PFAS Exposure Assessment Technical Toolkit (PEATT) Environmental Assessment

Division of Environmental Health Epidemiology

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Contents

Executive Summary

Per- and polyfluoroalkyl substances (PFAS) are a large group of chemicals widely used in commercial and industrial processes. PFAS consist of a very strong carbon-fluorine bond that provides high thermal and chemical stability and prevents breakdown in the natural environment. Studies on the public health implications of PFAS are still in process,but results to-date have been inconsistent. Studies indicate that PFAS exposure may pose risks to the developmental, immune, metabolic, and endocrine health of those exposed. PFAS contamination was discovered in public drinking water supplies in Pennsylvania's Bucks and Montgomery counties, which was linked to operations in the nearby military bases. In 2018, the Pennsylvania Department of Health (DOH) conducted biomonitoring of 235 randomly selected community members who live in any of the four public water system (PWS) service areas surrounding 2 military bases, as part of a pilot biomonitoring project to evaluate the PFAS Exposure Assessment Technical Tools (PEATT) developed by the Centers for Disease Control and Prevention (CDC) and the Agency for Toxic Substances and Disease Registry (ATSDR). The pilot project was funded through the Association of State and Territorial Health Officials (ASTHO). Four PFAS compounds, perfluorooctanoic acid (PFOA), perfluorooctane sulfonic acid (PFOS), perfluorohexane sulfonic acid (PFHxS) and perfluoronanonoic acid (PFNA) were consistently detected in the serum samples of the pilot study participants, and the levels detected were higher than the national averages. In 2019, DOH performed additional sampling on the pilot biomonitoring project participants. This included collection of household dust samples and tap water samples from 10% of the households (n=14) and urine sample collection from 186 participants. Household dust samples were analyzed for 33 compounds, and concentration levels varied widely among the 14 households sampled. PFOA, PFOS, PFHxS, and PFNA were detected in all samples, and detections ranged from 3.94-522.00, 3.20-1,110.00, 1.44-862.00, and 1.24-276.00 ng/g, respectively. Household tap water samples were analyzed for 14 compounds. PFOA, PFOS, PFHxS, and PFNA were detected in 71%, 86%, 43%, and 57% of post-filtered water samples, respectively. The detected levels ranged from 0.65-7.48 ng/L (PFOA), 0.46-7.67 ng/L (PFOS), 0.46-4.20 ng/L (PFHxS), and 0.50-1.01 ng/L (PFNA). Univariate analysis indicated a positive association between PFNA levels in serum and tap water. Urine samples from 10% (n=24) of the participants were analyzed for 16 PFAS compounds. None of the urine samples analyzed had PFAS levels above detection limits. Per the study protocol, because the initial 10% of urine samples did not have any PFAS detections, the remaining urine samples are being stored in CDC's biorepository and are not being analyzed at this time.

Background

PFAS are a group of synthetic chemicals with thousands of compounds widely used in manufacturing industries and commercial products since the 1950s. Their high thermal and chemical stability prevents breakdown in the natural environment (Krafft and Riess 2015). Although some longer-chain PFAS (PFOA and PFOS) have been phased out of production in North America, they are still being used in imported products from developing countries (Organization for Economic Cooperation and Development, 2015).

While ingestion of contaminated food and water is considered a major source of human exposure, PFAS are used in a wide range of consumer products. These chemicals are released into the indoor environment and are known components in household dust (Knobeloch et al. 2012, Winkens et al.

2018), making household dust a potential exposure source (Fromme et al. 2009; Strynar and Lindstrom, 2008).

In 2018, DOH received federal funding through ASTHO to implement a pilot project to evaluate the CDC-developed PEATT. As part of the pilot project, DOH evaluated the serum samples of 235 randomly selected members from the communities in the service areas in the PWSs of Horsham Water and Sewer Authority (HWSA), Warminster Municipal Authority (WMA), Warrington Township Water and Sewer District (WTWSD), and WTWSD/North Wales Water Authority (NWWA). Test results showed elevated average PFAS levels among study participants compared to the national averages. A detailed report on this biomonitoring pilot project is available on the DOH website.

Upon successful completion of the biomonitoring pilot project, DOH received additional funding from ASTHO to expand the pilot project by conducting environmental exposure assessment and additional biomonitoring for PFAS in urine. The specific objectives of the additional funding were (1) test indoor household dust and tap water samples from 10% of households that participated in the pilot biomonitoring project for PFAS and (2) collect all and test a subset of urine samples from participants of the pilot biomonitoring project for PFAS.

Methods

Fourteen households from the list of 119 households that participated in the pilot biomonitoring project were randomly selected for testing indoor household dust samples and tap water samples. DOH contracted with an external contractor to collect dust and tap water samples from selected households, per CDC protocol. Dust and tap water samples were collected during August-September, and urine samples were collected during July-November of 2019.

