Maryland Department of the Environment

Summary Report for MDE's PFAS in Public Drinking Water Study

Background

The Maryland Department of the Environment (MDE) has concluded a multi-phased Public Water Systems (PWS) study to better understand the occurrence of PFAS in the state public drinking water sources. The study started in September 2020, with an initial focus on Community Water Systems (CWSs) during the first four phases, followed by Non-Transient Non-Community Water Systems (NTNCs), which include schools and offices, during the fifth phase. The study concluded in 2025, with a total of 1,880 samples analyzed from 877 public water systems.

The data collected during those five years was compiled and analyzed to determine what patterns could be found looking at the type of source water, the sample type (finished versus raw water), the geology and the geography.

Source Types

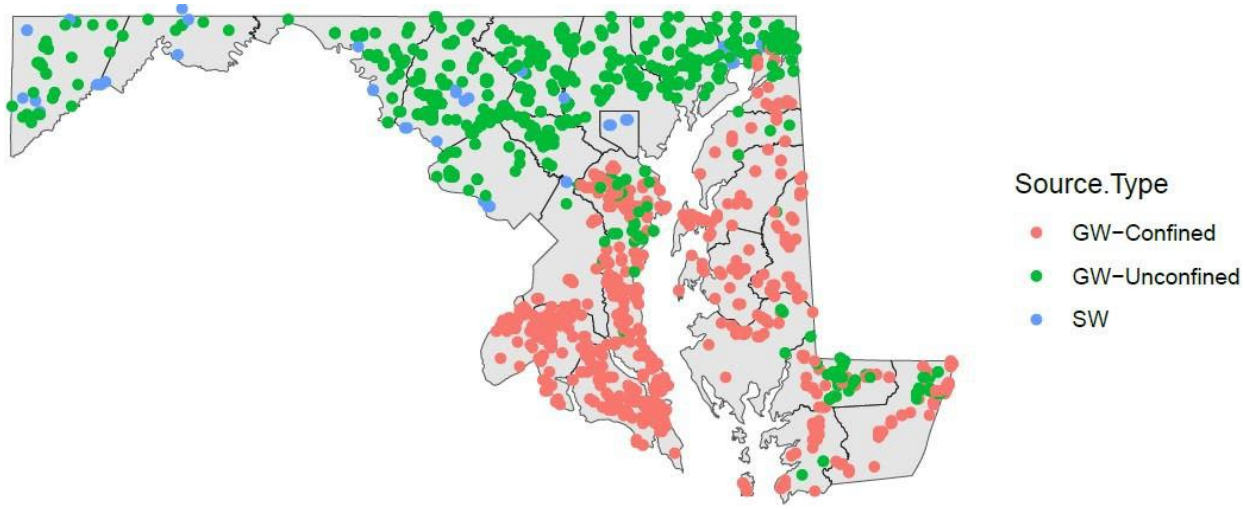

Figure 1: Map showing sampling locations and which water source type category.

Marylanders receive their drinking water from both groundwater (aquifers) and surface water (rivers, lakes, streams and reservoirs) sources. Although water for the majority of Marylanders comes from a few large surface water PWSs, most PWSs in Maryland are relatively small groundwater systems. Groundwater sources can be categorized as confined and unconfined aquifers. A confined aquifer is a groundwater-bearing geological formation that is trapped between impermeable layers of rock or clay called confining beds. Maryland's confined aquifers are found primarily in the southeast of the State, in

the Coastal Plain, and include the Piney Point, Aquia, Magothy, Upper Patapsco, Lower Patapsco and Patuxent aquifers. These confined aquifers are naturally protected by clay layers that prevent surface contamination from easily reaching groundwater.

Unconfined aquifers are groundwater-bearing structures composed of permeable material, like sand or gravel, that receive direct recharge from precipitation and surface water. They are not protected by an impermeable confining layer above, making them more vulnerable to contaminants.

Maryland can be split into two geological regions: the fractured rock region and the coastal plain region. These two regions are separated by the Fall Line, which runs roughly along Interstate 95 (I-95), with the fractured rock region to the west and the coastal plain region to the east. Figure 2 below shows where the Fall Line is located on the map of Maryland.

