

Section NR 106.99(2)(f), Wis. Adm. Code, allows for flexibility in the implementation of other site-specific source reduction activities not already covered in other sections to be included in the minimization plan. For example, if a permittee suspects that inflow and infiltration into the sewerage system from a contaminated site is the cause of their exceedances, then one component of the plan could be to sample various parts of the sewerage system to track down where the highest concentrations originate. The next step in this process would then be to re-line or replace the sewerage system in that area. If contaminated sites are discovered and a responsible party is identified, municipalities may seek compensation for costs incurred.

Another example is if the permittee suspects that their source water is the primary source of PFOS or PFOA to the sewerage system. While a POTW's options may be limited in these cases, the minimization plan could include investigations into what is causing this source water contamination, and whether there are any actions that can be taken at a local level to mitigate these sources or treat the public water supply before distribution to the community.

As indicated previously, the department does not anticipate that domestic contributions by themselves will be significant enough at POTWs to trigger the need for a minimization plan, as previous sampling efforts have shown that, to exceed the calculated PFOS and/or PFOA water quality-based effluent limits, there is often a source or sources. That said, in cases where there are no industrial dischargers, contaminated sites, legacy contributions, or source water issues, the department will work with facilities to troubleshoot other possible sources to come up with an effective PMP. Putting more emphasis on the outreach and education component, for example, may be appropriate in those limited cases.

Section 2.02: Primary and Secondary Industry Discharger Plans

This guidance is not intended to spell out exact sources for each industrial category; rather, this section outlines requirements details the components of a PFOS and PFOA minimization plan, as described in NR 106.

Primary industries are identified in Appendix A of 40 CFR Part 122; secondary industries are defined in s. NR 200.02(17), Wis. Adm. Code as "*An industrial facility or activity that is not classified as a primary industry.*" In addition to the general components of a minimization plan, s. NR 106.99(3), Wis. Adm. Code outlines the components of a PFOS and PFOA Minimization Plan specific for industrial dischargers.

COMPONENTS OF AN INDUSTRIAL PFOS AND PFOA MINIMIZATION PLAN

Pursuant ss. NR 106.99(3)(a)-(f), Wis. Adm. Code

- *Source identification and inventory*
- *Improvement of operational controls or maintenance*
- *Substitution of raw materials or chemical additives with low or zero PFOS, PFOA, and PFOS and PFOA precursor alternatives*
- *Institution of alternative processes*
- *Clean-up of historical contamination*
- *Other activities that the department, in consultation with the permittee, determines to be appropriate for the individual permittee's circumstances*

Industrial PFOS and PFOA minimization plans will be different from municipal plans in that they will focus on the raw materials and processes used at the facility itself, while the department anticipates that POTW minimization plans will focus more on the upstream contributions to the sewerage system.

While the above-listed components are specifically called out as required in an industrial discharger's minimization plan, the department recognizes that the implementation of a PFOS and PFOA minimization plan will be heavily site-specific, and some or even most of the components outlined in ss. NR 106.99(3)(a)-(f), Wis. Adm. Code, may not result in reductions or be appropriate for a particular facility. The department requires that the above components be evaluated, and the minimization plan should reflect how that evaluation is/was conducted. The first iteration of the minimization plan should focus on source identification and inventorying, which includes a plan to sample various raw materials, industrial components (e.g., sampling tanks for legacy contamination), and processes. Once informed by the data collected onsite, the facility's minimization plan should be modified to focus on whatever sources are identified.

Industries – Source Identification

Just as the POTWs are required to identify the sources of PFOS and PFOA to their sewerage systems, so are industrial facilities required to identify these sources within their facilities. Since PFOS and PFOA have been phased out of production, the department anticipates that most sources of these compounds for industries will be from source water, legacy contamination, equipment and parts which utilize products like Teflon®, and chemicals/additives used in manufacturing or maintenance activities which contain small amounts of PFOS and/or PFOA, or their precursors. This source identification will be site-specific for all affected industrial facilities (e.g. sources at a pulp/paper manufacturer are going to be different from sources at a metal finisher). With that said, the department's preference for these plans is that industries develop an inventory of all potential sources of PFOS and/or PFOA at their facility.

Internal sampling at industrial facilities will be a significant aspect to these plans. The first iteration of the PFOS and PFOA minimization plan should include a sampling plan of source water, raw materials, and the wastewater from all major process components at the industrial facility. Source water data can be found for many surface waters using DNR's PFAS Interactive Data Viewer: https://dnr.wisconsin.gov/topic/PFAS/DataViewer. The department anticipates this sampling plan will be the most efficient way of identifying PFOS and/or PFOA sources within the facility. Unlike s. NR 106.99(2)(b), Wis. Adm. Code, which requires municipal source monitoring to be completed in 24 months, the industry minimization plan requirements do not include a timeline. However, the department recommends industries complete the monitoring within the same 24-month timeline.

If facilities are unable to identify sources based on the above inventorying and sampling, facilities may compare their wastewater fingerprints to published fingerprints for their industry (see Appendix D, EPA's ELG Plan 15, EPA's Multi-Industry PFAS Study, and scholarly literature on this topic). Deviations from typical signatures may be suggestive of the fingerprints of potential sources.

Industries – Other Components

The other identified components will rely on the specific facility in question. What is an appropriate PFOS and PFOA minimization plan for a metal finisher may not be appropriate for a pulp/paper manufacturer. Thus, the department will allow facilities some latitude to alter the focus areas of the source reduction measures resulting from the sampling portion of the minimization plan.

Some examples of other components that the department would expect from these minimization plans include the following:

Aqueous Film Forming Foam (AFFF, or Class B Firefighting Foam) Containment Measures – The department recognizes that sometimes emergencies occur which require the usage of AFFF, such as petroleum-based fires. To minimize the potential impact to the environment in these situations, industrial facilities should consider how AFFF might be contained in the event of its necessary use. Though AFFFs are no longer manufactured containing PFOS or its precursors, 6:2 FTS is a fluorotelomer compound which can be a precursor to other PFAS compounds which do not degrade naturally in the environment. As part of this plan provision, facilities should include a screening process for any purchases of new foams to ensure they do not contain PFOS or its precursors.

Product Substitution – Industries should evaluate all additives and other potential PFOS-or-PFOA-containing products used at their facilities. One recommendation would be to put in an additive evaluation process where any new additives which have the potential to be discharged are screened for PFOS and PFOA and committing to use only those additives with no or low concentrations.

Tank and Process Equipment Cleanout – PFOS and PFOA, since they are considered "long-chain" PFAS compounds, can adhere to the walls and surfaces of equipment in which they are held. This means that legacy contamination can be an ongoing source of PFOS or PFOA to the facility's effluent, long after the facility ceases usage of those products. Facilities should consider all equipment which encountered PFOS or PFOA-containing products and make plans to clean them out. It's important to note that simply pressure washing a tank can result in significant concentrations of PFOS or PFOA released into the environment. To account for this, facilities should first containerize the wash water, sample it for PFOS and PFOA, and then consider their disposal options based on those concentrations. Facilities should take precautions necessary to minimize any potential releases of PFOS and PFOA above surface water quality standards. In some cases, replacement of tanks or pipes that are sources of legacy contamination may be necessary.

Alternative Disposal Options – USEPA has provided interim guidance on disposal options of PFAS-contaminated waste streams. This guidance identifies thermal treatment (incineration), landfilling, and underground waste disposal wells. Wisconsin has no Class I injection wells, but industries may consider shipping the contaminated waste out of state if underground injection is determined to be the best available disposal option. While the DNR Water Quality Program will not require that industrial direct dischargers take a specific alternative disposal route, the result should be the reduction or elimination of PFOS and PFOA being discharged to the environment.

Wastewater Treatment – There are currently three proven treatment technologies that have been widely used to treat for PFOS and PFOA. They are granular activated carbon (GAC), ion exchange resins (IX), and reverse osmosis (RO). These treatment systems each have their own limitations. The primary downside is that they are not destruction technologies and result in a concentrated waste product or waste stream that still requires disposal. Thus, while treatment should always be considered, the department recommends it only be implemented when all other source reduction options have been evaluated and the subsequent reductions documented.

Chapter 3 - Department Evaluation of Minimization Plans

Once the department has made the determination that a minimization plan must be developed pursuant to s. NR 106.98(4), Wis Adm. Code, the permittee will be notified. The plans must be submitted to the department for review and approval within 90 days of notification pursuant to s. NR 106.985(2)(a), Wis. Adm. Code. The department will provide a written response to the plan (approval, conditional approval, or rejection) within 120 days of receiving the plan. See timeline below.