Dust sampling

One-gram dust samples were vacuumed using a flowing airstream passing through a sampling nozzle at a specific velocity and flow rate. Dust was separated from the air via cyclone and collected in catch bottles attached to the bottom of the cyclone. Samples were taken from 3 floor locations ─ living room, kitchen, and master bedroom -- in each household and combined into one composite sample. Where necessary, additional locations were vacuumed to meet the required 1 gram of dust. In most households, the 3 standard locations did not yield enough dust to achieve the necessary weight, and additional locations were vacuumed. Each dust sample was capped, labeled, and placed upright in storage containers, kept in ambient temperature, and shipped to SGS AXYS laboratory in Canada for analysis.

Dust samples were analyzed for 33 PFAS and PFAS precursors using an EPA-validated isotope dilution method (SWA 846). These compounds included perfluorobutanoic acid (PFBA), perfluoropentanoic acid (PFPeA), perfluorohexanoic acid (PFHxA), perfluoroheptanoic acid (PFHpA), PFOA, PFNA, perfluorodecanoic acid (PFDA), perfluoroundecanoic acid (PFUnA), perfluorododecanoic acid (PFDoA), perfluorotridecanoic acid (PFTrDA), perfluorotetradecanoic acid (PFTeDA), perfluorobutanesulfonic acid (PFBS), perfluoropentanesulfonic acid (PFPeS),

PFHxS, perfluoroheptanesulfonic acid (PFHpS), PFOS, perfluorononanesulfonic acid (PFNS), perfluorodecanesulfonic acid (PFDS), pentacosafluorododecane-1-sulphonic acid (PFDoS), fluorotelomer sulfonic acid 4:2 (FTS 4:2), fluorotelomer sulfonic acid 6:2 (FTS 6:2), fluorotelomer sulfonic acid 8:2 (FTS 8:2), perfluorooctanesulfonamide (PFOSA), 2-N-methyl-perfluorooctanesulfonamido acetic acid (N-MeFOSA), 2-N-ethyl-perfluorooctanesulfonamido acetic acid (N-EtFOSA), 2-(N-methylperfluorooctanesulfonamido) acetic acid (MeFOSAA), 2-(N-ethyl-perfluorooctane sulfonamido) acetic acid (EtFOSAA), N-methylperfluorooctanesulfonamidoethanol (N-MeFOSE), N-ethyl perfluorooctane sulfonamide ethanol (N-EtFOSE), Hexafluoropropylene oxide dimer acid (GenX, HFPO-DA), 4,8-dioxa-3H-perfluorononanoic acid (ADONA), 9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid (9CI-PF3ONS) and 11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11CI-PF3OUdS). Field blanks were collected and analyzed to ensure quality control.

Tap water sampling

Tap water samples were collected from the primary drinking water location, which was the kitchen faucet of each house. Pre- and post- filtered samples were collected from households with a water filtration system. Water filtration system used in participating households included pitcher, refrigerator, faucet, or whole-house system. Faucets were first flushed for 3 to 5 minutes to stabilize water temperature, and samples were collected in 250 mL polypropylene bottles with screw caps. Preservation reagent was added to each sample bottle, and samples were agitated by hand to dissolve the preservative. Samples were placed in insulated coolers with ice packs to cool to less than 10 degrees Celsius (but not frozen) and maintained at that temperature until overnight shipment to Alpha Analytical Laboratories in New Jersey for analysis. Samples were analyzed for 14 PFAS compounds — N-ethyl perfluorooctanesulfonamidoacetic acid (NEtFOSAA), N-methyl perfluorooctanesulfonamidoacetic acid (NMeFOSAA), perfluorobutanesulfonic acid (PFBS), perfluorodecanoic acid (PFDA), perfluorododecanoic acid (PFDoA), perfluoroheptanoic acid (PFHpA), PFHxS, perfluorohexanoic acid (PFHxA), PFNA, PFOS, PFOA, perfluorotetradecanoic acid (PFTA), perfluorotridecanoic acid (PFTrDA), and perfluoroundecanoic acid (PFUnA).

Urine sampling

All 235 participants of the pilot biomonitoring project were contacted for urine sample collection. Participants were mailed collection kits containing an invitation letter with informed consent/assent forms, high-density polyethylene urine collection containers, plastic specimen bags, a collection log, freezer packs, insulated cooler bags, and instructions for urine collection. Instructions asked participants to collect a non-fasting, first morning urine sample and record the date and time on the collection log. Following collection, participants were instructed to cap the collection container, seal it in the plastic bag, place it in an insulated cooler bag with a freezer pack, and store it in their freezer until they could transport their samples to Bucks/Montgomery County Health Department location. County health departments received participants' samples in their cooler bags and stored the bags in their freezers until a DOH representative collected the specimens and transported them to Pa. Bureau of Laboratories (BOL). BOL packed frozen samples on dry ice and shipped them overnight in batches to the CDC laboratory in Atlanta for analysis. Chain of custody was maintained for all samples.

