MICHIGAN DEPARTMENT OF
ENVIRONMENT, GREAT LAKES, AND ENERGY

SUMMARY REPORT:

Initiatives to Evaluate the Presence of PFAS in Municipal Wastewater and Associated Residuals (Sludge/Biosolids) in Michigan

June 2020

WATER RESOURCES DIVISION

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Contents

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as contracted by the Michigan Department of Environment, Great Lakes and Energy.

EXECUTIVE SUMMARY

In 2018 the Michigan Department of Environment, Great Lakes, and Energy (EGLE), Water Resources Division (WRD), implemented two initiatives to assess potential environmental impacts of Per- and Polyfluoroalkyl Substances (PFAS) associated with municipal wastewater. The first initiative, the Industrial Pretreatment Program (IPP) PFAS Initiative, was launched in February 2018. The purpose of the IPP PFAS Initiative was to evaluate the potential for PFAS from industrial sources to pass through wastewater treatment plants (WWTP) to receiving waters (groundwater, lakes, and streams), and to reduce or eliminate significant industrial sources of PFAS to the municipal system, if found. The initiative was based on existing federal and state regulations and was implemented by 95 municipal WWTPs utilizing existing control authorities developed under their approved IPPs. During the IPP PFAS Initiative, Perfluorooctanoic Acid (PFOA) was not detected above state water quality values in any WWTP effluent. As a result, Perfluorooctane Sulfonic Acid (PFOS) has become the main regulatory driver for PFAS control. Two years into implementation, of the 95 WWTPs with IPPs, 46% did not identify any significant industrial sources of PFOS or PFOA to their system, 23% identified significant industrial sources but the WWTP discharge still meets state water quality values, and 31% identified significant industrial sources and the WWTP discharge exceeds state water quality values. In addition, 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 from WWTP discharges.

The WRD launched a second initiative in the fall of 2018. Under this initiative, a study of 42 municipal WWTPs was conducted 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 understanding of 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, WRD was able to identify 6 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.

This document provides a brief summary of the status and findings of these two initiatives. 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.

BACKGROUND

PFAS are a class of emerging pollutants of human-made chemicals that were first developed in the late 1930s and started to be used in commercial products in the late 1940s. A recent survey reported more than 4,000 PFAS had been identified (OECD, 2018). Due to their unique chemical properties, PFAS production increased as these chemicals were incorporated into components of inks, varnishes, waxes, firefighting foams, metal plating, cleaning solutions, coating formulations, lubricants, water and oil repellents, paper, and textiles (Paul et al., 2009). Examples of industries using PFAS include automotive, aviation, aerospace and defense, biocides, cable and wiring, construction, electronics, energy, firefighting, food processing, household products, oil and mining production, metal plating, medical articles, paper and packaging, semiconductors, textiles, leather goods, and apparel (OECD, 2013).

The carbon-fluorine bond that exists in PFAS is one of the strongest bonds in nature; they are tough to break and are resistant to thermal, chemical, and biological degradation. Widespread use of PFAS in consumer products and manufacturing/industrial processes, in conjunction with extreme resistance to degradation, have resulted in the presence of PFAS in municipal wastewater. While WWTPs are not the source of PFAS, they are a central point of collection and serve as a key location to control and potentially mitigate their release into the environment. Effluents discharged from WWTPs and biosolids applied to the land for beneficial reuse have been identified as potential PFAS release pathways into the environment by the Interstate Technology and Regulatory Council (ITRC) (ITRC, 2017). This puts WWTPs in a key position to control the environmental spread of PFAS and a key participant in protecting both human and environmental health.

PFAS OCCURRENCE IN WWTPs

PFAS have been identified in WWTPs since the early 2000s during the 3M-sponsored multicity study from Alabama, Tennessee, Georgia, and Florida. PFAS were also later identified in WWTPs from Minnesota, Iowa, California, Illinois, New York, Kentucky, Georgia, and Michigan (Boulanger et al., 2005; Higgins et al., 2005; Schultz et al., 2006; Sinclair and Kannan, 2006; Loganathan et al., 2007; Sepulvado et al., 2011; and Houtz et al., 2016). Some of the most frequently detected PFAS were Perflouoroalkyl Acids (PFAA), such as PFOA and PFOS.

In Michigan, surface water and fish tissue sampling performed by EGLE in 2013 and 2014 in the Flint River found concentrations of PFOS above Michigan's Rule 57, Water Quality Values, as established under Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA). Based on PFOS levels identified in the fish, in 2015 and later updated in 2018 as part of the "Eat Safe Fish" program, the Michigan Department of Health and Human Services issued restrictive fish consumption advice for some fish species in the Flint River watershed, including the Holloway and Mott Reservoirs. Concentrations of PFOS in the fish were higher than what was identified in other areas of the state at that time and the advice was more restrictive than the previous advice based on mercury and PCBs.

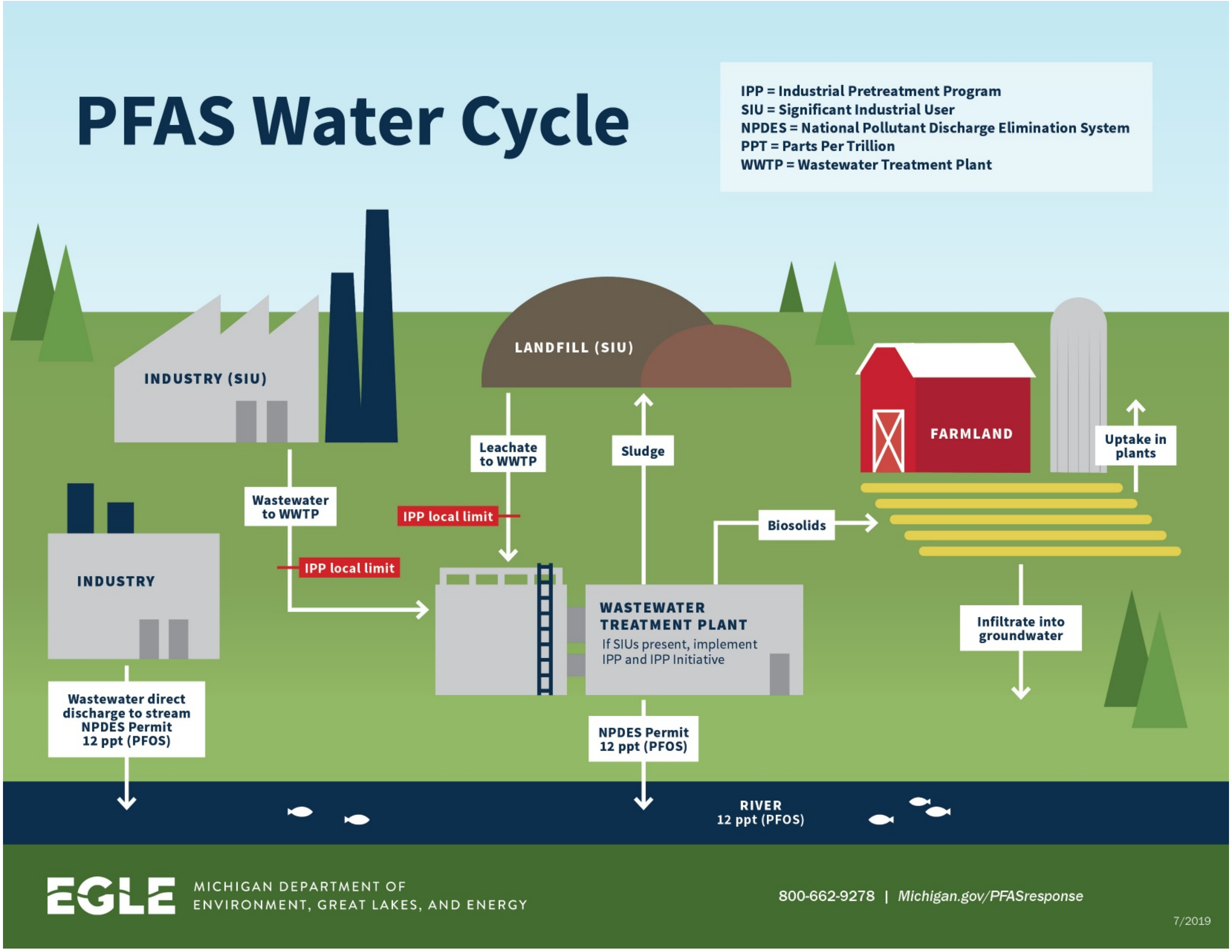
Beginning in 2016, EGLE initiated an investigation to identify significant sources of the contaminant to the Flint River and its tributaries. In July 2017, after two rounds of intensive sampling in the watershed, the source investigation led to the discovery of high concentrations of PFOS originating from a decorative chrome plating facility located in the city of Lapeer. The plating facility was discharging industrial process wastewater to the city of Lapeer WWTP. High levels of PFOS in the industrial process wastewater from the facility were then passing through the conventional treatment processes at the Lapeer WWTP and were discharged as part of the WWTP's treated effluent into the South Branch of the Flint River. In addition, PFOS was concentrating in the residuals or biosolids generated at the WWTP to the extent that the solids were determined to be "industrially impacted" and no longer appropriate for land application (see explanation on page 19). At that time, the concentration of PFOS in the effluent was as high as 2,000 nanograms per liter (ng/L) and 2,100 micrograms per kilogram (µg/kg) in the biosolids.

The occurrence of PFAS in municipal WWTPs may be affected by many factors including:

- Geographical location.
- The type and number of industrial dischargers within the sewershed or acceptance of trucked waste at WWTPs.
- Past or ongoing PFAS releases into the groundwater or atmosphere that enter the WWTP from inflow during wet weather events or infiltration during high groundwater periods.

An example of a PFAS water cycle is provided in Figure 1.

