MICHIGAN DEPARTMENT OF ENVIRONMENT, GREAT LAKES, AND ENERGY

MICHIGAN INDUSTRIAL PRETREATMENT PROGRAM (IPP) PFAS INITIATIVE

Identified Industrial Sources of PFOS to Municipal Wastewater Treatment Plants

August 2020

EGLE, WATER RESOURCES DIVISION

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INTRODUCTION

IPP PFAS INITIATIVE

As a special effort under the National Pollutant Discharge Elimination System (NPDES) program, the Michigan Department of Environment, Great Lakes, and Energy (EGLE), Water Resources Division (WRD), launched the Industrial Pretreatment Program (IPP), Per- and Polyfluoroalkyl Substances (PFAS) Initiative in February 2018. This initiative aims to reduce and eliminate certain PFAS from industrial sources that may pass through municipal wastewater treatment plants (WWTP) and enter lakes and streams, potentially causing fish consumption advisories or polluting public drinking water supplies. The program was developed after EGLE identified a WWTP passing through perfluorooctane sulfonic acid (PFOS) from an industrial user discharging to their system to the Flint River at concentrations far exceeding the state's water quality standard (see discussion below on *PFAS Regulation in Michigan Surface Waters*) in June 2017. This effort is just one part of a comprehensive, multi-media approach by the State of Michigan to address PFAS in the environment. For more information on the larger program, visit Michigan.gov/PFASResponse.

PFAS REGULATION IN MICHIGAN SURFACE WATERS

EGLE determines the concentration of substances in surface waters that would not be expected to cause adverse effects to human health, aquatic life, and wildlife using the methodology described in Michigan's state laws and rules, Rule 323.1057 ("Rule 57") of the Part 4, Water Quality Standards (WQS), administrative rules promulgated pursuant to Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended. Due to limited studies and data on PFAS, the only PFAS that have Michigan Rule 57 values are PFOS and perfluorooctanoic acid (PFOA) as listed below in Table 1. These values were established in March 2014 and May 2011, respectively. The most stringent values are the human noncancer values, which are based on human fish and water consumption. Values for protection of aquatic life (the other three values) are much less restrictive. An explanation of the Rule 57 process is available at Michigan.gov/WaterQuality under "Laws, Rules, and Standards."

Table 1: Michigan Rule 57 Values for PFOS and PFOA

PFAS, ng/l or ppt*	Human Noncancer Value (nondrinking water source)	Human Noncancer Value (drinking water source)	Final Chronic Value	Final Acute Value	Aquatic Maximum Value
PFOS	12	11	140,000	1,600,000	780,000
PFOA	12,000	420	880,000	15,000,000	7,700,000

*ng/l=nanograms per liter, ppt=parts per trillion. These units are considered equivalent

To date, effluent sampling has determined that 31 WWTPs in Michigan have exceeded Michigan's WQS for PFOS. Only one WWTP has exceeded the 420 ppt WQS for PFOA. No WWTPs have been found to exceed the 12,000 ppt for PFOA. EGLE is using the WQS as screening levels in absence of effluent limits. EGLE has therefore focused its efforts on reducing PFOS in WWTP effluent.

IPP PFAS INITIATIVE IMPLEMENTATION

To date, EGLE has required 95 WWTPs with required IPPs to evaluate their industrial users as potential sources of PFOS and PFOA. It should be noted that in Michigan, municipalities act as IPP Control Authorities, even for WWTPs of less than five million gallons per day (MGD) in design flow, meaning that IPP compliance and enforcement is implemented locally. EGLE began the IPP PFAS Initiative with a series of regional meetings and a webinar for municipal WWTP staff to inform them about PFAS, suggest potential sources for evaluation, and outline EGLE's expectations for actions under the initiative (to learn more, see the **IPP PFAS Information web page** at **Michigan.gov/IPP**).

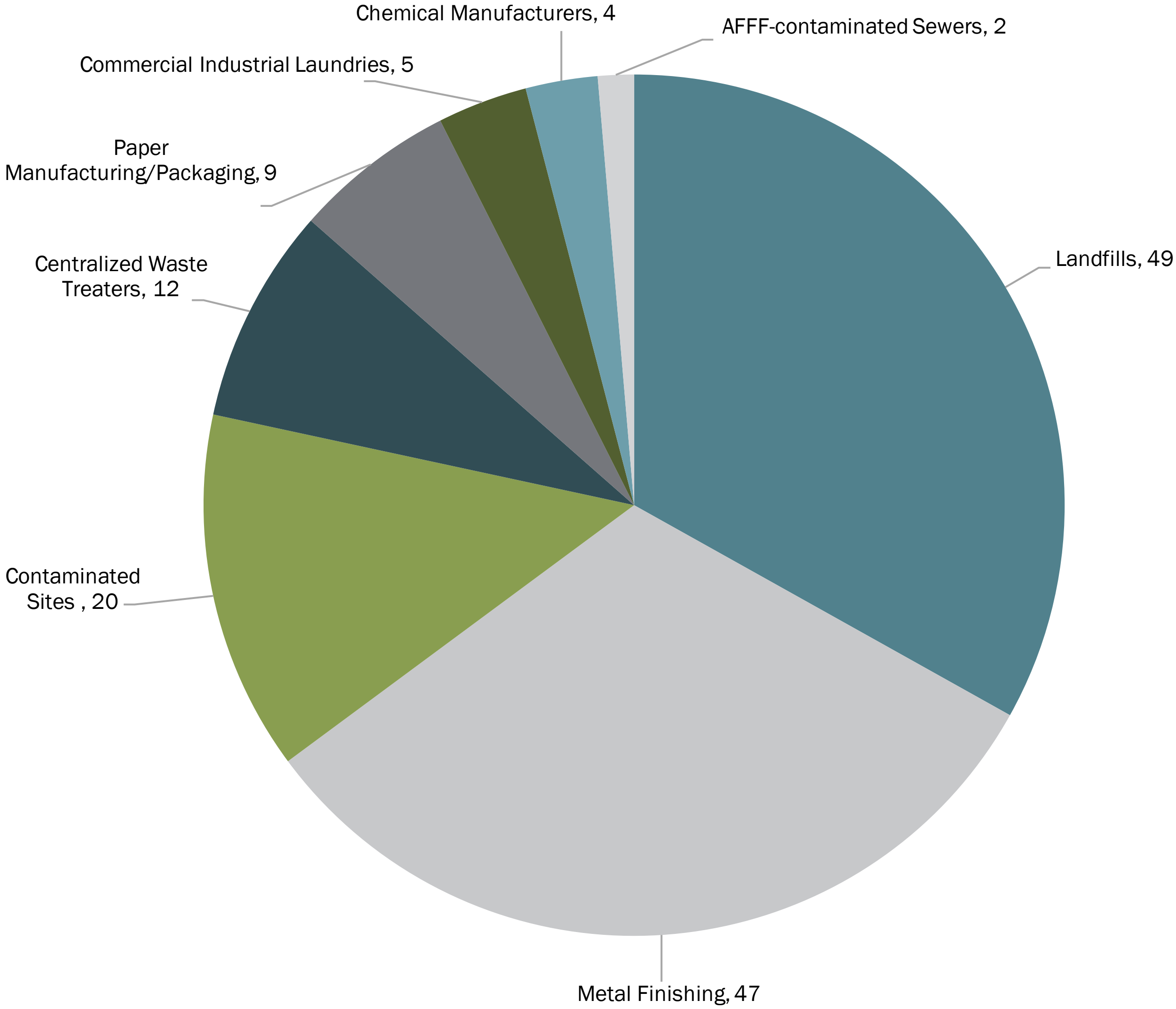
Based on literature reviews and knowledge of Michigan, EGLE highlighted the following industrial categories as potential sources of PFOS and/or PFOA to WWTPs: metal finishers and electroplaters utilizing fume suppressants, tanneries, leather and fabric treaters, paper and packaging manufacturers, landfill leachate, centralized waste treaters, and sites where aqueous film forming foam (AFFF) was used. WWTP staff were asked to evaluate these potential sources via records review and interviews with industry staff and then sample the effluent of those industries that were likely to have used PFOS and/or PFOA in the past or were currently using some type of PFAS-containing chemical in their processes.

