KETOS

REPORT

PFAS Contamination in the US

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Chapter 1 – Introduction

PFAS (Per- and Polyfluoroalkyl Substances) are a large group of manufactured chemicals that are widely used for their water- and stain-resistant properties.

Among the most studied PFAS are PFOA and PFOS. PFOA (Perfluorooctanoic acid) and PFOS (Perfluorooctanesulfonic acid) are known to be persistent, bioaccumulative, and toxic. In popular media, they're also known as Forever Chemicals.

Exposure to PFOA and PFOS has been associated with several adverse health effects, including but not limited to:

- Developmental effects in fetuses and infants
- Increased risk of cancer (e.g., kidney and testicular cancer)

- Liver damage
- Immune system effects
- Thyroid disruption

On April 10, 2024, the Environmental Protection Agency (EPA) announced the final National Primary Drinking Water Regulation (NPDWR) for six PFAS chemicals. The table below shows acceptable levels of PFAS that will be permitted in drinking water by April 2029. While the final goal is to have no detectable PFAS contamination in drinking water, enforceable levels of PFAS lie in the parts per trillion range. To put that in context, in the future, having more than a single drop of PFAS in an Olympic-sized swimming pool will qualify the water as unacceptably dangerous for human consumption. This is a welcome measure that is undoubtedly positive from a public health perspective.

Compound	Final MCG (Maximum Contaminant Goal)	Final MCL (enforceable levels)
PFOA	Zero	4.0 parts per trillion (ppt)
PFOS	Zero	4.0 ppt
PFHxS	10 ppt	10 ppt
PFNA	10 ppt	10 ppt
HFPO-DA (commonly known as Gen X Chemicals)	10 ppt	10 ppt
Mixtures containing two or more of PFHxS, PFNA, HFPO-DA, and PFBS	1 (unitless) Hazard Index	1 (unitless) Hazard Index

The Safe Drinking Water Act (SDWA) requires that once every five years, the EPA must issue a list of unregulated contaminants to be monitored by public water systems (PWSs). Alongside its issuance, the EPA releases reports and datasets as part of the Unregulated Contaminant Monitoring Rule (UCMR).

The fifth Unregulated Contaminant Monitoring Rule (UCMR 5) was published on December 27, 2021. UCMR 5 requires sample collection for 30 chemical contaminants between 2023 and 2025 using analytical methods developed by the EPA and consensus organizations.

Given that PFAS chemicals are transitioning from unregulated to regulated chemicals, utilities from all over the country are gearing up to meet the challenge of eliminating PFAS from public drinking water.

At KETOS, we believe that 'you cannot manage what you cannot measure.' As part of our ongoing efforts to help utilities deal with PFAS more effectively, KETOS is publishing the results of our detailed investigation into the UCMR 5 dataset to find out more about PFAS contamination in the USA. KETOS is also making this data available through the Databricks Marketplace as part of our new offering - KETOS PRISM.

The UCMR 5 dataset (publicly available via the EPA), contains measurements of PFAS made at Public Water Supply (PWS) systems throughout the US. In addition to the raw data provided by the EPA, KETOS has enhanced this dataset by adding location information (latitude and longitude), state, county and demographic data to create a dataset that can be used to gain valuable insights into the state of unregulated contaminants in the US.

The following are the most important high-level insights from the dataset:

1. The dataset contains 117,682 measurements of five different PFAS chemicals – PFOA, PFOS, PFHxS, PFNA, HFPO-DA - spread across 4,610 unique locations in all 50 states of the USA. Each location sampled is a Public Water Supply (PWS) regulated under the Clean Water Act. The sampled locations are a small subset of the total number of PWS in the US.

2. Out of the total number of measurements, about 4,518 measurements of PFAS chemicals (or 3.4%) exceeded detectable limits.

3. Every single location that had a detectable level of PFOS and PFOA had a concentration that equalled or exceeded the MCL (four parts per trillion). This is an alarming finding from a public health perspective.

4. The maximum levels of PFOS and PFOA measured in the US exceeded acceptable thresholds by multiples of up to 5800%.

5. A total of 889 locations, close to 1/5th of the total, had more than one contaminant measured with detectable levels of PFAS. This suggests a significant co-occurrence of PFAS contaminants. Studies indicate that the co-occurrence of more than one type of PFAS chemical compounds the potential health risks associated with exposure.

6. The data suggests a high degree of clustering/contaminant hot spots in places where detectable levels of PFAS were measured. If a particular location has detectable levels of a PFAS chemical, nearby locations with PFAS measurements have a higher likelihood of having detectable levels of PFAS. A PWS with detectable PFAS levels typically has another PWS location with detectable PFAS levels within a 10-mile radius.

   This is a snapshot of some of the eye-opening insights that we gathered from this dataset. We believe that every person involved in public health and policy should take note of this dataset and the implications of its insights.

   Subsequent chapters in this report will dive into each of these insights in greater detail.

889

locations had more than **one contaminant measured with detectable levels of PFAS**

Chapter 2 – A Deep Dive into the UCMR 5 PFAS Data

The UCMR 5 dataset contains measurements of five types of PFAS chemicals:

1. PFOA (PerfluoroOctanoic Acid)

2. PFOS (PerfluoroOctaneSulfonic Acid)

3. PFNA (Perfluorononanoic Acid)

4. PFHxS (PerfluoroHexaneSulfonic Acid)

5. HFPO-DA (HexaFluoroPropylene Oxide Dimer Acid)

Through 2023 and 2024, a total of 23,546 measurements of each type of PFAS chemical were conducted and recorded (as of September 2024) in the UCMR 5 dataset.

The measurements are categorized into detectable (Non-Null values) and undetectable, respectively. In this analysis, we interpret undetectable measurements to be equal to zero parts per trillion (0 ppt) concentration uniformly.

The table below shows that up to 6.7% (roughly one out of every 15-16) measurements had a detectable value of a PFAS chemical.

Contaminant	Total Measurements	Measurements with Detectable Levels of PFAS	Percentage Detectable (%)
HFPO-DA	23,546	35	0.15%
PFHxS	23,528	1,293	5.50%
PFNA	23,546	65	0.28%
PFOA	23,534	1,574	6.69%
PFOS	23,528	1,551	6.59%

Out of the 4,610 unique PWS systems at which samples were taken, 889 locations (roughly 16% or one in six) had at least one detectable PFAS measurement. 702 (roughly one in seven) locations had two or more detectable PFAS measurements of multiple contaminants. Given the health risk compounds with the co-occurrence of PFAS chemicals, the fact that the plurality of locations that had at least one PFAS also had two co-occurring PFAS chemicals is a concerning insight.

We also examined the maximum values measured for each contaminant in the dataset. Given that acceptable values for each PFAS ranged from four parts per trillion to 10 parts per trillion (0.004 µg/l to 0.01 µg/l), it would help determine the maximum extent of excess PFAS exposure found in the US. Maximum values recorded in the dataset for each contaminant, along with the county and state information, are shown below.

| Contaminant	Max Value (µg/L)	County	State	Approx. Threshold Exceedance Multiple
PFOA	0.235	Montgomery	PA	59X
PFOS	0.1536	Pierce	WA	38X
PFHxS	0.0841	Wetzel	WV	8X
PFNA	0.051	Ada	ID	5X
HFPO-DA	0.034	Robeson	NC	3X

While it isn't possible to determine the time period of sustained exposure from the data provided, the fact that the maximum exposure of 59X or 5800% (59 times the maximum acceptable PFOA value) occurred anywhere in the US is an alarming statistic. *From a public health policy perspective, given that PFAS has been an unregulated contaminant until now, it might be prudent to assume the worst in such situations.*

The table below shows the key statistics in the distribution of detectable levels of PFAS chemicals. A key insight here is that every single location that had detectable levels of PFOA and PFOS, had measurements beyond the MCL of four parts per trillion. The public health implication of this statistic is that PFOA and PFOS distribution in the US is bimodal (i.e. in areas where PFAS occurs, it always occurs in levels that are dangerous to human health as determined by the MCL).