Urine samples were analyzed for 16 PFAS compounds — perfluorobutane sulfonate (PFBuS), PFHxS, perfluoroheptanoate (PFHpA), PFNA, perfluoromethylheptane sulfonates (Sm-PFOS), n-perfluorooctane sulfonate (n-PFOS), perfluorodecanoate (PFDeA), n-perfluorooctanoate (n-PFOA), perfluoroundecanoate (PFUA), branched perfluorooctanoates (Sb-PFOA), tetrafluoro-2-propanoate (HFPO-DA, Gen X), dodecafluoro-3H-4,8-dioxanoate (NADONA), 9-chlorohexadecafluoro-3-oxanonane-1-sulfonate (9CL-PF3ONS), perfluorobutanoate (PFBA), perfluoropentanoate (PFPeA), and perfluorohexanoate (PFHxA). Analyses were conducted using online solid phase extraction liquid chromatography- tandem mass spectrometry method (Kato et al. 2018).

Dissemination of Sampling Results

Household dust and tap water results were mailed to the participants as soon as their results were ready, along with a comparison of average levels found in other similar studies. Water test results included both pre- and post-filtered water test results if a filtration system was available. Information on the urine sampling was mailed to all individuals who provided a sample. Participants whose urine samples were analyzed received their individual results along with a comparison to the range of levels detected in the US population (Calafat et al. 2019). Participants whose urine samples were not analyzed but stored for potential future testing were provided with the overall community average and the US population range.

Data analysis

Laboratory results of PFAS levels in indoor household dust and drinking water were analyzed to obtain summary statistical information (geometric mean and 95% confidence interval, median, and range). For analysis, non-detect values in dust sample results were replaced by a value equal to the corresponding reporting limit (RL) divided by square root of 2. The RL is the lowest concentration at which an analyte can be detected in a sample, and its concentration can be reported with a reasonable degree of accuracy and precision. It is a laboratory specific number. Non-detects in water test results were replaced by the corresponding method detection limit (MDL). The EPA defines MDL as the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix containing the analyte. Results from filtered water samples were used for all analyses when a filtration system was available in the household. The relationship (unadjusted) between levels of 4 PFAS compounds that were consistently detected in the serum samples of the pilot study participants with levels of those compounds in household dust and tap water were also analyzed (*proc mixed*) using log-transformed concentration levels. The 14 households tested for PFAS in dust and tap water samples had a total of 25 members. The data pertaining to the serum PFAS levels of these 25 individuals were retrieved from the pilot biomonitoring project dataset. The concentration of PFAS compounds found in the household dust and tap water samples were assigned to all members in the household to create a database for analyzing the relationship of serum PFAS levels with PFAS levels in household dust and tap water samples. All statistical analyses were performed using SAS EG v 7.1. A p-value ≤ 0.05 was considered statistically significant in all analyses. P-values are calculated based on the hypothesis or assumption that there is no difference between the groups compared. In simple terms the lower the p-value, the more confident we are that the alternate hypothesis is true — that there is significant difference between the groups compared.

Results

PFAS levels in household dust samples are presented in Table 1. Of the 33 PFAS compounds tested for, only 28 had values above the RL. Table 1 excludes PFAS compounds HFPO-DA, ADONA, 9CI-PF3ONS, 11CI-PF3OUdS, and PFDOS, which had no observed values above the RL.

As shown in Table 1, the concentration of most of the PFAS compounds showed a wide range among the households tested. The four consistently detected PFAS compounds in the serum samples of the community members (PFOA, PFOS, PFHxS, and PFNA) were present in the dust samples collected from all the 14 households. PFHxA, PFHpA, PFDA, and EtFOSAA were also detected in the dust samples in all tested households. PFTeDA was detected in dust samples from 13 households. Other compounds were detected in the dust samples from a fewer number of households.