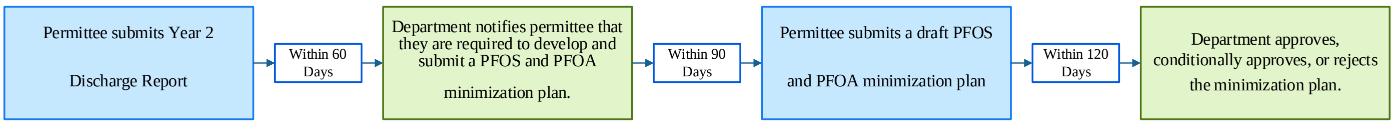

Figure 3 - Timeline of Minimization Plan Submittal

If a permittee's minimization plan is rejected by the department, a revised plan addressing all deficiencies and concerns must be submitted within 30 days of department notification (pursuant s. NR 106.985(2)(a), Wis. Adm. Code). As soon as possible after department approval, permit modification for incorporation of the minimization plan actions will occur pursuant to s. NR 106.985(2)(b), Wis. Adm. Code. During public notification of the permit modification, the minimization plan will also be available for public comment.

As stated previously, the overall goal of minimization plans is to improve effluent quality, reduce any adverse impact of the discharge on uses of the receiving waters, ensure reasonable progress towards attainment of the WQS, and, ultimately, reduce the effluent discharge below calculated effluent limits. The site-specific plans will utilize administrative code requirements and the components further explained above in Chapter 2. When evaluating and approving PFOS and PFOA minimization plans, s. NR 106.99(4), Wis. Adm. Code, outlines the following considerations for the department:

Type and Size of Discharger – Permittees should include the following:

- Treatment system design flow rate.
- Highest annual average flow rate.
- Highest monthly average flow rate.
- Highest recorded peak daily flow rate.
- Summary of the treatment system type and corresponding components (e.g., activated sludge, lagoon treatment system).
- For Industries: Industry type, products produced, and NAICS code(s) applicable to all onsite operations.

Operations that Generate Wastewater

- For POTWs: Any non-domestic wastewater contributors, any industries that ceased discharge to the sewerage system within the past ten years, any known PFAS-contaminated sites within the service area, and community size.
- For Industries: Types of production systems and/or processes that generate the wastewater, where sanitary wastes are sent onsite, any known PFAS contamination on-site (e.g., past use of AFFF), past industrial operations on site (if applicable), and types of additives used (both for industrial applications and water quality conditioners).

- **Concentrations of PFOS and PFOA** – This could include results from the effluent, influent, intake, in-plant, biosolids or sludge, industrial users, or raw materials, if applicable and available.

If data is available, permittees should provide a summary of the mass contribution of PFOS and/or PFOA from each source to the treatment or sewerage system.

- A comparison of influent and effluent data and conclusions about where any potential transformation of precursor compounds is occurring within the treatment system.

Monetary Costs of Potential PFOS and PFOA Minimization Plan Elements – These costs can be approximate based on the facility's experience implementing source reduction measures for other pollutants or costs already incurred.

- For example: if a POTW is considering setting local limits for PFOS and PFOA, they could include potential costs to both them and the community at large of implementing this action, such as the cost of pretreatment to affected industries, local community employment impacts, or even costs to landfills hauling their leachate elsewhere.
- For POTWs: Potential impacts to ratepayers as a result of the implementation.
- For Industries: Provide information on potential effects on the ability to maintain staffing levels, if applicable. Industries may also choose to provide potential capital and operation and maintenance costs which could be incurred from the implementation of a minimization plan.

Environmental Costs and Benefits of the PFOS and PFOA Minimization Plan Elements – The department does not expect an extensive full cost-benefit environmental analysis. Rather, the expectation is that facilities note other non-financial costs related to implementing a particular action.

Characteristics of the Community – Permittees should provide, if applicable:

- The Median Household Income (MHI) of the surrounding community.
- The percentage of the local population below the Federal Poverty Level (FPL).
- The percentage of the local population which is unemployed.
- For Industries: Number of employees.

Opportunities for Material or Product Substitution

- An inventory of all materials and products that have the potential to be discharged should be provided in the minimization plan, along with an identification of any potential sources of PFOS and/or PFOA (or their precursors).
- Facilities should provide an indication as to whether substitution in the next few years for any of them is feasible.

Opportunities Available for Support from or Cooperation with Other Organizations

- For POTWs, organizations such as Wisconsin Rural Water Association, American Water Works Association, Wisconsin Wastewater Operators' Association, League of Wisconsin Municipalities, and the Municipal Environmental Group may be able to offer support or additional resources to assist their members in the implementation of a minimization plan.
- For POTWs, there is also the USEPA's WaterTA program, which could be a resource for minimization plan development. Municipalities can email the WaterTA@epa.gov email regarding nearly any drinking water or wastewater issue and be matched up with one of their contracted technical assistance providers for free assistance.
- For industrial facilities, various trade organizations and nonprofit groups such as the National Council for Air and Stream Improvement, Wisconsin Manufacturers and Commerce, and the Wisconsin Paper Council may be able to offer support or additional resources to assist their members in the implementation of a minimization plan.

Actions The Discharger Has Taken in The Past to Reduce PFOS or PFOA Use or Discharges – If applicable, permittees should identify all source reduction measures that have been taken to date. If available, sampling data should also be provided to show how effective those measures were in reducing PFOS and/or PFOA concentrations.

Any Other Relevant Information – Permittees are encouraged to make note of any other information relevant to the implementation of their PFOS and PFOA minimization plan.

The above considerations will allow the department to evaluate minimization plans holistically, weighing the benefits of several factors as opposed to relying on only one. Utilizing the factors above will help the department approve plans to ensure best use of resources to reduce sources of PFOS and PFOA, and to prevent other undesirable environmental outcomes from occurring. Appendix E provides a template available to facilities for getting started on the development of these minimization plans.

Appendix A – PFOS and PFOA Minimization Plan Implementation Timeline

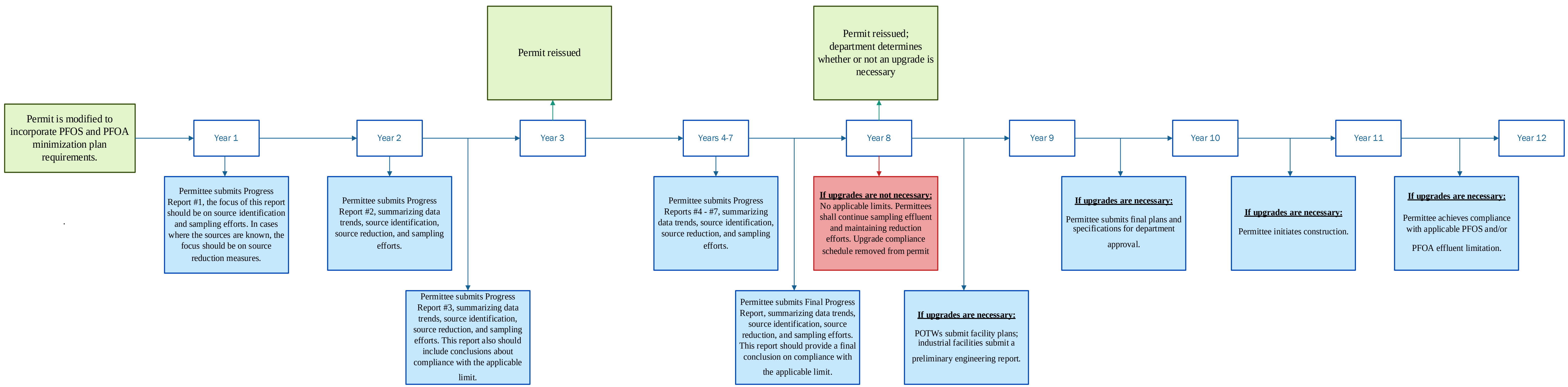

Figure 4 - PFOS and PFOA Minimization Plan Implementation Timeline

Appendix B – PFAS Fingerprints of POTWs in Wisconsin

To inform the economic impact analysis for adoption of water quality standards for PFOS and PFOA, DNR collected PFAS samples at 78 POTWs in 2021-2022. The data is described and visualized below:

Table 1 - PFAS Fingerprints of POTWs in Wisconsin

	Baseline POTWs						Industrially Impacted POTWs (with SIUs from sectors known or suspected to be PFAS sources)					
	Median (ng/L)	Avg (ng/L)	Min (ng/L)	Max (ng/L)	S.D. (ng/L)	Detect %	Median (ng/L)	Avg (ng/L)	Min (ng/L)	Max (ng/L)	S.D. (ng/L)	Detect %
PFBA	4.8	4.8	ND	12.0	3.2	88.5	6.4	13.9	ND	134.0	25.7	93.6
PFPeA	10.6	13.2	ND	47.3	10.7	96.2	9.0	29.0	ND	814.0	117.8	87.2
PFHxA	14.0	16.1	5.0	29.6	7.9	100.0	15.1	76.2	3.9	2390.0	346.6	100.0
PFHpA	1.5	2.6	ND	10.3	2.7	96.2	2.3	3.9	0.5	37.5	6.0	100.0
PFOA	5.6	7.0	0.9	22.8	4.8	100.0	5.0	10.3	1.3	114.0	18.2	100.0
PFNA	0.6	1.0	ND	4.6	1.3	69.2	0.6	0.8	ND	7.3	1.2	68.1
PFDA	0.7	1.0	ND	4.2	1.0	84.6	0.6	0.8	ND	4.8	1.0	70.2
PFUnA	ND	ND	ND	0.8	0.2	3.8	ND	ND	ND	0.1	0.0	2.1
PFDoA	ND	0.2	ND	1.0	0.3	42.3	ND	0.1	ND	0.7	0.2	21.3
PFTrDA	ND	ND	ND	0.1	0.0	3.8	ND	ND	ND	0.0	0.0	0.0
PFTeDA	ND	0.1	ND	0.7	0.2	19.2	ND	ND	ND	0.4	0.1	6.4
PFBS	2.3	3.3	ND	11.3	3.3	76.9	3.7	8.7	ND	82.0	15.0	76.6
PFPeS	ND	0.1	ND	2.0	0.4	15.4	ND	0.3	ND	3.8	0.8	31.9
PFHxS	1.1	2.0	ND	11.3	2.3	96.2	2.4	4.8	ND	58.3	8.8	91.5
PFHpS	ND	ND	ND	ND	0.0	0.0	ND	ND	ND	0.5	0.1	4.3
PFOS	1.8	2.4	ND	9.7	2.1	96.2	2.6	3.0	ND	9.3	2.3	95.7
PFDS	ND	ND	ND	ND	0.0	0.0	ND	ND	ND	0.2	0.0	2.1
4:2 FTSA	ND	ND	ND	ND	0.0	0.0	ND	0.2	ND	3.5	0.7	6.4
6:2 FTSA	ND	0.3	ND	6.5	1.3	19.2	0.7	7.3	ND	153.0	24.8	57.4
8:2 FTSA	ND	ND	ND	0.8	0.2	3.8	ND	ND	ND	0.7	0.2	8.5
FOSA	ND	1.2	ND	11.0	2.8	19.2	ND	1.4	ND	12.4	3.3	19.1
NMeFOSAA	ND	0.6	ND	3.3	0.8	46.2	0.7	0.9	ND	6.6	1.2	63.8
NEtFOSAA	ND	0.4	ND	5.8	1.1	26.9	ND	0.3	ND	2.1	0.5	40.4
NMeFOSE	ND	ND	ND	0.2	0.0	3.8	ND	ND	ND	0.5	0.1	2.1
NEtFOSE	ND	ND	ND	0.2	0.0	3.8	ND	ND	ND	ND	0.0	0.0
HFPO-DA	ND	ND	ND	ND	0.0	0.0	ND	0.1	ND	2.7	0.4	4.3
Σ34 PFAS*	51.6	56.4	17.4	127.0	26.5	100.0	63.8	162.1	17.1	3418.9	493.4	100.0

**Note that 8 additional PFAS compounds not listed in this table were also analyzed in all samples, but these were non-detect at all facilities. These compounds were PFNS, PFDoS, NMeFOSA, NetFOSA, 10:2 FTSA, DONA, 9Cl-PF3ONS, and 11Cl-PF3OUdS.*

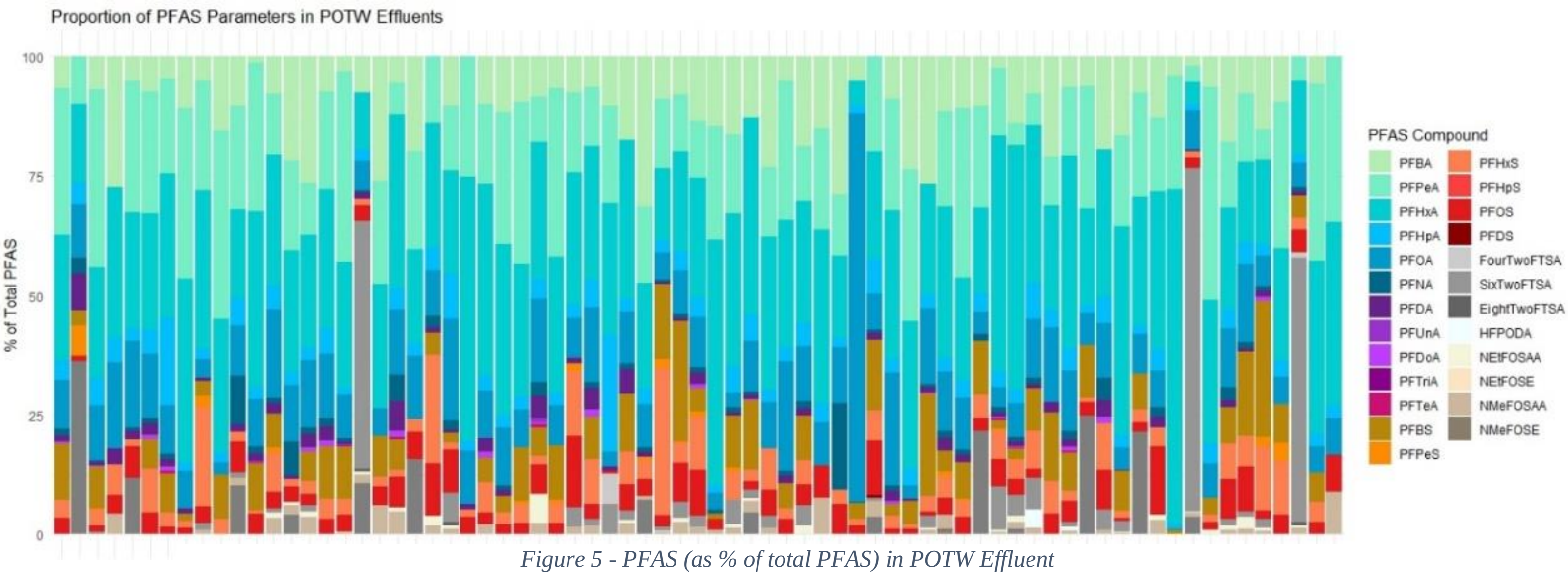

Figure 5 - PFAS (as % of total PFAS) in POTW Effluent

POTWs are sorted from no SIU contributions (left) to greatest percent of influent flow from SIUs (right)

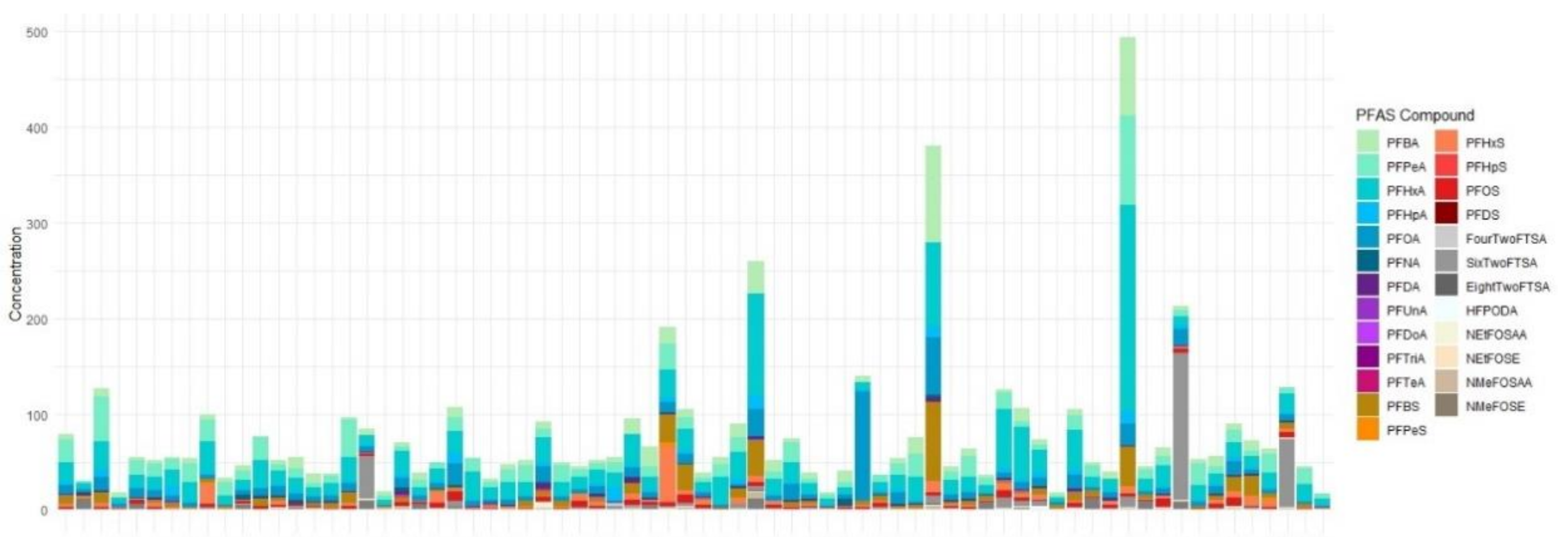

Figure 6 - PFAS Concentrations in POTW Effluents (excluding one outlier POTW)