Contaminant	Average (parts per trillion ppt)	Typical (ppt)	Maximum (ppt)	Minimum (ppt)	MCL (ppt)
HFPO-DA	8.7	6.7	34	5.2	10
PFHxS	6.8	4.7	84.1	3	10
PFNA	8.2	6.5	51	4	10
PFOA	7.9	6	235	4	4
PFOS	10.2	6.7	153.6	4	4

The typical PFAS and PFOS measurement in the US is ~50% higher than the MCL value of 4 ppt, which underscores our earlier point regarding public policy responses based on these measurements.

A visual representation of the distribution of PFAS measurements is shown below. While the typical value is close to the MCL, it is clear that an unacceptably large percentage of the measurements are 50% to 100% larger than the respective MCLs for each contaminant.


Distribution of Contaminant Levels in Parts per Trillion
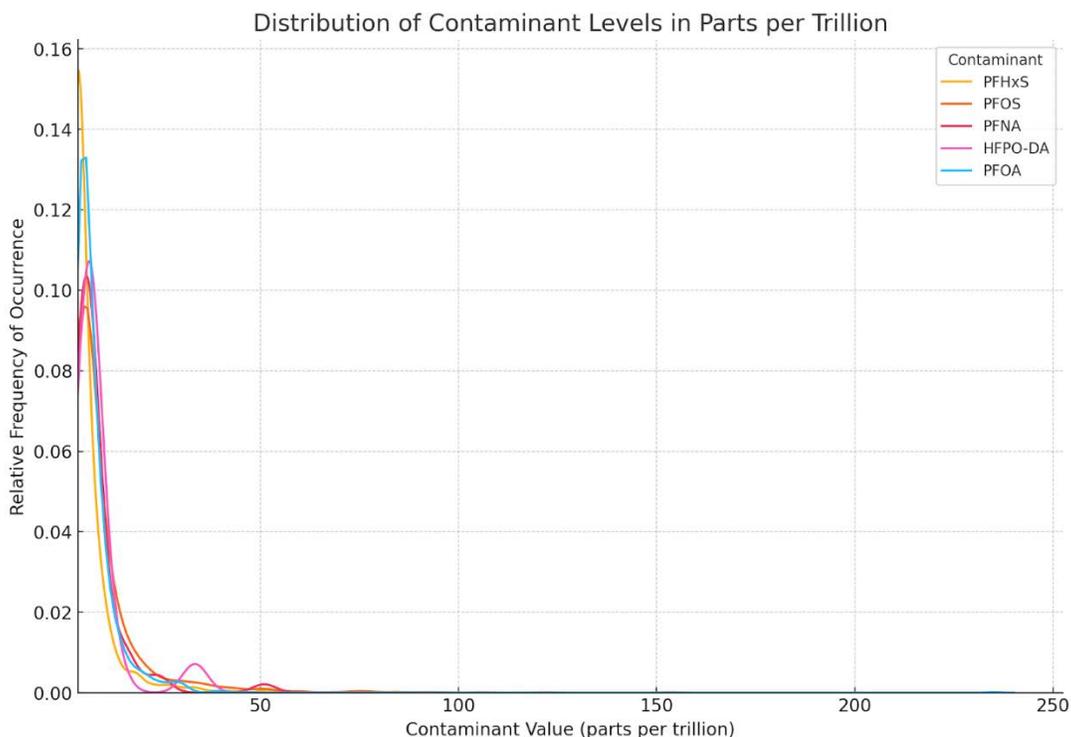
Chapter 3 – Geographic and Demographic Analysis of the UCMR 5 PFAS Data

In the previous chapter, we presented insights aggregated at the country level. In this chapter, we break down these insights by state.

The first metric we present is the state-wide distribution of the proportion of total measurements with detectable PFAS levels.

Proportion of detectable PFAS Measurements by State (Aggregated Across All Contaminants)

Percentage of detectable PFAS Measurements
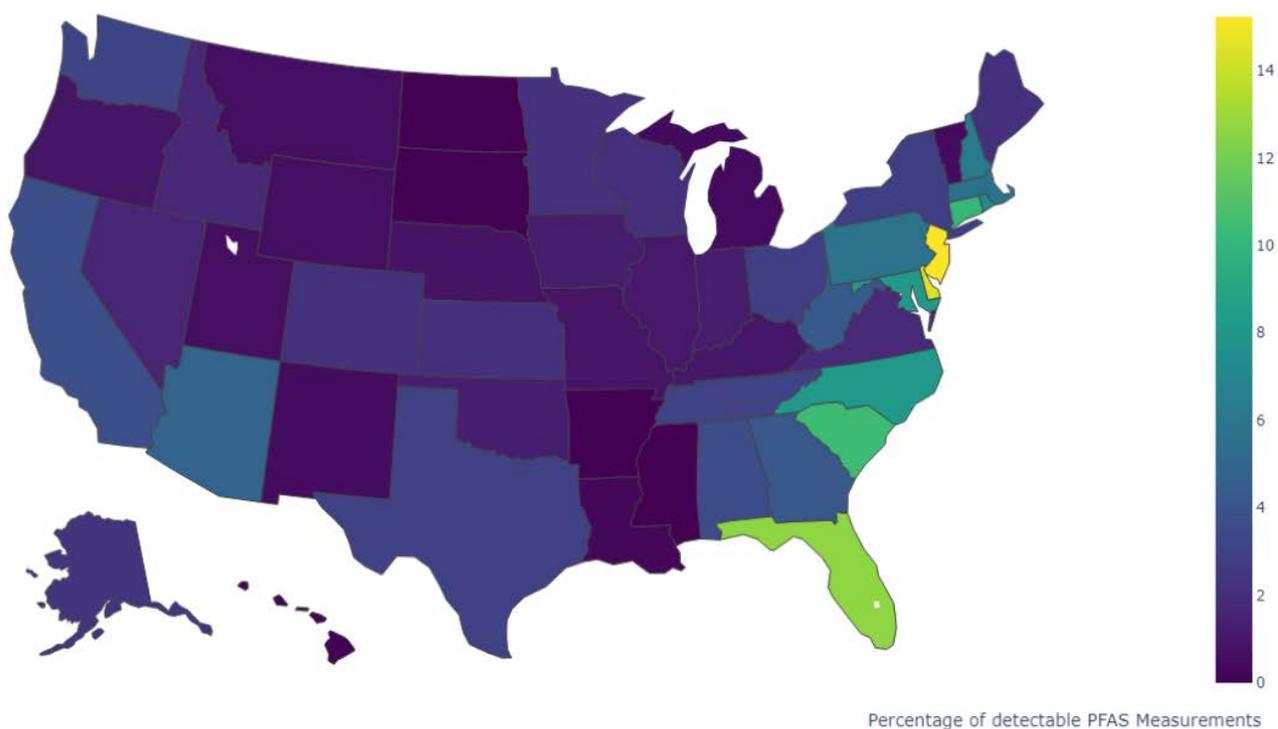
At one end of the incidence spectrum, we found that Arkansas (AR), Mississippi (MS), North Dakota (ND) and South Dakota (SD) had no detectable levels of PFAS in the reported measurements. At the other end, we found that several states had incidence levels as high as 5% to 15%. The states with the top 10 incidence levels of detectable PFAS levels (as a proportion of total measurements) are shown in the figure below.