FINDINGS: SIGNIFICANT AND OTHER SOURCES AND VARIABLE IMPACTS

SIGNIFICANT SOURCES

Sources of PFOS identified in the IPP PFAS Initiative were similar to those identified in literature reviews. EGLE's WRD defined *sources* as those industrial users with discharges greater than 12 ppt PFOS, which was used as a screening level. The majority of significant PFOS sources to WWTPs were landfills that accepted industrial wastes containing PFOS, metal finishers, and contaminated sites associated with industries or activities with PFOS usage. Other sources found included centralized waste treaters (CWTs), paper manufacturing/packaging, commercial industrial laundries, chemical manufacturers, and sewers contaminated with AFFF. It should be noted that there were industries in all these categories that discharged PFOS at concentrations less than the PFOS screening level. Some potential sources suggested by literature were likely absent since those industries are not prevalent in Michigan. Figure 1 shows source types by number in each category. Note that this simple count does not indicate concentrations of PFOS in effluent or impact on WWTP effluent. It also should be noted that several sources were found by other means than the IPP PFAS Initiative, i.e. other reports or communications.

Figure 1. Sources of PFOS, Number by Type



Effluent discharged by municipal WWTPs without significant industrial sources met WQS, leading EGLE to conclude that general consumer use of products with PFAS coatings and/or ingredients (residential laundering, cleaning carpets, etc.) is not a significant source of PFOS to WWTPs. The effluent of WWTPs without significant sources of PFOS ranged from two to seven ppt, which appears to be the anthropogenic background concentration for sanitary sewage in Michigan.

Sources of PFOS to WWTPs in Michigan are shown in Table 2, which lists general industry categories found to be sources, numbers of industries per category and subcategory, percentages of industries discharging PFOS in each source type and subtype, and ranges of concentrations found in wastewater discharged to sanitary sewers above the IPP PFAS Initiative screening level of 12 ng/l. The concentrations shown are those prior to pretreatment or reduction efforts. The percentages by source type relate to the same line of the table. For example, 49 of the 56 landfills or 88 percent of all landfills evaluated were found to be sources of PFOS, with 100 percent of active Type II landfills and 83 percent of closed Type II landfills found to be sources.

Table 2: Sources of PFOS to WWTPs in Michigan

Industry/Category/Type	Total Number Evaluated[1]	Number (%) Sources of PFOS by Type[2]	Range Effluent PFOS exceeding screening level of 12 ppt
Landfills	56	49 (88%)	13-5,000
• Type II Sanitary Landfills	48	44 (92%)	20-5,000
○ Active	25	25 (100%)	29-5,000
○ Closed	23	19 (83%)	20-420
• Type III Sanitary Landfills	7	4 (57%)	13-4,000
○ Active	3	1 (33%)	33-100
○ Closed	4	3 (75%)	13-4,000
• Hazardous Waste Landfill	1	1 (100%)	60
Metal Finishing	320	47 (15%)	20-240,000
• Chrome Plating	50	33 (66%)	24-240,000
• Chromate Conversion Coating[3]	23	9 (39%)	16-9,950
• Other or Unknown	247	5 (2%)	20-250
Contaminated Sites	40	20 (50%)	14-34,000
• Metal Finishers	11	6 (55%)	20-8,000
• Miscellaneous Sources	12	3 (25%)	14-37.51
• Mixed Manufacturing	4	3 (75%)	86-34,000
• Former Landfills	6	2 (33%)	18-42
• Paper Manufacturing	3	2 (66%)	24-240
• Paint Manufacturing	2	2 (100%)	360-6,047
• Leather Tannery	1	1 (100%)	19-514
• AFFF Infiltration	1	1 (100%)	82-456
Centralized Waste Treaters (CWTs)	16	12 (75%)	13-8,400
Paper Manufacturing, Packaging	14	9 (64%)	16-410
Commercial Industrial Laundry Facilities	12	5 (42%)	24-69
Chemical Manufacturers	17	4 (24%)	18-4,600,000
AFFF-contaminated Sewers	2	2 (100%)	240-45,000

[1]Estimated based on 2018 WWTP IPP Annual Report data for total metal finishers; others estimated based on industries surveyed and/or sampled during the IPP PFAS Initiative. Number of types per subcategory may be low since sewer users that did not meet local screening criteria may not have been sampled. The information presented in this document has been compiled from many sources including, but not limited to, compliance submittals, laboratory reports, voluntary surveys, emails, internet searches and personal communications. These sources contained variable levels of detail. This document represents our best effort to compile, organize, and summarize this information at this point in time.

[2]*Sources* are those exceeding the screening level of 12 ppt PFOS at least once.

[3]Excludes chromate conversion coaters that also perform chrome plating

VARIABLE IMPACTS ON WWTPS AND RECEIVING STREAMS

Since both WWTPs and industrial sources of PFOS vary in size, some WWTPs with sources have been able to meet Michigan's WQS while others have not. The highest concentrations of PFOS in WWTP effluent, indicative of significant pass through of pollutants from industrial users, were found primarily in small to medium-sized (0.19 to 2 MGD) WWTPs with one or more industrial sources discharging PFOS-contaminated process wastewater that made up a significant portion (around five percent) of WWTP flow. Loading is important; lower concentrations at higher flows may also cause or contribute to pass through of pollutants. Pass through from WWTPs is sometimes intermittent when sources discharge low volume but high strength batches, especially for smaller WWTPs.