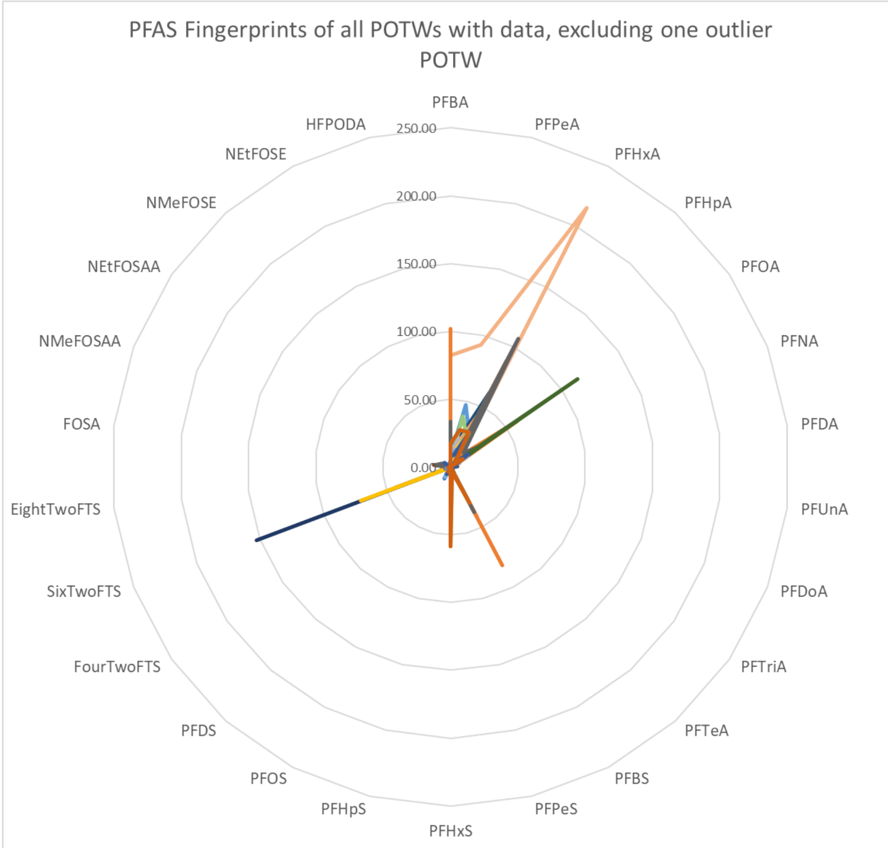

Figure 7 - PFAS Fingerprints of all POTWs

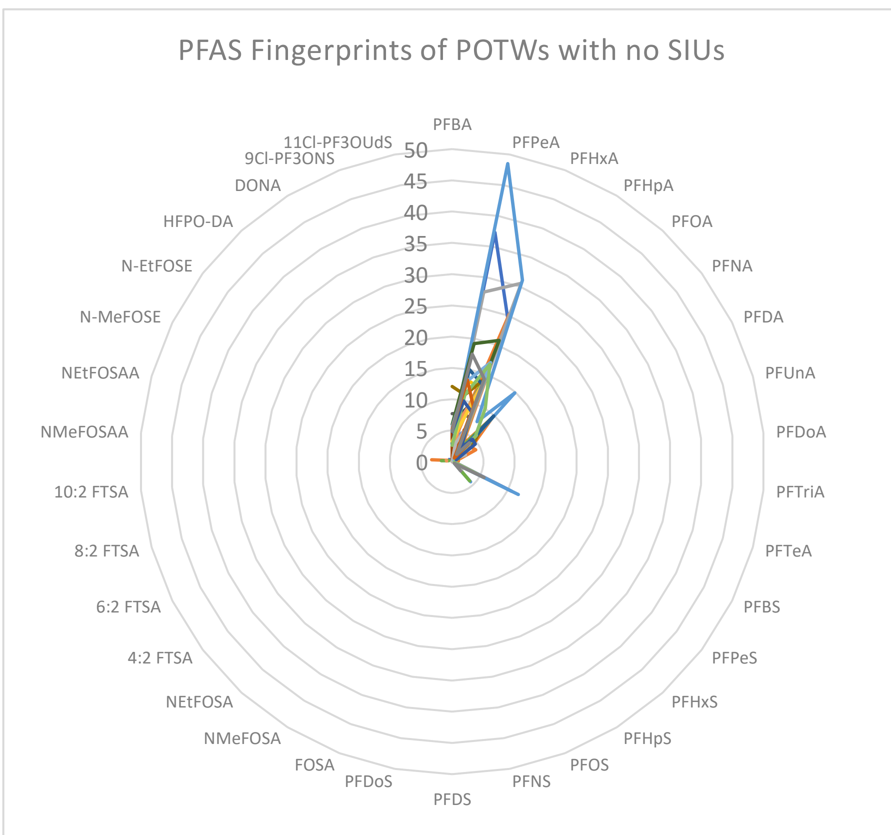

Figure 8 - PFAS Fingerprints of POTWs with no SIUs

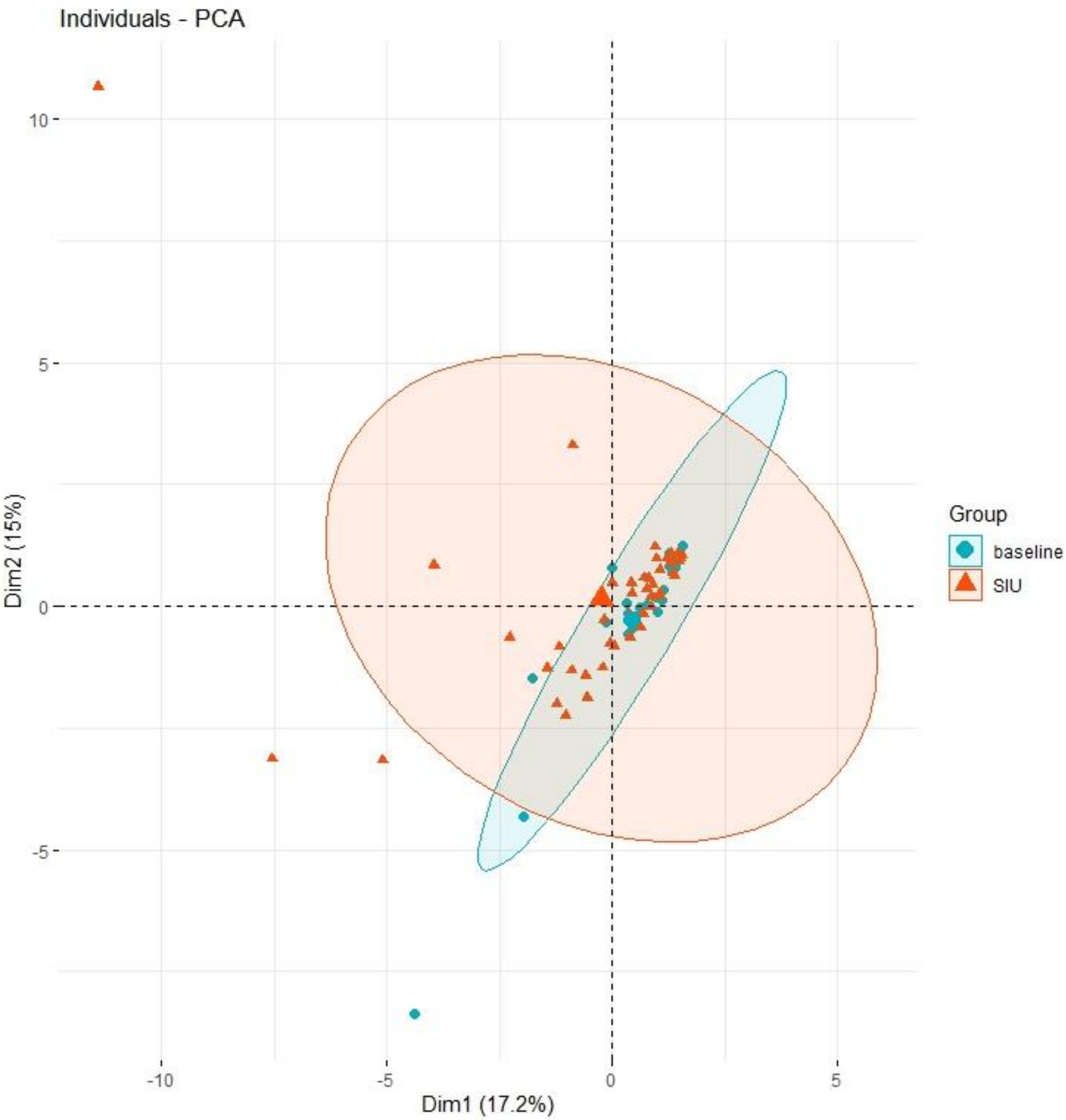

Figure 9 - PFAS Fingerprint in POTW Principal Componet Analysis Plot

This principal component analysis plot of POTW effluent fingerprints demonstrates that POTWs without inputs from SIUs known or suspected to be PFAS sources have similar fingerprints, whereas those with SIU contributions vary more in fingerprint.

PCA was completed using the covariance matrix, standardizing the data by dividing by each variable's standard deviation, and mean centering the data by subtracting each variable's mean from the data within each variable.

Appendix C – R Code for Principal Component Analysis and Other Data Visualization

Note that the following is provided as a resource to aid in PFOS and PFOA source identification and data visualization. Learning and utilizing this tool is not required for facilities implementing minimization plans. R is an open-source statistical analysis tool that allows users to perform various statistical tests, operations, and visualizations on data imported from excel or other data management platforms. The code below allows a user to import an excel spreadsheet into R and use bar charts, principal component analysis, and other tools to compare it a POTW's effluent fingerprint to fingerprints of various other POTWs in Wisconsin.