At a glance, the only significant geographical pattern exhibited by the data is that the states with the highest incidence of detectable PFAS levels are all on the east coast of the USA. The reason for this is unclear and could not be estimated from the dataset.

PFAS Incidence %
(percentage of measurements with detectable PFAS levels)
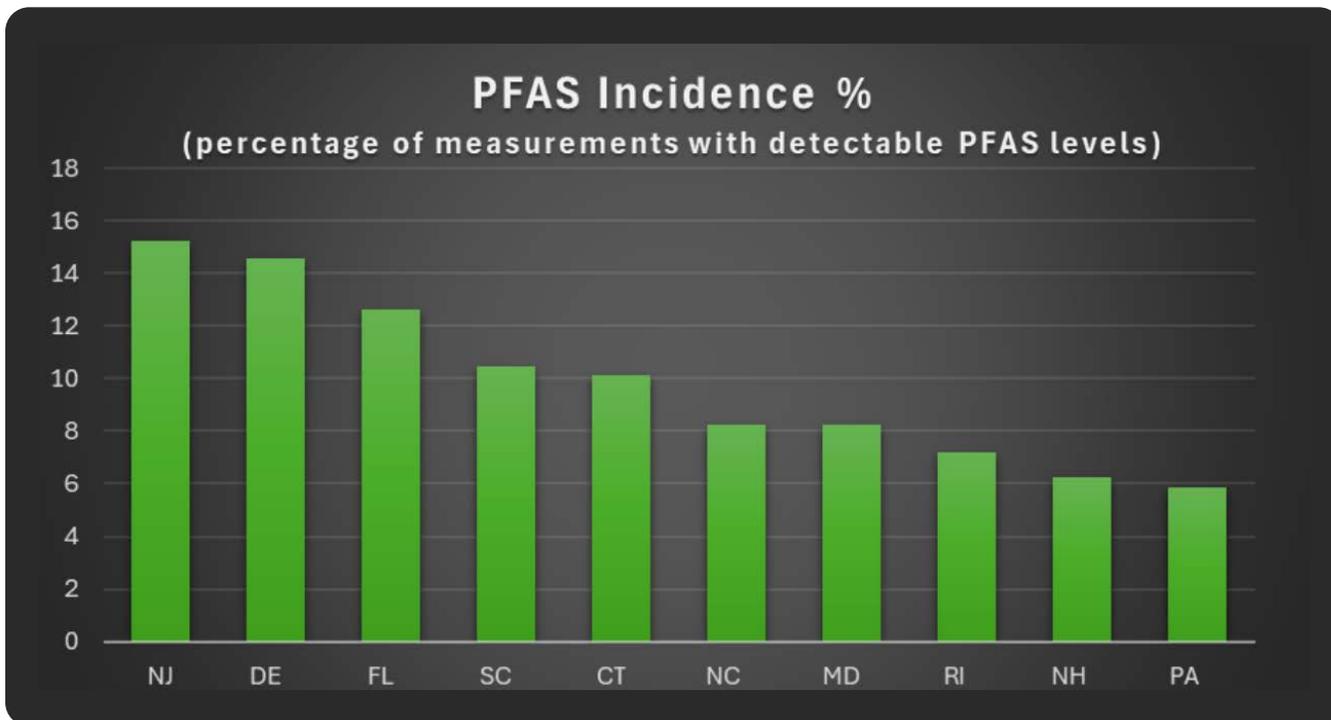
We also analyzed the proportion of the population that was potentially exposed to detectable levels of PFAS. The data for this was obtained from EPA databases that have demographic information related to PWS systems. Once each unique PWS system was assigned an associated population count indicating the number of users served, it became possible to join this dataset with the original UCMR 5 PFAS dataset and infer the percentage of the population in each state that may have been exposed to high PFAS levels.

The figure below reveals important insights that aren't revealed by the PFAS incidence numbers. For example, up to 80% of the population served by the PWS systems in some states, such as Delaware (DE), that were sampled may have been exposed to detectable levels of PFAS chemicals. This assumes that the entire population served by a given PWS is in danger of consuming PFAS through drinking water. The actual number may vary due to the variability in personal water consumption sources - bottled water versus tap water and so on.

Seven states had 50% or more of their population (as represented in the sample) exposed to detectable PFAS levels. The insights become quite alarming when seen in the context of the PFOA and PFOS insights noted in the previous chapter - all locations with detectable levels of PFOA and PFOS in the US had measurements higher than the MCL.

Percentage of population exposed to PFAS
(% pop. served by PWS' with detectable PFAS levels)
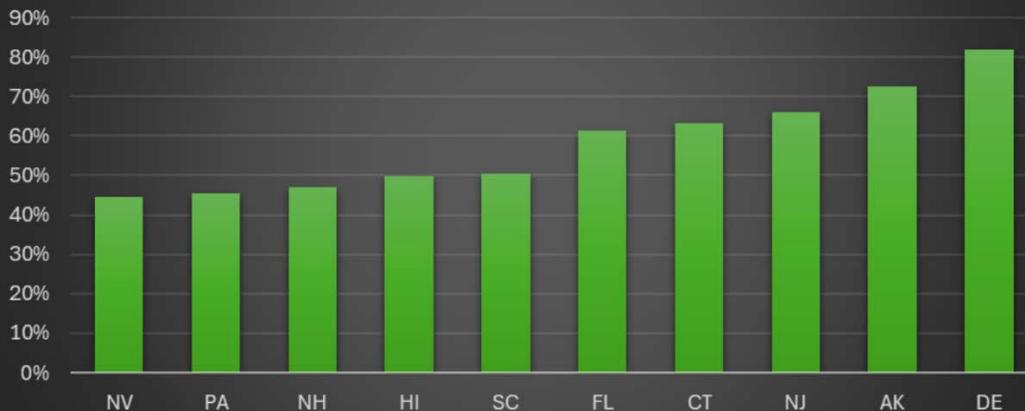
Additionally, given that we do not know the time duration of PFAS exposure, from a public health perspective it might be prudent to

1. Determine serum/skin PFAS levels in potentially exposed populations.

2. Assume that this exposure may have been persistent so that other mitigating steps can be taken.

The national distribution of this statistic is shown in the map below. It's clear from this map as well that 'problem areas' largely lie on the East Coast with a few exceptions, including Alaska (AL), Nevada (NV) and Kentucky (KY).