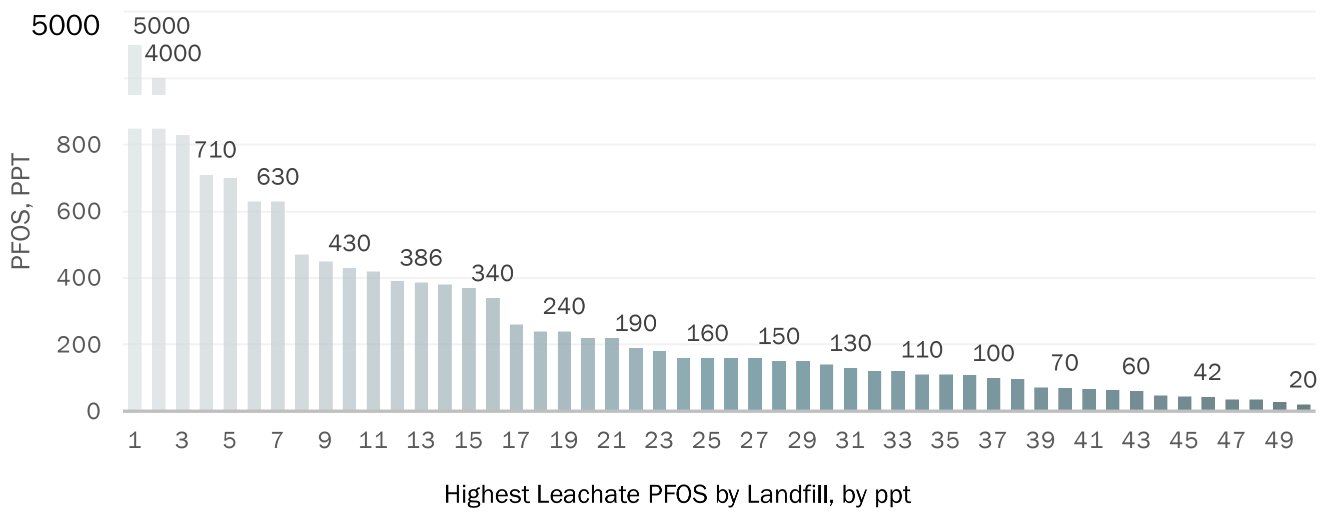
Similarly, EGLE has found that in-stream PFAS concentrations may vary widely due to the intermittent nature of some source discharges (i.e. point sources as well as storm water and groundwater discharges from contaminated sites, some of which may not yet be identified) as well as seasonal stream flow variation and size of the receiving stream. Early indications are that accumulations of PFOS found in fish tissue may be the best indication of long-term average concentrations in lakes and streams. Fish tissue sampling resulted in more restrictive fish consumption advisories downstream from two WWTPs that were found to be passing through PFOS from significant industrial sources.

DISCUSSION OF SOURCES

LANDFILL LEACHATE

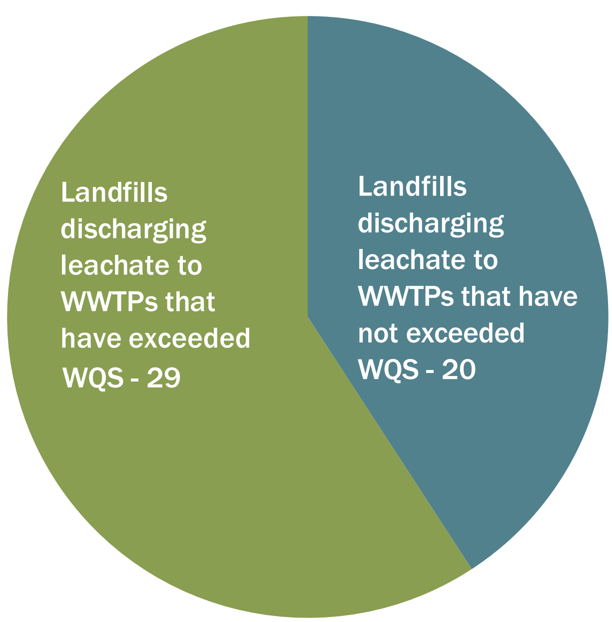
Sanitary landfills and Hazardous Waste landfills that accept or have accepted industrial wastes containing PFOS and discharge leachate, or truck leachate, to WWTPs are a significant source. In Michigan, sanitary landfills are classified as either Type II or Type III landfills. A Type II landfill is a municipal solid waste landfill which receives household waste but may also receive other types of nonhazardous wastes such as commercial solid waste, nonhazardous sludge, conditionally exempt small quantity generator waste, and industrial nonhazardous solid waste. A Type III landfill is any landfill that is not a municipal solid waste landfill or hazardous waste landfill and includes all of the following: construction and demolition waste landfill; industrial waste landfill; a landfill that accepts waste other than household waste, municipal solid waste incinerator ash, or hazardous waste from conditionally exempt small quantity generators; coal ash landfill; and an existing coal ash impoundment that is closed or is actively being closed as a landfill. Hazardous waste landfills receive non-liquid hazardous waste. Leachate from 44 Type II sanitary landfills, four Type III sanitary landfills, and one hazardous waste landfill have been identified as significant sources, with concentrations ranging from 13 to 5,000 ppt PFOS as shown below in Figure 2. Only two of the 49 landfills, or 8 percent, were discharging PFOS concentrations greater than 1000 ppt. Included in the number of active Type II landfills counted in Table 2 is a facility that receives leachate from three separate landfills.

Figure 2. Landfill Leachate Sources of PFOS to WWTPS, Highest Concentrations in ppt



The impact to a WWTP from leachate is dependent on the amount of leachate received, the concentration of PFOS in the leachate, and the overall volume of sanitary sewage treated by the WWTP. As noted in the *Findings* section above, sanitary sewage is generally low in PFOS. Municipal WWTPs are not designed to remove PFOS from wastewater, but if the leachate volume is small compared to the volume of sanitary sewage received by the WWTP, the acceptance of leachate may not result in PFOS passing through at concentrations above the WQS. The range of volume of leachate discharged or hauled daily to WWTPs can be from the thousands to the hundreds of thousands of gallons. For this reason, smaller WWTPs are more likely to pass through PFOS when receiving landfill leachate. There are WWTPs in Michigan where landfill leachate is their primary source of PFOS. Of the 49 landfills with leachate exceeding the screening level of 12 ppt PFOS, 29 landfills (59 percent) discharge to WWTPs that have exceeded the WQS for PFOS while 20 (41 percent) discharge to WWTPs that have not exceeded WQS (See Figure 3 below).

Figure 3: Landfills with Leachate Greater than Screening Levels and Impact on WWTPs



Some WWTPs have restricted the volume of landfill leachate accepted rather than require pretreatment to meet WQS. It is unclear if this approach will be successful over the long term. EGLE has recommended that maximum allowable headworks loading studies or similar mass balance calculations be performed to determine allowable loadings of leachate to WWTPs that will not result in the pass through of PFOS and/or PFOA.

In 2018, the Michigan Waste and Recycling Association conducted a statewide study to determine levels of PFOS and PFOA in leachate of 32 active municipal solid waste landfills. All the leachate samples collected had detectable levels of PFOS and PFOA. The concentration range of PFOS and PFOA identified in the study align with the findings of the IPP PFAS Initiative.

METAL FINISHING

Facilities that conduct metal finishing (including electroplaters) are a significant PFOS source for many WWTPs in Michigan. They are categorized by federal regulation according to specific core processes that change the surface of an object to improve its appearance and/or durability. The majority of sources at six of the ten WWTPs discharging at 50 ppt or greater PFOS were metal finishers. Five of those six WWTPs had a single chrome plating metal finisher source and were WWTPs of medium size (less than 2.5 MGD discharge). The remaining WWTP was larger (43 MGD) and had multiple sources, the majority of which were chrome plating metal finishers.

This finding aligns with known uses of PFAS. The United States Environmental Protection Agency (USEPA) allowed for use of PFOS-based fume suppressants as a control technology for hexavalent chromium emissions under the National Emissions Standards for Hazardous Air Pollutants (NESHAP) for chromium electroplating in 1995. Hexavalent chromium is a known hazardous compound and human studies have established that inhaled hexavalent chromium is a human carcinogen, resulting in an increased risk of lung cancer. Adding fume suppressants to the plating bath reduces the surface tension and, subsequently, the ability for hexavalent chromium to form bubbles. Fume suppressants are widely used across the industry due to their effectiveness in reducing hexavalent chromium emissions and their relative costs compared to other available control technologies. The USEPA did not ban the use of PFOS-based fume suppressants in chrome electroplating tanks until 2015.