Table 1. PFAS Levels (ng/g) in Household Dust Samples (n=14)

PFAS compound	n (above reporting limit)	Geometric Mean	95% confidence interval	Median	Range	Reporting limit range
Perfluorooctanoic Acid (PFOA)	14	66.44	28.59-154.40	72.60	3.94-522.00	NA
Perfluorooctanesulfonic (PFOS)	14	35.97	13.66-94.67	26.35	3.20-1110.00	NA
Perfluorohexanesulfonic (PFHxS)	14	21.08	6.53-68.07	12.01	1.44-862.00	NA
Perfluorononanoic Acid (PFNA)	14	24.32	8.68-68.10	23.60	1.24-276.00	NA
Perfluorohexanoic Acid (PFHxA)	14	24.80	12.24-50.23	22.30	4.22-167.00	NA
Perfluoroheptanoic Acid (PFHpA)	14	21.84	8.25-57.79	24.70	1.29-368.00	NA
Perfluorodecanoic Acid (PFDA)	14	24.52	9.97-60.33	22.35	2.16-297.00	NA
N-ethyl Perfluorooctane Sulfonamido Acetic Acid (EtFOSAA)	14	15.52	7.08-34.04	14.00	1.36-121.00	NA
Perfluorobutanoic Acid (PFBA)	13	10.93	6.56-18.23	9.36	4.18-52.80	3.240
Perfluoropentanoic Acid (PFPeA)	11	7.08	3.26-15.36	13.30	2.44-51.50	1.620
Perfluoroundecanoic Acid (PFUnA)	13	12.14	4.00-36.88	11.70	0.84-269.00	0.809
Perfluorododecanoic Acid (PFDoA)	13	14.22	4.93-41.04	12.50	1.54-360.00	0.809
Perfluorotridecanoic Acid (PFTrDA)	12	4.82	1.62-14.32	3.59	1.11-275.00	0.809-0.811
Perfluorotetradecanoic Acid (PFTeDA)	13	7.85	2.83-21.77	6.23	0.91-242.00	0.809
Perfluorobutanesulfonic Acid (PFBS)	11	2.37	1.18-4.73	2.08	1.26-27.80	0.806-0.809
Perfluoropentanesulfonic Acid (PFPeS)	5	0.97	0.59-1.60	2.09	1.17-9.70	0.805-0.812
Perfluoroheptanesulfonic (PFHpS)	5	0.91	0.56-1.49	1.26	0.86-10.70	0.806-0.813
Perfluorononanesulfonic Acid (PFNS)	1	0.60	0.54-0.68	1.24	1.24-1.24	0.805-0.813
Perfluorodecanesulfonic (PFDS)	9	2.15	0.97-4.75	3.61	0.97-61.70	0.806-0.811
Fluorotelomer sulfonic acid 4:2 (FTS 4:2)	1	2.57	2.00-3.30	11.60	11.60-11.60	3.220-3.250
Fluorotelomer sulfonic acid 6:2 (FTS 6:2)	12	17.17	6.78-43.46	13.70	3.39-716.00	3.240
Fluorotelomer sulfonic acid 8:2 (FTS 8:2)	11	11.35	5.01-25.68	12.80	4.86-407.00	3.230-3.240
Perfluorooctanesulfonamide (PFOSA)	4	0.99	0.53-1.87	5.40	1.04-15.40	0.806-0.813
2-N-Methylperfluorooctanesulfonamido acetic acid (N-MeFOSA)	1	0.86	0.48-1.56	29.70	29.70-29.70	0.933-0.935
2-N-Ethylperfluorooctanesulfonamido acetic acid (N-EtFOSA)	1	1.50	1.36-1.66	2.75	2.75-2.75	2.020-2.030
N-Methylperfluorooctane Sulfonamidoacetic Acid (MeFOSAA)	12	5.70	1.66-19.52	4.26	1.40-1680.00	0.809-0.811
N-methyl Perfluorooctanesulfonamidoethanol (N-MeFOSE)	12	42.53	16.14-112.12	58.95	12.40-5320.00	0.806-8.090
N-ethyl Perfluorooctane Sulfonamide Ethanol (N-EtFOSE)	8	15.32	5.85-40.09	27.60	7.48-1850.00	6.050-6.090

Note: Households with non-detectable values for a specific PFAS compound were set to a value equal to the corresponding RL/√2. The geometric mean and corresponding 95% confidence interval were calculated using all values, including those set to the ND level and observed values. The median and range exclude values below the RL. Source: Pennsylvania Department of Health, 2020

Information on the source of drinking water for the 14 households tested for PFAS in tap water is presented in Table 2. Of the 14 households, 6 received water from the WMA. One household had a private well as their drinking water source.