Percentage of Population served by sampled PWS with detectable PFAS levels

Percentage of Population exposed to PFAS
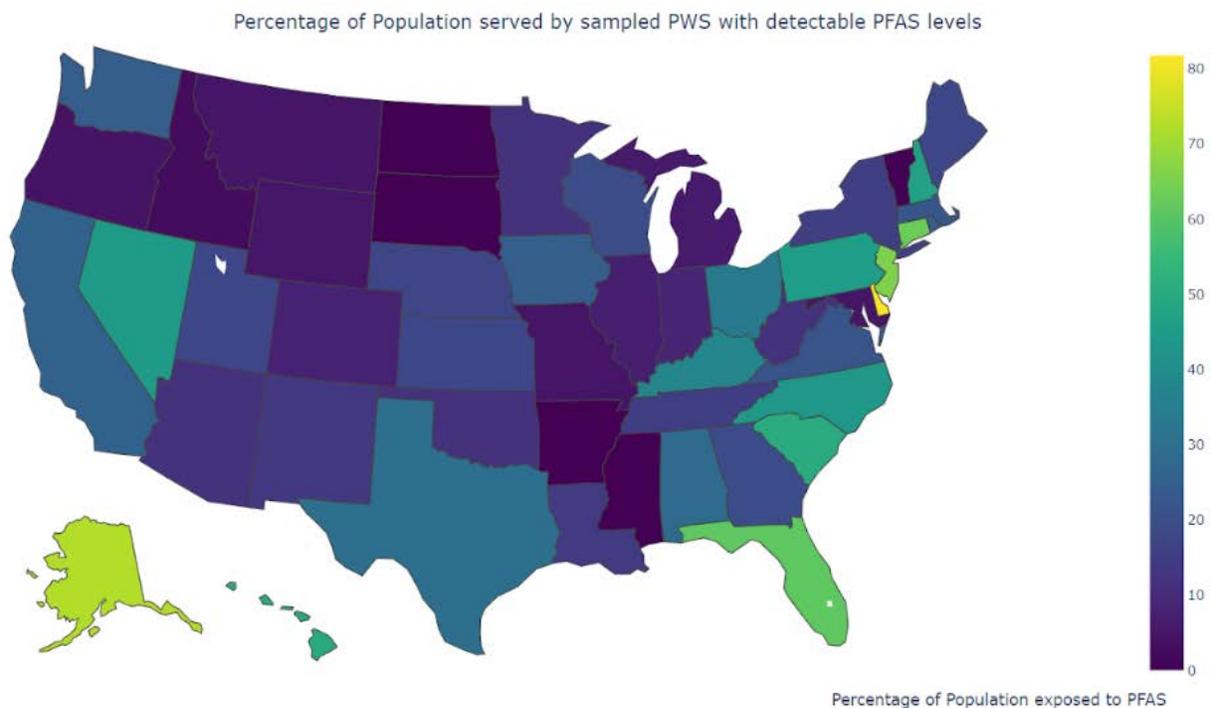
This analysis can be extended to find the distribution of co-occurrences of PFAS chemicals. The figure below shows the top 10 states with the highest proportions of populations served by PWS' with more than one detectable PFAS chemical.

Percentage of population exposed to two or more PFAS
(%pop served by PWS with >=2 detectable PFAS measurements)
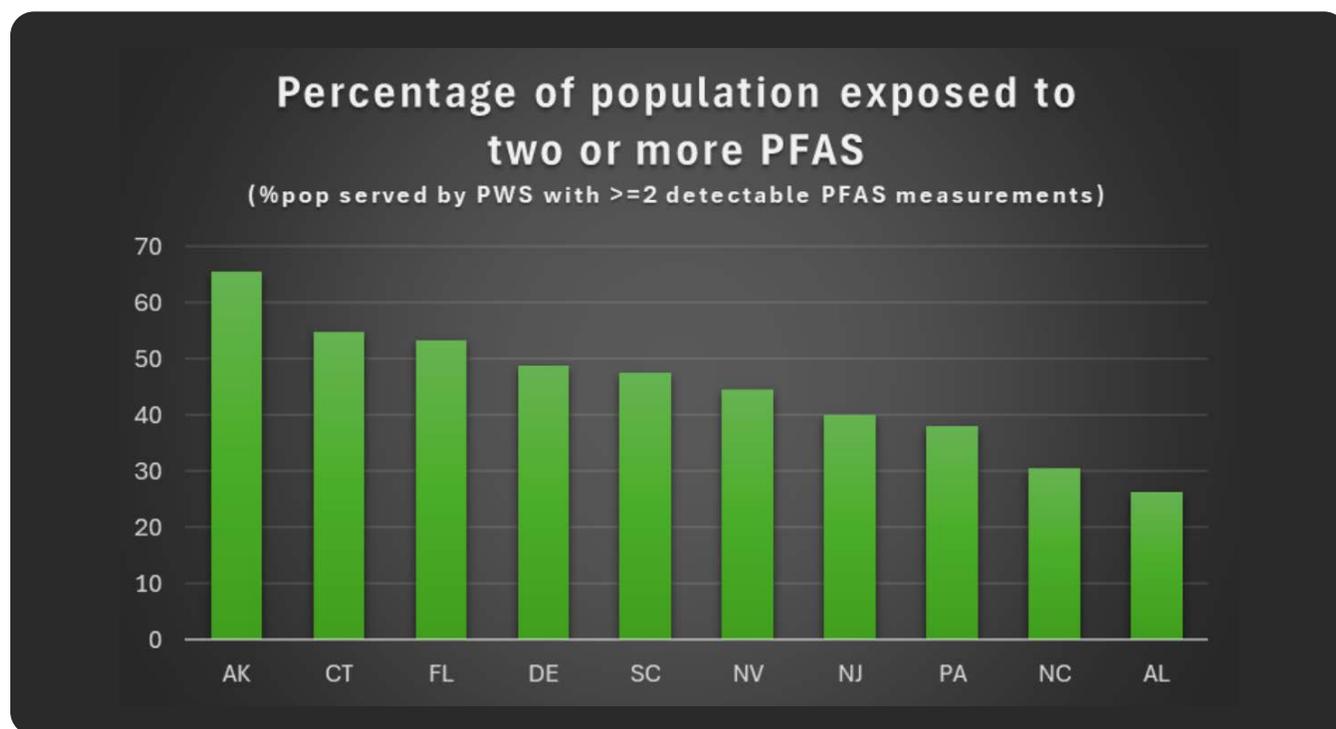
It features the same states that showed high proportions of single contaminants, but the rankings among these states have changed. It's striking that in AK, for example, the percentage of the population (again, as sampled in the UCMR 5 survey) exposed to two or more PFAS is within 5 percentage points of the number exposed to one PFAS chemical.

The heatmap below shows hotspots in PFAS data. Each unique location in the UCMR 5 dataset with a detectable PFAS measurement receives a corresponding intensity value that decays as you move away from the measurement location. Stronger red values imply that these locations have a greater number of detectable PFAS measurements. The visualization is better understood through a web browser interface due to its interactive nature. The snapshot displayed here is only at a particular resolution, but it illustrates the insights discussed previously at a single glance.