Figure 1: PFAS Water Cycle



Due to the widespread use of PFAS in many industries and consumer products, industrial discharges are expected to be the primary sources of PFAS to WWTPs. Examples of industrial discharges that could be PFAS sources to WWTPs include:

- Electroplating and Metals Finishing (mainly chrome plating)
- Landfills
- Centralized Waste Management Facilities
- Airfields – Commercial, Private, and Military
- Department of Defense Facilities
- Fire Department Training Facilities
- Industrial Laundries
- Petroleum or Petrochemical
- Chemical Manufacturers
- Plastics Manufacturers
- Textile and Leather Facilities
- Paint Manufacturers
- Pulp and Paper Facilities

MICHIGAN INDUSTRIAL PRETREATMENT PROGRAM

The discharge of pollutants from industrial wastewaters to publicly owned treatment works (POTW) is regulated in Michigan through the IPP. It should be noted that a POTW is a municipal WWTP along with its collection system (system of sanitary sewers that transport waste to the WWTP). For purposes of this document, we use the terms "municipal WWTPs" and "POTWs" interchangeably. The IPP is a significant part of the federal Clean Water Act, NREPA, and the National Pollutant Discharge Elimination System (NPDES). The purpose of the IPP is to:

- Regulate the disposal of industrial wastewater into the sanitary wastewater collection system.
- Protect the physical structures and safety of operation and maintenance personnel of the wastewater collection and treatment system.
- Protect the health and safety of the public and the environment.
- Comply with pretreatment regulations as required under Federal General Pretreatment Regulations and Categorical Standards, state laws and regulations, and local sewer use ordinances.

Industrial users are generally prohibited from discharging specific pollutants to POTWs if these pollutants would:

- Pass through the POTWs and violate water quality standards; and/or
- Interfere with the operation or performance of the POTWs, including management of residuals, including biosolids.

MICHIGAN IPP PFAS INITIATIVE

PFAS are regulated by EGLE under Part 201, Environmental Remediation; and Part 31, Water Resources Protection, of the NREPA and their administrative rules, specifically Rules 299.44-299.50 (Generic Cleanup Criteria) and Rule 57 (Toxic Substances) of the Michigan Administrative Code, respectively. The Michigan Rule 57 values are developed to protect humans, wildlife, and aquatic life. The applicable (most stringent) values for PFOS and PFOA are noncancer human values, as follows:

- PFOS: 12 ng/l or parts per trillion (ppt) for surface waters that are not used for drinking water and 11 ng/l for those used as a drinking water source.
- PFOA: 12,000 ng/l for surface waters that are not used for drinking water and 420 ng/l for those used as a drinking water source.

For NPDES permittees, the permit requires permittees to prohibit discharges that cause their POTWs to pass through pollutants greater than water quality standards to surface water. The permit further prohibits NPDES permittees from accepting discharges that restrict, in whole or part, their management of biosolids.

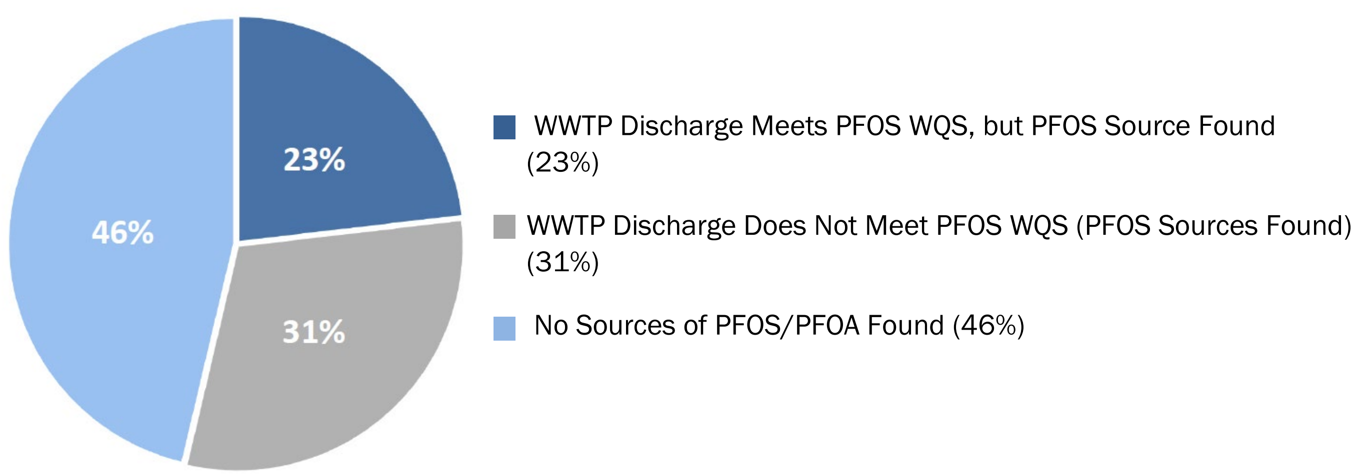
In Michigan, there are approximately 400 municipal WWTPs. Of these, 95 are required by their NPDES permits to implement IPPs. To evaluate potential PFAS presence at these POTWs and to evaluate the potential for PFAS passing through the WWTPs to receiving waters (groundwaters, lakes, and streams), the WRD launched the IPP PFAS Initiative in February 2018. The IPP PFAS Initiative required all 95 WWTPs with IPPs to evaluate the potential for PFOA and/or PFOS to be passing through their treatment systems to receiving waters and to reduce or eliminate sources if found. The municipal WWTPs were required to:

- Identify industrial users to their system that were potential sources of PFAS.
- Sample probable sources and their WWTP discharge (effluent) if sources were above screening criteria (typically 11 or 12 ng/l for PFOS and 420 or 12,000 ng/l for PFOA).

- Require source reductions at confirmed sources. This is accomplished through pollutant minimization plans, equipment/tank change outs/clean outs, product replacements, and installation of treatment to remove PFAS, specifically PFOS, before discharge (pretreatment).
- Monitor progress of industrial users reducing PFOS.
- Submit required reports and monitoring results.

During the IPP PFAS Initiative, PFOA was not detected above water quality values in any WWTP effluent. As a result, PFOS has become the main regulatory driver for PFAS control, with 31% of WWTP effluents reporting results above the applicable water quality values (Figure 2). 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 POTWs is highly effective at reducing the discharge of this pollutant into the environment. Some initial findings are provided below.

Figure 2: PFAS Compliance Status 95 WWTPs with IPPs as of March 26, 2020 (EGLE, 2020)



Some key observations that were made during the IPP PFAS Initiative as of January 2020 are:

- A total of 68 out of 95 WWTPs with IPPs either have no sources or have sources but have discharges at or less than the PFOS water quality values.
- A total of 93 out of 95 WWTPs were able to complete the initial screening of their industrial users within 1 year of starting the initiative. Most were able to complete the initial screening within 6 months.
- Low levels of PFOS (approximately 3 to 7 ng/L) were detected in wastewater even when no significant industrial sources were present. This suggests that there are background levels of PFAS in domestic sanitary sewage in most communities.
- Depending on the PFOS concentrations in the effluent, sampling is being required semiannually, quarterly, and monthly at 22, 19, and 10 WWTPs, respectively.
- Source reduction efforts have resulted in substantial drops in PFOS concentrations being discharged at the WWTPs (Table 1).

Table 1. Substantial PFOS Reduction at WWTPs with Exceedances (EGLE, 2020)

Municipal WWTP	Recent PFOS, Effluent* (ng/L)	PFOS Reduction (highest to most recent)	Actions Taken to Reduce PFOS
Ionia	<7.6	99%	Treatment (GAC) at source (1)
Lapeer	11	99%	Treatment (GAC) at source (1)
Port Huron	13	99%	Eliminated source PFOS (2)
Wixom	18	99%	Treatment (GAC) at source (1)
Howell	3.7	95%	Treatment (GAC/resin) at source (1)
Bronson	13	96%	Treatment (GAC) at source (1)
Kalamazoo	3.1	92%	Treatment (GAC) at source (2), change water supply
K.I. Sawyer	27	89%	Eliminated leak PFOS-containing firefighting foam
GLWA (Detroit)	30	No Value	Treatment (GAC) at sources (8)
Belding	7.2	49%	Restricted landfill leachate quantity accepted