1. Begin by opening this excel spreadsheet, which contains PFAS effluent concentrations for 78 POTWs sampled in 2021-2022 as part of DNR's data collection for the PFOS and PFOA standards adoption process, excluding one outlier POTW and a few POTWs with incomplete data. Data are only included for the 26 variables for which at least one POTW had a detection value. Your POTW may sample for more than 26 variables, but the code below only allows for entry of the 26 variables detected in the original dataset for 78 POTWs.

2. Add the average or median PFAS effluent concentrations for your POTW of interest (median suggested if outlier results would skew the fingerprint) in the green cells in row 75. Alternatively, you may add additional rows in rows 75 and beyond for each sample taken to visualize each sample. Enter "Permittee" in column A for each new row added and "74" or the POTW name in column B for each row added. Enter 0 for non-detections with sufficiently low limits of detection.
3. If you do not have R and R Studio downloaded on to your computer, please follow the instructions here to download R: https://cran.r-project.org/, and here to download R Studio: https://posit.co/downloads/. Both are open source and free to download and use.
4. Open R Studio and open this file (or copy and paste the code below) into R Studio.

5. Enter the file path for the working directory and excel spreadsheet file in the code (step 3 – lines 29-31).
6. Press "run" for each line. It will walk you through the code line-by-line, with some lines producing graphics that help you to visualize your facility's PFAS fingerprint and how it compares to other Wisconsin POTWs' fingerprints. Where the plots visualize POTWs by facility number, your POTW of interest will be labeled "74" (or the POTW name if you entered that instead).
   Note: If you run into any trouble and are not familiar with R, you could consider copying the code into ChatGPT, noting the line of code where you receive the error, and sharing the error message. ChatGPT can be helpful in troubleshooting and explaining how to overcome the error. Note that any results obtained through ChatGPT should be verified as incorrect results can be produced. Note that the department does not formally endorse the use of ChatGPT.

R Code:

```
---
title: 'POTW PFAS Fingerprint Data Visualization'
author: "Jason Knutson, Wisconsin Department of Natural Resources"
date: "6/20/2024"
---

#Step 1 - Install any packages not already loaded on to your computer.  If you have previously used R on your computer, you may skip any lines of code in this step for packages already installed.
install.packages("tidyverse")
install.packages("readxl")
install.packages("ggplot2")
install.packages("factoextra")
install.packages("scatterplot3d")
install.packages("rgl")
install.packages("tidyr")
install.packages("dplyr")
install.packages("sfsmisc")

#Step 2 - Load installed packages
library(tidyverse)
library(readxl)
library(ggplot2)
library(factoextra)
library(scatterplot3d)
library(rgl)
library(tidyr)
library(dplyr)
library(sfsmisc)

#Step 3 - Load excel spreadsheet into R
setwd("[file path]") #set working directory. Insert the file path for the folder where you have your data saved, such as "C:/Users/[username]/Desktop/filename")
wweffluent <- read_excel("[file path]") #load the data in and name it "wweffluent". Insert the file path for the excel file itself.

#Step 4 - Principal Component Analysis (PCA)
pca <- prcomp(wweffluent[,c(3:28)], center=TRUE, scale = TRUE)
summary(pca)
#visualize principal components - #74 is POTW of interest
biplot(pca, scale = 0)
#display loading scores - #74 is POTW of interest
options(max.print=100000)
pca$x
#chart total variance explained by each principal component
var_explained = round(100 * pca$sdev^2 / sum(pca$sdev^2),1)
barplot(var_explained, main="Scree plot", xlab = "Principal Component", ylab = "Percent Variation")
var_explained
#Plot fingerprints as points and PFAS as vectors - #74 is POTW of interest
fviz_pca_biplot(pca, repel = TRUE, col.var = "#2E9FDF", col.ind = "#696969", labelsize = 0.4, pointsize = 2)
```

```
#Plots with 95th percentile confidence ellipses (i.e., ellipse surrounding 95% of data from each grouping - baseline, SIU).  Larger icon is center of the group. Yellow square is POTW of interest.
fviz_pca_ind(pca, col.ind = as.factor(wweffluent$Group), palette = c("#00AFBB",  "#FC4E07", "#E7B800"), geom = c("point"),
        addEllipses = TRUE, legend.title = "Group",pointsize = 2,
        repel = TRUE)

#Step 5 - Plot PFAS concentrations as points on box and whisker plot of baseline POTW signatures data
#remove Total PFAS Column from dataset
wweffluent1 <- wweffluent %>%
  select(-Total_PFAS)
#separate data into subsets of baseline facilities and the permittee of interest
baseline_data <- wweffluent1 %>%
  filter(Group == "baseline")
permittee_data <- wweffluent1 %>%
  filter(Group == "Permittee")
#reshape data for plotting
baseline_data_long <- baseline_data %>%
  pivot_longer(
    cols = -c(Group, Facility),
    names_to = "PFAS",
    values_to = "Concentration")
print(baseline_data_long)
permittee_data_long <- permittee_data %>%
  pivot_longer(
    cols = -c(Group, Facility),
    names_to = "PFAS",
    values_to = "Concentration")
# Convert PFAS to factor with levels from baseline_data_long to ensure consistency
baseline_data_long$PFAS <- factor(baseline_data_long$PFAS, levels = unique(baseline_data_long$PFAS))
#plot data in box and whisker plot
ggplot() +
  geom_boxplot(data = baseline_data_long, aes(x = PFAS, y = Concentration)) +
  geom_jitter(data = permittee_data_long, aes(x = PFAS, y = Concentration), color = "red", shape = 16, size = 3) +
  labs(title = "PFAS Fingerprint of POTW of Interest compared to Baseline POTW Fingerprints",
       x = "PFAS",
       y = "Concentration (ng/L)") +
  theme_minimal() +
  theme(axis.text.x = element_text(angle = 45, hjust = 1)) +
  scale_x_discrete(labels = baseline_data_long$PFAS)

#Step 6 - Print stacked bar charts of PFAS fingerprints (Total concentrations)
# Define specific colors for each PFAS parameter
parameter_colors <- c(
  # Blue/Green/Purple
  PFBA = "darkseagreen2", PFPeA = "aquamarine2", PFHxA = "darkturquoise", PFHpA = "deepskyblue",
  PFOA = "deepskyblue3", PFNA = "deepskyblue4", PFDA = "darkorchid4", PFUnA = "darkorchid3",
  PFDoA = "darkorchid1", PFTriA = "darkmagenta", PFTeA = "deeppink3",
```

```
  # Red/Orange/Yellow
  PFBS = "darkgoldenrod", PFPeS = "darkorange", PFHxS = "coral", PFHpS = "brown1",
  PFOS = "#e41a1c", PFDS = "darkred",
  # Gray
  FourTwoFTS = "#cccccc", SixTwoFTS = "#969696", EightTwoFTS = "#636363",
  # Other colors
  HFPODA = "azure", NEtFOSAA = "beige", NEtFOSE = "bisque", NMeFOSAA = "bisque3",
NMeFOSE = "bisque4"
)
# Order the parameters to stack in a certain order
parameter_order <- c(
  "PFBA", "PFPeA", "PFHxA", "PFHpA", "PFOA", "PFNA", "PFDA", "PFUnA", "PFDoA", "PFTriA",
"PFTeA",
  "PFBS", "PFPeS", "PFHxS", "PFHpS", "PFOS", "PFDS",
  "FourTwoFTS", "SixTwoFTS", "EightTwoFTS",
  "HFPODA", "NEtFOSAA", "NEtFOSE", "NMeFOSAA", "NMeFOSE"
)

#Reshape Data for plotting in stacked bar chart of total concentrations
reshaped_wweffluent <- wweffluent %>%
  pivot_longer(
    cols = -c(Group, Facility),
    names_to = "PFAS",
    values_to = "Concentration")
reshaped_wweffluent2 <- reshaped_wweffluent %>%
  select(Group, PFAS, Concentration, Facility)
#remove Total PFAS values from data
totalbarchart_wweffluent <- reshaped_wweffluent2 %>%
  filter(PFAS != "Total_PFAS")
print(totalbarchart_wweffluent) #to make sure it worked

# Convert PFAS_Parameter to factor with specified order
totalbarchart_wweffluent$PFAS <- factor(totalbarchart_wweffluent$PFAS, levels = parameter_order)

#Create stacked bar chart of total concentrations - POTW of interest is on far right
totalbarchart_wweffluent %>%
  ggplot(aes_string(x = "Facility", y = "Concentration", fill = "PFAS")) +
  geom_bar(stat = "identity") +
  scale_fill_manual(values = parameter_colors) +
  labs(title = "Concentration of PFAS Parameters in POTW Effluents", x = "POTW", y = "Concentration",
fill = "PFAS Compound") +
  theme_minimal() +
  theme(legend.position = "right", axis.text.x = element_text(angle = 45, hjust = 1))

#Step 7 - Print stacked bar charts of PFAS fingerprints (Percent of Total Concentrations) - NOTE: Must
run Lines 86-107 of Step 6 first for this to work
#Convert PFAS Concentrations to percent of Total PFAS
wweffluent$PFBA <- wweffluent$PFBA / wweffluent$Total_PFAS
wweffluent$PFPeA <- wweffluent$PFPeA / wweffluent$Total_PFAS
wweffluent$PFHxA <- wweffluent$PFHxA / wweffluent$Total_PFAS
wweffluent$PFHpA <- wweffluent$PFHpA / wweffluent$Total_PFAS
```

```
wweffluent$PFOA <- wweffluent$PFOA / wweffluent$Total_PFAS
wweffluent$PFNA <- wweffluent$PFNA / wweffluent$Total_PFAS
wweffluent$PFDA <- wweffluent$PFDA / wweffluent$Total_PFAS
wweffluent$PFUnA <- wweffluent$PFUnA / wweffluent$Total_PFAS
wweffluent$PFDoA <- wweffluent$PFDoA / wweffluent$Total_PFAS
wweffluent$PFTriA <- wweffluent$PFTriA / wweffluent$Total_PFAS
wweffluent$PFTeA <- wweffluent$PFTeA / wweffluent$Total_PFAS
wweffluent$PFBS <- wweffluent$PFBS / wweffluent$Total_PFAS
wweffluent$PFPeS <- wweffluent$PFPeS / wweffluent$Total_PFAS
wweffluent$PFHxS <- wweffluent$PFHxS / wweffluent$Total_PFAS
wweffluent$PFHpS <- wweffluent$PFHpS / wweffluent$Total_PFAS
wweffluent$PFOS <- wweffluent$PFOS / wweffluent$Total_PFAS
wweffluent$PFDS <- wweffluent$PFDS / wweffluent$Total_PFAS
wweffluent$FourTwoFTS <- wweffluent$FourTwoFTS / wweffluent$Total_PFAS
wweffluent$SixTwoFTS <- wweffluent$SixTwoFTS / wweffluent$Total_PFAS
wweffluent$EightTwoFTS <- wweffluent$EightTwoFTS / wweffluent$Total_PFAS
wweffluent$FOSA <- wweffluent$FOSA / wweffluent$Total_PFAS
wweffluent$NMeFOSAA <- wweffluent$NMeFOSAA / wweffluent$Total_PFAS
wweffluent$NEtFOSAA <- wweffluent$NEtFOSAA / wweffluent$Total_PFAS
wweffluent$NMeFOSE <- wweffluent$NMeFOSE / wweffluent$Total_PFAS
wweffluent$NEtFOSE <- wweffluent$NEtFOSE / wweffluent$Total_PFAS
wweffluent$HFPODA <- wweffluent$HFPODA / wweffluent$Total_PFAS
#Reshape Data for plotting in stacked bar chart of % PFAS
reshaped_wweffluent <- wweffluent %>%
  pivot_longer(
    cols = -c(Group, Facility),
    names_to = "PFAS",
    values_to = "Concentration")
reshaped_wweffluent2 <- reshaped_wweffluent %>%
  select(Group, PFAS, Concentration, Facility)
#remove Total PFAS values from data
percentbarchart_wweffluent <- reshaped_wweffluent2 %>%
  filter(PFAS != "Total_PFAS")
print(percentbarchart_wweffluent) #to make sure it worked

# Convert PFAS_Parameter to factor with specified order
percentbarchart_wweffluent$PFAS <- factor(percentbarchart_wweffluent$PFAS, levels =
parameter_order)

#Create colored stacked bar charts with concentrations as percent of total PFAS - POTW of interest is on
far right
percentbarchart_wweffluent %>%
  ggplot(aes_string(x = "Facility", y = "Concentration", fill = "PFAS")) +
  geom_bar(stat = "identity") +
  scale_fill_manual(values = parameter_colors) +
  labs(title = "Proportion of PFAS Parameters in POTW Effluents", x = "POTW", y = "% of Total PFAS",
fill = "PFAS Compound") +
  theme_minimal() +
  theme(legend.position = "right", axis.text.x = element_text(angle = 45, hjust = 1))
```