This visualization is useful as it unearths insights that are lost in aggregation. For instance, the hotspots in coastal and north Texas, Central Colorado, Central, and South California are lost in aggregation in previous charts due to the high number of measurements and population of each state.
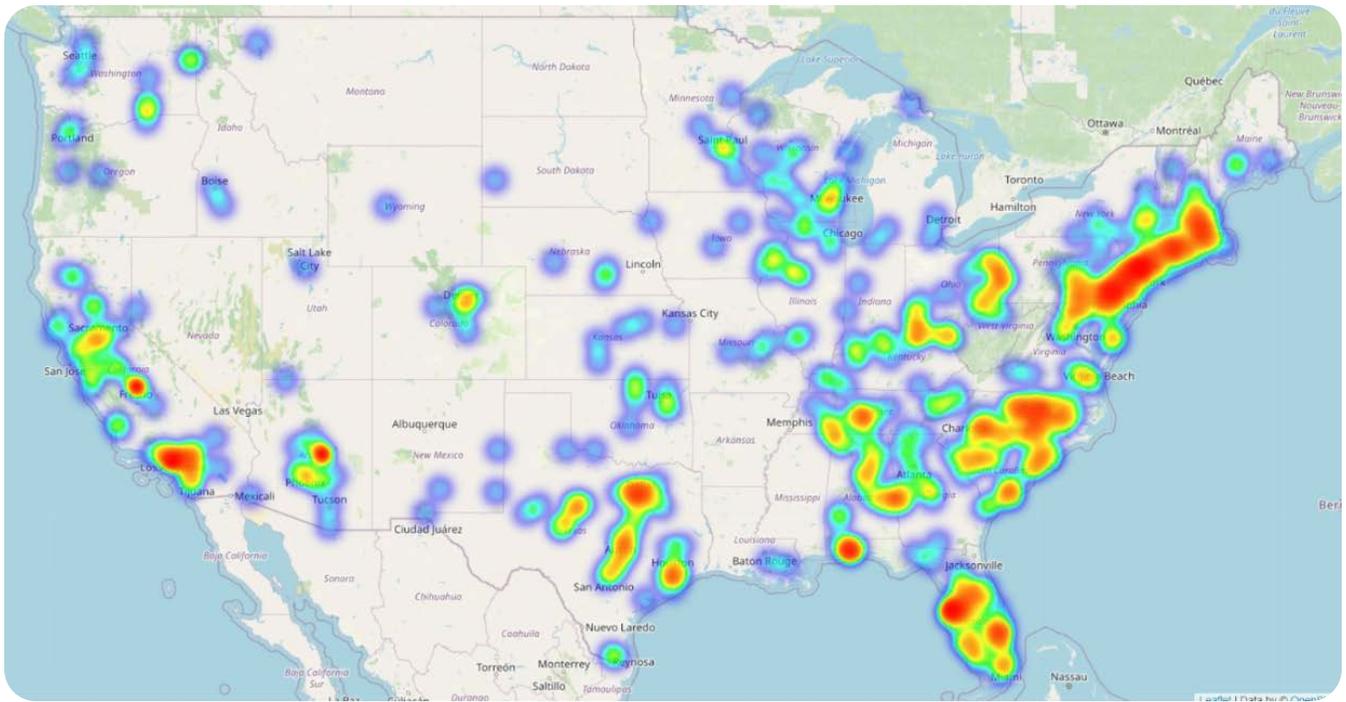
The median national distance between nearest neighbors having detectable levels of PFAS is about 9.28 miles. In other words, a PWS with detectable PFAS levels typically has another PWS location with detectable PFAS within a 10-mile radius.

Distribution of Nearest Neighbor Distances for Locations with Detectable PFAS Levels
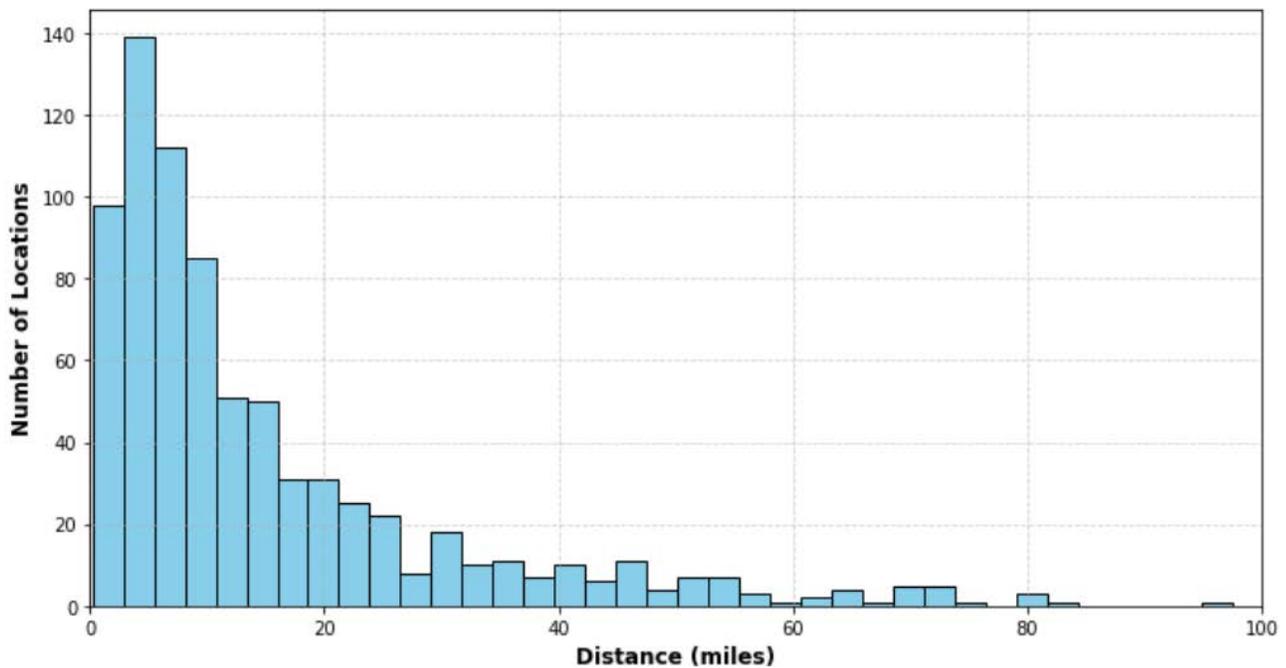
If we repeat this analysis to find out the typical distance from a location with no detectable PFAS levels to a nearest neighbor with detectable PFAS levels, we find that this distance jumps to about 23 miles. In other words, if a location has no detectable PFAS levels, you typically have to go more than twice as far to find another location that has detectable PFAS levels.

Distribution of distances to nearest detectable PFAS location for locations with no detectable PFAS levels
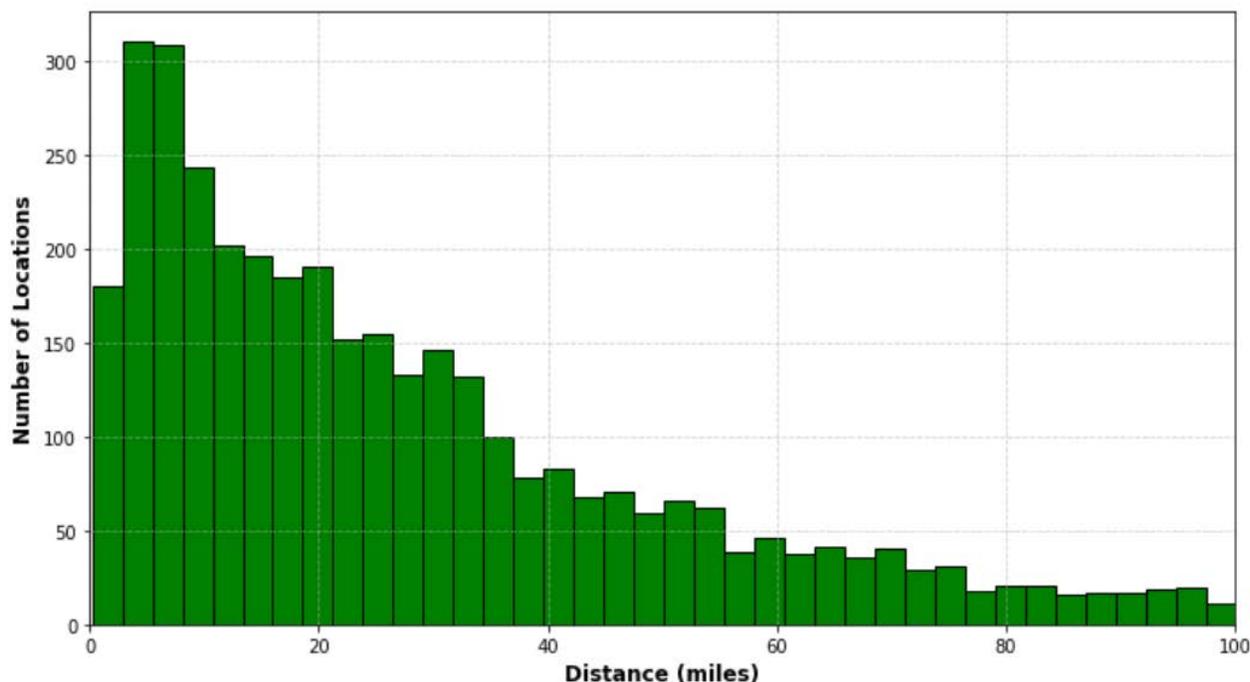
From the geographical analysis presented in this chapter, it is clear that some parts of the populations served by PWS systems in Texas, California, parts of the Midwest, the South, and the entire eastern coast of the US may be at a higher risk of PFAS exposure via their drinking water supply.