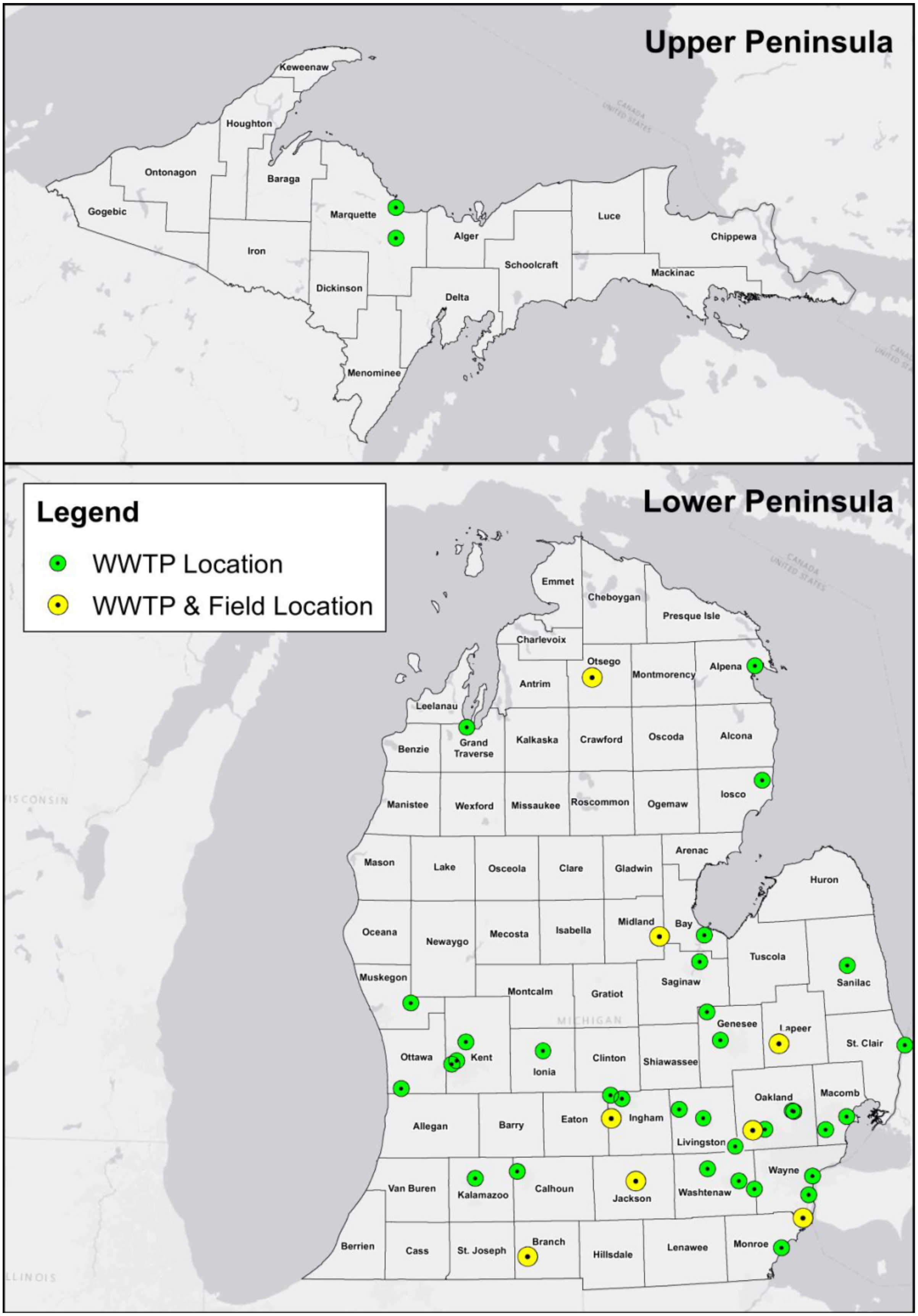
*Data received as of March 26, 2020

STATEWIDE PFAS ASSESSMENT OF 42 WWTPs AND ASSOCIATED RESIDUALS (SLUDGE/BIOSOLIDS)

In the fall of 2018, the WRD launched a statewide PFAS assessment of 42 WWTPs to better understand the occurrence and fate of PFOS and PFOA at municipal WWTPs. The WRD contracted with AECOM to collect influent, effluent, and associated residuals (biosolids/sludge). At selected facilities, additional samples from treatment processes were collected to calculate mass balances for PFOS and PFOA.

Facility selection for the study included the 20 largest municipal WWTPs and an additional 22 municipal plants with various treatment processes and flows and generally spread geographically. A total of 22 agricultural fields associated with 8 of the selected WWTPs were screened for potential PFAS impacts utilizing soil, surface water, tile drain, and groundwater samples. A field selection process was developed that took into account, among other things, PFOS concentrations in biosolids, dates of land application, dry tons applied, and application rates. The locations of selected WWTPs and agricultural fields are presented in Figure 3. The study assessed the occurrence of 24 PFAS compounds, as shown in Table 2. This statewide PFAS sampling study provides a robust evaluation of potential PFAS impacts to the WWTPs and associated residuals, particularly biosolids, in Michigan.

Figure 3. PFAS Sampling Locations of WWTPs and Land-Applied Biosolids Fields*



*Provided by AECOM Technical Services, Inc.

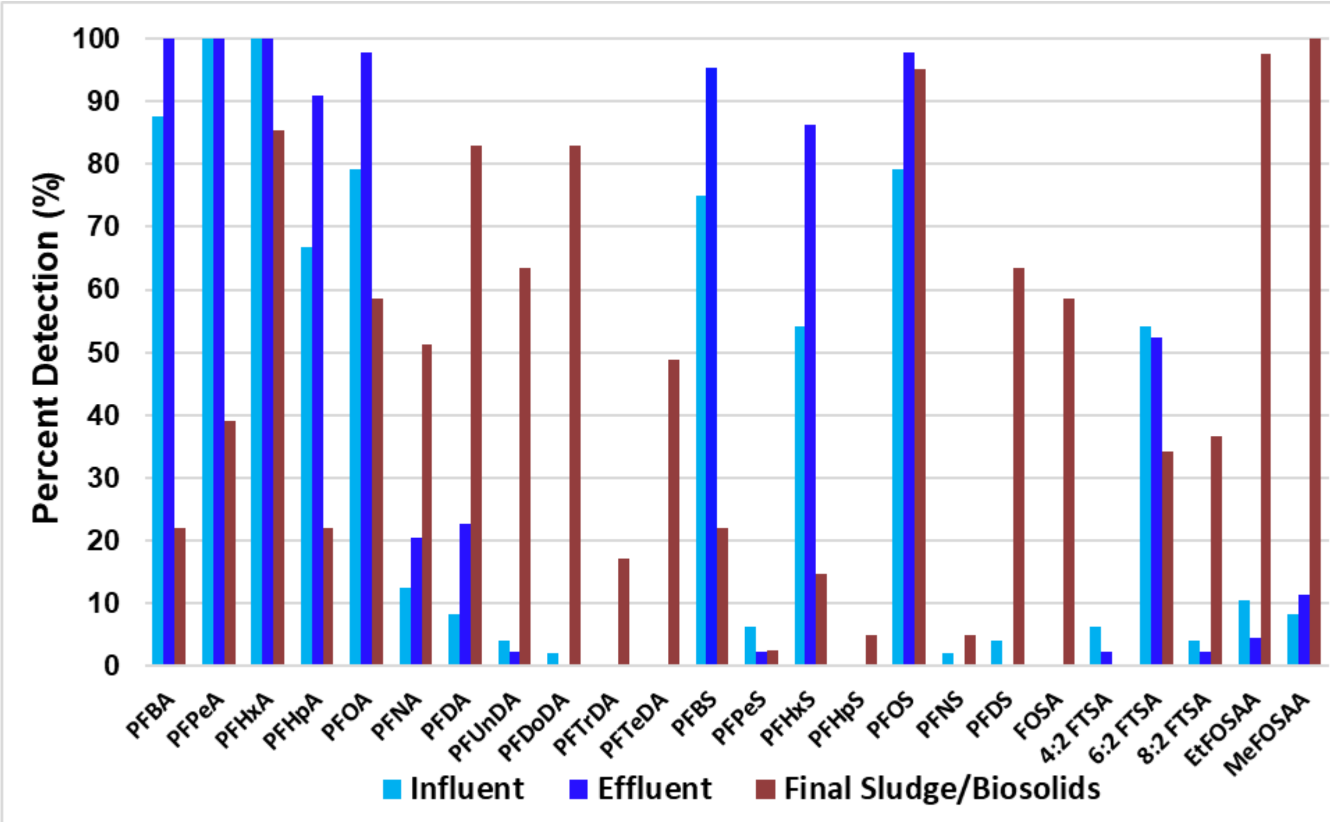
Table 2. PFAS Analyte List

PFAS Family	PFAS Name	Acronym	CAS #
Perfluoroalkyl Carboxylic Acids (PFCA)	Perfluorobutanoic Acid	PFBA	375-22-4
	Perfluoropentanoic Acid	PFPeA	2706-90-3
	Perfluorohexanoic Acid	PFHxA	307-24-4
	Perfluoroheptanoic Acid	PFHpA	375-85-9
	Perfluorooctanoic Acid	PFOA	335-67-1
	Perfluorononanoic Acid	PFNA	375-95-1
	Perfluorodecanoic Acid	PFDA	335-76-2
	Perfluoroundecanoic Acid	PFUnDA	2058-94-8
	Perfluorododecanoic Acid	PFDoDA	307-55-1
	Perfluorotridecanoic Acid	PFTrDA	72629-94-8
	Perfluorotetradecanoic Acid	PFTeDA	376-06-7
Perfluoroalkane Sulfonic Acids (PFSA)	Perfluorobutane Sulfonic Acid	PFBS	375-73-5
	Perfluoropentane Sulfonic Acid	PFPeS	2706-91-4
	Perfluorohexane Sulfonic Acid	PFHxS	355-46-4
	Perfluoroheptane Sulfonic Acid	PFHpS	375-92-8
	Perfluorooctane Sulfonic Acid	PFOS	1763-23-1
	Perfluorononane Sulfonic Acid	PFNS	474511-07-4
	Perfluorodecane Sulfonic Acid	PFDS	335-77-3
Perfluoroalkane Sulfonamides (FASA)	Perfluorooctane Sulfonamide	FOSA	754-91-6
(n:2) Fluorotelomer Sulfonic Acids	6:2 Fluorotelomer Sulfonic Acid	4:2 FTSA	757124-72-4
	6:2 Fluorotelomer Sulfonic Acid	6:2 FTSA	27619-97-2
	8:2 Fluorotelomer Sulfonic Acid	8:2 FTSA	39108-34-4
N-Ethyl Perfluoroalkane Sulfonamidoacetic Acids (N-EtFASAA)	N-Ethyl Perfluorooctane Sulfonamidoacetic Acid	EtFOSAA	2991-50-6
N-Methyl Perfluoroalkane Sulfonamidoacetic Acids (MeFASAA)	N-Methyl Perfluorooctane Sulfonamidoacetic Acid	MeFOSAA	2355-31-9

PFAS OCCURRENCE IN MUNICIPAL WWTPS

PFAS compounds were identified in all of the 42 WWTP samples, including influent, effluent, and biosolids/sludge samples (Figure 4). The detection of PFAS in all WWTP samples indicates that PFAS are likely present in many industrial discharges. The short-chain PFAS from various PFAS families were more frequently detected in the liquid process flow (influent and effluent). Long-chain PFAS were predominantly detected more frequently in the solid process flow (biosolids/sludge), which indicates a higher affinity for the solids for long-chain PFAS. In Figure 4, PFAS are ordered with short-chain PFAS on the left with increasing chain length as you move to the right within their respective families (see Figure 7 for additional information). PFOS was frequently detected in both the aqueous and solid process flows.