The following discussion about types of metal finishers is based on information gleaned from WWTP investigations, surveys, IPP submittals, and company Web pages. Of the approximately 320 metal finishers discharging to WWTPs in Michigan, the effluent of 226 was sampled at least once as part of the IPP PFAS Initiative. Metal finishers sampled included those conducting one or more of the following processes: chrome plating (both hexavalent and trivalent chromium and decorative and hard chrome plating), chromate conversion coating, aluminum anodizing, copper plating, phosphate coating, passivating, and powder coating. Not all metal finishers were able to be tallied by type. A number of metal finishers were sampled but the specific processes used were not reported to EGLE. Other metal finishers were not sampled because they did not meet screening criteria to be considered a likely source of PFOS.

In general, metal finishers that had a history of using fume suppressants were found to discharge PFOS. Of the approximately 320 metal finishers discharging to WWTPs, only 47 (15 percent) were found to be discharging PFOS greater than the screening criteria, with 16 (5 percent) discharging greater than 1,000 ppt PFOS. All but five of the 47 metal finishers discharging PFOS above screening criteria (12 ppt PFOS) used hexavalent chromium and/or trivalent chromium in their current or past processes. Those five reported no known chromium use or information was not available.

Decorative chrome plating, hard chrome plating, and chromate conversion coating, all using hexavalent chromium in their process, appear to be the predominant types of metal finishing that are sources of PFOS to WWTPs. Chrome platers either using or previously using hexavalent chromium were the most significant source of PFOS among metal finishers. Chrome plating involves electroplating a thin layer of chromium to provide corrosion resistance, increase surface hardness and/or provide a decorative finish. Hard chrome plating is used to improve corrosion and abrasion resistance and is generally a thicker plating than decorative chrome plating, which is generally thinner and used for cosmetic purposes, such as plating plastic with a shiny chrome surface. Decorative chrome plating deposits a 0.003-2.5 micron chrome layer in less than five minutes with an electrical current range of 540-2,4000 amperes; hard chrome plating deposits a 1.3-760 micron layer in 20 minutes to 36 hours with an electrical current range of 1,600-6,500 amperes.

In either type of chrome plating, the electrical current generates chromium fumes. Temperature of chromic acid etch tanks and chrome plating tanks is also a factor. These tanks are heated (up to approximately 160 degrees Fahrenheit for some applications) and water constantly evaporates and must be replenished. In addition, chromium fumes may be generated from aeration of chrome plating and chromic acid etch tanks conducted to prevent settling of chromium in the bottom of the tanks.

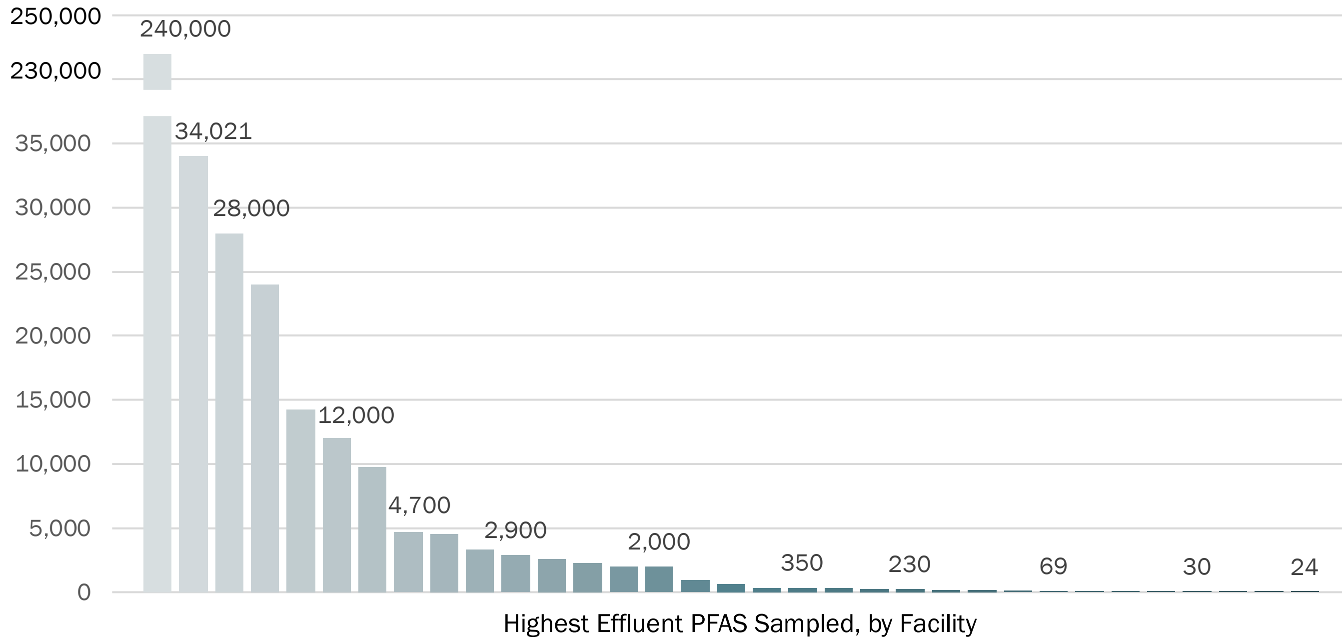
Decorative chrome platers that plate on plastic typically etch plastic parts with chromic acid, which is hexavalent chromium, to prepare them for plating. Several of the decorative chrome platers used chromic acid etch baths and fume suppressants to control associated air emissions. Plating on plastics (also referred to as POPs) is a growing sector of the industry. Plating on plastic allows for both lower costs for raw materials and provides products which are lower weight and may be attractive to certain industrial customers.

Of the approximately 50 chrome platers in Michigan that discharge to a WWTP, 33 (66 percent) were found to be sources of PFOS. Almost all (47 or 94 percent) of the chrome platers either use or used hexavalent chromium, although many use trivalent chromium as well. Due to employee safety concerns, environmental hazards and the associated increased costs, there has been a movement to replace hexavalent chrome with trivalent chrome in decorative chrome plating. Trivalent chromium has a relative inability to cross cell membranes compared to hexavalent chromium (USEPA, August 1998). Therefore, it is considered significantly less toxic and makes it subject to both less regulations and costs than hexavalent chromium. However, trivalent chromium generally cannot be used for hard chrome plating because there are limits to the thickness that can be achieved. There are also differences in the plating color as well as increased costs (equipment, chemicals, testing, and maintenance) for manufacturers (TURI, 2012).

The 34 percent of chrome platers that were not found to be sources of PFOS most likely chose mechanical controls (such as enclosed lines, air jet systems, etc. along with large capacity scrubbers) to manage hexavalent chromium rather than chemicals containing PFAS (typically used in conjunction with scrubbers). In at least one case, a decorative chrome plating facility was built after the 2015 PFOS ban and PFOS-based fume suppressants were never used at that facility, although fume suppressants containing PFAS, specifically 6:2 fluorotelomer sulphonic acid (FtS), are used..