The eastern coast of the US has not only the highest density of PFAS locations by region on average but also a greater proportion of the population at risk of PFAS exposure.

Having analyzed the geographical prevalence of PFAS in the US, the next chapter digs a little deeper to find why certain geographical areas have a higher chance of having PFAS contamination than others.

# Chapter 4 – Risk Factors Associated with PFAS Contamination

Recent studies ([1], [2]) on sources of PFAS indicate that proximity to certain sources of industrial discharge and waste, such as solid waste landfills, electroplaters, industrial laundries and carpet cleaners, increase the risk of PFAS contamination.

The Environmental Working Group (EWG) has listed 31 known and suspected industrial sources of PFAS pollution. Using KETOS PRISM's extensive database of EPA-regulated facilities (and their locations), we performed a proximity analysis to correlate the occurrence of detectable levels of PFAS in PWS (via the UCMR 5 PFAS occurrence dataset) to suspected and known industrial sources of PFAS.

First, we calculated the distribution of nearest neighbors from each location with detectable PFAS levels to all facilities that fall to a specific category of interest - for instance, all known industrial laundry facilities. We then repeated this calculation for locations with no detectable PFAS levels.

Computing these two distributions for each industrial category of interest provides valuable insights into the likelihood of PFAS contamination based on the proximity of a given PWS to facilities belonging to individual categories. It also allows us to statistically compare which categories of industrial facilities are more likely to be associated with PFAS occurrence.

The figures below show a comparison of nearest neighbor distributions for two categories known and one category suspected to be associated with PFAS contamination: industrial laundries/dry cleaners and solid waste landfills, and surgical and medical manufacturing facilities.

Distribution of Nearest Neighbor Distances to Industrial Laundry and Drycleaning facilities
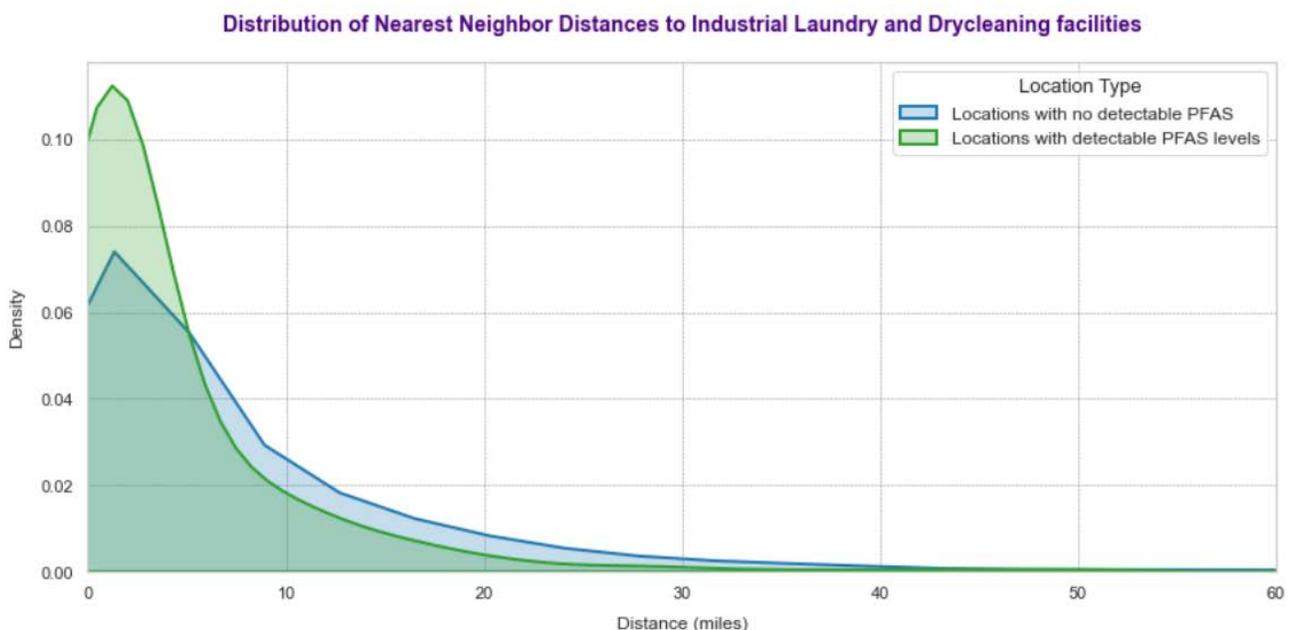
**Distribution of Nearest Neighbor Distances to Solid Waste Landfills**
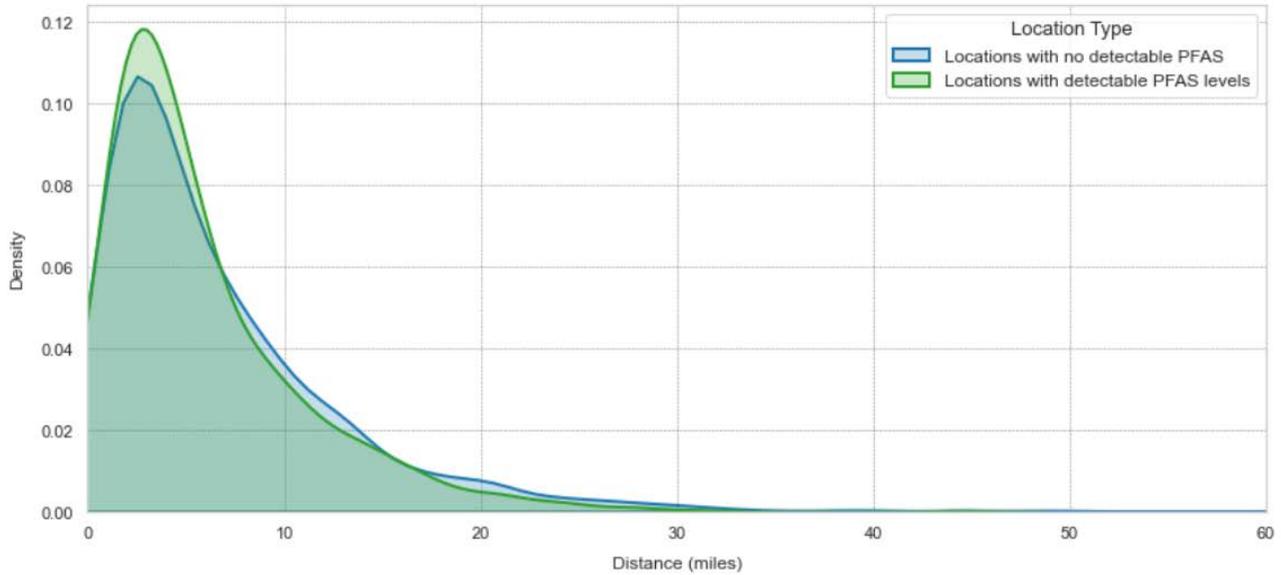
Distribution of Nearest Neighbor Distances to Surgical and Medical Instrument Manufacturing Facilities
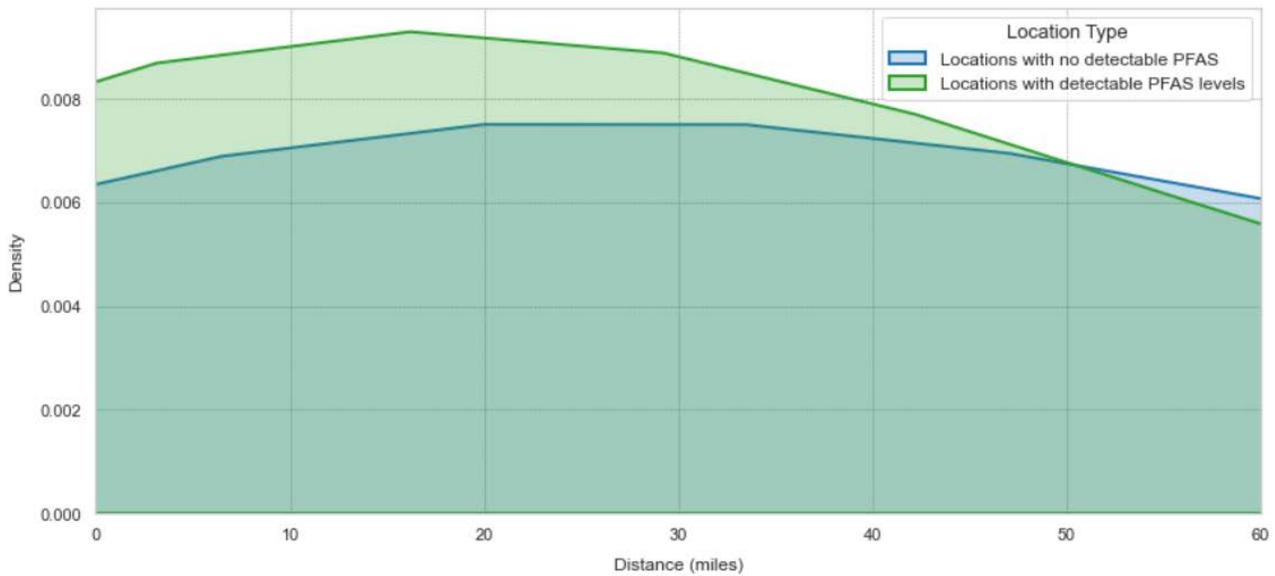
Qualitatively, a few things immediately stand out from these graphs. The first is that the nearest neighbor distance from locations that have detectable PFAS levels is much lower than for locations that do not have detectable levels of PFAS. This insight is true across the three categories shown above. Secondly, more facilities with detectable levels of PFAS have low nearest neighbor distances to facilities from each of these categories.