Figure 4. Percent Detection of PFAS in Influent, Effluent, and Final Biosolids/Sludge*

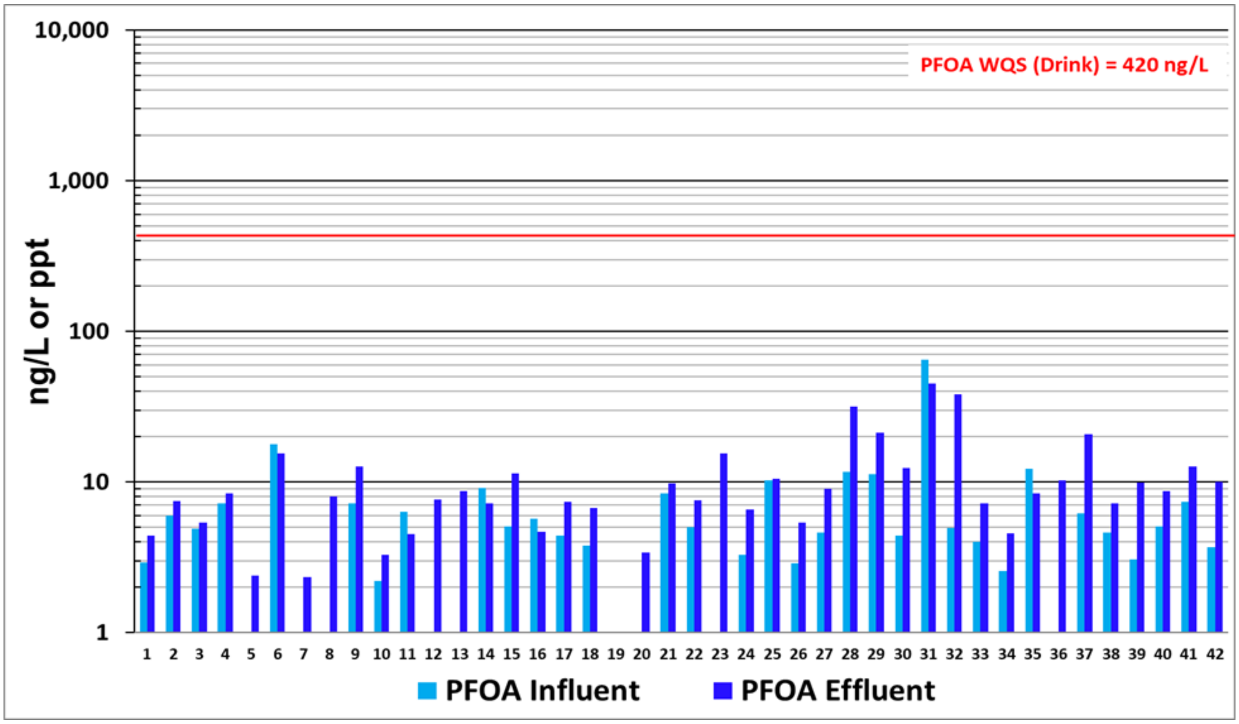


*Provided by AECOM Technical Services, Inc.

The PFOA and PFOS concentrations in all 42 WWTPs are presented in Figures 5 and 6, respectively. Many of the effluent PFOA and PFOS concentrations were higher than the influent, which could indicate the possible transformation of precursors or could be attributed to the operation of the WWTPs. The recirculation of return activated sludge (RAS), filtrate (liquid that has passed through a filter), or centrates (liquid portion of sludge mixture that is separated from the solids portions in a centrifuge), which are expected to have higher PFAS concentrations than those in the influent, may result in higher PFAS concentrations in the effluent. The most conservative water quality values for surface water used as a drinking water source are also presented in Figures 5 and 6. The PFOA concentrations in both the influent and effluent samples were well below the water quality value for PFOA. However, some of the WWTPs had PFOS concentrations, including the effluent, above the water quality values for PFOS. As a result, PFOS was found to be the main driver for regulatory compliance.

Figure 5. PFOA Influent and Effluent Concentrations in WWTPs*

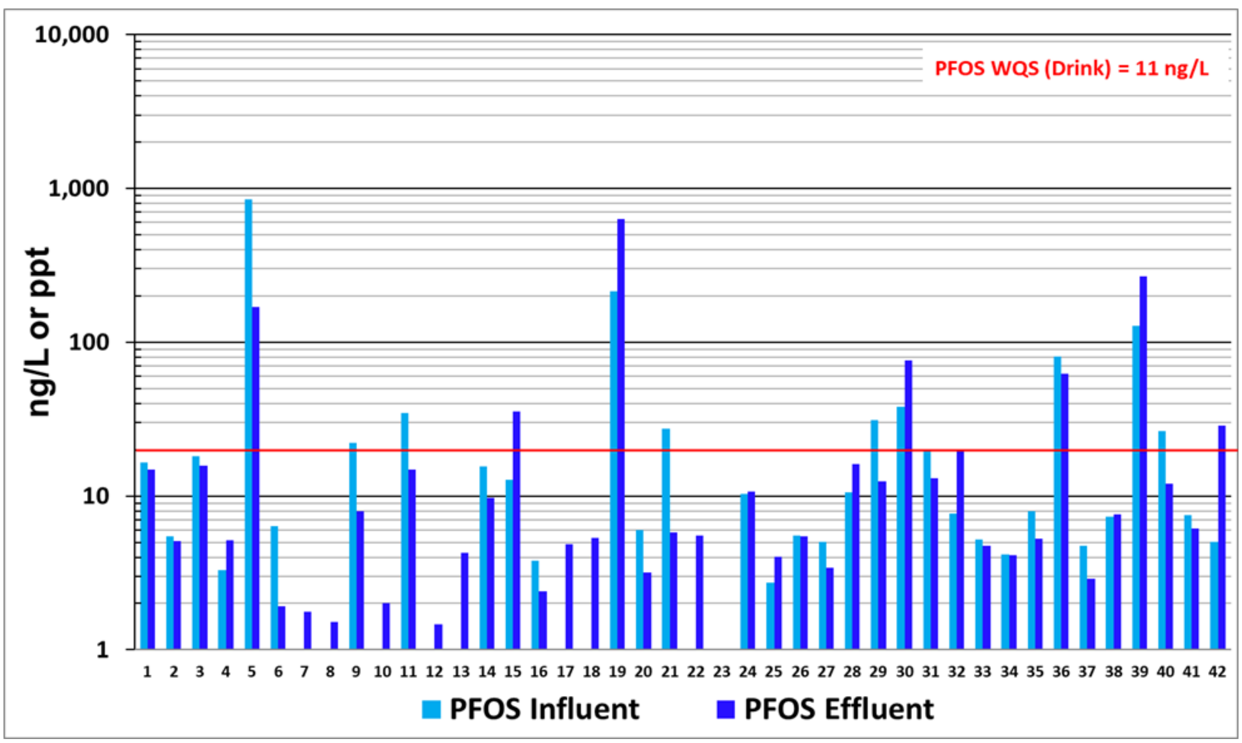
NOTE: The PFOA water quality value depicted in the chart is the most conservative value and only applies to surface waters used as a drinking water source. The PFOA water quality value for surface water not used as a drinking water source is 12,000 ng/L.



*Provided by AECOM Technical Services, Inc.

Figure 6. PFOS Influent and Effluent Concentrations in WWTPs*

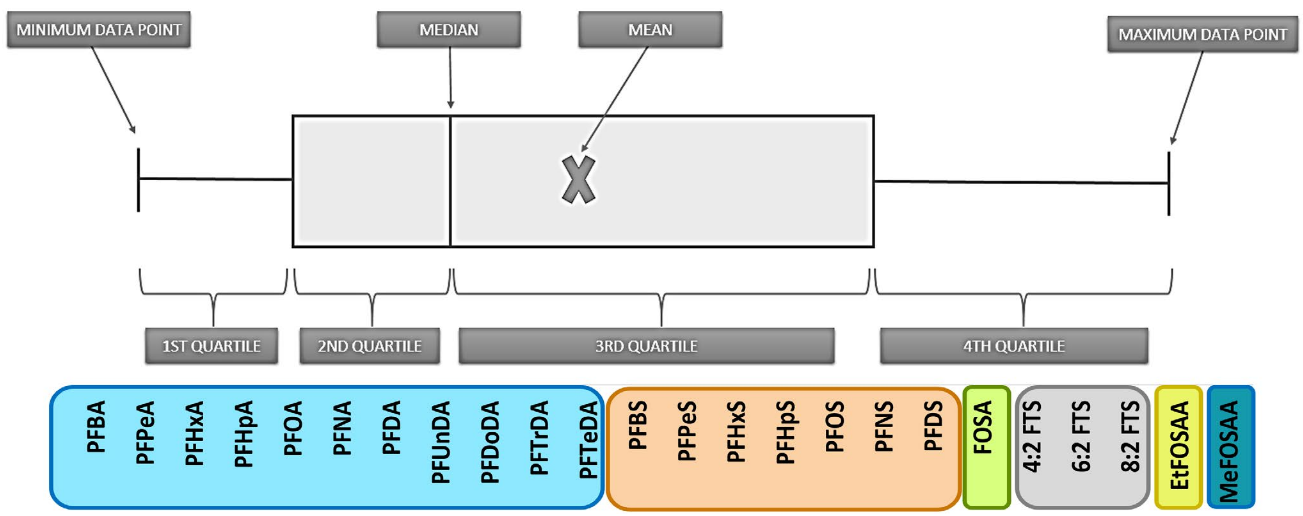
NOTE: The PFOS water quality value used is the most conservative value and only applies to surface waters used as a drinking water source. The PFOS water quality value for surface water not used as a drinking water source is 12 ng/L.



*Provided by AECOM Technical Services, Inc.

The PFAS concentrations for all 24 compounds were also plotted as a box plot, including color-coding for each PFAS family with an increasing chain length from left to right. The box plots also included whiskers for the minimum and maximum concentrations and 25th, 50th, and 75th percentiles, including the mean concentrations (Figure 7).