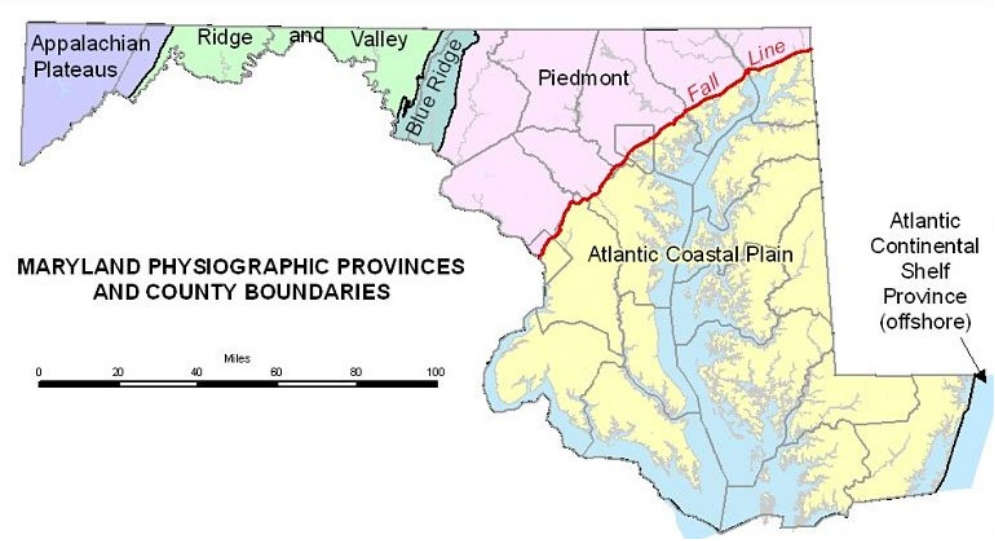

Figure 2: Map from Maryland Geological Survey displaying Fall Line.

Water system wells in the fractured rock region of the state are generally more susceptible to contamination than water system wells in the coastal plain region because of the lack of deep confining layers.

Most of the samples taken during this study were collected from groundwater sources (97%), and of these, most were from unconfined aquifers. Table 1 shows a breakdown of the number of samples and the number of samples with PFAS detections taken at each source type.

Source Type	Number of Samples	Number of Detections
Groundwater Confined	814	13
Groundwater Unconfined	1,015	781
Surface Water	51	33
Total	1,880	827

Table 1: Number of samples and detections taken at each water source type.

Out of the total 1,880 samples taken, 827 samples had PFAS detections (44%). Samples with detections included anything above the reporting limit. The majority of these detections came from unconfined aquifers.

Figures 3-5 are maps identifying the absence/presence of PFAS detections in each source type across the state:

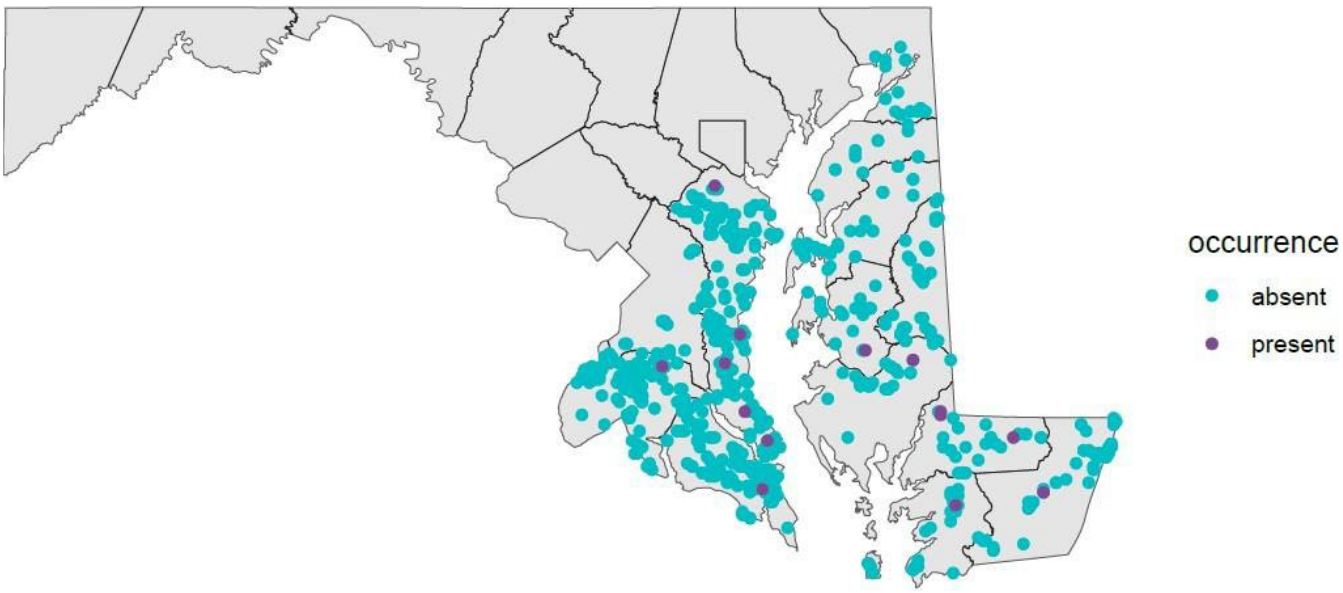

Figure 3: Confined Aquifer Groundwater Samples with/without PFAS Detection

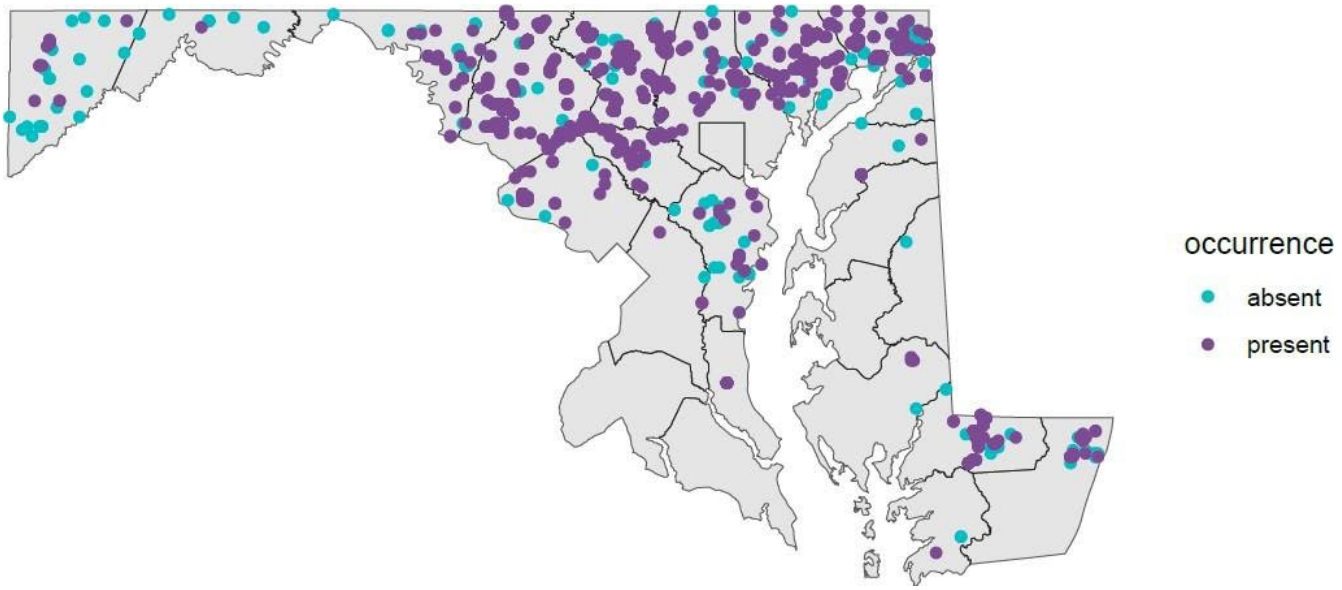

Figure 4: Unconfined Aquifer Groundwater Samples with/without PFAS Detection

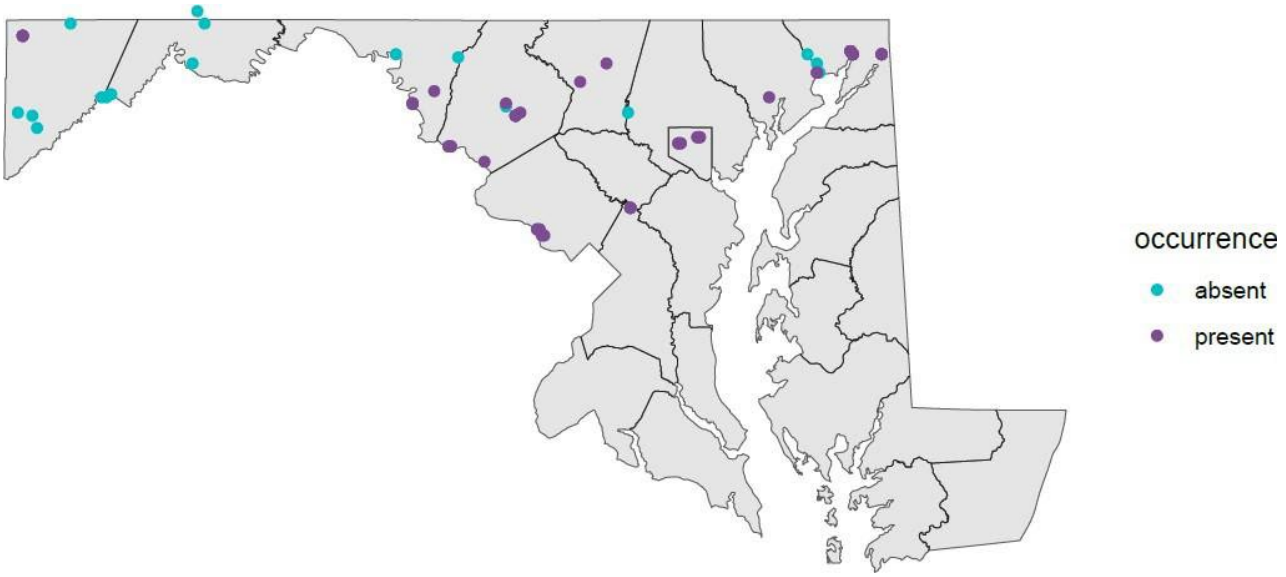

Figure 5: Surface Water Samples with/without PFAS Detection

Analytes Detected

Over the five sampling phases, 1,880 samples were analyzed, including both raw and finished water samples. Raw water samples are untreated samples collected at wells with raw taps or from surface waterbodies. Finished water samples consist of treated water entering the distribution system. At the time when this study was conducted, the majority of treatment systems in Maryland's PWSs would not have been expected to remove PFAS from water. As a consequence, this report does not separately analyze raw water versus treated water results. The sample types are distinguished in the source data. More recently, PWSs with elevated PFAS levels have begun installing treatment systems specifically designed for PFAS removal.

All samples were collected with corresponding field blanks. Sites with initial PFAS detections were generally resampled. A total of 877 public water systems were sampled. Out of the total samples collected, 1,053 samples had no PFAS detections and were labeled as below the reporting limit (<RL).

Figure 6 shows the different percent detections of the PFAS compounds across all samples. The most commonly detected PFAS analytes were PFOA, PFHxA, PFBS, PFPeA, PFBA, PFOS, PFHxS and PFHpA. The sampling methods used in this study only look at certain analytes, meaning that there could be other analytes present that were not observed.