Discharges of PFOS from chrome platers found to be sources of PFOS varied widely, but concentrations at some were significant. See Figure 4 to see the range of highest effluent PFOS results prior to pretreatment. A number of chrome platers have installed pretreatment since these samples were taken and their effluent PFOS either meets local screening concentrations or shows significant reductions.

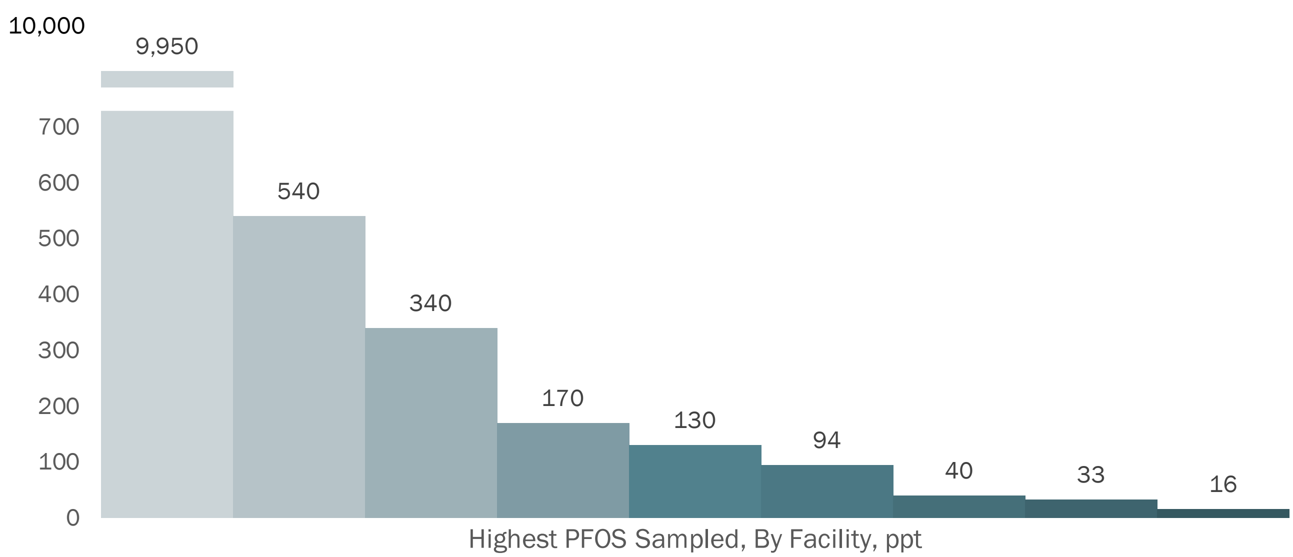
Figure 4. Chrome Plater Sources, Highest Effluent PFOS Sampled, ppt



Nine metal finishers that conduct chromate conversion coating were found to be sources of PFOS to WWTPs, but concentrations of PFOS were generally much lower than those for chrome platers. Chromate conversion coating is an extra step used to inhibit corrosion, act as a primer, or provide a decorative finish. The process uses chromate, which is hexavalent chromium, to create a micro-coating from a chemical reaction with the base metal. See Figure 5 below for highest effluent results for nine factories conducting chromate conversion coating that exceeded screening levels.

Many of these PFOS sources have reduced effluent concentrations over time. Some have eliminated source lines or conducted cleaning and at least one has installed pretreatment. At least two of these facilities also conduct chrome plating and another trivalent chromium passivation. Two chrome platers that also conduct chromate conversion coating were excluded from Figure 5 since concentrations of PFOS are likely associated with chrome plating rather than chromate conversion coating.

Figure 5. Chromate Conversion Coating Sources, Highest PFOS Effluent Sampled, ppt



Based on data we have seen from a range of sources, it appears that the PFOS found in chrome plating (and a lesser extent chromate conversion coating) wastewater originates from historical use of fume suppressants (also called demisters, defoamers, surfactants, mist suppressants, etc.). These chemicals were lawful to use until September 2015 and were used to protect worker health and safety as well as contribute to product quality. After September 2015, PFOS-based fume suppressants were prohibited from being added to chromium electroplating and anodizing tanks under the 2012 revisions of the NESHAP (40 CFR Part 63, Subpart N). These rules define PFOS-based fume suppressants as those containing one percent or greater PFOS by weight.

The NESHAP revision was developed concurrently with a national effort to phase out the manufacture and use of long-chain PFAS, including PFOS and PFOA, under the USEPA's *2010/2015 PFOA Stewardship Program* due to concerns about the impact of PFOA and long-chain PFAS on human health and the environment. The NESHAP regulation does not prohibit PFOS-based fume suppressants for chromate conversion coating, but these products are generally not available due to the stewardship program phase out.

The conclusion that PFOS currently found in wastewater is from historical use of PFOS-containing chemical products is supported by the findings of a recent study requested by EGLE, in coordination with USEPA Region V, and conducted by EGLE and the USEPA Office of Research and Development (ORD) to research the question of whether chemicals currently used by chrome platers might be contributing to PFOS concentrations observed in their effluent. EGLE sampled nine different fume suppressant products and effluent (prior to pretreatment for PFOS) from 11 chrome platers and sent samples to the USEPA ORD for detailed analysis. USEPA researchers did not find PFOS or PFOS precursors in currently used fume suppressants, although most contained PFAS, primarily 6:2 FTS. However, PFOS was found in chrome plater effluent, leading EGLE to conclude that PFOS originates from historical use of PFOS-containing fume suppressants. For more information about this study, **Targeted and Non-Targeted Analysis of PFAS in Fume Suppressant Products at Chrome Plating Facilities**, refer to **www.michigan.gov/documents/egle/wrd-ep-pfas-chrome-plating_693686_7.pdf**.