Figure 7. **PFAS Analyte List by Families and Box Plot Data Legend***



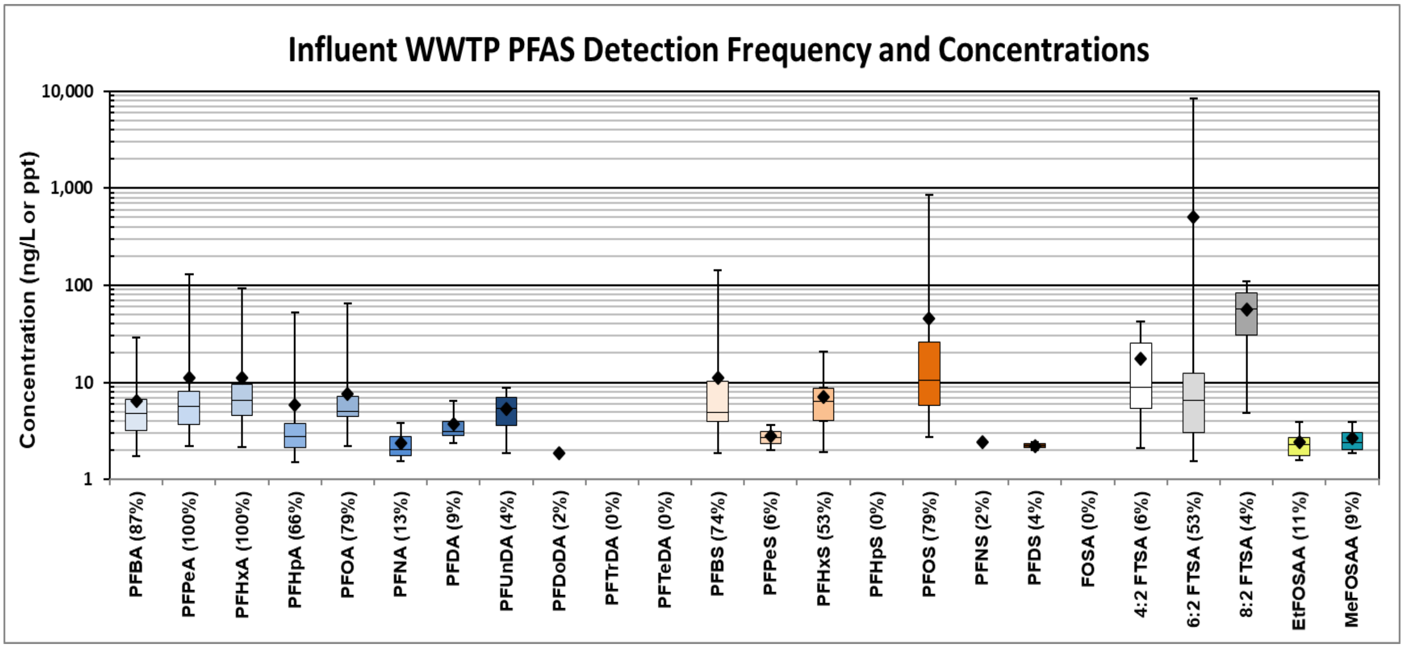
*Provided by AECOM Technical Services, Inc.

The box plot graphs for the influent, effluent, and biosolids/sludge concentrations and detection frequencies are presented in Figures 8, 10, and 12, respectively. The dot plot graphs for the influent and effluent are shown in Figures 9 and 11, respectively. There was a wide range of concentrations detected for most of the PFAS detected in all 3 matrices, including a number of very high results, which resulted in high biased mean concentrations above the median. The average concentration in biosolids/sludge of the 42 WWTPs for PFOS was 195 µg/kg, while the median concentration was only 13 µg/kg (Figure 13). Only 7 biosolids/sludge sample results from 6 WWTPs were above the average concentrations of 195 µg/kg. These 7 samples were from small to mid-sized POTWs (0.2-3.8 MGD) and all 6 facilities identified highly elevated discharges of PFOS to their collection system from industrial sources. As we identify and address facilities with elevated PFOS concentrations, we expect to find lower concentrations in biosolids on average in Michigan moving forward. For example, by removing the 7 industrially impacted samples, the recalculated average concentration in biosolids is reduced to 16 µg/kg and the median is reduced to 11 µg/kg (Figure 14).

An analysis of archived biosolid samples (collected in 2001), which represent 94 wastewater treatment facilitates from 32 different states and the District of Columbia, indicated that PFOS was the most abundant PFAS analytes detected with an average concentration of 402 µg/kg dry weight (minimum: 308, maximum: 618) followed by PFOA at 34 µg/kg (minimum: 12, maximum: 70) (Venkatesana and Halden, 2013).

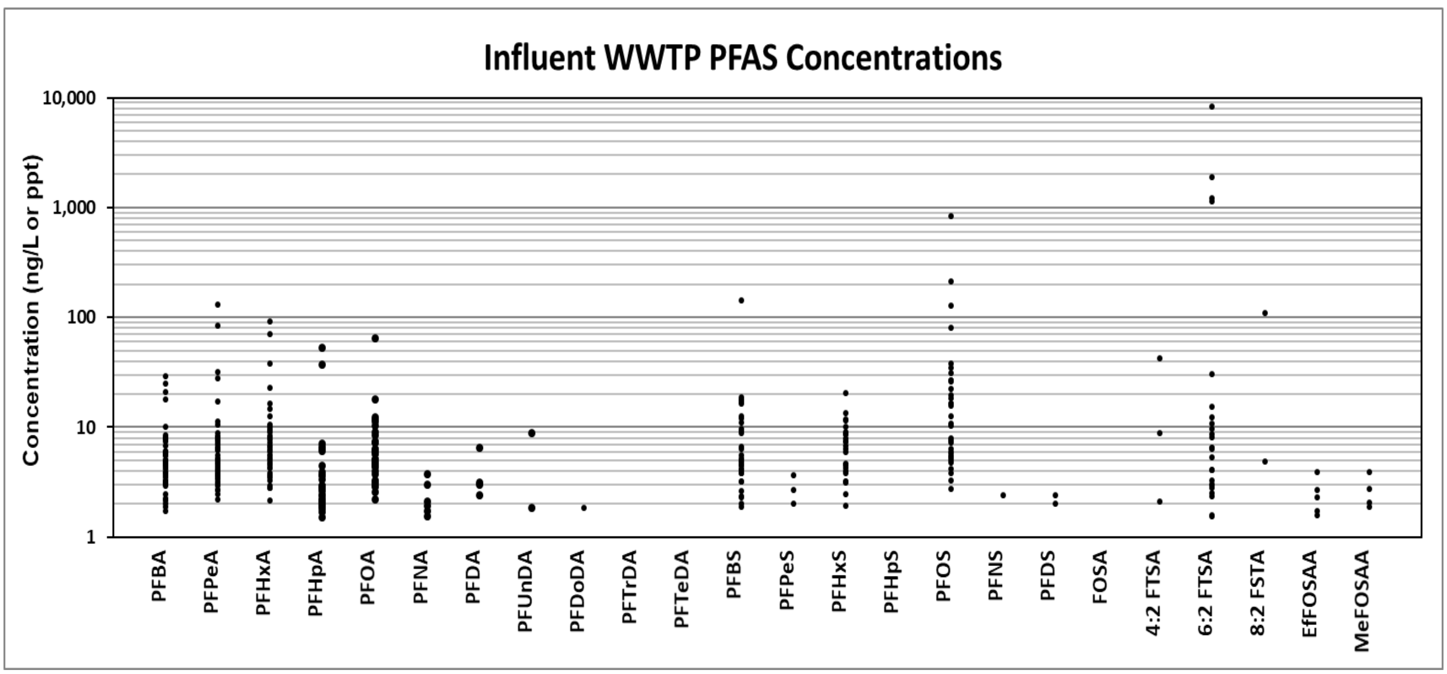
The PFOS concentrations in biosolids/sludge identified during the 2018 Michigan assessment were similar to those reported in literature for WWTPs that receive industrial discharges in Switzerland, Australia, and parts of the United States. The concentrations in Michigan were significantly higher than those reported in Kenya for WWTPs where only 1 out of 9 WWTPs had industrial discharges. The results indicate that PFOS concentrations are strongly correlated with industrial discharges and often with chrome or metal finishers. Many of the WWTPs that reported high concentrations of PFOS received industrial discharges from chrome platers or metal finishers. Many of those industries currently use mist suppressants that have high 6:2 FTSA concentrations while mist suppressants used prior to 2015 had high PFOS concentrations.