Appendix D – Potential Sources of PFAS to POTWs

The following list, which is not all encompassing, contains examples of potential sources of PFOS and/or PFOA that are anticipated to be the most significant. EPA's ELG Plan 15 (Section 6.3; https://www.epa.gov/system/files/documents/2023-01/11143_ELG%20Plan%2015_508.pdf) and Multi-Industry PFAS Study (https://www.epa.gov/system/files/documents/2021-09/multi-industry-pfas-study_preliminary-2021-report_508_2021.09.08.pdf) contain data on PFAS fingerprints from some of these sectors, with average concentrations visualized in radar graphs below:

- *Landfills* – Leachate from landfills may have some amount of PFAS. That said, the mass contribution from landfills is expected to be minor relative to other sources. Landfills are anticipated to have the greatest impact on smaller POTWs (flow rates <1 MGD). POTWs are encouraged to calculate the PFOS and/or PFOA mass loading from landfills contributing to their sewerage systems to determine the potential effect on final effluent concentrations. In cases where landfills are shown to contribute a relatively minor mass of PFOS and/or PFOA when compared to other industrial sources, POTWs are encouraged to focus their efforts on the largest mass contributors first.

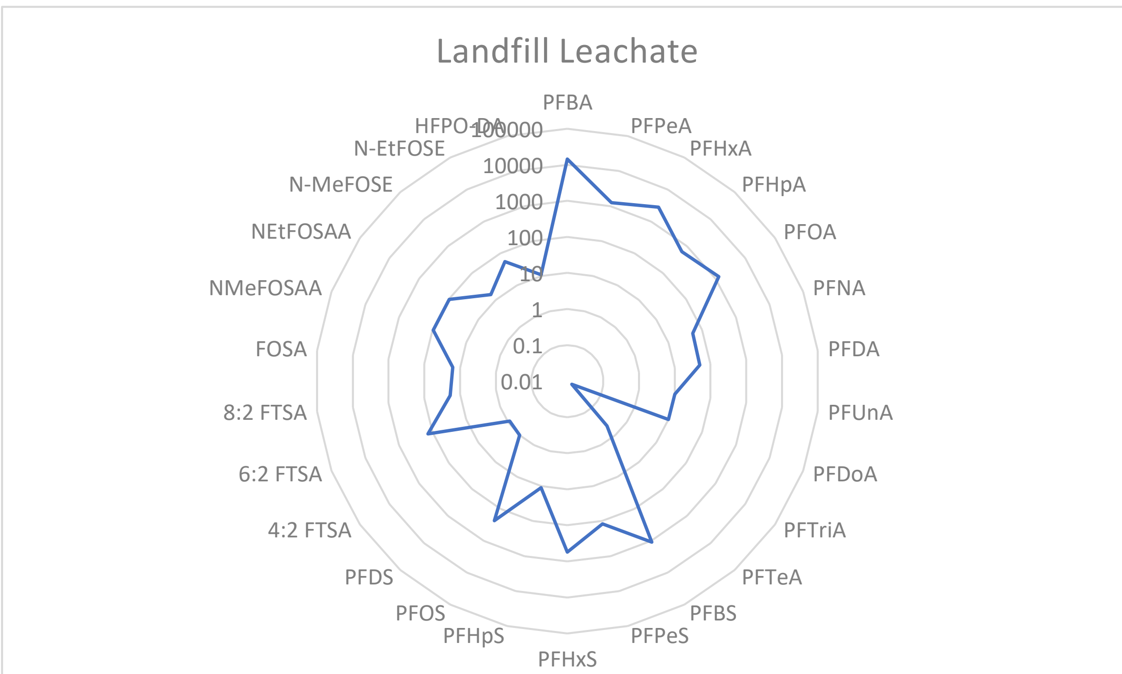

Figure 10 - Landfill Leachate PFAS Fingerprint

(Data provided by EPA, 2023a)

- *Airports* – If a POTW receives any amount of runoff from an airport and/or an area (such as a military base) where AFFF was historically used for testing or training purposes, then that would be a potential source that should be identified in any PFOS and PFOA minimization plan. Fingerprints often reflect those of AFFF. First generation AFFF, which is produced by electrochemical fluorination, often results in a fingerprint containing elevated concentrations of PFOS and PFHxS. Second generation AFFF, which is produced via fluorotelomerization, often results in a fingerprint containing high 8:2 FTS and 6:2 FTS and their degradation by-products. The second generation AFFF, while they were not made with PFOA, contained polyfluorinated precursors to PFCAs, meaning PFOA could be one of the terminal compounds from second generation AFFF. Modern AFFF, which is produced via short-chain fluorotelomerization, often contains high concentrations of 6:2 FTS and its degradation by-products (Annunziato et al. 2020, Balgooyen & Remucal 2023, Houtz et al. 2013, Houtz et al. 2018, Weiner 2013). 6:2 FTS has been shown to break down into ten different compounds under sulfur-limiting conditions: PFBA, PFPeA, PFHxA, 4:3 FTCA, 5:3 FTCA, 6:2 FTCA, 6:2 FTUA, 5:2 FTOH, 5:2 FT ketone, and 6:2 FTOH (Shaw et al. 2019).