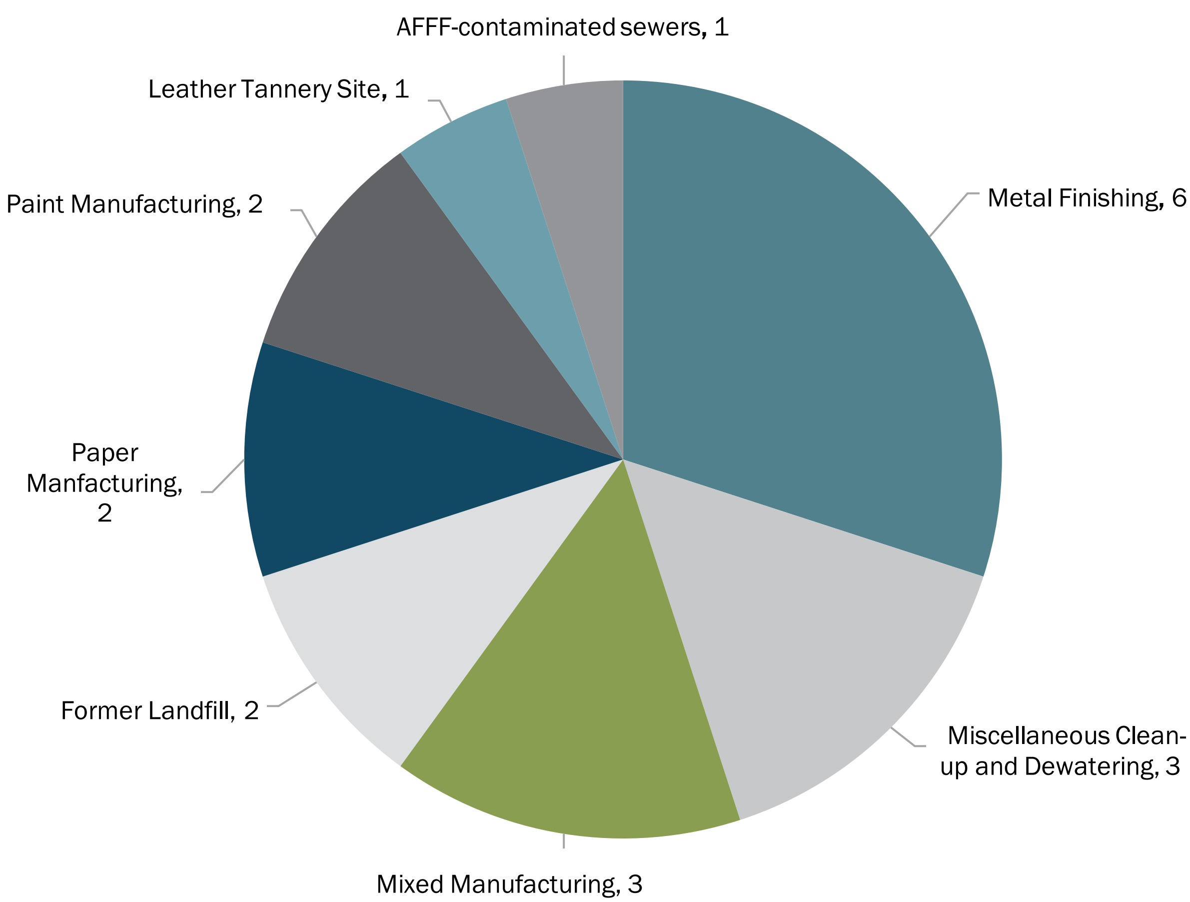
It should be emphasized that some chrome platers did not use PFOS-containing chemicals to control fumes and have not been found to be sources of PFOS to WWTPs. In 2018 EGLE's Air Quality Division (AQD) inspected all 58 chrome platers then subject to regulation under 40 CFR Part 63, Subpart N. This rule limits the addition of PFOS-based fume suppressants after September 2015. The AQD did not find any chrome platers in violation of this federal requirement. About half of the inspected sources subject to Subpart N were found to still use PFAS-based fume suppressants, likely 6:2 FTS as discussed above and in the USEPA/EGLE study *Targeted and Non-Targeted Analysis of PFAS in Fume Suppressant Products and Effluent Samples*.

PFAS-based fume suppressants are not the sole mechanism for complying with the NESHAP. In an EGLE survey, nearly half of the chrome platers regulated under the NESHAP utilized mechanisms other than chemical fume suppression. These include enclosures and physical controls such as scrubbers and composite mesh pad scrubbers; physical fume suppression via plastic balls; and non-PFAS based chemicals. Some platers have substituted trivalent chromium, which has lower toxicity, for hexavalent chromium or have avoided chromium altogether.

CONTAMINATED SITES

Forty contaminated sites were evaluated for PFOS by WWTPs. The sites were contaminated by a wide range of industrial activities. The 20 confirmed sources included contaminated groundwater from former metal finishers (six), mixed manufacturing sites (three), closed landfills (two), former paint manufacturers (two), former paper manufacturing sites (two), a former leather tannery, and a site where AFFF infiltrated into the sanitary sewers. Table 2 includes a miscellaneous category with 12 difficult to categorize sites that were evaluated by WWTPs. Three of the 12 miscellaneous sites were confirmed as sources: a construction dewatering site, a groundwater clean-up at chemical wholesaler, and contamination from a manufacturer of gages. Investigations into the sources of PFOS at these sites are ongoing. Also included in the miscellaneous category are four WWTPs that conducted sanitary sewer monitoring to evaluate potential PFOS/PFOA infiltration due to general concerns about contaminated sites but did not confirm any sources. The general types of contaminated sites found to be sources of PFOS are shown below in Figure 6.

Figure 6. Number of Contaminated Sites by Type that are Sources of PFOS to WWTPs



Contaminated sites evaluated included sites that actively pump treated and untreated groundwater into sanitary sewers as well as sites where contaminated groundwater reached the sanitary sewers via infiltration or inflow. Of 40 contaminated sites evaluated, 27 pumped treated or untreated groundwater into sanitary sewers while the remaining 13 were suspected infiltration/inflow sites. Of the 27 sites pumping groundwater, all 27 were sampled and 13 were confirmed PFOS sources. Thirteen infiltration/inflow sites were sampled and seven were confirmed as sources.

Pumped Groundwater Sites

Thirteen contaminated sites that actively pump treated or untreated groundwater to WWTPs have been identified as significant sources of PFOS. To date, these contaminated sites are associated with mixed manufacturing, metal finishers, paint manufacturers, paper manufacturers, and a few miscellaneous clean-ups including construction dewatering as listed above in Table 2. Since being identified as sources, several of these sites have installed granular activated carbon to remove PFOS. Active remediation projects occurring at a chemical manufacturing site and a former foundry were also evaluated but not found to be sources of PFOS.

Inflow and Infiltration of Contaminated Groundwater

Seven sites were found to be sources of PFOS via infiltration/inflow of contaminated groundwater into sanitary sewers. Infiltration/inflow of PFOS into sanitary sewers from sites contaminated by chrome plating, leather tanning, landfill operations, paper manufacturing, an AFFF site and a miscellaneous clean-up site have been confirmed as PFOS sources by WWTPs as part of the IPP PFAS Initiative. For example, one WWTP receives PFOS when groundwater contaminated by leather tannery waste enters sanitary sewers located in the zone of contamination through cracks in the sewers. PFOS loadings to the WWTP are especially high during seasonal high groundwater periods. A former air force base with contaminated soils and groundwater from repeated training exercises using AFFF has been found to be a source of PFOS to the sanitary sewers in another community, with 82 to 456 ppt PFOS found in nearby sanitary sewers. Contaminated groundwater from the former air force base has migrated off-site and also impacted residential wells and surface waters. In addition, AFFF was used on several fires in the area, creating additional contaminated areas.

Some contaminated sites in Michigan have a complicated history and the origins of PFOS discharges are unclear and may stem from multiple sources. One example is a 413-acre former manufacturing complex operated from 1904 to 2010. PFAS contamination has been documented at the site in the last few years, including PFOS at 27,580 ppt infiltrating into the sanitary sewer. Since significant amounts of groundwater infiltrate into the sanitary sewers at the site, the site contributes significant loadings of pollutants. It is the primary known source of PFOS to the WWTP. Various former operations that may be contributing PFOS to sanitary sewers include metal finishing and associated pretreatment of wastewater, fire-fighting training, and paint/enameling operations. Although not the focus of this discussion, it should be noted that PFAS contaminates soils, groundwater, and storm water runoff at this site.