Figure 8. Influent WWTP PFAS Detection Frequency and Concentrations - Box Plot*



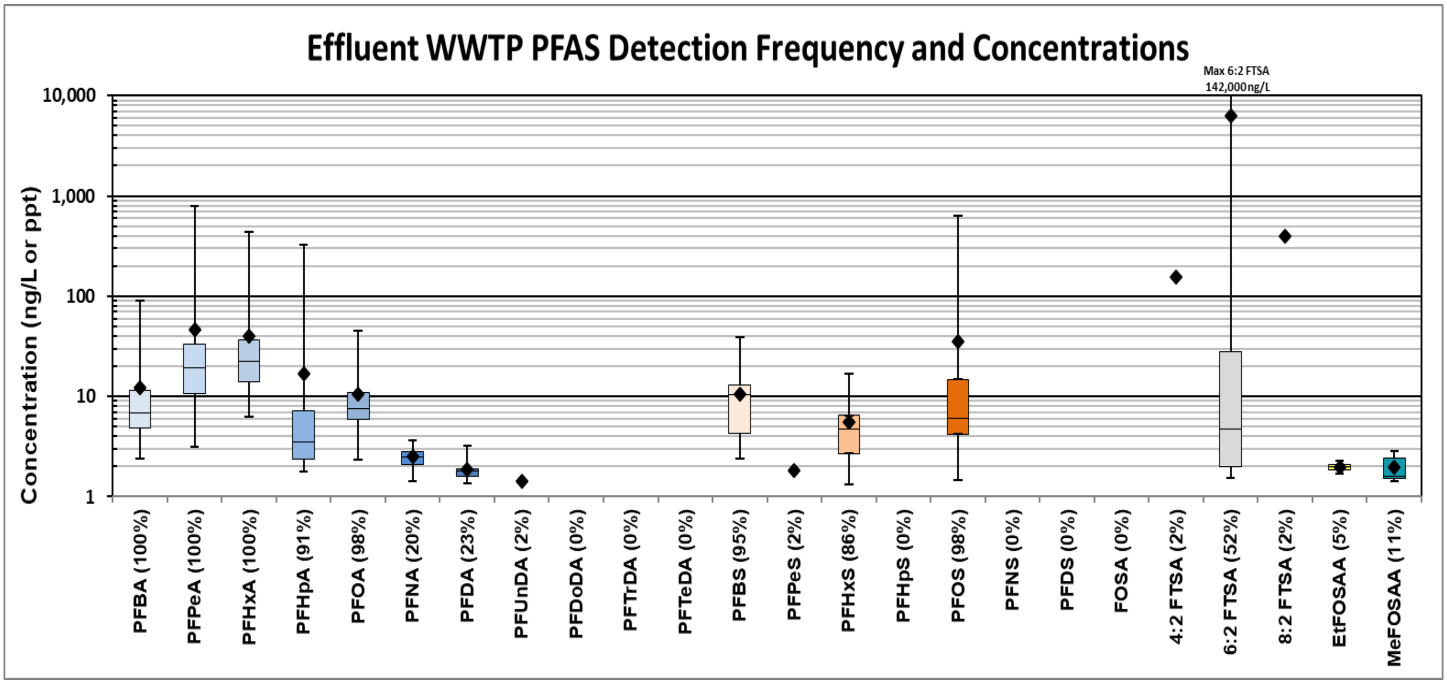
*Provided by AECOM Technical Services, Inc.

Figure 9. Influent WWTP PFAS Concentrations - Dot Plot*



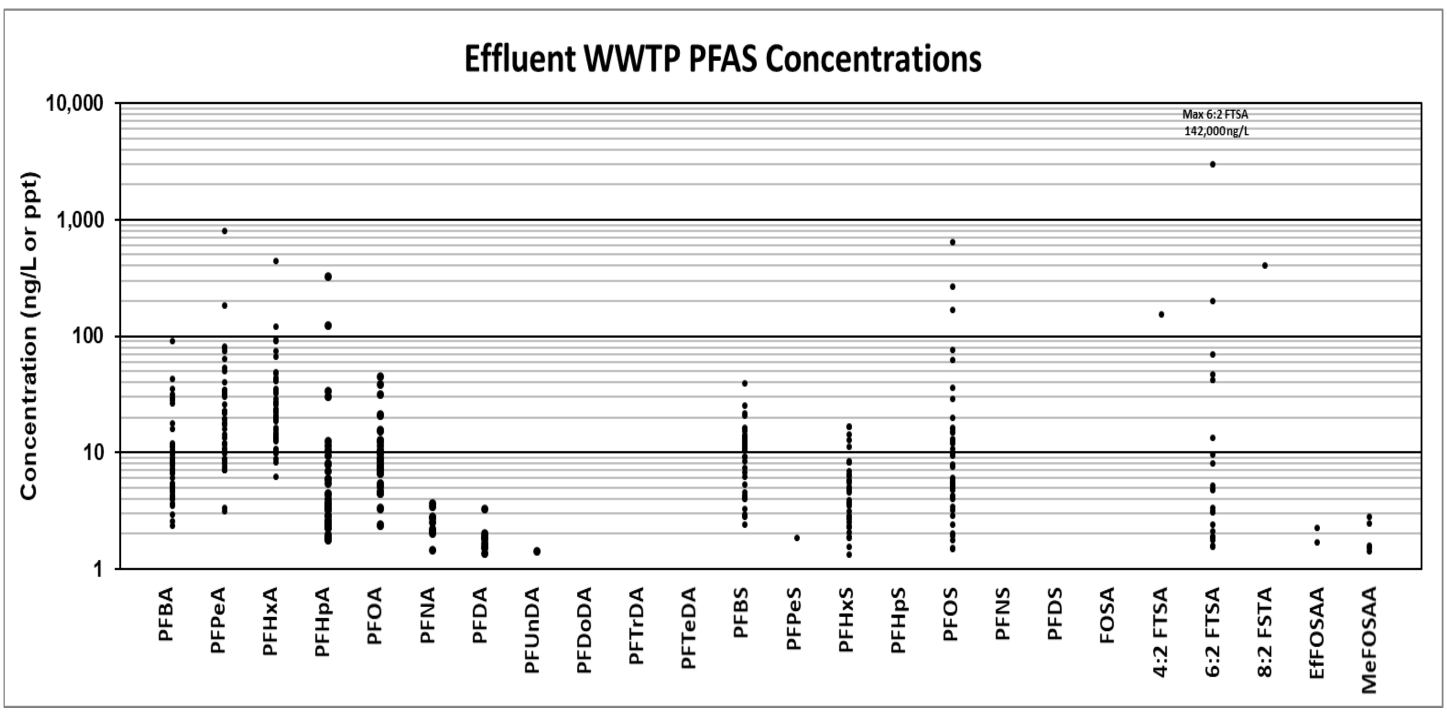
*Provided by AECOM Technical Services, Inc.

Figure 10. Effluent WWTP PFAS Detection Frequency and Concentrations - Box Plot*



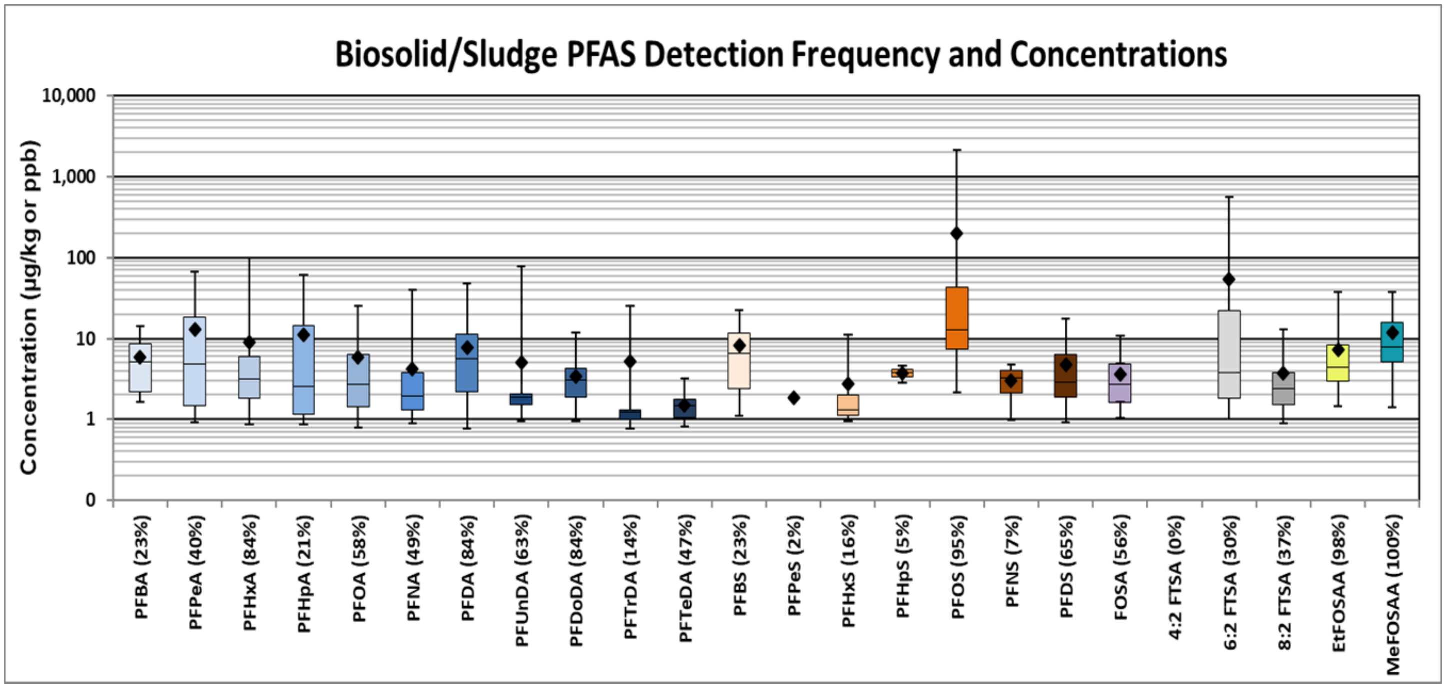
*Provided by AECOM Technical Services, Inc.

Figure 11. Effluent WWTP PFAS Concentrations - Dot Plot



*Provided by AECOM Technical Services, Inc.

Figure 12. Biosolids/Sludge PFAS Detection Frequency and Concentrations - Box Plot*



*Provided by AECOM Technical Services, Inc.