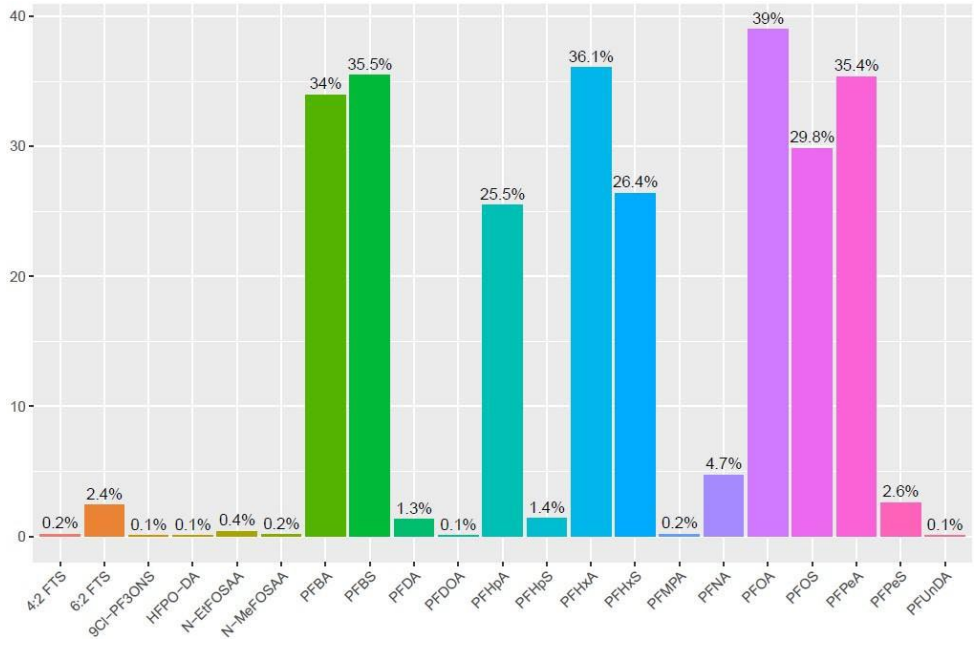

Figure 6: PFAS compounds percent detection in samples.

Types of PFAS Compounds Overview

Under the Safe Drinking Water Act the EPA has set National Primary Drinking Water Regulations establishing legally enforceable levels, called Maximum Contaminant Levels (MCLs), for six of the most commonly occurring PFAS compounds in drinking water. Table 2 shows the individual PFAS MCLs.

PFAS Compound	Maximum Contaminant Level (MCL) (parts per trillion)
PFOA	4.0 ppt
PFOS	4.0 ppt
PFHxS	10 ppt
PFNA	10 ppt
HFPO-DA (commonly known as GenX Chemicals)	10 ppt
Mixtures containing two or more of PFHxS, PFNA, HFPO-DA, and PFBS	1 (unitless) Hazard Index

Table 2: Breakdown of individual PFAS MCLs.

Over the course of the study, EPA analytical Method 533 and Method 537.1 were used for sampling PFAS in drinking water totaling 29 different PFAS analytes. Method 537.1 was utilized during the first four phases and included 18 different PFAS compounds. Once the lab had the capabilities for Method 533, we shifted to using that method in Phase 5, and it included 25 PFAS analytes, 11 of those were compounds not included in Method 537.1. The following eight analytes were not identified in any samples: 11Cl-PF3OUdS, 8:2 FTS, ADONA, NFDHA, PFEESA, PFMBA, PFTA, PFTrDA. For the remaining 21 PFAS compounds, the five most frequently detected compounds were PFOA (39%), PFHxA (36.1%), PFBS (35.5%), PFPeA (35.4%) and PFBA (34%)..