Drinking Water Source Contamination

Contaminated sites can also impact WWTPs when PFAS contaminates the drinking water source that, following use, is discharged into the sanitary sewers as municipal, commercial, and industrial wastewater. For example, a WWTP eliminated a significant source of PFOS when a municipal well was found to be contaminated by a former paper manufacturer using a 3M product for coating paper. The municipality was able to switch to an alternative source and this resulted in a significant reduction of PFOS loading to the sanitary sewers. Another community uses treated river water as its drinking water source. A WWTP located upstream was found to be passing through PFOS from a chrome plater and the community later attributed PFOS in WWTP effluent to elevated PFOS in its drinking water. Treatment at the upstream WWTP's plater has led to reduced PFOS in the downstream WWTP's effluent and the river as a result.

Combined Sewer Inflow of Contaminated Storm Water

WWTPs can also receive PFOS via inflow of contaminated storm water run-off into sanitary sewers. WWTPs with combined sanitary and storm water systems could be impacted by storm water contaminated by PFOS. A WWTP is receiving storm water contaminated with PFOS due to a petroleum refinery's use of AFFF in a fire training area. This facility is located within a section of combined sewers that discharge to the WWTP. The AFFF usage contaminated the surrounding ground and entered an on-site drainage ditch.

CENTRALIZED WASTE TREATERS

CWTs treat wastewater and industrial process by-products that come from other industries. These facilities receive a wide variety of hazardous and non-hazardous industrial waste for treatment. If a CWT receives waste from sources of PFOS such as landfill leachate, plating waste, and/or paper sludge, PFOS may be discharged to the receiving WWTP if adequate treatment is not used. Most CWTs in Michigan discharge to larger WWTPs. As indicated above, municipal WWTPs are not designed to remove PFOS; however, larger WWTPs typically receive larger volumes of sanitary sewage, which is typically low in PFOS. This may reduce PFOS concentrations in WWTP effluent, thereby lessening a CWT's potential impact on surface waters.

PAPER, CARDBOARD AND PACKAGING MANUFACTURERS

Manufacturers of paper, cardboard and packaging products have been found to discharge low to moderate concentrations of PFOS under the IPP PFAS Initiative. Of ten sources evaluated, nine were found to have discharges of PFOS above the screening level. At the time of this report, most paper/cardboard manufacturers under the IPP PFAS Initiative were still attempting to identify PFOS sources; however, in one case the PFOS source is believed to be recycled paper used in the manufacturing process. While not discovered under the IPP PFAS Initiative, a paper mill in Michigan that makes its product from 100 percent recycled paper stock and discharges process wastewater to the groundwater is being investigated by EGLE as the source of nearby drinking water well contamination. Internal sampling of process wastewater at this mill identified PFOS ranging from 68 to 420 ppt. This finding may support recycled paper as a PFOS source.

In other paper manufacturing cases, it is believed that previously used paper coatings contained PFOS. Previous use of PFOS-containing coatings is a "legacy" issue similar to the chrome plating industry's use of fume suppressants containing PFOS. Residual PFOS contamination from previous use is still impacting current discharges of PFOS. These findings are consistent with recent literature on PFAS in paper manufacturing. One paper making facility used a PFOS process chemical from 3M in combination with a starch during the paper making process from 1980 to 1989. The process wastewater along with any unused or excess product was discharged to the sanitary sewer system. The facility ceased discharging process wastewater to the WWTP in 1989 and has only been discharging sanitary wastewater. However, due to the 1980s-era process wastewater discharge, residual PFOS has remained in the sewer lines resulting in PFOS from the facility's sanitary wastewater discharging to the WWTP.

Some paper manufacturing companies have operated their own landfills for their waste products. These landfills produce leachate containing PFOS that is often discharged to WWTPs. The on-site landfill at one former paper manufacturing facility which discharged to a WWTP, counted as a closed Type III landfill, had PFOS concentrations ranging from 13 to 62 ppt.

COMMERCIAL INDUSTRIAL LAUNDRIES

Commercial Industrial laundry facilities were found to discharge low concentrations of PFOS under the IPP PFAS Initiative. These facilities were laundering articles of clothing that were likely treated with a PFAS-based stain and/or dirt resistant coating. After discontinuing the practice of laundering those articles of clothing, the level of PFOS in the effluent decreased to below PFOS screening levels. At least one facility was laundering items used by manufacturers that were sources of PFOS. These items are now dry cleaned and PFOS concentrations so far have been below screening levels.

CHEMICAL MANUFACTURERS

A small percentage of chemical manufacturers sampled had levels of PFOS above the screening levels. Three out of the four facilities with levels of PFOS above the screening levels in their discharge manufacture chemical compounds that are used by the metal finishing industry. The fourth facility manufactures synthetic lubricating oils and greases and uses a synthetic fluoropolymer of tetrafluoroethylene in the manufacturing process.

AFF SANITARY SEWER CONTAMINATION

Sometimes floor drains, sanitary sewer lines, and pump stations have become contaminated by AFFF, causing discharges of PFOS above screening levels to sanitary sewers. At least one WWTP is receiving PFOS from a fire station where a floor drain and sanitary sewer were contaminated by a firetruck containing AFFF that had a leaky valve. Although the valve was fixed and AFFF and contaminated fire truck water disposed of off-site, it appears that sanitary sewer lines contain residual PFOS that continue to discharge PFOS to the WWTP. This community plans to clean the drain and sanitary sewer to reduce PFOS.

The historical and current use of AFFF at military installations is a source of PFOS to WWTPs. At one facility, when the fire suppression system (which contained AFFF) was tested, the foam would then be discharged to the sanitary sewer system. Over time, this practice has contaminated the sanitary lines. The facility does discharge a small volume of process wastewater; however, most of the discharge is sanitary wastewater. It is believed that the source of PFOS to the WWTP as this site is due to the AFFF contaminated sewer lines.

PFOS REDUCTION

As discussed in the Metal Finishing section above, five WWTPs had single industrial sources that were chrome platers. All five WWTPs have required the industrial sources to install pretreatment, and as of the date of this report all five sources have installed pretreatment and have either reduced discharges below 12 ppt or made significant reductions in PFOS discharges. Likewise, there has also been corresponding reductions in PFOS concentration in biosolids although these improvements clearly lag the improvements seen in effluent. Recent biosolids/sludge sample results at two of these facilities show reductions of nearly an order of magnitude. Pretreatment has been installed at the source for discharges ranging in volume from 5,000 gallons discharged twice a week to 400,000 gallons per day. See Table 3 for highlights in source reduction under the IPP PFAS Initiative.

All effective treatment has been conducted at the source rather than at the municipal WWTP. At least one WWTP tried to augment its treatment for PFOS by increasing virgin carbon dosing from 4,460 lbs/day to 7,400 lbs/day but the effort was not determined to significantly reduce effluent PFOS. As of the date of this report, all source pretreatment has used granulated activated carbon (GAC) in series, sometimes followed by resin for polishing. Changeout of GAC media is needed frequently and there have been issues with media fouling due to other pollutants in wastewater, such as iron, and interference with other treatment chemicals used, such as polymers used as coagulants.