To what extent does this insight hold across categories? We repeated the proximity analysis, but this time, instead of comparing the distributions visually, we calculated the total proportion of locations in each of the two groups (with and without detectable PFAS levels) that had at least one facility from each category within a 2, 5, 10 and 15-mile radius. The results for the 10-mile radius proximity are shown in the figure below.
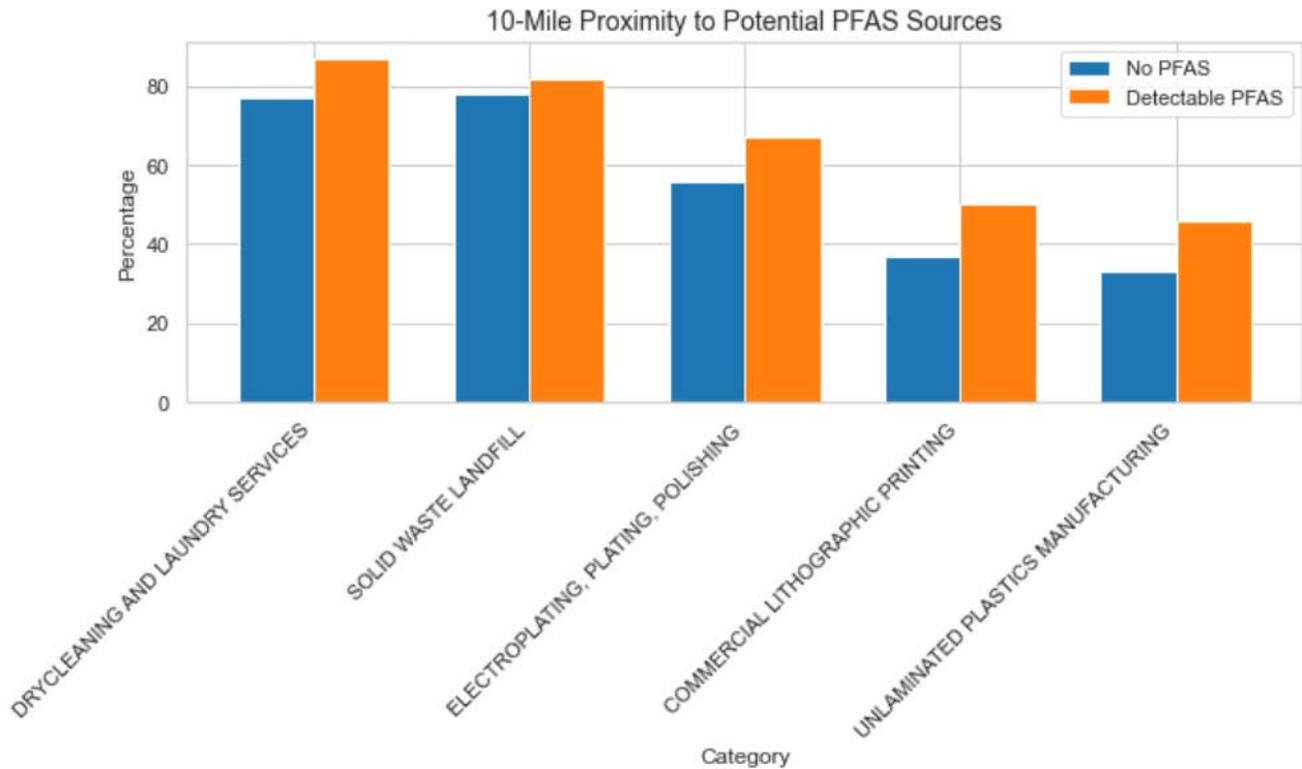
For each category, locations with detectable PFAS levels have significantly higher percentages than those with no detectable PFAS levels. On average, a location with detectable levels of PFAS is significantly more likely to have an industrial facility belonging to one of the categories that are suspected of being linked to PFAS occurrence.

One particular statistic of note is Laundry and Dry Cleaning Services. We found that 87% of locations with detectable PFAS levels had at least one industrial laundry facility within a 10-mile radius. This number drops to 77% for locations with no detectable levels of PFAS.