When determining the list of most frequent compounds, there were differences in analytical methods used, meaning that only certain compounds were analyzed in certain samples. EPA Method 533, which was only used during Phase 5, includes several short-chain PFAS compounds not covered by Method 537.1. Specifically, PFPeA and PFBA were analyzed only using EPA Method 533, so the only detections happened in Phase 5 samples. These two compounds were analyzed in a subset of 577 samples, whereas the other PFAS compounds were analyzed across all 1,880 samples. Therefore, the percent presence for each compound is calculated based on the total number of samples in which that specific compound was analyzed. When looking just at the overall count of detects for each compound PFOA, PFHxA, PFBS, PFOS and PFHxS are the most frequently detected. Out of the 6 parameters with MCLs, PFOA had the highest percentage of samples exceeding its 4 ppt MCL at 17%.

Parameter	Exceedance (%)
PFOA	17
PFOS	15
PFHxS	3
PFNA	1
HFPO-DA	0
HI	4

Table 3: Exceedance Percentages for PFAS with MCLs.

We also ran a summary of statistics for all PFAS compounds across all samples that were above the reporting limit and did not include <RL results. The five PFAS compounds with the highest detections were PFOS (270 ppt in Carroll County), PFHxS (173 ppt in Frederick County), PFPeA (140 ppt in Harford County), PFHxA (111 ppt in Harford County), and PFOA (919 ppt in Baltimore County). All of these detections were located in the fractured rock region of the state. Table 4 shows the summary statistics of each PFAS parameter with the amount of times it was detected in samples and the median and max detection amounts. Table 4 also indicates which parameters were included in each sampling method.

Parameter	Number of Detections	Median	Max	Method 533 (N=577)	Method 537.1 (N=1303)
PFOA	733	3.54	91.9	X	X
PFOS	561	3.92	270	X	X
PFHxS	496	2.36	173	X	X
PFNA	89	2.06	27.8	X	X
HFPO-DA	1	1	1	X	X
PFBS	667	3.23	44.5	X	X
PFUnDA	1	1.4	1.4	X	X
9Cl-PF3ONS	1	2.78	2.78	X	X
N-EtFOSAA	5	2.07	4.68		X
N-MeFOSAA	2	2.87	3.67		X
PFHpS	8	2.95	5.59	X	
PFHpA	479	2.39	34.1	X	X
PFDA	25	2.36	12.1	X	X
PFBA	196	3.16	40.7	X	
PFPeS	15	2.52	24.2	X	
6:2 FTS	14	2.76	24.1	X	
PFHxA	678	3.62	111	X	X
PFDoA	1	6.88	6.88	X	X
4:2 FTS	1	10.2	10.2	X	
PFPeA	204	5.08	140	X	
PFMPA	1	17.7	17.7	X	

Table 4: Summary Statistics by PFAS Compound.

Types of PFAS Across Sources

The percentage of samples with PFAS detected was calculated for each water source category. Groundwater from unconfined aquifers had the highest percentage of samples with PFAS detections at 72.3%, whereas groundwater from confined aquifers had the lowest at 3.2%. Figure 7 displays the PFAS detections across the different source types.

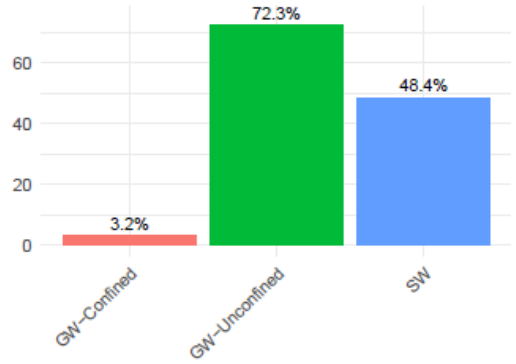

Figure 7: Percent of samples with PFAS detected per water source category.

We then calculated the samples with PFAS detections above the MCLs and/or HI above 1. Out of the total 1,880 samples, 20.2% had at least one PFAS compound exceeding the MCL and or an HI above 1. Only one surface water system had an MCL exceedance. The majority of the water systems that were above the MCLs were in the fractured rock region versus the coastal plain region. All systems sampled in the coastal plain region with results above the MCLs have one or more water sources in shallow unconfined aquifers. Table 5 presents the percent exceedance for each source type where PFAS concentrations were over the MCLs or where the HI exceeded one. Figure 8 shows the geographical locations of samples containing at least one PFAS compound above the MCL and/or a HI greater than one.