- *Firefighting Training Centers* – There are several facilities in Wisconsin where, much like airports, AFFFs were historically used in firefighting training operations.

- *Fire Suppression Systems* – There could be old fire suppression systems in place at facilities which contain AFFFs.

- *Centralized Waste Treatment Facilities* – These facilities may be sources of PFOS and/or PFOA if they historically accepted wastes from any of the industrial sectors listed in this document. Fingerprints from this sector may vary based on the types of wastewater accepted by the facility.

- *Pulp/Paper Manufacturers* – Despite the phaseout of PFOS and PFOA manufacturing, historic contamination present at pulp/paper mills may be sources of PFOS and/or PFOA contamination. This is especially true of mills which currently or historically manufactured coated products. In February 2024, the US Food and Drug Administration announced that coated paper food packaging containing intentionally added PFAS is no longer sold in the US. Recycled wastepaper at recycle mills may also be a source of legacy contamination.

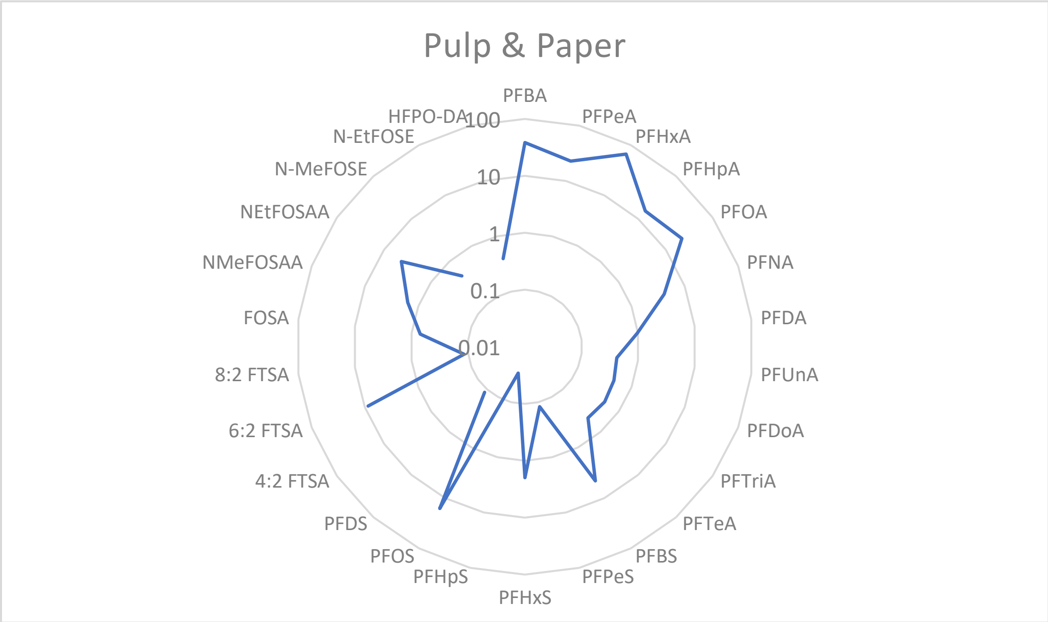

Figure 11 - Pulp & Paper PFAS Fingerprint
(Data provided by EPA's ELG Plan, 2023b)

- *Metal Finishers* – Historically, metal finishers utilized mist/fume suppressants which contained PFOS for chrome or nickel-plating operations. Though this industrial sector has largely moved towards shorter-chain PFAS formulations such as 6:2 FTS, legacy contamination may be an issue in the processing tanks used onsite.

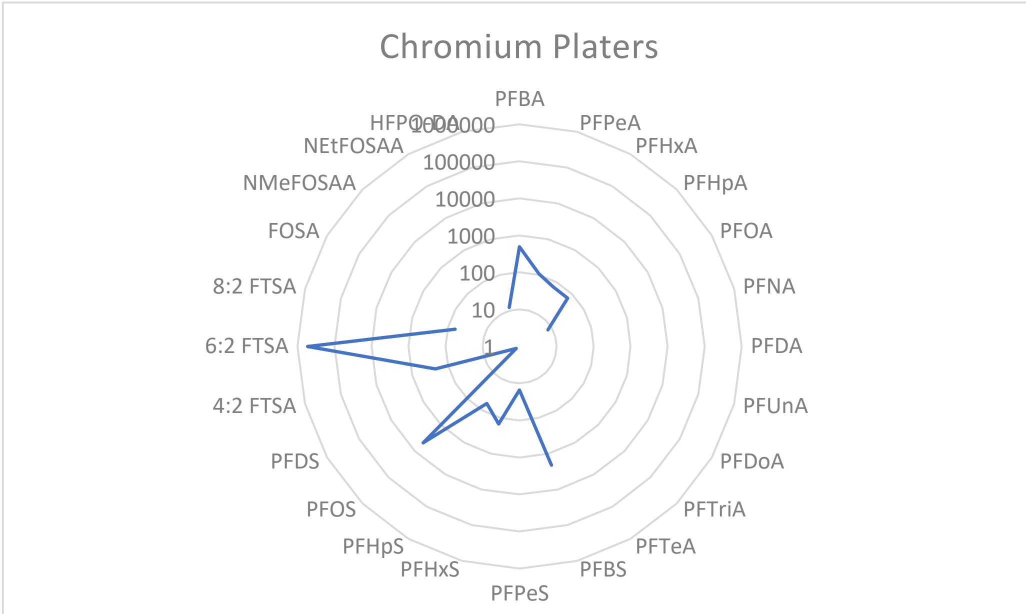

Figure 12 - Chromium Platers PFAS Fingerprint
(Data from EPA's Multi-Industry PFAS Study, 2021)

- *Power Plants* – The sources of PFOS and/or PFOA at power plants are anticipated to largely be dependent on where they source their cooling water. For example, if a power plant reuses effluent from another industry which has detectable concentrations of PFOS and/or PFOA, then a cooling tower may ultimately concentrate those compounds in the power plant's effluent. PFAS compound signatures may vary depending on concentrations in the source water.

- *Textiles and Tanneries* – These types of operations may be sources of PFOS and/or PFOA as they have historically been used in consumer-applied coatings for the purposes of repelling water and oil. Some applications include: protective outerwear, umbrellas, tents, sails, carpets, and upholstery.

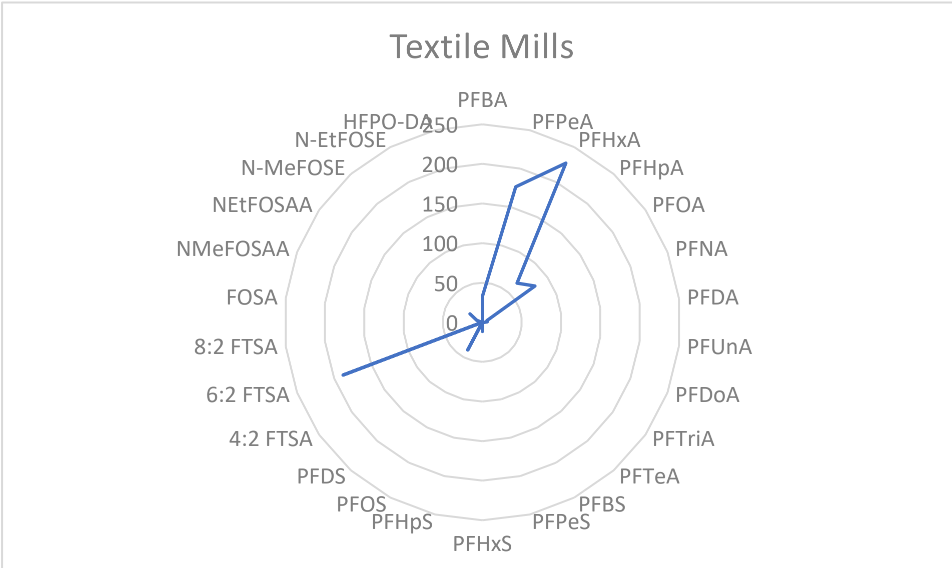

Figure 13 - Texile Mills PFAS Fingerprint (Data from EPA's ELG Plan, 2023b)

- *Commercial Laundries* – The primary anticipated source of PFOS and/or PFOA at these facilities is the shedding of these compounds from clothes which were treated with a PFAS-based stain-resistant coating.

- *Chemical Manufacturers* – Most chemical manufacturers are not anticipated to be significant sources of PFOS and/or PFOA, as this depends largely on the type of chemicals produced and/or used at the facility.