Figure 13. PFOS Concentrations in Biosolids/Sludge

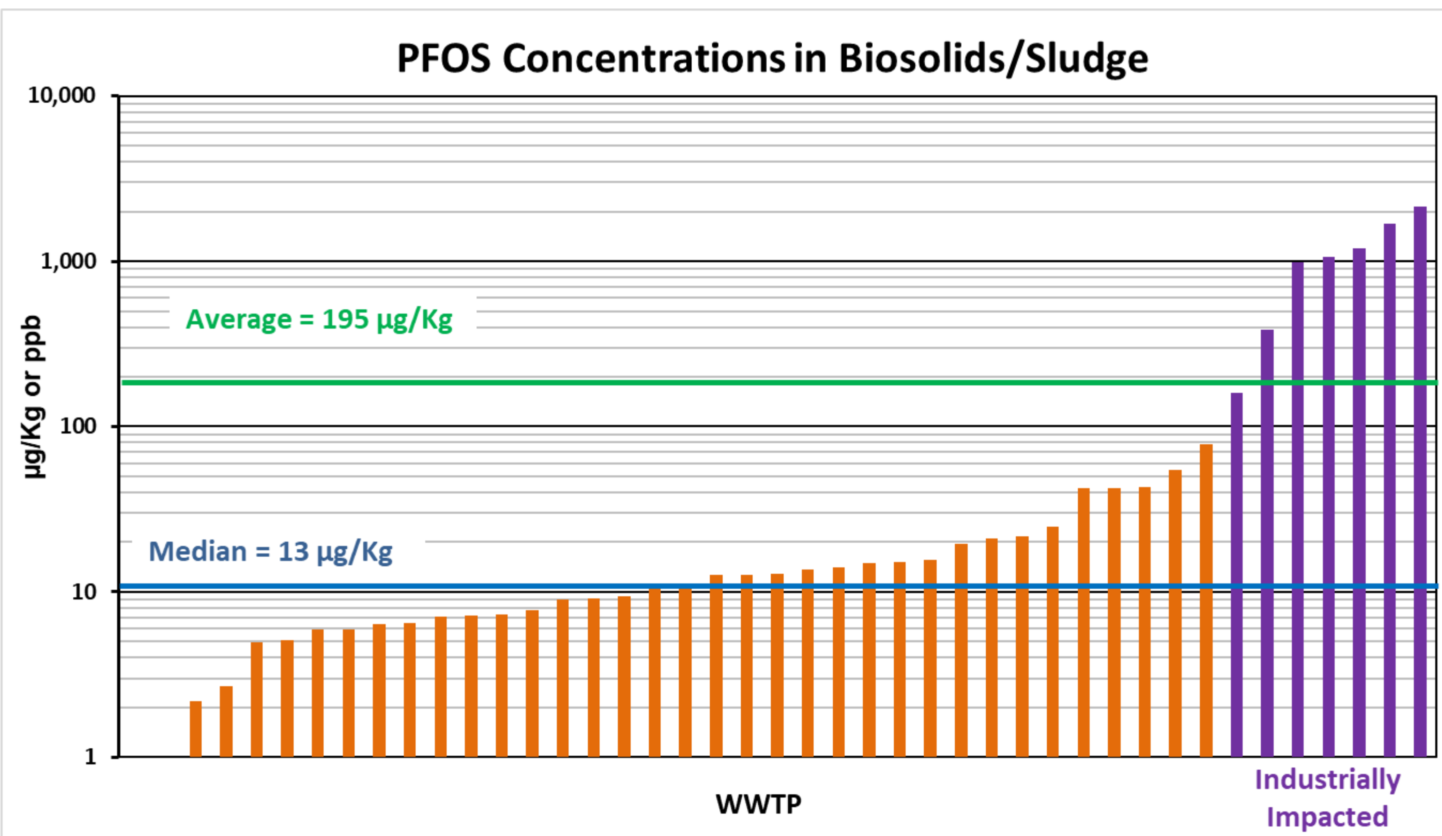


Figure 14. PFOS Concentrations in Biosolids/Sludge (Excluding Industrially Impacted Results)

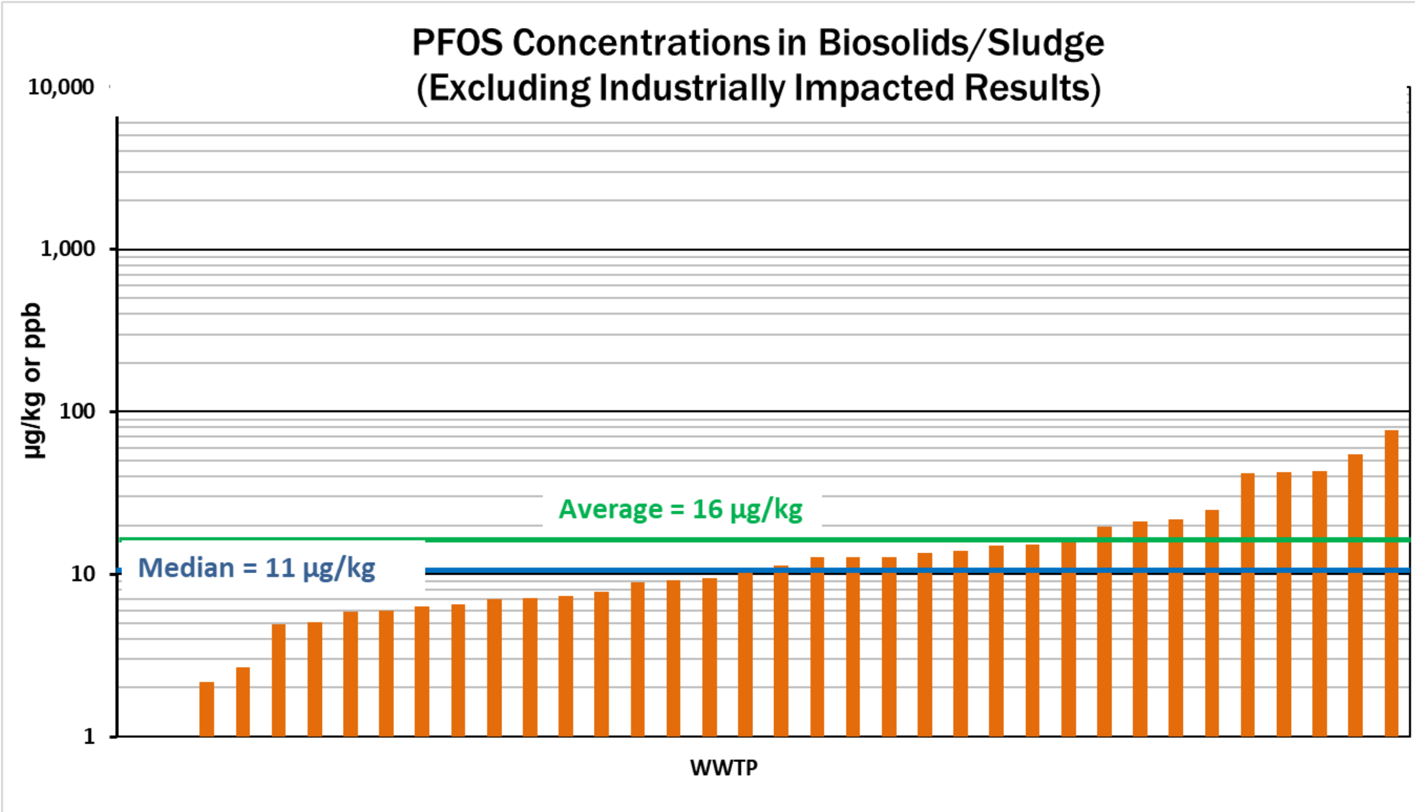
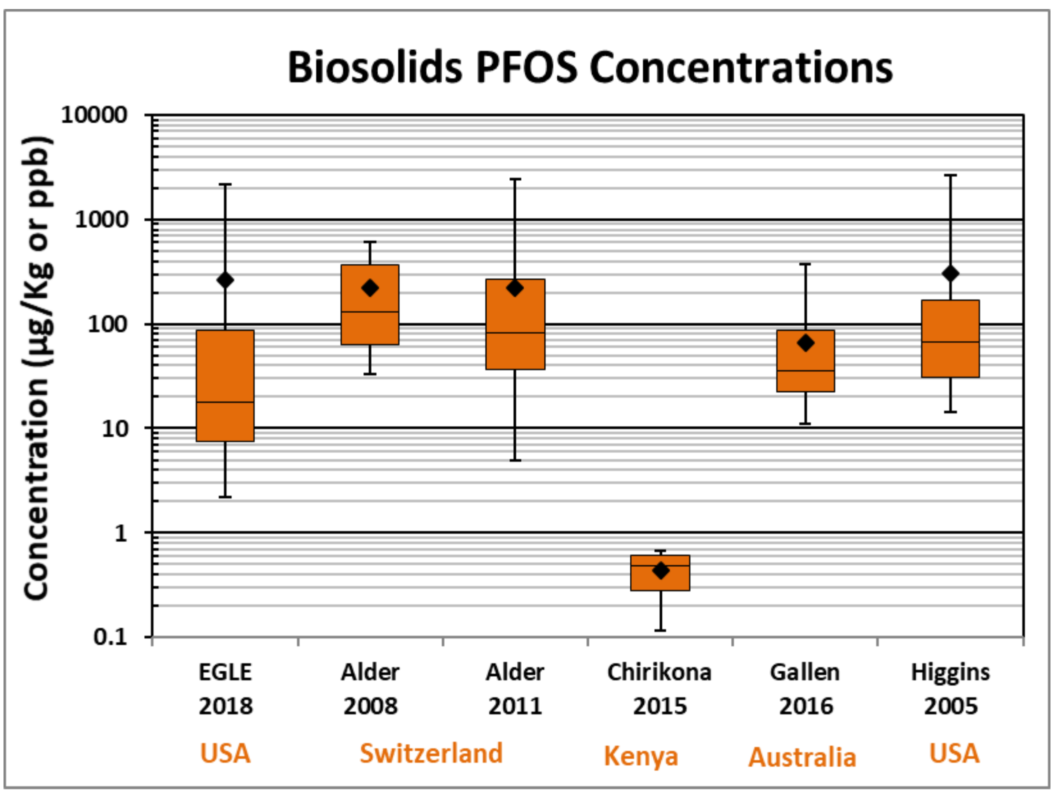


Figure 15. PFOS Biosolids Concentrations in Michigan and Published Literature*



*Provided by AECOM Technical Services, Inc.