Source Type	Number of Samples	Exceedance (%)
GW- Confined	814	0
GW- Unconfined	1015	38
SW	51	2

Table 5: Percent of samples within each source type with PFAS concentration exceeding MCLs or with a HI above 1.

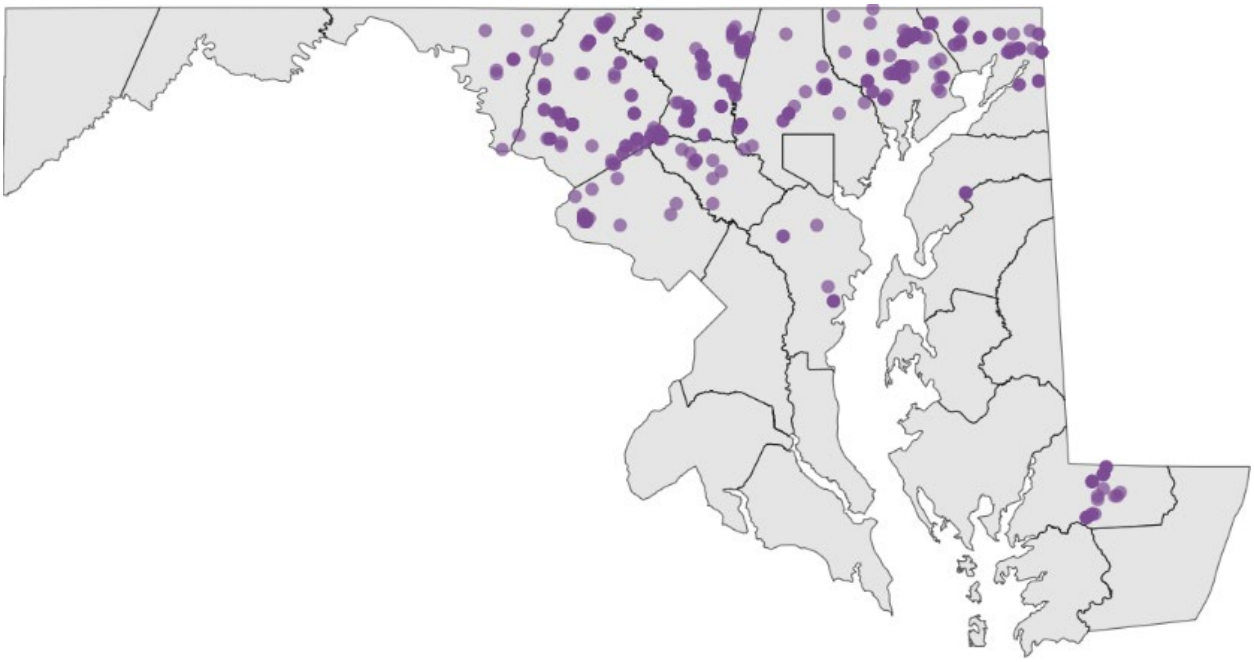

Figure 8: Samples with at least one PFAS Compound above the MCL and/or HI above one.

Figures 9, 10 and 11 show the range of concentrations for each source type. Only samples that had detections were included, <RL were not plotted. Groundwater from unconfined aquifers had the highest number of PFAS analytes detected across its samples and the largest range of concentrations, spanning from 0.5 to 270 ppt. Surface water samples, in contrast, only had six analytes detected with the majority being the regulated PFAS compounds. The compounds detected in surface water were also present at a significantly lower concentration range compared to those in unconfined aquifers.

Confined aquifers had the lowest concentrations out of all source type categories. It seems more likely that PFAS detections in water from confined aquifers was the result of flaws in well construction resulting in contamination from surficial aquifers, or contamination from within the well or water system, rather than the presence of PFAS in the aquifer itself. The compounds that were detected across all source types are: PFOA, PFOS, PFHxS, PFHpA and PFHxA. Among the regulated compounds, PFOS and PFOA have the highest median concentrations across all source types.