Table 2. Household Source of Drinking Water (N=14)

Source of drinking water (current residence)	Number of households	Percentage
Horsham Water and Sewer Authority (HWSA)	4	28.57
Warrington Township Water and Sewer District/ North Wales Water Authority (WTWSD/NWWA)	1	7.14
Warminster Municipal Authority (WMA)	6	42.86
Warrington Township Water and Sewer Department (WTWSD)	2	14.29
Private well	1	7.14

Source: Pennsylvania Department of Health, 2020

The levels of different PFAS compounds in the tap water samples (filtered water when a filtration system was installed) from the selected 14 households are presented in Table 3. Of the 14 compounds analyzed, only 7 had values above the MDL. Table 3 excludes PFAS compounds PFDA, NMeFOSAA, PFUnA, NEtFOSAA, PFDoA, PFTrDA, and PFTA, which had no observed values above the MDL.

Table 3. PFAS Levels (ng/L) in Tap Water (n=14)

PFAS compound	n (above method detection limit)	Geometric Mean	95% confidence interval	Median	Range	Method detection limit range
Perfluorooctanoic Acid (PFOA)	10	1.55	0.93-2.57	2.95	0.65-7.48	0.55-0.57
Perfluorooctanesulfonic Acid (PFOS)	12	1.13	0.70-1.85	1.31	0.46-7.67	0.44-0.45
Perfluorohexanesulfonic Acid (PFHxS)	6	0.57	0.40-0.81	0.63	0.46-4.20	0.42-0.44
Perfluorononanoic Acid (PFNA)	8	0.62	0.49-0.77	0.94	0.50-1.01	0.42-0.44
Perfluorohexanoic Acid (PFHxA)	11	0.99	0.55-1.76	1.93	0.34-3.50	0.23-0.24
Perfluorobutanesulfonic Acid (PFBS)	9	0.65	0.38-1.13	1.00	0.32-6.19	0.25-0.26
Perfluoroheptanoic Acid (PFHpA)	11	0.62	0.39-0.99	1.18	0.33-2.14	0.23-0.24

Note: Households with non-detectable values for a specific PFAS compound were set to the MDL for that compound. The geometric mean and corresponding 95% confidence interval were calculated using all values, including those set to the ND level and observed values. The median and range exclude values below the method detection limit. Source: Pennsylvania Department of Health, 2020

Even though PFAS compounds were detected in drinking water samples, the levels for PFOA and PFOS were below the US Environmental Protection Agency's (EPA) Lifetime Health Advisory Level (LHAL) of 70 parts per trillion (ppt). Of the 14 samples tested, 4 did not have any PFAS compound at levels above the MDL.

Table 4 presents the association between selected serum PFAS levels and PFAS levels in household dust and drinking water samples.

Table 4. Associations Between Selected Serum PFAS Levels and PFAS Levels in Household Dust and Drinking Water Samples

Serum PFAS (µg/L)	Household dust PFAS (ng/g) - estimate (p value)				Drinking water PFAS (ng/L)- estimate (p value)			
	PFOA (n=25)	PFOS (n=25)	PFHxS (n=25)	PFNA (n=25)	PFOA (n=17)	PFOS (n=19)	PFHxS (n=9)	PFNA (n=11)
PFOA (n=25)	0.146 (0.09)	–	–	–	0.061 (0.65)	–	–	–
PFOS (n=25)	–	0.155 (0.15)	–	–	–	0.031 (0.88)	–	–
PFHxS (n=25)	–	–	0.178 (0.11)	–	–	–	–0.182 (0.51)	–
PFNA (n=16)	–	–	–	0.106 (0.19)	–	–	–	0.715 (0.03)

Note: Estimates were calculated using log-transformed values and mixed effects models. Non-detectable serum PFAS values were set to the laboratory's limit of detection of 0.5 (ng/mL) divided by √2. Non-detectable water values for a specific PFAS compound were set to the method detection limit for that compound. Source: Pennsylvania Department of Health, 2020

A random subset of 24 (10% of the total participants in the pilot biomonitoring project) urine samples were tested for 16 PFAS compounds. No samples had levels above the level of detection for any PFAS compound; therefore, no additional analyses were performed, per CDC protocol.

Major project activities, along with a timeline are presented in Appendix 1. Appendix 2 presents the questions received from the community members during the project period.

Discussion

The pilot biomonitoring study detected four PFAS compounds (PFOA, PFOS, PFHxS, and PFNA) consistently in the serum samples of community members. The levels of these compounds detected in the serum sample of the study participants were higher than the national averages reported in NHANES (2013-2014) survey and were comparable to the levels detected in other communities exposed to PFAS through contaminated drinking water. New Hampshire residents exposed to drinking water contaminated with PFAS from a nearby military base showed an average community serum level of 3.1 µg/L for PFOA, 8.6 µg/L for PFOS and 4.1 µg/L for PFHxS in 2015 (Daly *et al.*, 2018). In 2009, Minnesota residents exposed to drinking water contaminated with PFAS from industrial sources had average community serum levels of 15.4, 35.9 and 8.4 µg/L for PFOA, PFOS, and PFHxS, respectively (Landsteiner *et al.*, 2014). The PFAS compounds consistently found in our community study are also similar to the ones reported in these studies. PFNA was another compound detected consistently in the pilot biomonitoring study.

Household dust samples from the selected 14 households showed a very wide range of PFAS concentrations. Of the 33 compounds analyzed for, 28 were found in at least one household sample. All household samples showed levels of PFOA, PFOS, PFHxS, and PFNA. The wide range of PFAS levels detected in the dust samples could be attributed to the source of dust. In many cases, samples had to be collected from different locations, which could have been used by the household members for activities involving PFAS containing consumer products. Wide ranges for PFAS levels in household dust samples have previously been reported (Frazer et al. 2013). The geometric means of PFAS compounds in household dust samples in current analyses were higher than those reported by Frazer et al. 2013 (e.g. PFOA 23.7 vs. 66.44ng/g, PFOS 26.9 vs. 35.97ng/g, PFNA 10.9 vs. 24.32ng/g). Karaskova et al. 2016 also reported lower geometric means (8.18, 9.10, 2.11 and 4.54 ng/g respectively for PFOA, PFOS, PFHxS, and PFNA) for these compounds than those recorded in the current study (Table 1).

Drinking water was known to be contaminated with PFAS at high levels prior to 2016 in the community. However, current analysis of drinking water samples from a random subset of 14 households showed levels well below the EPA's LHAL of 70ppt for PFOA and PFOS combined. Of the households with public water system hookups (13), none showed total PFOA and PFOS levels above 5.24 ng/L. One household with a private well had a total PFOA and PFOS (combined) level approximately 3 times higher than the highest concentration found in consumers of public water. Post-filter levels were higher in this household than pre-filter, showing the potential importance of regular filter maintenance. The effectiveness of a filter in removing PFAS depends on the input concentration, age of the filter, size of the filter, flow rate, and other raw water quality factors (New Hampshire Department of Environmental Services).

Analysis to identify the relationship between levels of selected serum PFAS compounds with those in dust and drinking water samples failed to indicate any significant association, except in the case of PFNA levels in tap water, where a positive association was observed (Table 4). Serum PFNA levels for 9 out of the 25 participants were non-detects, and the values were substituted with the value of the level of detection divided by square root of 2. Likewise, water PFNA levels were non-detects for 3 out of the 14 households and were substituted with the MDL for analysis. Prior studies have explored the relationship between serum PFAS and PFAS levels in dust and drinking water samples. Frazer et al. (2013) analyzed PFAS in dust as predictors of PFAS in serum as continuous variables and found no significant associations. However, when modeled as tertiles, dust PFNA appeared as a significant predictor of serum PFNA. Another recent study (Zhang et al. 2019) reported a significant correlation between PFOA concentration in drinking water and blood (correlation coefficient 0.87). The geometric mean PFOA and PFOS concentrations in drinking water in that study were 2.5 ± 6.2 ng/L and 0.7 ± 11.7 ng/L, and the mean blood concentrations were 2.1 ± 1.2 ng/mL and 2.6 ± 1.3 ng/mL, respectively.

Although serum PFAS levels were elevated in this population, urine PFAS levels were below the level of detection in all analyzed samples. This is similar to findings by Calafat et al. (2019), estimating fewer than 0.1% of the US general population had detectable urinary concentrations of PFAS compounds examined in 2013-2014 NHANES data, including PFOA, PFOS, PFHxS, and PFNA. This is despite serum data suggesting nearly universal exposure. A study in North Carolina detected Gen X, considered a PFOA substitute compound, in the Cape Fear River Basin at an average concentration of 680 ppt, yet Gen X was not detected in area residents' urine samples (Pritchett et al. 2019). Another study (Wang et al. 2018) reported 100% detection frequency for PFOA, PFNA, PFDA, PFUnDA, PFHxS, and PFOS in serum samples, whereas the corresponding detection frequencies in urine samples were only 33.33%, 5.13%, 7.69%, 10.26%, 10.26% and 76.92% respectively.

Conclusions

This pilot biomonitoring study in 2018 involving residents in the Warminster, Warrington, and Horsham communities in southeastern Pennsylvania showed that participants had elevated levels of PFAS compounds in their blood compared to the US general population. The subsequent environmental testing in 2019 using household dust and tap water samples (post-filtration) indicated wide ranges of PFAS concentrations in the dust sample, whereas the levels of PFOA and PFOS (combined) were lower compared to the LHAL of 70 ppt. Additional biomonitoring using

urine samples indicated non-detectable levels of PFAS compounds in all samples tested. A preliminary analysis suggested no association between PFAS levels in household dust and tap water and serum PFAS levels, except for PFNA levels in tap water and serum.

Limitations and Challenges

Sample size: Dust and water samples were collected only from 14 households. Though urine samples were collected from 186 participants, only 10% of the collected samples were tested.

Exposure assessment: Wide ranges of PFAS levels were observed in dust samples. Dust samples had to be collected from multiple locations to meet the quantity needed for analysis per the protocol. Some of these locations might have been used for activities involving PFAS-containing products.

Timing of the study: Testing of serum and urine specimens took place approximately 2 and 3 years (respectively) after contamination was discovered and remediated. Serum and urine concentrations measured in our study likely do not capture the peak exposure levels. The seasonal timing of the testing was also a challenge due to participants traveling and summer vacations, particularly for the families with multiple children who have challenging schedules due to summer sports and extra-curricular activities.

Urine collection: Due to serum having already been collected during the previous year, urine collection was performed by the participants in their own homes without the guidance of a health professional. Although participants were asked to collect first-morning urine, time of collection was self-reported, and collection was performed on an honor system in terms of being able to verify who provided the sample. Although participants were asked to freeze samples immediately and store them in a frozen state and were given freezer packs and insulated cooler bags to assist with maintaining this state during transport to a county health department, consistency could not be verified.

Environmental assessment: Dust sampling was performed in 14 homes. Although all samples were collected in a consistent manner by the same technician, samples were composites from multiple locations in the house. Dust samples were collected mainly from the kitchen, living room, and master bedroom floors. In addition to these consistent locations, additional vacuuming was needed to collect the minimum required sample, and these additional locations varied from home to home.

Feedback and Recommendations

Selection process: Although the need for a scientifically designed random sampling exposure assessment is appreciated, we recommend the ability to incorporate volunteer participants into the testing as well. This subset of participants could be analyzed separately from the randomly chosen sample and compared. Having an option to test volunteers would improve relations with the affected community and provide greater ability to analyze different subsets of the population, including at-risk and occupationally exposed residents.

Questionnaires: Although household testing was performed, there were no questionnaires to assess variables between households. Age of home, building materials, renovations, type of furniture, and activities that take place in the home are all variables that can contribute to the amount of PFAS present in the household's dust.

Results process: Only 10% of total collected urine samples were analyzed, meaning most participants who provided samples had no results to be reported. In the 24 analyzed samples, all readings showed PFAS levels below the limit of detection for all compounds. Urine sampling required a commitment from the participant, and 162 participants followed through with the process without receiving any analysis of their samples. Results letters for household dust and tap water provided levels of PFAS compounds in both media. Although each household was provided with their PFAS compound levels found in their dust sample, there is no standard "safe" level of any compound for comparison. Participants might now know their levels for each compound but not know the source of the PFAS compound, or how to reduce the levels.

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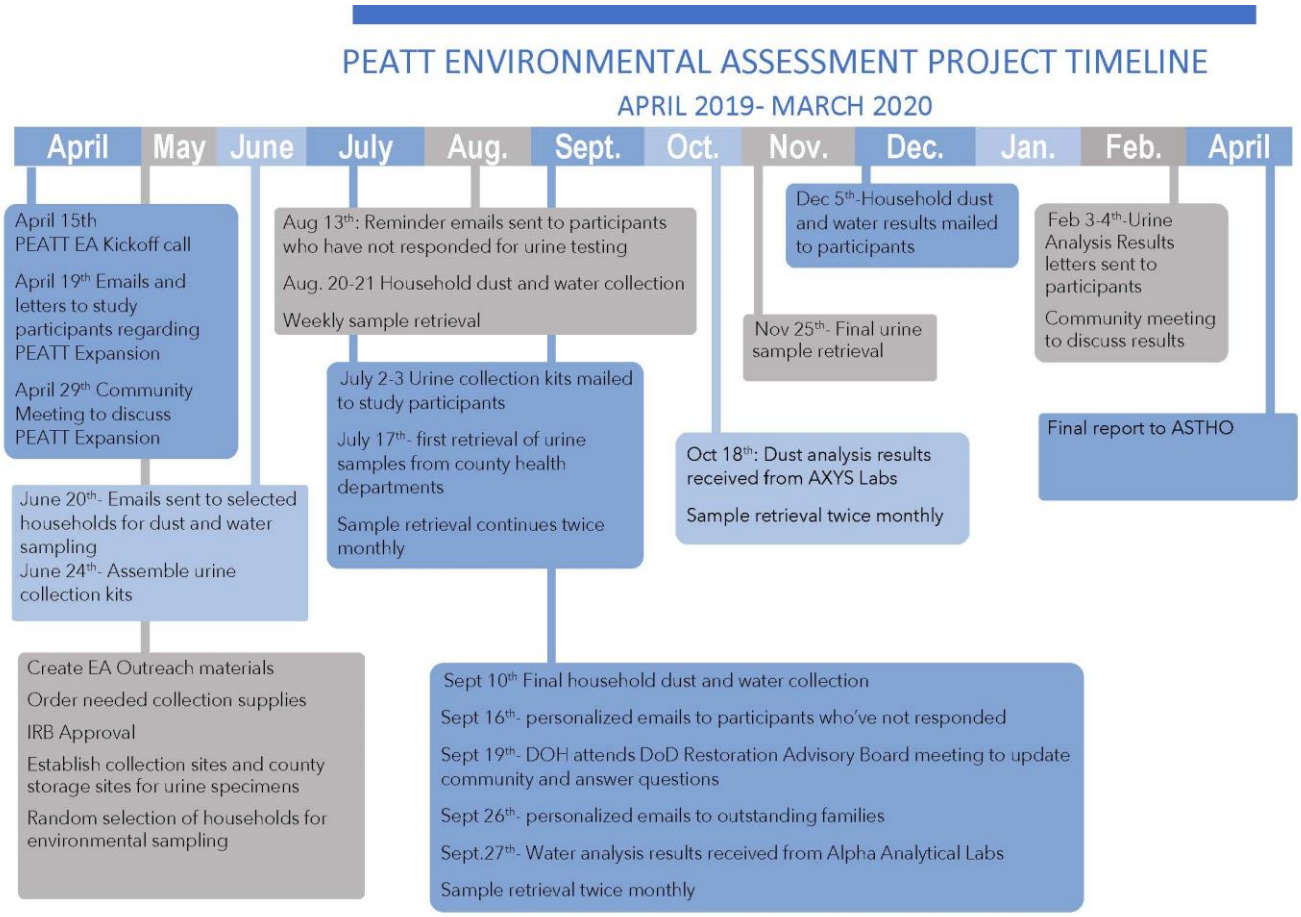
Appendix 1: Activities and Timeline

Activities

- Weekly correspondence occurred via emails and phone calls between DOH and stakeholders at ATSDR/CDC, Pa. BOL and Bucks and Montgomery Ccounty Health Departments. These calls facilitated logistics of sample collection, transport, shipment, and overall communication through the duration of the project.
- DOH created its own outreach communication materials, which included cover letters and emails to participants, consent/assent forms, instructions for urine storage, transport, and drop-off, reminder letters and emails, phone scripts, results letters, public presentations, and press releases. DOH modified the PEATT-supplied consent/assent form and invitation letter.
- Initial email notifications, initial cover letters, and consent/assent forms were sent to all 235 individuals who provided blood samples in the 2018 PEATT Pilot Study. One hundred eighty-six of the 235 provided urine samples in 2019.
- Urine collection began in July 2019 and continued through November of the same year. Each county health department served as a weekday daytime-hour drop-off location for sample storage in freezers. Participants were also offered evening-hour drop-off options at the Horsham Township Library twice monthly.
- DOH sent biweekly emails to participants reminding them to return their samples and consent forms. This occurred from August through November of 2019.
- DOH maintains an active website with details about the PEATT Pilot Project and general information on PFAS for public review. This has been in progress since 2016 and includes information/documents related to the cancer investigations conducted in the study area. These include PFOS and PFOA fact sheet, PFAS Family Tree, Cancer Data Review-(1985-2013), Cancer Data Review (1985-2013) – Addendum 1, Addendum 2, and PEATT.
- DOH also responded to questions from citizens during the period regarding the environmental assessments.

Timeline – Major events 2019-2020



Appendix 2: FAQ

Some of the more frequently asked questions from community members:

1. **"Why are you measuring urine, dust, and tap water?"** This is probably the most frequently asked question from the community during the environmental assessment, and we encountered it in email, phone call, and face-to-face situations throughout the duration of the study. We explained that our biomonitoring pilot study was used in creating a national environmental assessment that is measuring PFAS in blood, urine, household dust, and tap water. By testing our initial participants in these additional parameters, we join the other sites across the nation in collecting this information.
2. **"When will we see the results of our urine testing?"** We explained that only a small random sample (10%) of the collected specimens will be analyzed for PFAS due to the testing method undergoing refinement. If those 10% show high levels of PFAS compounds, then the remaining

samples will be analyzed. Participants were disappointed that they were expected to go through the extra effort of providing urine specimens, keeping them in frozen states, and transporting them to county health departments without assurance of an analyzed result.

3. **"Will we be a part of the bigger study? Will you be able to come back and do more testing on more people?"** This was a constant question from the community, media, and legislators. We eventually were able to tell people "yes" we are a site in the Multi-Site Study.