PFAS ASSESSMENT OF BIOSOLIDS AND AGRICULTURAL FIELDS

Through implementation of the IPP PFAS Initiative and the statewide study, EGLE identified 6 WWTPs with biosolids/sludge that were classified as being industrially impacted based on PFOS concentrations in the residuals (Figure 13). Each of these POTWs also had high concentrations of PFOS in their effluent. In this use, the term "industrially impacted" is used to describe residuals that have PFOS concentrations above 150 µg/kg and where the WWTP has identified a significant industrial source(s) of PFOS to their system. The choice of 150 µg/kg as the threshold for sludge to be considered industrially impacted was based on a number of factors, including concentrations found within available literature, as well as an analysis of data from this study indicating a natural "break-point" in the data above that level. In general terms, the concentrations observed at 5 of the 6 POTWs identified as having industrially impacted biosolids were substantially higher (an order of magnitude in most instances) than others observed. It is important to note that this is not a risk-based number and as more information about fate and transport of these chemicals becomes available, including the field study results, this level will be reevaluated as necessary.

Two of the facilities identified were already sending their sludge to a landfill for disposal and EGLE confirmed the continuation of that disposal method with the POTW going forward. The remaining 4 POTWs had active biosolids land application programs which EGLE suspended while the facilities worked to address the industrial sources of PFAS to their POTWs. All 6 facilities are implementing the IPP PFAS Initiative which requires reduction of PFOS above screening criteria at the source. Five of the POTWs have already addressed their primary source of PFOS through enforcement of their IPP, which led to installation of granular activated carbon (GAC) treatment by their industrial users or elimination of the source, and their respective effluents and biosolids have shown greatly reduced concentrations of PFOS as a result.

To better our understanding of the fate of PFAS in municipal biosolids, EGLE performed an evaluation of agricultural fields with land-applied biosolids from 8 WWTPs. The initial selection of agricultural fields was based on PFAS and PFOS concentrations in effluent and biosolids from WWTPs (Table 3). Eleven agricultural fields associated with 5 WWTPs that had lower PFAS concentrations in the effluents and biosolids and 11 agricultural fields associated with 3 WWTPs that had some of the highest PFAS concentrations were selected. The selection of the agricultural fields was biased toward higher potential impacts at fields that had a higher mass of biosolids applied per acre. Since biosolids are generally applied uniformly across an area of application, the selection of sample sites was also biased toward locations on the fields where higher PFAS concentrations were expected (i.e., downgradient, low lying areas).

Screening of soils, surface water, tile drains, and ponded water was conducted at all fields (where present). In addition, groundwater monitoring wells were installed at fields from 4 WWTPs, including 3 WWTPs with higher impacted biosolids and 1 with lower impacted biosolids.

PFAS was observed in various environmental matrices such as soil, groundwater, surface water, tile drains, and perched or ponded water. Overall, higher PFAS concentrations were identified in the agricultural fields associated with higher impacted biosolids in all environmental matrices compared to those agricultural fields associated with lower impacted biosolids. Although, PFAS was detected at fields that received biosolids from less impacted WWTPs, concentrations were significantly lower, and in some cases, below detection limits. It should be noted that screening found low concentrations in some agricultural fields associated with higher impacted WWTPs also.

Additional information, including summary field reports, will be provided as part of a detailed report expected in the summer of 2020.

Table 3. Field Results - Ranges for Total PFAS, PFOS, and PFOA

Biosolids Application Rates	Lower Impacted WWTPs	Higher Impacted WWTPs
Total land-applied biosolids – (dry tons - dT)	176 - 400	39 - 1,422
Average dT/Acre	2 - 10	1 - 4
Weighted Use Ratio (Total dT/Site Acres)	6 - 23	4 - 28

	Lower Impacted WWTPs			Higher Impacted WWTPs		
Environmental Matrices	**Total PFAS**	**PFOS**	**PFOA**	**Total PFAS**	**PFOS**	**PFOA**
Effluent (ng/L)	4 - 15	2 - 5	2 - 11	300 - 143,360	169 - 635	ND - 10
Biosolids (µg/Kg)	34 - 214	3 - 90	ND - 18	1,173 - 2,358	1,060 - 2,150	ND - 5
Soil (µg/Kg)	ND - 15	ND - 9	ND - 2	1 - 182	1 - 172	ND - 2
Groundwater[2] (ng/L)	ND - 97	ND - 2	ND - 6	ND - 541[1]	ND - 18[1]	ND - 61[1]
Surface Water[2] (ng/L)	ND - 52	ND - 5	ND - 6	2.5 - 2,647	ND - 2,060	ND - 64
Tile Drain[2] (ng/L)	ND - 58	ND	ND - 6	9 - 2,495	1 - 2,080	ND - 95
Ponded Water[2] (ng/L)	6 - 346	ND - 2	ND - 53	17 - 968	ND - 533	2 - 53

[1]Perched groundwater at one location had Total PFAS = 41,823 ng/L, PFOS = 35,300 ng/L, and PFOA = 1,930 ng/L.
[2]Groundwater, surface water, tile drain, and ponded water samples were not collected in every agricultural field.

SUMMARY AND CONCLUSIONS

Statewide assessments of PFAS in WWTPs and agricultural fields determined that PFAS were frequently detected in municipal wastewater, residuals, and at land application sites where biosolids were applied. However, individual PFAS concentrations varied significantly among WWTPs. Concentrations of individual PFAS showed high variability, which suggests that a variety of industrial discharges have an impact on WWTPs. Of the PFAS, PFOS was determined to be the main regulatory driver for WWTPs with effluents exceeding the water quality values. PFOS was also detected at high concentrations in the biosolids/sludge from WWTPs with known significant industrial sources of PFOS. The short-chain PFAS were more frequently correlated with aqueous WWTP process flows, while long-chain PFAS were strongly associated with solids process flows. This indicates that long-chain PFAS, such as PFOS, are expected to accumulate in the biosolids/sludge. The highest variation was observed for 6:2 FTSA and PFOS. PFAS precursors that are known to degrade to PFOS, such as FOSA, EtFOSAA, and MeFOSAA, were also detected and found to accumulate in biosolids/sludge. Average concentrations may not be representative when summarizing overall PFAS concentrations in WWTP samples because the means are highly biased due to a small number of samples with high results.

Many PFOS concentrations identified in biosolids/sludge during the assessment were similar, with overall concentrations somewhat lower than those reported in literature examining the topic. This indicates that the PFOS concentrations from Michigan are similar to those identified in the past in the United States and other countries (Figure 14). Michigan's data was collected after the discontinuation of the use of PFOS in industrial applications and most of the other studies were conducted prior to the phase-out of their use, which may explain Michigan's lower results.

Through the IPP PFAS Initiative, EGLE has successfully identified WWTPs that received PFAS from industrial dischargers. EGLE has also been successful in working with WWTPs that exceed the PFOS water quality values to implement source reduction to decrease the PFOS concentrations in the influent, effluent, and biosolids/sludge. EGLE has focused efforts on identifying POTWs with industrially impacted biosolids and preventing further land application of biosolids from those facilities until sources of PFOS can be controlled.

Screening of agricultural fields that received biosolids applications found significantly higher PFAS concentrations in various environmental matrices associated with WWTPs with elevated levels of PFAS in their biosolids. However, site-specific environmental conditions were determined to be very important when evaluating potential impacts and exposure pathways. Some agricultural fields that had land-applied biosolids from WWTPs with high PFAS impacts did not have high PFAS concentrations in environmental matrices (soils, surface waters, groundwater, etc.). Also, significantly lower PFAS concentrations were detected at land application sites receiving less impacted biosolids. additional information will be included in a detailed report expected in the summer of 2020.

REFERENCES

Boulanger, B., J.D. Vargo, J.L. Schnoor, and K.C. Hornbuckle. 2005. "Evaluation of Perfluorooctane Surfactants in a Wastewater Treatment System and in a Commercial Surface Protection Product." Environmental Science and Technology 39:5524-5530.

Higgins, C.P., J.A. Field, C.S. Criddle, and R.G. Luthy. 2005. "Quantitative Determination of Perfluorochemicals in Sediments and Domestic Sludge." Environmental Science and Technology 39:3946-3956.

Houtz, E.F., R. Sutton, J.S. Park, and M. Sedlak. 2016. "Poly- and perfluoroalkyl substances in wastewater: Significance of unknown precursors, manufacturing shifts, and likely AFFF impacts." Water Research 95:142-149.

ITRC (Interstate Technology Regulatory Council). 2017. "History and Use of Per- and Polyfluoroalkyl Substances (PFAS)." *(The link provided was broken and has been removed)*

Loganathana, B.G., K.S. Sajwan, E. Sinclair, K.S. Kumar, and K. Kannan. 2007. "Perfluoroalkyl sulfonates and perfluorocarboxylates in two wastewater treatment facilities in Kentucky and Georgia." Water Research 41:4611-4620.

OECD (Organisation for Economic Co-operation and Development). 2018. "Toward a new comprehensive global of per- and polyfluoroalkyl substances (PFASs): Summary report on updating the OECD 2007 List of per- and polyfluoroalkyl substances (PFASs)." Paris: OECD.

OECD (Organisation for Economic Co-operation and Development). 2013. "Synthesis paper on per- and polyfluorinated chemicals (PFCs)." Paris: OECD.

Paul, A.G., K.C. Jones, and A.J. Sweetman. 2009. "Perfluoroalkyl contaminants in the Canadian Arctic: evidence of atmospheric transport and local contamination." Environmental Science and Technology 43:386-392.

Schultz, M., C.P. Higgins, C.A. Huset, R.G. Luthy, D.F. Barofsky, and J.A. Field. 2006. "Fluorochemical Mass Flows in a Municipal Wastewater Treatment Facility." Environmental Science and Technology 40:7350-7357.

Sinclair E. and K. Kannan. 2006. "Mass Loading and Fate of Perfluoroalkyl Surfactants in Wastewater Treatment Plants." Environmental Science and Technology 40:1408-1414.

Sepulvado, J.G., A.C. Blaine, L.S. Hundal, and C.P. Higgins. 2011. "Occurrence and Fate of Perfluorochemicals in Soil Following the Land Application of Municipal Biosolids." Environmental Science and Technology 45:8106-8112.

Venkatesana, A.K. and R.U. Halden. 2013. "National inventory of perfluoroalkyl substances in archived U.S. biosolids from the 2001 EPA National Sewage Sludge Survey." Journal of Hazardous Materials 252-253:413-418.