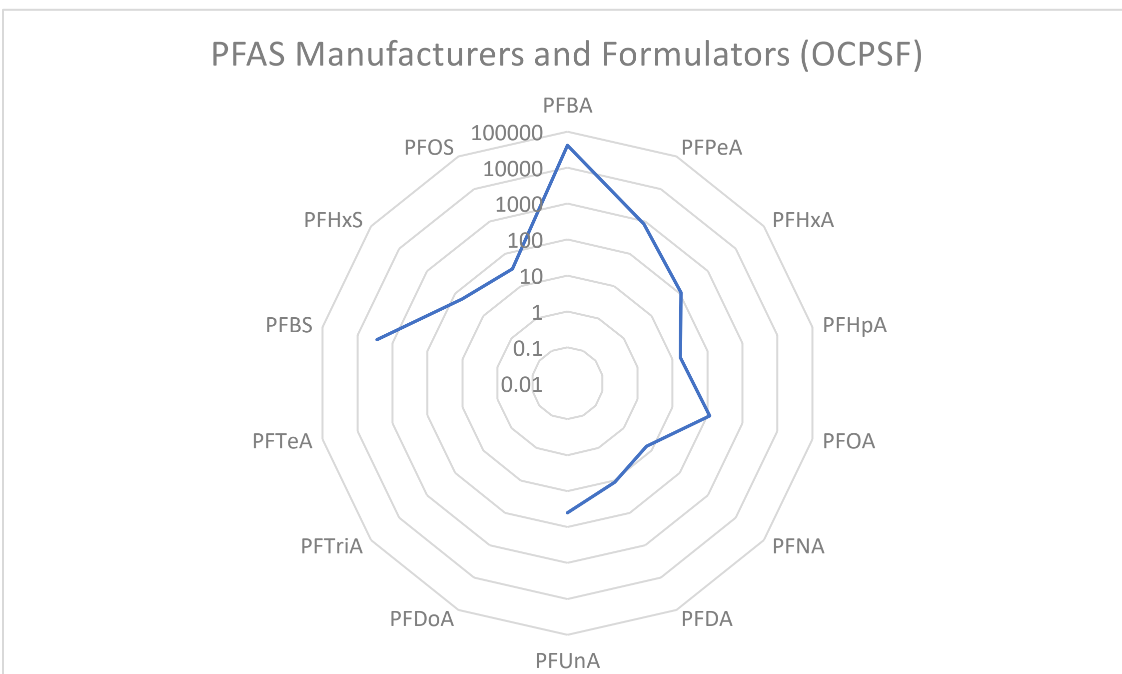

Figure 14 - PFAS Manufacturers and Formulators PFAS Fingerprint (Data from EPA's Multi-Industry PFAS Study, 2011)

- *Cookware Manufacturers* – Cookware manufacturers historically utilized PFOA extensively in the application of PTFE on nonstick pots and pans.

- *Plastics Manufacturers* – PFOA was historically utilized as a mold release. The industry has switched to shorter-chained PFAS compounds.

- *Electronics Manufacturers* – PFOA, by way of PTFE, was historically used in the manufacturing of insulators, solder sleeves, printed circuit boards, cell phones, computers, speakers, and transducers. Current usage of PFOA and PFOS in these applications has ceased and been replaced with shorter-chained PFAS compounds.

- *Other Industries* – There may be other industries not identified in this document that are sources of PFOS and/or PFOA based on historic usage of these compounds or other factors. The department's understanding of these compounds is evolving, and the regulatory landscape has the potential to change as new information becomes available.

Source Water – The second primary source of PFOS and/or PFOA contamination at a POTW may be from the drinking water source for the community itself. POTWs are encouraged to get source water data to understand what the background levels are in the community. It's important to note that federal funding to aid in the installation of drinking water treatment is available to communities whose water sources exceed the federal maximum contaminant levels.

Domestic Sources – In addition to the source water, there may be contributions of PFOS and/or PFOA from domestic sources such as septage tank wastes and toilet paper. While department efforts to sample wastewater effluent show that domestic sources are not anticipated to be the sole source of PFOS and/or PFOA in situations where discharges have reasonable potential to exceed standards, there is information to suggest that there may be some contribution from the community.

Contaminated Groundwater (Inflow and Infiltration) – If a portion of the sewerage system intersects with a PFAS contaminated groundwater plume, then inflow and infiltration of that groundwater may be a significant source of PFOS and/or PFOA to the POTW. POTWs are encouraged to review known contaminated sites in their community if the sampling data shows there is a source not yet identified through other means.

Legacy Contamination – PFOS and PFOA are known as "forever chemicals" due to their ability to remain in the environment long after they have stopped being used. Therefore, it is important for a POTW to investigate possible sources where PFAS may have been used including current industrial discharges, sites where industries have been abandoned or shut down, or the collection system itself where legacy contamination may be found. In limited cases where sampling of other sources identified above yields no definitive results, POTWs may choose to take samples from various points of the sewerage system itself.

Appendix E – PFOS and PFOA Minimization Plan Template

NOTE: This template is provided as a reference and starting point for facilities to use when developing Minimization Plans and is not required to be used.

[**Insert Facility Name**]
PFOS and PFOA Minimization Plan
Permit Number: **[Insert Permit No.]**
Date: [**Insert Date**]

Narrative

Depending on the documentation available at the time of minimization plan submittal, additional narrative may need to be provided in support of selected minimization actions. In addition to providing background for the department, the minimization plan narrative will help other readers (municipal or non-governmental) become familiar with the facility planning process and reasoning behind the minimization plan approach. All minimization plans should provide some degree of narrative and address the following topics:

- A brief summary of actions taken during the previous permit term and the results of those actions to establish a baseline of what has been done to date.
- A brief discussion on reductions expected with implementation of the proposed PFOS and/or PFOA minimization actions.

Source Identification

Provide a summary of known and potential sources of the pollutant(s). Information can be presented in any form, but the table below is provided as a template for presenting source information. However, depending on the facility and feasibility of sampling influent sources and applicable outfalls (surface water, land treatment, sludge, etc.) it may be more appropriate to present information in a figure that shows the amount of pollutant coming in versus the amount going out to surface water.

[Pollutant] Source Category	Annual Average Mass (lbs/day)	Annual Percent of Total
TOTAL		**100%**

Data Analysis

Provide a trend analysis dating back to before the implementation of the minimization plan. Include influent and effluent data where available. Reference or attach any facility planning or evaluation study that evaluated facility performance capabilities (only include studies that are recent or otherwise applicable for the evaluation of the existing facility and current conditions). Provide an explanation for any "spikes" in data that may have been observed during the current permit term.

Planned Actions

In the table below, list specifically, what steps the facility plans to undertake (and when) to reduce levels of PFOS and/or PFOA to the treatment plant. It is important to note, however, that a facility may not be allowed the full seven years to implement minimization plan activities, as this is dependent on the success of the first three years of implementation. The length of time the department will allow a facility to implement the minimization plan will be site-specific and re-evaluated at permit reissuance and whenever updates are made to the minimization plan.

Minimization Plan Activities	1st Year	2nd Year	3rd Year	4th Year	5th Year	6th Year	7th Year
1.							
a.							
b.							
2.							
a.							
b.							
3.							
a.							
b.							
4.							
a.							
b.							
5.							
6.							

Appendix F – PFOS and PFOA Minimization Plan Annual Report Checklist

NOTE: Permittees are not required to fill out and submit this checklist with their annual report. Rather, this checklist is provided as a resource to aid facilities in completing their annual report to ensure that the proper information is reported to the department.

Section I: General Information

Permittee Name:
Pollutant:
Annual Report Year Covered (i.e., 2024):
Permit Term (i.e., 10/01/2022 – 09/30/2027):

Section II: Summary of Pollutant Reduction Work Done to Date

Pollutant Source Identification

- ☐ List and discuss sources of pollutants. The discussion should include whether the specific source is controllable. If not controllable, include details as to why not.

Actions Completed

- ☐ Discuss the source reduction measures completed during the previous year. It should be identified if this action was to minimize or maintain a pollutant source.
- ☐ For each of the actions, provide a detailed summary* and attach any supplemental information. This could include date/date range of action, copy of meeting minutes, inspection results, rebates, etc.
- ☐ If any actions triggered next steps, these actions should be included along with a planned schedule.

Actions Not Completed

- ☐ Include a list of planned actions for the year, according to the approved minimization plan, that were not completed.
- ☐ A detailed explanation* as to why the planned actions were not completed should be included. This could have been due to operator time, funding, or additional barriers.
- ☐ Discuss in detail the encountered barriers that prevented completion of the action items.
- ☐ Along with a new time frame, include steps to ensure planned actions will occur in the future.

* This is the main focus of the report and should clearly reiterate the setbacks to the planned actions.

Section III: Summary of Progress

Data Analysis

- ☐ All data collected for the previous years should be included. This data could include any influent, effluent, blanks, industry, or other sampling performed.

- ☐ Provide data in one or more of the following formats:

  ☐Graphs ☐Tables, Averages ☐Raw Data

- ☐ Include an analysis summary of the data. This could include high effluent due to seasonality, industrial loads, or unknown spikes.

Section IV: Planned Actions

Actions Planned

- ☐ List the planned actions for the upcoming year, according to the approved minimization plan. This list should also include any follow-up/next step actions identified in Section II above.

Section V: Final Report

Only applies to the final report prior to permit expiration.

- ☐ This should be a discussion on the ability to meet the final water quality limit and additional steps the facility can take during the next permit term to meet the final limit.

- ☐ Submit an updated minimization plan if the facility is anticipating the need to further reduce effluent concentrations.

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