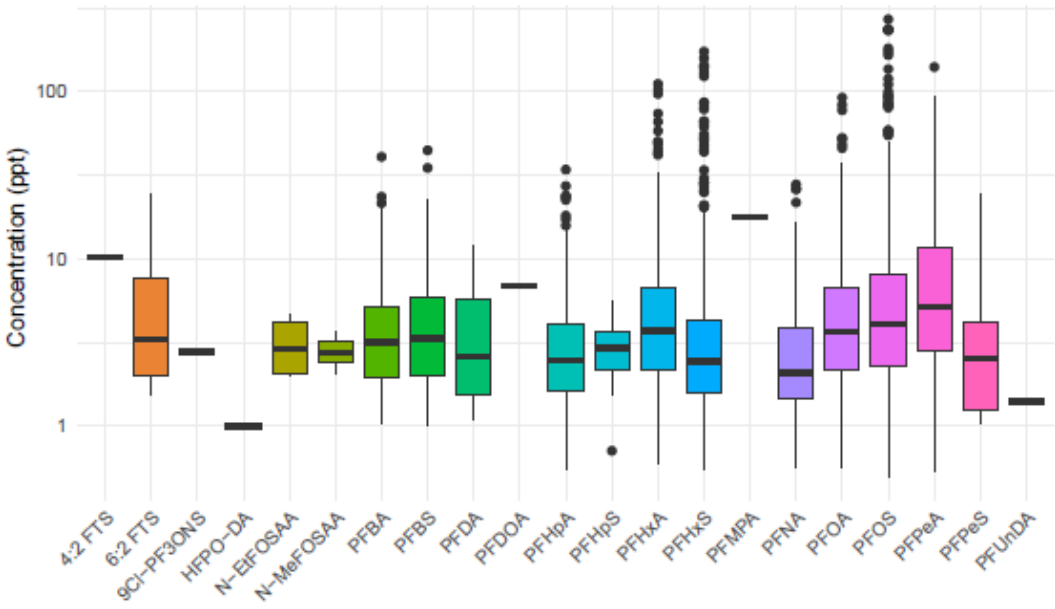

Figure 9: PFAS results range in samples from unconfined aquifers, shown in log10 scale.

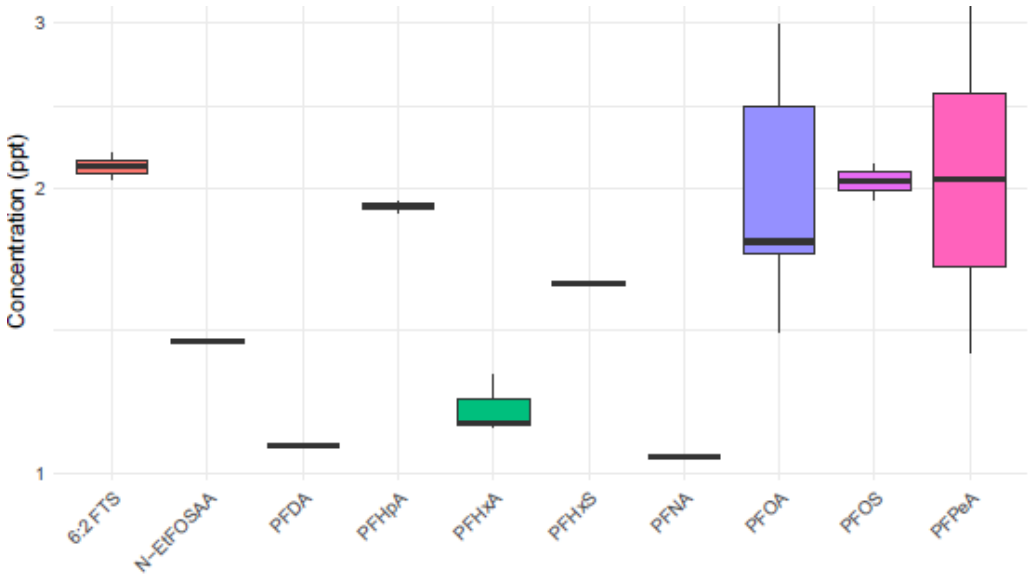

Figure 10: PFAS results range in samples from confined aquifers, shown in log10 scale.

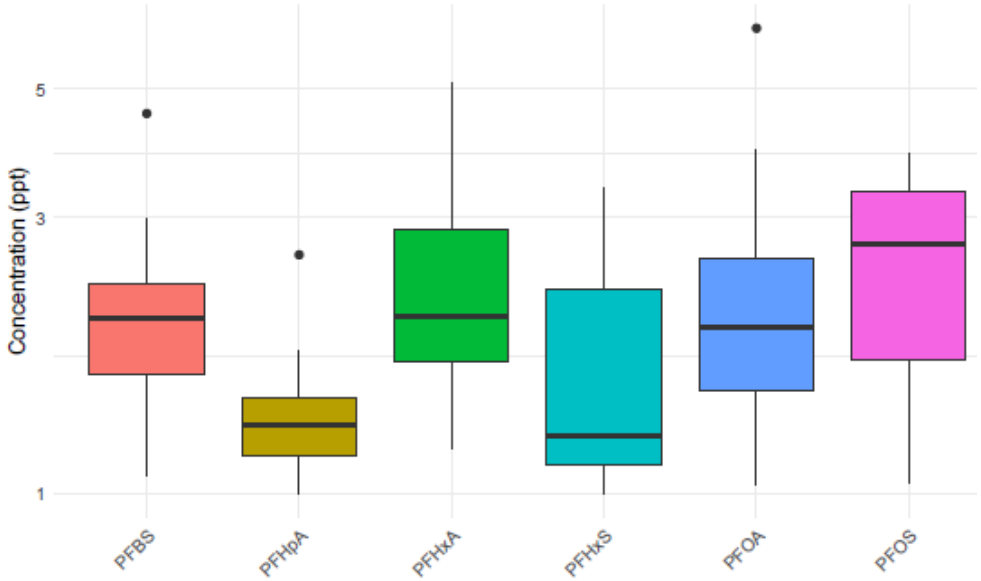

Figure 11: PFAS results range in samples collected from surface water in log10 scale.