Category	Locations with no detectable PFAS levels			Locations with detectable PFAS levels		
	% locations with at least 1 location in category within a 2 mile radius	% locations with at least 1 location in category within a 5 mile radius	% locations with at least 1 location in category within a 10 mile radius	% locations with at least 1 location in category within a 2 mile radius	% locations with at least 1 location in category within a 5 mile radius	% locations with at least 1 location in category within a 10 mile radius
Dry Cleaning and Laundry Services (Except Coin-operated)	45	62	77	57	75	87
Solid Waste Landfill	20	52	78	21	56	82
Electroplating, Plating, Polishing, Anodizing, and Coloring	19	38	56	24	49	67
Commercial Lithographic Printing	10	23	37	13	33	50
Unlaminated Plastics Film and Sheet (Except Packaging) Manufacturing	5	18	33	9	24	46

From our analysis it is also clear that locations with detectable PFAS levels have different proximity values to other categories of industrial facilities. However, we found that the proximity numbers (percentage locations that have facilities belonging to a specific category within a certain radius) were higher for these locations as compared to those with no PFAS levels without exception across all categories.

Having examined the spatial correlations between PFAS occurrence and industrial facilities of different kinds, we would now like to suggest concrete measures that can be taken to mitigate the risk of PFAS contamination.

Whether you are a utility interested in minimizing PFAS risk for your clients, a law firm or a policymaker interested in investigating the sources of PFAS contamination, or simply a concerned citizen, we believe that the next chapter is both extremely relevant and actionable.

Chapter 5 – Mitigating PFAS Risk

Based on KETOS' extensive research on PFAS occurrence in the US presented in previous chapters in this report, we first want to make a few straightforward observations that summarize the insights presented in this report

The geographical and demographic extent of PFAS contamination is a more serious problem than originally anticipated for a simple reason - PFAS chemicals were unregulated until recently. Due to this, PFAS mitigation was previously entirely voluntary.

1. It is possible that several millions of people were exposed to PFAS through contaminated water for extended periods of time. Without time-series measurement data, it is difficult to estimate the period of exposure. That said, it stands to reason that the exposure may have been long-standing, given the unregulated legal status of these contaminants.

2. PFOA and PFOS, when detected, are always present in levels that can be considered dangerous to human health, especially given that exposure can be cumulative and these chemicals can persist for long durations in and outside the human body.

3. PFAS occurrence is extremely location-dependent and clustered with a typical nearest neighbor distance of ~10 miles. North Dakota, for instance, has a significantly lower occurrence of PFAS than New Jersey and the other Eastern Coastal states. If a location within 10 miles of the jurisdiction of your interest has a PFAS measurement, the chances of finding PFAS contamination in your drinking water increase significantly.

4. Certain types of industries (industrial dry cleaning and laundry, for instance) have a higher degree of proximity to locations with detectable PFAS levels than those with no detectable PFAS levels. Being within a 10-mile radius of one of these categories of industrial facilities greatly increases the likelihood of finding PFAS contamination in drinking water.
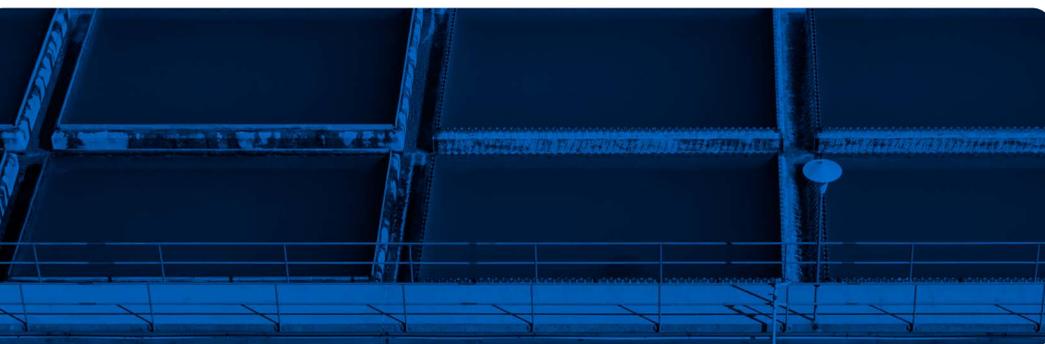
Recommendations for Utilities

Know your PFAS risk. As PFAS contamination is highly location-dependent, utilities must first understand their own PFAS exposure risk. Using KETOS PFaaS (PFAS Proximity Finder as a (free) Service) tool, utilities can assess the proximity of their water sources to known PFAS contamination sites, industrial facilities, and high-risk areas. This data-driven approach will help utilities make informed decisions about where to focus testing efforts. Contact us at info@ketos.co to learn more about our PFAS-related services.

"You can't manage what you don't measure." Utilities should begin systematic, continuous PFAS monitoring to measure the contamination levels over time. Time-series data is critical to understanding the duration of contamination and guiding long-term mitigation efforts. KETOS PFaaS tool integrates PFAS detection data and offers utilities predictive tools to anticipate where PFAS may spread, empowering them to proactively manage their risk.

Mitigation through treatment. Based on known PFAS levels, utilities should explore installing advanced treatment technologies, such as granular activated carbon (GAC) or reverse osmosis, to remove PFAS from water supplies. Regular monitoring and analysis of PFaaS data will help track the effectiveness of these treatments and inform necessary adjustments.

Recommendations for Policy Makers

Develop a regulatory framework. The unregulated legal status of PFAS in the past has led to widespread contamination. Now that PFAS is recognized as a serious public health concern, policymakers should establish stringent regulations for PFAS monitoring, reporting, and mitigation. The PFaaS tool offers valuable insights by highlighting high-risk areas based on proximity to known PFAS sites and industrial facilities. This data can inform regulatory decisions and help prioritize regions that need urgent attention.

Support infrastructure for PFAS detection. Given that many water utilities may lack the resources for comprehensive PFAS testing, policymakers should encourage or mandate PFAS monitoring for all utilities, especially those within proximity to high-risk areas (e.g., industrial dry cleaning and laundry facilities). Funding should be made available to ensure smaller utilities can access the necessary testing and treatment technologies.

Public transparency. Our research shows that a large proportion of the sampled population in several states may have inadvertently been exposed to PFAS. The time period of exposure is not possible to determine, but in the interest of public health it is reasonable to assume long-term exposure. In addition to mandatory reporting of PFAS levels of water in the future, policy makers need to create a concrete voluntary plan for testing PFAS prevalence in the blood and skin of people in potentially strongly-affected areas.

We encourage the use of the PFaaS tool to make PFAS contamination information easily accessible to the public, allowing citizens to check PFAS risks in their area and stay informed about potential health threats.

Recommendations for the General Public

Understand what's in your water. Individuals have the right to know if their drinking water is contaminated. With the KETOS PFaaS tool, residents can easily check the PFAS contamination risk in their area based on proximity to known contamination sites and industrial facilities.

Take action on PFAS exposure. If PFAS contamination is detected or the area is flagged as high-risk, individuals should consider using home water filtration systems certified to remove PFAS, such as activated carbon filters or reverse osmosis systems. Regularly monitoring local PFAS data through the PFaaS tool will keep individuals informed about potential changes in contamination levels. If possible, getting blood and skin samples tested for PFAS prevalence will go a long way in determining cumulative historical exposure to PFAS.

Advocate for safe water. Citizens should actively engage with local utilities and policymakers to ensure that PFAS testing and treatment are prioritized. Using the PFaaS to understand the regional risk of PFAS contamination can give the public valuable data to support their case for safer drinking water standards and stricter regulations on PFAS-emitting industries.

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