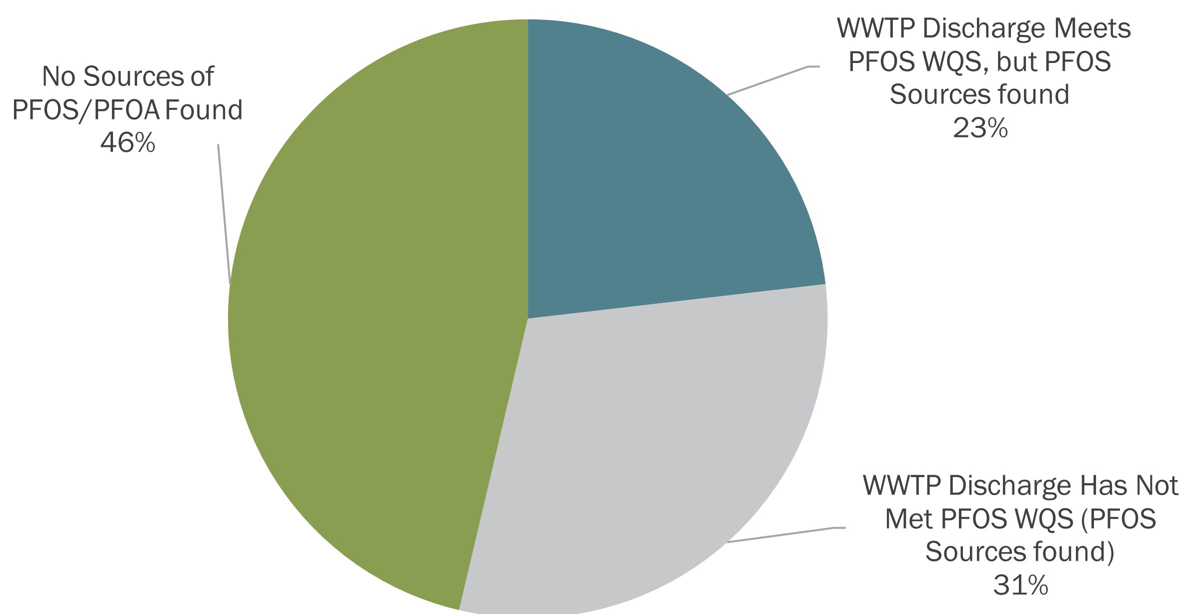
Two chrome platers conducted extensive cleaning of tanks, pits, and equipment associated with their plating lines. Both efforts resulted in some PFOS reduction, but pretreatment remained necessary prior to discharge. Cleaning may be problematic at industries since PFOS may be found in etch tanks, plating tanks, rinse tanks, secondary containment pits, parts racks, air pollution control equipment (which may return contaminated liquids to plating tanks and/or pretreatment systems), and associated pipes, ducts, and valves. In addition, cleaning may not reduce PFOS to acceptable levels, and equipment and surfaces may require replacement. It is expensive to clean or replace all affected equipment.

CONCLUSION AND NEXT STEPS

EFFECTIVENESS

Through the IPP PFAS Initiative, EGLE has successfully identified WWTPs that received PFOS from industrial dischargers. EGLE has effectively worked with WWTPs that have exceeded the PFOS water quality values to implement source reduction to decrease the PFOS concentrations in the influent, effluent, and biosolids/sludge. Thirty-one percent of WWTPs reported effluent that exceeded water quality values at some point in time (Figure 7).

Figure 7: PFAS Compliance Status, 95 WWTPs with IPPs (as of June 26, 2020)



Two years into implementation, there is significant evidence to support that utilizing the established authorities under the IPP to identify and control industrial sources of PFAS (specifically PFOS) to WWTPs is highly effective at reducing the discharge of this pollutant into the environment. Source reduction efforts have resulted in substantial drops in PFOS concentrations being discharged at the WWTPs as shown in Table 3. Likewise, there have been corresponding reductions in PFOS concentrations in biosolids, although these improvements clearly lag the improvements seen in effluent.

Table 3: Substantial Reductions in PFOS concentrations at WWTPs

Municipal WWTP	PFOS, Effluent (ppt, most recent**)	PFOS Reduction in Effluent (highest to most recent)	Actions Taken to Reduce PFOS
Lapeer	<18*	99%	Treatment (GAC) at source (1)
Wixom	17*	99%	Treatment (GAC) at source (1)
Port Huron	15*	99%	Elimination of PFOS source (2)
Howell	4	97%	Treatment (GAC/resin) at source (1)
Bronson	12	97%	Treatment (GAC) at source (1)
Ionia	25*	95%	Treatment (GAC) at source (1)
Kalamazoo	5	88%	Treatment (GAC) at sources (2), change water supply
K I Sawyer	13*	95%	Eliminate leak AFFF, some cleaning
GLWA (Detroit)	37*	23%	Treatment (GAC) at sources (9)

*Greater than Michigan's Water Quality Standard of 12 ppt

**Data (rounded) received as of June 26, 2020

NPDES PERMITTING STRATEGY

Moving forward, EGLE developed a Municipal NPDES Permitting Strategy for PFOS and PFOA. The goal of the strategy is to continue to identify, reduce, and remove PFOS and PFOA at WWTPs. This strategy includes requirements for ongoing monitoring and regulation of PFOS and PFOA at WWTPs. Read more about the *Municipal NPDES Permitting Strategy for PFOS and PFOA* from EGLE at the following link: www.michigan.gov/documents/pfasresponse/Municipal_NPDES_Permitting_Strategy_for_PFOS_and_PFOA_WRD_092019_668823_7.pdf.

ONGOING STUDIES OF WWTP WASTEWATER AND SLUDGE/BIOSOLIDS

EGLE identified WWTPs with industrially impacted biosolids during the IPP PFAS Initiative and prevented further land application of biosolids from those facilities until sources of PFOS could be controlled. The WRD launched a second initiative in the fall of 2018, conducting a study of 42 municipal WWTPs to evaluate the presence of PFAS in influents, effluents, and associated residuals (sludge/biosolids) generated at the facilities. As part of this initiative, screening of 22 land application sites was conducted to further understand the potential impacts to the environment from land-applied biosolids.

For this study, the WRD contracted with a consulting firm, AECOM Technical Services, Inc., to perform sampling at the WWTPs and land application field sites. Samples were analyzed for 24 PFAS compounds. Initial findings from the study found that PFAS were frequently detected in municipal wastewater, residuals, and at land application sites where biosolids were applied. Concentrations in residuals were similar or lower than concentrations identified in previous studies in the United States and other countries with industrial sources.

Through implementation of the IPP PFAS Initiative and the statewide study, the WRD was able to identify six WWTPs with high PFOS concentrations in their WWTP discharge and biosolids/sludge and temporarily restrict land application from those facilities until sources of PFOS are controlled and concentrations in the residuals decrease. Screening of agricultural fields that received biosolids applications found significantly lower PFAS concentrations in various environmental matrices (soils, surface waters, etc.) associated with WWTPs with lower levels of PFAS in their biosolids as compared to those with elevated levels.

EGLE published a brief summary of the status and findings of these two initiatives in the ***Summary Report: Initiatives to Evaluate the Presence of PFAS in Municipal Wastewater and Associated Residuals (Sludge/Biosolids) in Michigan***, which is available at **www.Michigan.gov/documents/egle/wrd-pfas-initiatives_691391_7.pdf**. A more comprehensive report that provides additional information and analysis of the initiatives and results from the field screening is expected to be released later in 2020 and will be posted on the **Michigan PFAS Action Response Team WWTP/IPP Webpage** at **Michigan.gov/PFASResponse** under "Testing,"

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