Figure 12 provides a graphic representing the relative contribution of each PFAS in the different water source type categories. To assemble this graphic, the median concentration was calculated for each PFAS source type combination. The resulting medians were then normalized as percentages to emphasize the patterns instead of the magnitude and assess the general PFAS profiles. Groundwater from unconfined aquifers has the largest variety of PFAS substances with 21 different analytes detected, compared to only six found in surface water.

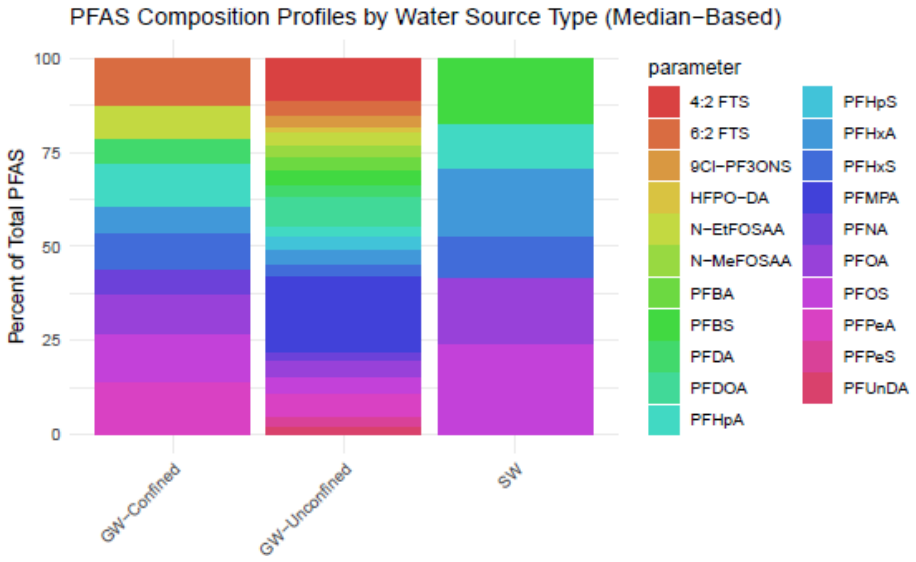

Figure 12: PFAS composition profiles by water source type.

Conclusion

Our findings from our PFAS in Public Drinking Water Study shows that out of all the source types for Maryland's drinking water, unconfined groundwater sources are most likely to have PFAS contamination due to their hydraulic connectivity with the land surface. Surface water sources were less likely to have contamination, likely due to having a greater variation of factors like residence time and mixing from multiple sources that can lead to dilution and transport of contamination. No groundwater from confined aquifers had MCL exceedances and a very low percentage of samples in confined sources had detects of PFAS compounds. Across all samples, the five most frequently detected PFAS compounds were PFOA (39%), PFHxA (36.1%), PFBS (35.5%), PFPeA (35.4%) and PFBA (34%).

One question that this study does not fully answer is about the presence of PFAS in surficial aquifers in coastal plain aquifers. Because PWSs will preferentially select confined aquifers as sources, the data from shallow aquifers east of the fall line are underrepresented. The limited data from this area, mostly from Anne Arundel, Wicomico and Worcester Counties, do appear to indicate the ubiquity of PFAS in shallow groundwater from unconfined aquifers regardless of geographic location. Further research is also needed to determine the sources and age of the contamination found during this study.

Additional Resources

Additional resources can be found through the following links:

- MDE's WSP PFAS Webpage: https://mde.maryland.gov/programs/Water/water_supply/Pages/PFAS_Home.aspx
- MDE's Phase 1 Report: https://mde.maryland.gov/programs/water/water_supply/Documents/PFAS_Public_Water_System_Study-Phase1Report.pdf
- MDE's Phase 2 Report: https://mde.maryland.gov/PublicHealth/Documents/Phase2Report_Apr2022_Final.pdf
- MDE's Phase 3 Report: https://mde.maryland.gov/PublicHealth/Documents/Phase3ReportFinal.pdf
- MDE's Phase 4 Report: https://mde.maryland.gov/programs/water/water_supply/Documents/Phase4ReportFinal.pdf
- MDE's Phase 5 Report: https://mde.maryland.gov/programs/water/water_supply/Documents/Phase5Report_Final.pdf
- EPA's PFAS Drinking Water Regulations: https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas