Orange County

New York | near Stewart Air National Guard Base

INFORMATION TO PROTECT OUR COMMUNITIES

Per- and Polyfluoroalkyl Substances (PFAS) Exposure Assessment

Appendix A, B, and C

National Center
for Environmental Health
Agency for Toxic Substances
and Disease Registry

06/29/2022

Appendix A: Additional Tables

Table A1. Dust sample results from Orange County EA compared to results from other U.S. studies (nanograms per gram)

PFAS	Orange County EA			Fraser et al. (2013) Household Dust—MA*		Karásková et al. (2016) Household Dust—U.S.†		Wu et al. (2015) Household Dust—CA Homes with Young Children‡		Wu et al. (2015) Household Dust—CA Homes with Older Adults Only‡		Scher et al. (2018) Household Dust—MN§	
	RL	GM	Range	GM	Range	Median	Range	GM	Range	GM	Range	Median	Range
PFBS	1.53–3.62	3.50	ND–20.0	NA	4.98–4.98	0.9	<0.73¶–2.6	–	–	–	–	<5	<5–58
PFPeS	1.54–3.64	NA	ND–3.46	–	–	–	–	–	–	–	–	–	–
PFHxS	1.53–3.62	NA	ND–560	NA	6.05–430	8.7	1.4–84.4	3.47	ND**–7,490	3.77	ND**–1,050	18	<5–790
PFHpS	1.53–3.62	NA	ND–3.14	–	–	<0.42¶	<0.42¶–2.9	–	–	–	–	–	–
PFOS	1.53–3.62	12.4	ND–383	26.9	14.1–280	14.1	5.7–239	29.0	ND**–6,670	34.6	ND**–1,040	67	8.4–2,000
PFDS	6.15–3.62	NA	ND–4.31	–	–	2.8	0.5–9.8	–	–	–	–	–	–
PFBA	6.15–14.5	NA	ND–40.8	13.9	4.89–999	–	–	–	–	–	–	24	<5–200
PFPeA	3.07–7.24	NA	ND–6.10	NA	5.39–249	1.7	<0.76¶–24.8	–	–	–	–	6.2	<5–66
PFHxA	1.53–3.62	6.16	ND–30.7	8.65	4.85–1,380	6.5	2.5–190	–	–	–	–	29	5.4–240
PFHpA	1.53–3.62	NA	ND–20.3	12.0	4.93–586	3.6	0.9–86.7	–	–	–	–	23	<5–260
PFOA	1.53–3.62	10.7	ND–57.5	23.7	5.71–894	9.0	2.9–318	41.4	ND**–2,360	45.0	ND**–728	51	9.9–970
PFNA	1.53–3.62	NA	ND–178	10.9	6.21–1,420	3.9	1.1–62.9	13.3	ND**–1,910	14.7	ND**–883	26	<5–450
PFDA	1.53–3.62	NA	ND–30.5	NA	6.97–26.8	1.8	0.4–64.0	8.51	ND**–2,520	7.76	ND**–355	13	<5–370
PFUnA	1.53–3.62	NA	ND–56.0	NA	10.8–39.4	1.2	<1.06¶–13.1	–	–	–	–	7.2	ND–67
PFDoA	1.53–3.62	NA	ND–9.50	NA	5.09–13.3	0.6	<0.72¶–9.0	–	–	–	–	8.2	ND–190
PFTrA	1.53–3.62	NA	ND–6.88	NA	10.3–10.3	ND¶	ND¶–2.1	–	–	–	–	–	–
PFTA	1.53–3.62	NA	ND–8.12	NA	11.2–11.2	0.8	<1.15¶–3.0	–	–	–	–	–	–
MeFOSAA	1.53–3.62	NA	ND–32.8	–	–	–	–	–	–	–	–	–	–
N-MeFOSE	15.3–36.2	NA	ND–102	NA	18–488	1.0	<0.57¶–9.9	–	–	–	–	–	–
EtFOSAA	1.53–3.62	16.1	ND–73.5	–	–	–	–	–	–	–	–	–	–
FtS 6:2	5.54–13.0	NA	ND–25.7	–	–	–	–	–	–	–	–	–	–
FtS 8:2	6.15–14.5	NA	ND–25.2	–	–	–	–	–	–	–	–	–	–

RL = reporting limit, GM = geometric mean, ng/g = nanograms per gram, NA = not applicable (i.e., too few detected results to calculate a GM), ND = not detected, — = PFAS was not measured as part of the study

* This study evaluated dust samples collected from homes, offices, and vehicles in the greater Boston, Massachusetts, area between January and March of 2009. This table presents results for dust samples collected in the main living areas of 30 homes.

† This study evaluated dust samples collected from living rooms and bedrooms from homes in Canada, the Czech Republic, and the United States during the spring and summer of 2013. The results presented in this table are from the 14 homes in the United States.

‡ As part of this study, dust samples were collected between 2007 and 2009 from carpet or area rugs in the main living areas of homes in California with and without young children residing in the home. This table presents results separately for dust samples collected in the 82 homes with young children and the 42 homes with older adults only.

§ As part of this study, dust samples were collected between July and September 2010 from 19 homes located in cities with PFAS–contaminated drinking water in Minnesota. Samples were collected at each home from an entryway to the yard as well as in an interior living space (e.g., family room, living room). The results presented in this table are for dust samples collected in interior living spaces only.

¶ Value was less than author–specified method detection limit. For this study, method detection limits varied because they were defined as mean concentration of procedural blanks plus three times the standard deviation of blank response. Values included in this table represent the upper bound of the method detection limit for a given PFAS, unless noted by “ND” (i.e., for PFTrA). For PFTrA, the upper bound method detection limit was greater than the maximum detected value. For PFTrA, the method detection limits ranged from 0.48 to 2.32 ng/g.

** Reporting limits for dust not specified in Wu et al. (2015).

Table A2. Comparison values for PFAS measured in blood from other exposure assessments

PFAS/Population	Reference	Geometric Mean for Blood (µg/L)
PFHxS		
Manufacturing workers, Decatur, AL	Olsen et al. 2003	180.0
Orange County EA[†]	This EA	8.3
Montgomery and Bucks Counties, PA	PA DOH 2019	6.6
Decatur, AL	ATSDR 2013	6.4
Little Hocking Water Association, OH	Frisbee et al. 2009	5.7*
Portsmouth, NH	NH DPHS 2016	4.1
Westhampton Beach/Quogue Area, NY	NYDOH 2019	3.0
General U.S. population (NHANES 1999/2000)	CDC 2019	2.1
General U.S. population (NHANES 2015/2016)	CDC 2019	1.2
PFOS		
Manufacturing workers, Decatur, AL	Olsen et al. 2003	941.0
Decatur, AL	ATSDR 2013	39.8
General U.S. population (NHANES 1999/2000)	CDC 2019	30.4
Little Hocking Water Association, OH	Frisbee et al. 2009	23.5*
Orange County EA[†]	This EA	10.6
Montgomery and Bucks Counties, PA	PA DOH 2019	10.2
Portsmouth, NH	NH DPHS 2016	8.6
Westhampton Beach/Quogue Area, NY	NYDOH 2019	6.6
General U.S. population (NHANES 2015/2016)	CDC 2019	4.7
PFOA		
Manufacturing workers, Decatur, AL	Olsen et al. 2003	899.0
Little Hocking Water Association, OH	Frisbee et al. 2009	227.6*
Decatur, AL	ATSDR 2013	16.3
General U.S. population (NHANES 1999/2000)	CDC 2019	5.2
Montgomery and Bucks Counties, PA	PA DOH 2019	3.1
Portsmouth, NH	NH DPHS 2016	3.1
Orange County EA[†]	This EA	2.0
General U.S. population (NHANES 2015/2016)	CDC 2019	1.6
Westhampton Beach/Quogue Area, NY	NYDOH 2019	1.5

µg/L = micrograms per liter

* The study reported medians instead of geometric means.

[†] Unadjusted geometric means from the Orange County EA are included in this table for comparison.

Appendix B: Additional Background Statistics

As described in the main body of this report, all statistical analyses (e.g., correlations, geometric means, univariate linear regression models, multivariate linear regression models) were completed in SAS version 9.4 (SAS Institute, Cary, NC) following the methods outlined in the study protocol. Several key details on these methods are provided below.

- Consistent with NHANES methodology and per the EA protocol, all non-detect observations were substituted with a value equal to the LOD divided by the square root of 2. Geometric means were not reported for PFAS with 40% or more non-detect observations. Additional information on the effect of this substitution method is provided below.
- Geometric means, 95% confidence intervals around geometric means, and percentiles were calculated with the SURVEYMEANS procedure in SAS. In this procedure, percentiles are based on the population cumulative distribution function.
- Univariate and multivariate regression analyses were conducted with the SURVEYREG procedure in SAS. Multivariate regressions were conducted using a backwards stepwise approach. "Interactions" were only considered when there was a suspected relationship between two variables. Due to the skewed distribution of PFAS blood levels, log transformed (log_{10}) values were used as dependent variables in all linear regression analyses.
- For this EA, all eligible residents within the sampling frame were invited to participate. This means a single household may have multiple participants. To account for the one–stage cluster sampling design used for this EA, household IDs were assigned to each participant. All statistics were calculated while accounting for clustering at the household level by including this household ID variable in a CLUSTER statement in SAS survey procedures. Additional information on the effect of clustering is provided below.
- A finite population correction was applied by including the total number of households in the sampling frame in a TOTAL statement in the SAS survey procedures. For this EA, a total of 2,922 households were identified within the sampling frame. A finite population correction corrects the standard errors when sampling without replacement from a finite population and is recommended when sample size is greater than 5% of the population being sampled.
- A p-value of less than 0.05 was used to identify statistically significant associations in regression models and 95% confidence limits were provided for all estimated geometric means.
- Age-adjusted statistics were calculated using the POSTSTRATA statement in the PROC SURVEYREG procedure in SAS. For age adjustments to the sampling frame population, the number of people in the sampling frame in different age categories starting with 'Under 15 years,' '15–34 years,' and each subsequent 5-year age interval (35–39 years, 40–4 years, etc.) was calculated from census block data from 2010 and was used as poststratum totals (_PSTOTAL_). The youngest age categories are the largest because of the few young EA participants. Similarly, for age-adjustments to the NHANES population, estimates of the U.S. population in each age category starting with "12–19 years,' '20–34 years,' and each subsequent 5-year age interval (35–39 years, 40–44 years etc. through 80+) were calculated.

Additional details on non-detect observations

As noted, all results reported below the LOD were substituted with a value equal to the LOD divided by the square root of 2. For blood, all PFAS and all samples were reported from the laboratory with an LOD of 0.1 µg/L, and non-detect observations were therefore substituted with a value equal to 0.071 µg/L.

The same method was applied to urine results (LOD=0.1 µg/L) and dust (LOD varies by PFAS and sample); no summary statistics were computed for tap water for this EA due to low detection frequency.

The study protocol also notes that a sensitivity analysis of aggregate PFAS blood data should be performed using other statistical methods to account for censoring. More specifically, for datasets in which less than 50% of the data are censored (i.e., not detected), the Kaplan-Meier method should be used to calculate summary statistics; and for data sets with between 50% and 80% censored results, maximum likelihood estimation should be used. Only high sample percentiles should be reported for data sets with more than 80% censoring. Given that no nationally representative comparison values using these methods are available, results of this sensitivity analyses should only be used as a comparison to results obtained using the simpler substitution method described above.

Based on these criteria, ATSDR compared geometric means for all PFAS measured in blood (except Sb-PFOA) using the two alternate substitution methods. As shown in Table B1, there is little to no difference in geometric mean estimates when using these methods, and alterative substitution methods would therefore have no effect on the conclusions of this report. This is expected for these data due to the single censoring threshold for all PFAS and blood samples [Helsel 2009].

Table B1. Comparison of geometric mean blood levels with various substitution methods

PFAS	Geometric Mean Calculated with LOD/Square Root of 2 (µg/L)	Geometric Mean Calculated with Kaplan Meier Approach (µg/L)	Geometric Mean Calculated with Maximum Likelihood Estimation (µg/L)
PFHxS	8.30	8.30	8.38
n-PFOS	7.18	7.18	7.21
sm-PFOS	3.27	3.27	3.32
n-PFOA	1.90	1.90	1.91
sb-PFOA	0.07	NA*	NA*
PFNA	0.51	0.52	0.52
PFDA	0.22	0.22	0.22
PFUnA	0.16	0.17	0.16
MeFOSAA	0.12	0.15	0.11

LOD = limit of detection, µg/L = micrograms per liter, NA = not applicable

* LOD does not meet the threshold set in EA protocol for sensitivity analyses (<20%).

More details on precision and clustering for PFAS blood data

As noted in the study protocol, this investigation was designed to estimate mean concentrations of PFAS in blood for the sampling frame population, with a given level of precision. The target sample size for this EA was based on a desired precision of 15% and 5% level of significance. Table B2 presents the estimated precision for the mean of the log transformed (ln) PFAS concentrations. This was calculated as the difference between the upper confidence interval of ln(PFAS) and the mean ln(PFAS), divided by mean ln(PFAS). Precision estimates ranged from 9% to 37%. Except for PFOA and PFNA, these values are all below the desired precision of 15% used to determine the target sample size for this EA. The collected data met the precision target specified in the EA protocol. Additional information on target precision is provided in the study protocol.

Note that throughout the main body of the report and Appendix C, geometric means are presented with 95% confidence intervals and regression modeling results are presented with p-values. These statistics provide further insight into the precision of those estimates.

To quantify the effect of clustering and to compare the results of this EA to the assumptions used to determine the target sample size for the EA (listed in the protocol), ATSDR calculated the intra-cluster correlation coefficient (ICC) and design effect for each PFAS that was detected in at least 60% of blood samples (Table B2). ICCs were estimated using variance components from the MIXED procedure in SAS. In brief, a mixed model was run for each PFAS while treating clusters (i.e., households) as a random effect. The ICC was calculated as the ratio of the variance attributable to the random effect (households) divided by the total of the random effect and error variances. The design effect was calculated using the DEFF option in the MODEL statement of the SURVEYREG procedure in SAS. This provides an estimate of the ratio of the actual variance to the variance computed under the assumption of simple random sampling. This information, along with the average number of study participants per house, was then used to calculate the effective sample size for each PFAS. This statistic provides an estimate of the sample size that would be required to achieve the same level of precision if a simple random sample study design was used.

The target sample size for this EA was 395 people, based on (1) an ICC of 0.54 for PFOS calculated from data collected as part of biomonitoring study conducted by the New York State Department of Health and the Pennsylvania Department of Health, (2) a design effect of 2.1, and (3) and effective sample size of 188 people. Refer to the study protocol for more details on how these values were derived.

Table B2. Statistics related to clustering in blood data (all participants)

PFAS	Household ICC (Unitless)	Design Effect (Unitless)	Effective Sample Size (n)	Standard Deviation of ln(PFAS) (µg/L)	Precision of Mean ln(PFAS) (%)
PFHxS	0.19	1.20	49.3	1.22	14.7
PFOS	0.34	1.32	44.6	1.09	11.8
n-PFOS	0.39	1.35	43.6	1.08	14.0
Sm-PFOS	0.19	1.21	48.9	1.15	24.9
PFOA	0.14	1.12	52.6	0.75	27.7
n-PFOA	0.12	1.11	53.2	0.81	32.3
Sb-PFOA	1.00	1.01	58.4	0.31	3.0
PFNA	0.65	1.58	37.3	0.98	37.4
PFDA	0.49	1.35	43.6	0.57	9.5
PFUnA	0.64	1.32	44.8	0.64	8.8
MeFOSAA	NA*	NA*	NA*	NA*	NA*

µg/L = micrograms per liter, NA = not applicable

* Per the protocol, geometric means were not calculated for PFAS detected in less than 60% of samples.

Blood ICCs for this EA ranged from 0.14 to 0.65, suggesting weak to moderate correlation, depending on the PFAS. The design effects ranged from 1.12 to 1.58, all of which are lower than the assumed design effect of 2.1. Effective sample size estimates ranged from 37 to 58. The design effect in this EA is smaller than that assumed in the protocol in part because of a smaller standard deviation of ln(PFAS) (the

protocol assumed a standard deviation of 1.63), and because of a smaller number of people per household. In this EA the average number of people per household was 1.23 (compared to 3.0, assumed in the protocol).

Appendix C: PFAS Blood Levels by Demographics and Exposure Characteristics

This appendix provides geometric mean blood PFAS concentrations and 95% confidence intervals stratified by demographic or exposure characteristics for the six PFAS with detection frequencies above 60% (i.e., PFHxS, PFOS, PFOA, PFNA, PFDA, and PFUnA). Also included are univariate regressions, multivariate regressions, and box and whisker plots. For each regression, the outputs shown are coefficient estimates, p–values, and marginal effects. The coefficient represents the increase in PFAS blood levels (in units of $\log_{10}$[µg/L]) per unit increase of the independent variable shown on the left side of the table for continuous variables, or when comparing to the reference category for categorical variables. The p-value indicates the significance of the results. Generally, p-values less than 0.05 indicate significant results. The marginal effect is the percent change in PFAS blood levels (in units of µg/L) per unit increase of the continuous variables, or in comparison to the reference category for categorical variables.

Contents

Table C1. Adult blood PFAS geometric means (GM), 95% lower confidence intervals (LCI), and 95% upper confidence intervals (UCI) in micrograms per liter*,†,‡

Variable	Category	Frequency§	PFHxS			PFOS			PFOA			PFNA			PFDA			PFUnA		
			GM	LCI	UCI	GM	LCI	UCI	GM	LCI	UCI	GM	LCI	UCI	GM	LCI	UCI	GM	LCI	UCI
All Adults																				
Age (years)	18 to <50	12	**3.10**	1.66	5.76	**4.49**	2.57	7.85	**1.29**	0.84	1.99	**0.27**	0.18	0.40	**0.16**	0.12	0.20	**0.13**	0.10	0.17
	50+	46	**11.20**	8.74	14.34	**13.80**	11.19	17.02	**2.29**	1.93	2.72	**0.63**	0.50	0.79	**0.24**	0.21	0.28	**0.17**	0.14	0.20
Sex	Female	32	**9.22**	6.13	13.88	**11.09**	7.69	16.00	**1.93**	1.46	2.55	**0.50**	0.37	0.67	**0.21**	0.17	0.25	**0.15**	0.12	0.19
	Male	26	**7.85**	5.43	11.37	**10.75**	8.22	14.05	**2.17**	1.75	2.69	**0.57**	0.45	0.71	**0.23**	0.20	0.27	**0.16**	0.14	0.20
Body Mass Index (kilograms per square meter)	<25	19	**6.77**	3.38	13.55	**10.02**	5.73	17.53	**1.59**	1.05	2.40	**0.46**	0.33	0.62	**0.20**	0.16	0.26	**0.15**	0.12	0.19
	25 to <30	17	**10.58**	7.52	14.87	**13.27**	9.57	18.40	**2.57**	1.95	3.39	**0.58**	0.41	0.81	**0.25**	0.19	0.33	**0.19**	0.13	0.26
	30 to <35	18	**8.65**	6.18	12.12	**9.90**	7.24	13.55	**2.13**	1.75	2.58	**0.62**	0.37	1.03	**0.22**	0.18	0.26	**0.15**	0.11	0.19
	35+	3	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA
Race and ethnicity combined	White alone, not Hispanic	41	**9.77**	7.42	12.86	**12.64**	10.07	15.87	**2.32**	1.92	2.81	**0.60**	0.46	0.78	**0.23**	0.19	0.27	**0.16**	0.13	0.20
	Not White or Hispanic	13	**5.63**	2.51	12.65	**6.71**	3.31	13.62	**1.29**	0.85	1.95	**0.32**	0.21	0.49	**0.18**	0.14	0.23	**0.15**	0.11	0.19
Length of residence at current address (years)	<10	14	**5.04**	2.28	11.11	**7.28**	3.75	14.14	**1.56**	0.99	2.48	**0.35**	0.24	0.53	**0.19**	0.14	0.25	**0.15**	0.11	0.20
	10 to <20	15	**4.60**	3.22	6.59	**6.24**	4.41	8.82	**1.42**	1.08	1.85	**0.35**	0.26	0.49	**0.19**	0.15	0.24	**0.15**	0.12	0.18
	20 to <30	12	**15.08**	10.99	20.68	**17.79**	13.80	22.92	**2.50**	1.92	3.25	**0.61**	0.50	0.74	**0.25**	0.22	0.29	**0.16**	0.12	0.22
	30+	17	**15.49**	11.98	20.02	**17.83**	14.01	22.68	**3.01**	2.44	3.72	**0.94**	0.62	1.43	**0.26**	0.19	0.35	**0.18**	0.12	0.26
Total length of residence in sampling frame over the past 20 years (years)	<10	5	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA
	10 to <15	9	**2.82**	1.68	4.75	**4.56**	3.42	6.10	**1.43**	0.95	2.14	**0.42**	0.33	0.53	**0.21**	0.15	0.27	**0.18**	0.13	0.24
	15 to 20	44	**12.85**	10.46	15.77	**15.36**	12.82	18.40	**2.36**	1.97	2.83	**0.62**	0.48	0.80	**0.24**	0.21	0.28	**0.16**	0.14	0.20
Current and primary source of drinking water	Public water system	43	**7.54**	5.30	10.72	**10.47**	7.65	14.35	**2.02**	1.62	2.52	**0.56**	0.42	0.75	**0.23**	0.20	0.26	**0.16**	0.14	0.20
	Bottled water	15	**12.44**	8.05	19.23	**12.39**	8.26	18.56	**2.08**	1.53	2.84	**0.45**	0.33	0.62	**0.19**	0.15	0.26	**0.15**	0.11	0.19
Tap water consumption at current home (average cups per day)	0	4	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA
	>0 to <2	0	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA
	2 to <4	7	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA
	4 to <6	16	**12.71**	8.88	18.20	**15.40**	11.62	20.40	**2.48**	2.00	3.08	**0.57**	0.49	0.67	**0.23**	0.19	0.27	**0.16**	0.13	0.21
	6 to <8	7	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA
	8+	23	**7.22**	4.90	10.65	**9.63**	6.77	13.69	**1.87**	1.41	2.48	**0.55**	0.35	0.85	**0.22**	0.19	0.25	**0.15**	0.12	0.19

Variable	Category	Frequency[§]	PFHxS			PFOS			PFOA			PFNA			PFDA			PFUnA		
			GM	LCI	UCI	GM	LCI	UCI	GM	LCI	UCI	GM	LCI	UCI	GM	LCI	UCI	GM	LCI	UCI
Current use of filter or treatment device for tap water at home	None, no filter or treatment device	23	**11.56**	7.86	17.00	**13.90**	10.19	18.96	**2.50**	1.98	3.16	**0.53**	0.43	0.66	**0.24**	0.19	0.30	**0.16**	0.12	0.21
	None, drink bottled water only	2	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA
	Use at least one filter or treatment device	33	**6.99**	4.54	10.78	**9.52**	6.50	13.96	**1.76**	1.35	2.30	**0.53**	0.36	0.79	**0.22**	0.18	0.25	**0.16**	0.13	0.20
History of kidney disease	No	56	**8.46**	6.24	11.46	**10.81**	8.28	14.10	**2.01**	1.66	2.43	**0.52**	0.41	0.67	**0.22**	0.19	0.25	**0.16**	0.13	0.19
	Yes	2	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA
Frequency of blood donation	Never/rarely	47	**9.07**	6.33	13.00	**11.48**	8.41	15.68	**2.08**	1.69	2.58	**0.52**	0.41	0.65	**0.23**	0.20	0.27	**0.16**	0.14	0.20
	Once or more a year	11	**6.78**	4.57	10.06	**8.89**	6.18	12.80	**1.83**	1.23	2.72	**0.56**	0.32	0.96	**0.19**	0.14	0.25	**0.14**	0.10	0.20
Frequency of house cleaning	A few times per month or less	36	**9.96**	7.29	13.61	**12.02**	9.24	15.62	**2.18**	1.78	2.66	**0.57**	0.42	0.78	**0.22**	0.18	0.26	**0.15**	0.12	0.19
	Three times per week or more	22	**6.73**	3.84	11.77	**9.38**	5.60	15.72	**1.82**	1.28	2.59	**0.47**	0.33	0.66	**0.23**	0.19	0.27	**0.17**	0.14	0.21
Frequency of stain-resistant product use	Never	53	**8.89**	6.50	12.17	**10.96**	8.31	14.47	**2.09**	1.72	2.54	**0.52**	0.40	0.68	**0.21**	0.18	0.25	**0.15**	0.13	0.18
	Rarely or more frequently	5	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA
Frequency of direct contact with soil at locations within the sampling frame	Three times per week or more	11	**8.55**	4.75	15.40	**11.80**	7.43	18.74	**2.27**	1.68	3.08	**0.54**	0.37	0.80	**0.24**	0.19	0.30	**0.17**	0.14	0.20
	A few times per month	15	**8.67**	5.92	12.69	**12.47**	9.18	16.94	**2.05**	1.42	2.95	**0.56**	0.41	0.77	**0.26**	0.19	0.35	**0.17**	0.11	0.25
	A few times per year or less	32	**8.55**	5.54	13.20	**10.02**	6.91	14.53	**1.95**	1.49	2.55	**0.51**	0.36	0.72	**0.20**	0.17	0.23	**0.15**	0.13	0.19

Variable	Category	Frequency[§]	PFHxS			PFOS			PFOA			PFNA			PFDA			PFUnA		
			GM	LCI	UCI	GM	LCI	UCI	GM	LCI	UCI	GM	LCI	UCI	GM	LCI	UCI	GM	LCI	UCI
Consumption of fruits and vegetables from locations within the sampling frame	No	28	**11.73**	8.52	16.16	**13.73**	10.40	18.14	**2.28**	1.83	2.85	**0.50**	0.40	0.62	**0.21**	0.18	0.25	**0.13**	0.11	0.17
	Yes	29	**6.29**	4.04	9.79	**8.80**	5.88	13.17	**1.84**	1.37	2.46	**0.56**	0.36	0.86	**0.23**	0.18	0.29	**0.19**	0.15	0.24
Consumption of local fish (i.e., fish caught within the sampling frame)	No	53	**8.48**	6.16	11.67	**10.80**	8.20	14.23	**1.97**	1.63	2.40	**0.53**	0.42	0.68	**0.22**	0.19	0.25	**0.16**	0.13	0.19
	Yes	5	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA
Frequency of local milk consumption (i.e., milk from animals within the sampling frame)	Never	53	**8.30**	6.00	11.49	**10.94**	8.24	14.52	**1.98**	1.62	2.43	**0.51**	0.41	0.63	**0.22**	0.19	0.25	**0.16**	0.13	0.19
	Rarely or more frequently	4	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA
Frequency of fast food consumption	Three times per week or more	10	**7.97**	2.63	24.17	**9.05**	3.48	23.53	**1.88**	0.98	3.62	**0.43**	0.21	0.88	**0.21**	0.12	0.38	**0.15**	0.08	0.28
	A few times per year or less	22	**9.36**	6.08	14.41	**11.99**	8.30	17.32	**2.03**	1.54	2.67	**0.50**	0.40	0.62	**0.22**	0.19	0.25	**0.16**	0.13	0.20
	A few times per month	26	**8.20**	5.94	11.33	**10.89**	8.14	14.56	**2.10**	1.67	2.63	**0.60**	0.40	0.89	**0.23**	0.19	0.27	**0.16**	0.13	0.20
Presence of carpeting in bedroom, living room, or kitchen	Other	28	**7.08**	4.85	10.34	**9.76**	7.07	13.48	**1.90**	1.52	2.37	**0.48**	0.39	0.59	**0.23**	0.20	0.26	**0.16**	0.14	0.20
	Carpet	30	**10.27**	6.63	15.90	**12.17**	8.19	18.09	**2.17**	1.62	2.91	**0.58**	0.38	0.87	**0.21**	0.17	0.27	**0.15**	0.12	0.20
Occupational exposures (count of jobs with potential PFAS exposures)	None	51	**8.57**	6.31	11.64	**10.86**	8.31	14.19	**2.07**	1.70	2.52	**0.53**	0.41	0.69	**0.22**	0.19	0.26	**0.16**	0.13	0.19
	One or more	6	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA

Variable	Category	Frequency[§]	PFHxS			PFOS			PFOA			PFNA			PFDA			PFUnA		
			GM	LCI	UCI	GM	LCI	UCI	GM	LCI	UCI	GM	LCI	UCI	GM	LCI	UCI	GM	LCI	UCI
Females only																				
Biological children	No	8	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA
	Yes	24	**9.81**	5.83	16.51	**12.48**	7.99	19.51	**2.04**	1.45	2.86	**0.54**	0.41	0.70	**0.23**	0.18	0.28	**0.17**	0.13	0.21
Number of biological children	0	8	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA
	1	8	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA
	2	10	**11.39**	5.43	23.86	**16.16**	9.32	28.03	**2.16**	1.32	3.52	**0.70**	0.50	0.98	**0.29**	0.21	0.41	**0.25**	0.18	0.35
	3+	6	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA
Breastfeeding or previously breastfed children	No	17	**12.48**	8.39	18.54	**12.69**	8.59	18.75	**2.12**	1.55	2.88	**0.47**	0.30	0.74	**0.19**	0.15	0.24	**0.13**	0.10	0.17
	Yes	15	**6.55**	3.17	13.52	**9.52**	4.96	18.30	**1.74**	1.07	2.83	**0.53**	0.35	0.79	**0.23**	0.18	0.31	**0.18**	0.13	0.25
Total duration of breastfeeding for all children (months)	0	17	**12.48**	8.39	18.54	**12.69**	8.59	18.75	**2.12**	1.55	2.88	**0.47**	0.30	0.74	**0.19**	0.15	0.24	**0.13**	0.10	0.17
	0< to <6	6	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA
	6 to <12	3	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA
	12 to <18	3	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA
	18+	3	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA	**NA**	NA	NA

* Several variables that were collected in the questionnaire are not included in these tables. These variables may not be included because they did not have sufficient variability or were not associated with PFAS blood concentrations in preliminary analyses. These variables include full-time vs. part-time residence, behavior change questions, and occupational history in specific industries.

† Geometric means and confidence levels are not shown for categories with fewer than 10 responses.

‡ Detection limits for all PFAS are 0.1 micrograms per liter (µg/L).

§ Some frequency counts may not sum to the total because of missing values. Some variable categories that were presented in the questionnaire were collapsed into larger variable categories.

Table C2. Adult univariate regression results including coefficient estimate (Coef.), p-value (p-val), and marginal effect (ME)*

Variable	Category	PFHxS			PFOS			PFOA			PFNA			PFDA			PFUNA		
		Coef.	p-val	ME (%)	Coef.	p-val	ME (%)	Coef.	p-val	ME (%)	Coef.	p-val	ME (%)	Coef.	p-val	ME (%)	Coef.	p-val	ME (%)
Age	NA—continuous variable	0.017	<.001	3.9	0.015	<.001	3.6	0.009	0.002	2.0	0.008	0.006	2.0	0.004	0.155	0.8	0.002	0.523	0.4
Sex	Male	-0.070	0.533	-14.8	-0.014	0.874	-3.1	0.050	0.498	12.2	0.057	0.301	14.1	0.050	0.251	12.3	0.028	0.571	6.7
	Female	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Body mass index	NA—continuous variable	0.010	0.458	2.4	0.002	0.839	0.5	0.008	0.306	2.0	0.007	0.514	1.5	0.002	0.661	0.5	0.000	0.975	0.0
Race and ethnicity combined	Not White, or Hispanic	-0.239	0.186	-42.4	-0.275	0.086	-46.9	-0.256	0.011	-44.5	-0.273	0.017	-46.7	-0.097	0.125	-20.0	-0.049	0.476	-10.7
	White alone, not Hispanic	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Length of residence at current address (years)	NA—continuous variable	0.015	<.001	3.4	0.012	<.001	2.8	0.009	<.001	2.0	0.010	0.001	2.3	0.003	0.127	0.7	0.001	0.612	0.3
Total length of residence in sampling frame over the past 20 years (years)	NA—continuous variable	0.079	<.001	20.0	0.065	<.001	16.1	0.031	0.002	7.4	0.035	<.001	8.4	0.018	0.007	4.3	0.010	0.222	2.4
Current and primary source of drinking water	Bottled water	0.217	0.078	65.0	0.073	0.509	18.3	0.014	0.864	3.2	-0.090	0.323	-18.8	-0.069	0.262	-14.8	-0.052	0.444	-11.2
	Public water system	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tap water consumption at current home (average cups per day)	NA—continuous variable	-0.012	0.316	-2.8	-0.010	0.404	-2.2	-0.001	0.893	-0.3	0.007	0.623	1.5	0.003	0.636	0.8	-0.005	0.523	-1.1
Current use of filter or treatment device for tap water at home	None, drink bottled water only	-0.151	0.458	-29.4	-0.305	0.240	-50.4	-0.086	0.528	-17.9	-0.154	0.444	-29.8	-0.300	0.081	-49.9	-0.127	0.463	-25.4
	Use at least one filter or treatment device	-0.218	0.087	-39.5	-0.164	0.129	-31.5	-0.152	0.055	-29.5	0.001	0.992	0.2	-0.042	0.494	-9.3	0.004	0.956	1.0
	None, no filter or treatment device	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
History of kidney disease	Yes	0.186	0.500	53.4	0.152	0.538	42.1	0.152	0.377	41.9	0.093	0.117	23.8	-0.041	0.192	-9.1	-0.052	0.649	-11.2
	No	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Variable	Category	PFHxS			PFOS			PFOA			PFNA			PFDA			PFUNA		
		Coef.	p-val	ME (%)	Coef.	p-val	ME (%)	Coef.	p-val	ME (%)	Coef.	p-val	ME (%)	Coef.	p-val	ME (%)	Coef.	p-val	ME (%)
Frequency of blood donation	Once or more a Year	-0.126	0.291	-25.2	-0.111	0.295	-22.5	-0.057	0.559	-12.2	0.028	0.812	6.6	-0.088	0.228	-18.4	-0.070	0.415	-14.9
	Never/rarely	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Frequency of house cleaning	Three times per week or more	-0.170	0.224	-32.5	-0.108	0.394	-21.9	-0.077	0.383	-16.3	-0.086	0.390	-18.1	0.022	0.706	5.3	0.048	0.485	11.7
	A few times per month or less	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Frequency of direct contact with soil at locations within the sampling frame	A few times per month	0.006	0.958	1.4	0.095	0.279	24.4	0.020	0.832	4.8	0.045	0.631	11.0	0.117	0.125	31.1	0.033	0.729	7.9
	Three times per week or more	0.000	0.999	0.1	0.071	0.582	17.8	0.066	0.452	16.5	0.027	0.810	6.5	0.087	0.143	22.2	0.033	0.562	7.9
	A few times per year or less	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Consumption of fruits and vegetables from locations within the sampling frame	Yes	-0.271	0.026	-46.4	-0.193	0.074	-36.0	-0.095	0.240	-19.6	0.050	0.632	12.1	0.044	0.469	10.8	0.158	0.022	44.0
	No	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Frequency of fast food consumption	A few times per month	-0.057	0.609	-12.4	-0.042	0.665	-9.2	0.014	0.847	3.4	0.079	0.411	19.9	0.018	0.712	4.2	-0.005	0.934	-1.2
	Three times per week or more	-0.070	0.787	-14.8	-0.122	0.583	-24.5	-0.033	0.830	-7.3	-0.066	0.688	-14.0	-0.014	0.913	-3.2	-0.034	0.810	-7.5
	A few times per year or less	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Presence of carpeting in bedroom, living room, or kitchen	Yes	0.161	0.202	45.0	0.096	0.390	24.7	0.059	0.465	14.5	0.082	0.412	20.7	-0.024	0.694	-5.3	-0.028	0.692	-6.2
	No	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Females only																			
Number of biological children	NA—continuous variable	0.068	0.207	16.9	0.073	0.159	18.3	0.076	0.034	19.1	0.041	0.417	9.9	0.034	0.234	8.1	0.035	0.258	8.5
Breastfeeding or previously breastfed children	Yes	-0.280	0.122	-47.5	-0.125	0.447	-25.0	-0.084	0.497	-17.7	0.051	0.697	12.4	0.097	0.245	24.9	0.146	0.112	39.8
	No	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Variable	Category	PFHxS			PFOS			PFOA			PFNA			PFDA			PFUNA		
		Coef.	p-val	ME (%)	Coef.	p-val	ME (%)	Coef.	p-val	ME (%)	Coef.	p-val	ME (%)	Coef.	p-val	ME (%)	Coef.	p-val	ME (%)
Total duration of breastfeeding for all biological children (months)	NA—continuous variable	-0.018	0.250	-4.1	-0.014	0.250	-3.3	-0.006	0.510	-1.5	-0.003	0.686	-0.6	0.000	0.999	0.0	0.001	0.805	0.2

* Not all categorical variables included in Table C1 are included in Table C2: variable categories that had fewer than 10 responses were not included in the regressions (Table C3). These variables include stain resistant product use, frequency of local milk consumption, local fish consumption, occupational exposures, and biological children (yes/no).

Table C3. PFHxS adult multivariate regression results including coefficient estimate (Coef.), p-value (p-val), and marginal effect (ME)

Parameter	Coef.	p-val	ME (%)
Age (continuous)	0.015	<.0001	3.5
Sex: male* (categorical)	1.408	0.0002	2457.4
Age × sex: male*,† (continuous)	-0.021	0.0007	-4.6
Years in sampling frame in the past 20 years (continuous)	0.076	<.0001	19.0
Current and primary source of drinking water: bottled water (categorical) ‡	0.176	0.0364	49.9

Model statistics: R^2 = 0.653 p-value = <0.0001, n = 58, n-households = 48, intercept = -1.462

* Reference category is adult participants who identified as female.

† This variable is an interaction term between age and sex.

‡ Reference category is adult participants who reported the public water supply as their current and primary source of drinking water.

Table C4. PFHxS adult female multivariate regression results including coefficient estimate (Coef.), p-value (p-val), and marginal effect (ME)

Parameter	Coef.	p-val	ME (%)
Age (continuous)	0.013	0.0019	3.0
Years in sampling frame in the past 20 years (continuous)	0.088	<.0001	22.6

Model statistics: R^2 = 0.683, p-value = <0.0001, n = 32, n-households = 32, intercept = -1.493

Table C5. PFOS adult multivariate regression results including coefficient estimate (Coef.), p-value (p-val), and marginal effect (ME)

Parameter	Coef.	p-val	ME (%)
Age (continuous)	0.014	<.0001	3.3
Sex: male* (categorical)	1.238	<.0001	1,630.1
Age × Sex: male*,† (continuous)	-0.018	<.0001	-4.0
Years in sampling frame in the past 20 years (continuous)	0.062	<.0001	15.5

Model statistics: R2 = 0.6534, p-value = <0.0001, n = 58, n-households = 48, intercept = -1.028

* Reference category is adult participants who identified as female.

† This variable is an interaction term between age and sex.

Table C6. PFOS adult female multivariate regression results including coefficient estimate (Coef.), p-value (p-val), and marginal effect (ME)

Parameter	Coef.	p-val	ME (%)
Age (continuous)	0.012	<.0001	2.7
Years in sampling frame in the past 20 years (continuous)	0.086	<.0001	21.9

Model statistics: R^2 = 0.770, p-value = <0.0001, n = 32, n-households = 32, intercept = -1.290

Table C7. PFOA adult multivariate regression results including coefficient estimate (Coef.), p-value (p-val), and marginal effect (ME)

Parameter	Coef.	p-val	ME (%)
Age (continuous)	0.010	0.0005	2.4
Sex: male* (categorical)	0.945	0.0081	781.6
Age × sex: male*,† (continuous)	-0.013	0.0124	-3.0
Years in sampling frame in the past 20 years (continuous)	0.030	0.0018	7.1

Model statistics: R2 = 0.354, p-value = <0.0001, n = 58, n-households = 48, intercept = -0.945

* Reference category is adult participants who identified as female.

† This variable is an interaction term between age and sex.

Table C8. PFOA adult female multivariate regression results including coefficient estimate (Coef.), p-value (p-val), and marginal effect (ME)

Parameter	Coef.	p-val	ME (%)
Age (continuous)	0.009	0.002	2.1
Years in sampling frame in the past 20 years (continuous)	0.043	0.0009	10.5

Model statistics: R^2 = 0.469, p-value = <0.0001, n = 32, n-households = 32, intercept = -1.095

Table C9. PFUnA adult multivariate regression results including coefficient estimate (Coef.), p-value (p-val), and marginal effect (ME)

Parameter	Coef.	p-val	ME (%)
Years in sampling frame in the past 20 years (continuous)	0.019	0.0207	4.4
Consumption of fruits and vegetables from locations within the sampling frame*: yes (categorical)	0.208	0.0016	61.3

Model statistics: R2 = 0.2148, p-value = <0.0001, n = 57, n-households = 47, intercept = -1.230

* Reference category is adult participants who reported that they do not consume fruits and vegetables from locations within the sampling frame.

Table C10. PFUnA adult male multivariate regression results including coefficient estimate (Coef.), p-value (p-val), and marginal effect (ME)

Parameter	Coef.	p-val	ME (%)
Years in sampling frame in the past 20 years (continuous)	0.017	0.0424	4.0
Consumption of fruits and vegetables from locations within the sampling frame*: yes (categorical)	0.275	<.0001	88.1

Model statistics: R2 = 0.4768, p-value = <0.0001, n = 26, n-households = 26, intercept = -1.221

* Reference category is adult male participants who reported that they do not consume fruits and vegetables from locations within the sampling frame.

Box and Whisker Plots (or Boxplots)

Figure C1. Boxplot of adult blood (serum) PFAS concentrations by age

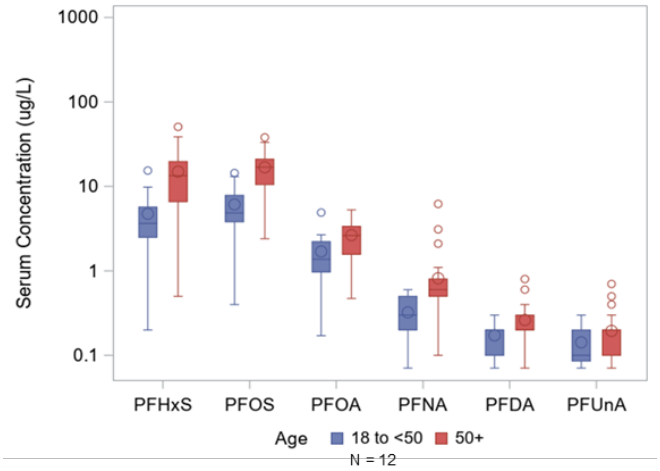

Figure C2. Boxplot of adult blood (serum) PFAS concentrations by body mass index

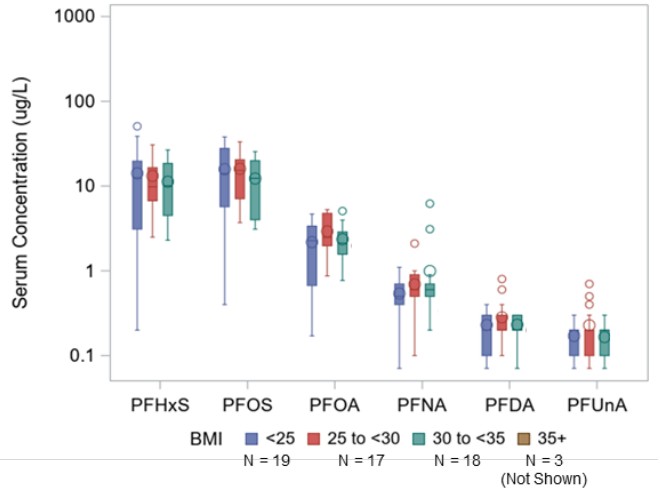

Figure C3. Boxplot of adult blood (serum) PFAS concentrations by years in current home

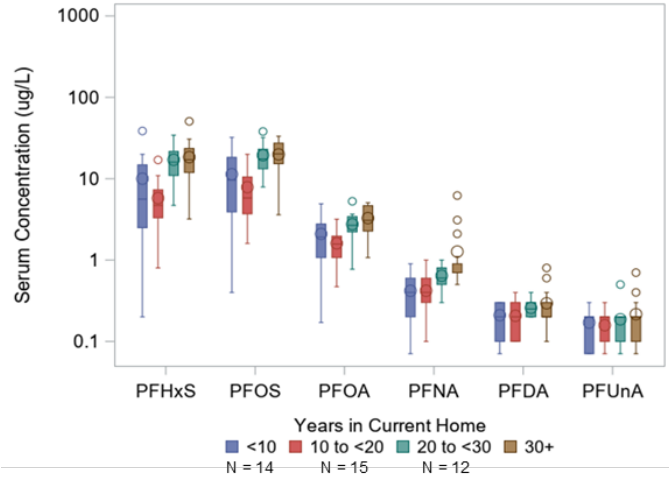

Figure C4. Boxplot of adult blood (serum) PFAS concentrations by years in sampling frame (past 20 years)

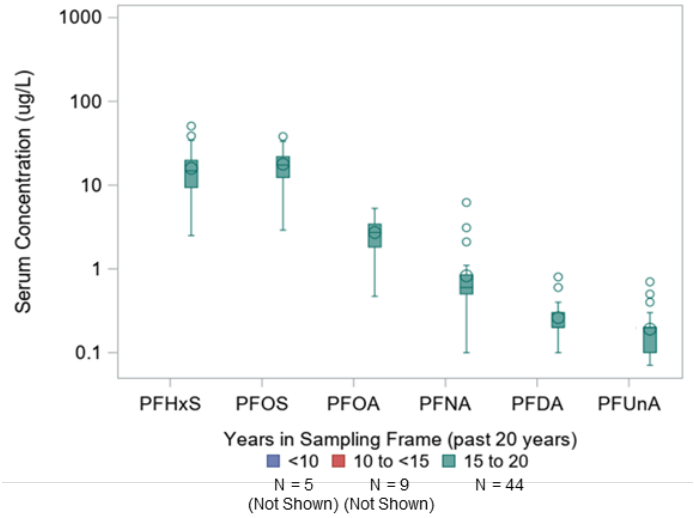

Figure C5. Boxplot of adult blood (serum) PFAS concentrations by cups of tap water drank at home

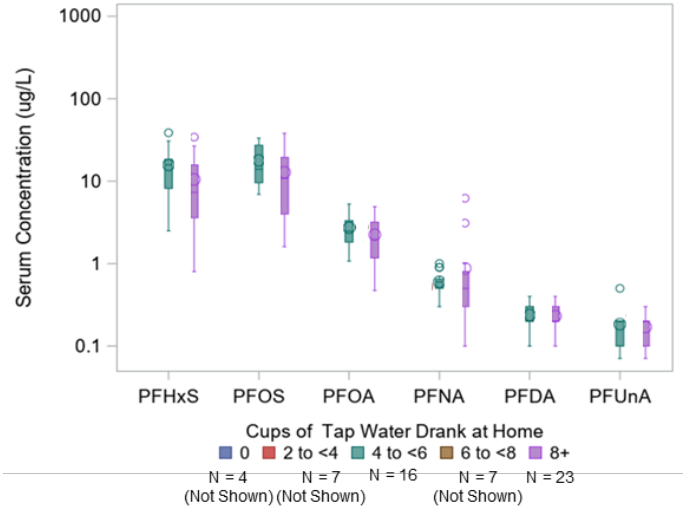

Figure C6. Boxplot of adult blood(serum) PFAS concentrations by drinking water source

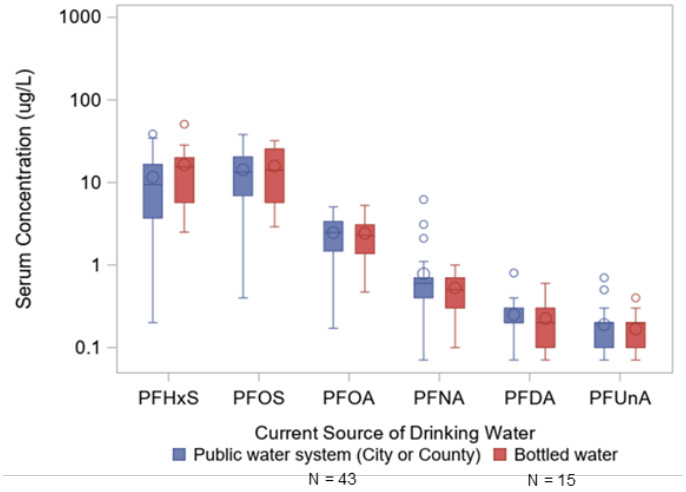

Figure C7. Boxplot of adult blood (serum) PFAS concentrations by water filter type

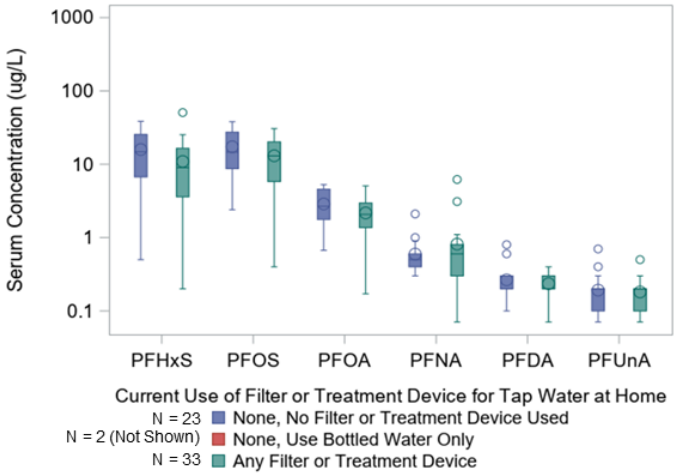

Figure C8. Boxplot of adult blood (serum) PFAS concentrations by kidney disease history

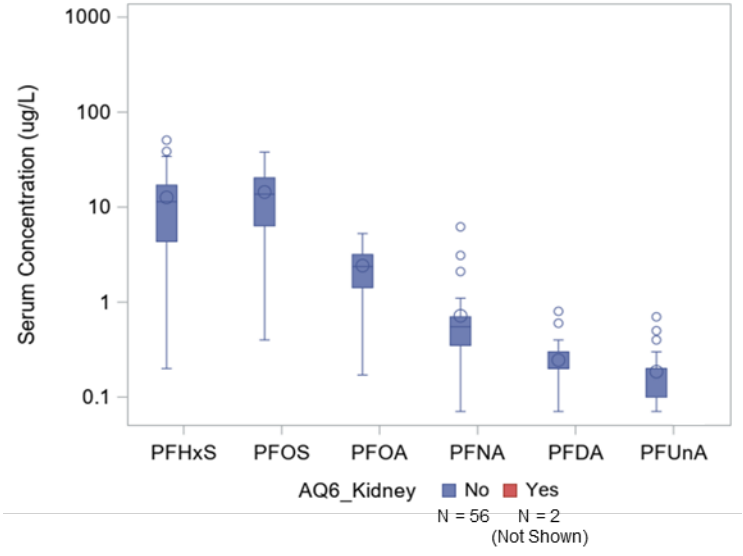

Figure C9. Boxplot of adult blood (serum) PFAS concentrations by blood donation frequency

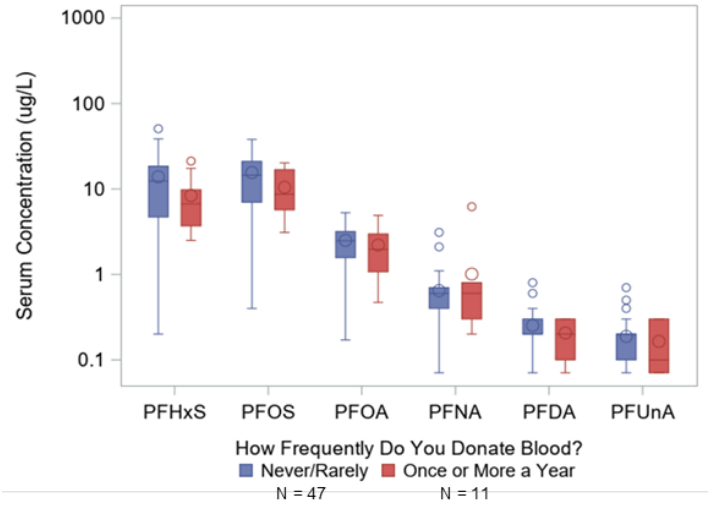

Figure C10. Boxplot of adult blood (serum) PFAS concentrations by home cleaning frequency

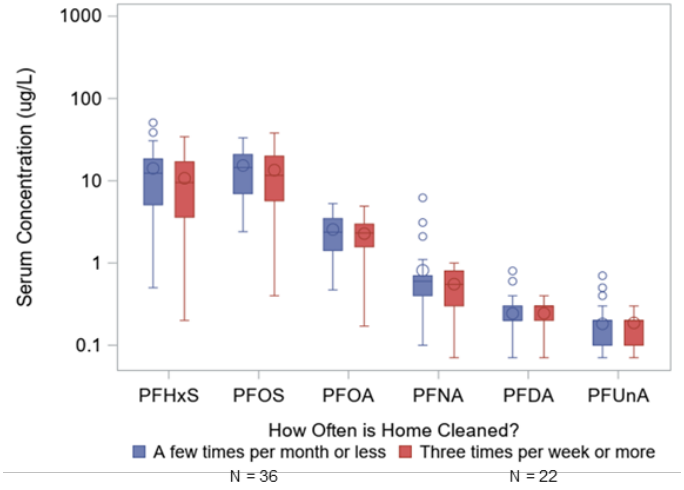

Figure C11. Boxplot of adult blood (serum) PFAS concentrations by stain-resistant product use

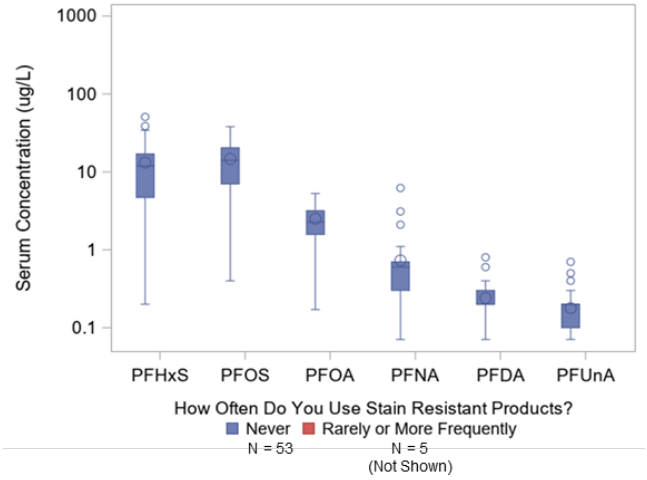

Figure C12. Boxplot of adult blood (serum) PFAS concentrations by frequency of contact with soil

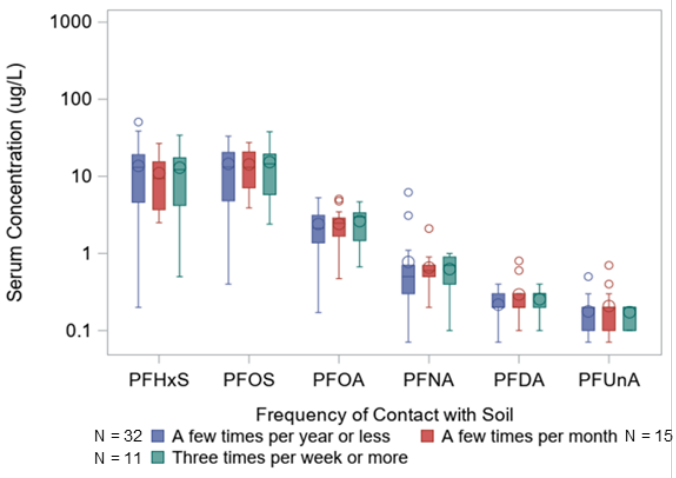

Figure C13. Boxplot of adult blood (serum) PFAS concentrations by local fruit and vegetable consumption

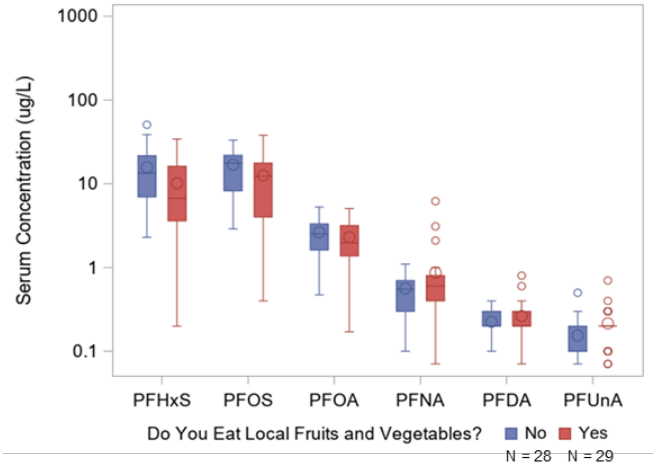

Figure C14. Boxplot of adult blood (serum) PFAS concentrations by local fish consumption

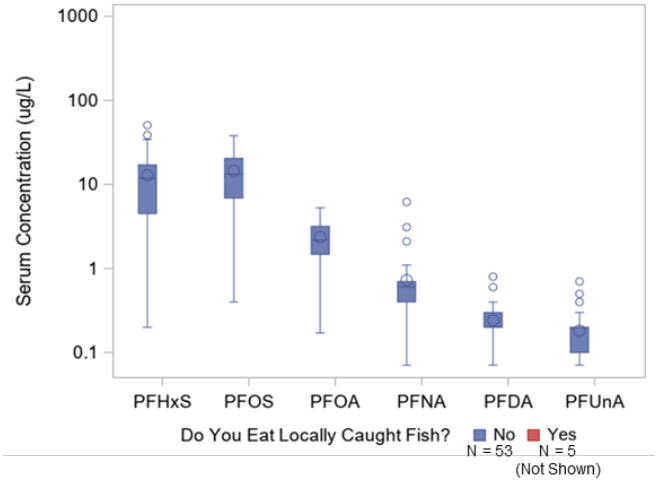

Figure C15. Boxplot of adult blood (serum) PFAS concentrations by local milk consumption

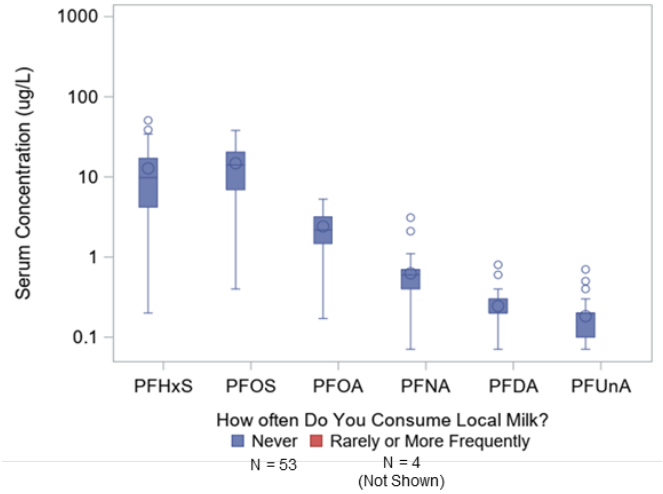

Figure C16. Boxplot of adult blood (serum) PFAS concentrations by fast food consumption frequency

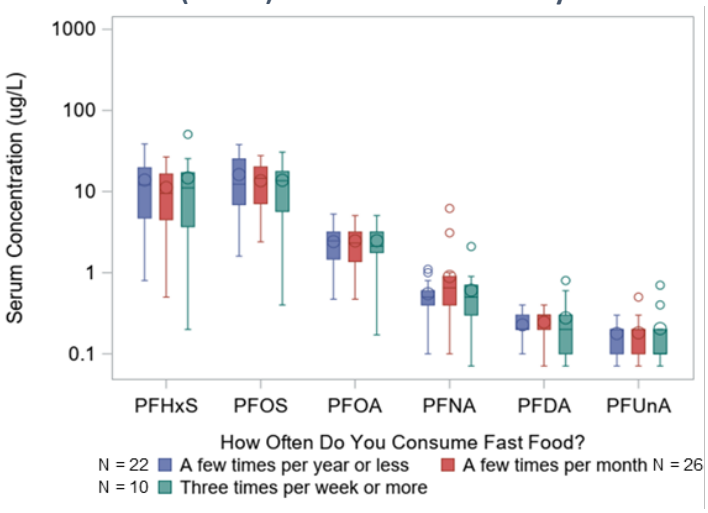

Figure C17. Boxplot of adult blood (serum) PFAS concentrations by presence of carpet in home

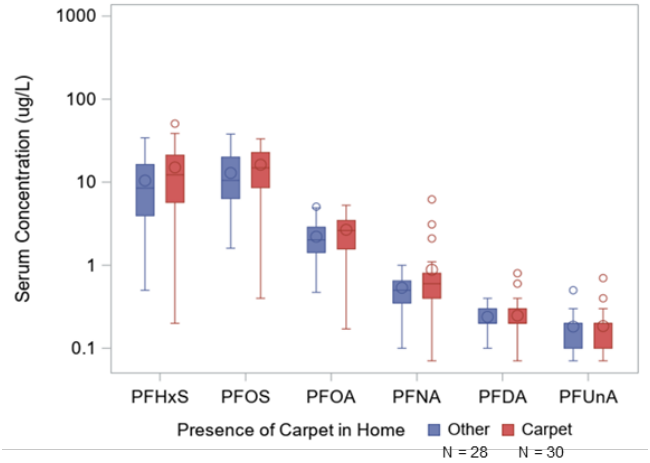

Figure C18. Boxplot of adult blood (serum) PFAS concentrations by occupational exposure

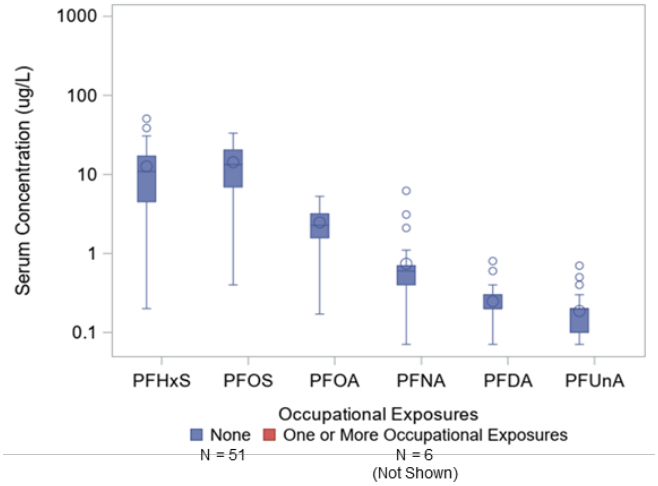

Figure C19. Boxplot of adult female blood (serum) PFAS concentrations by breastfeeding history

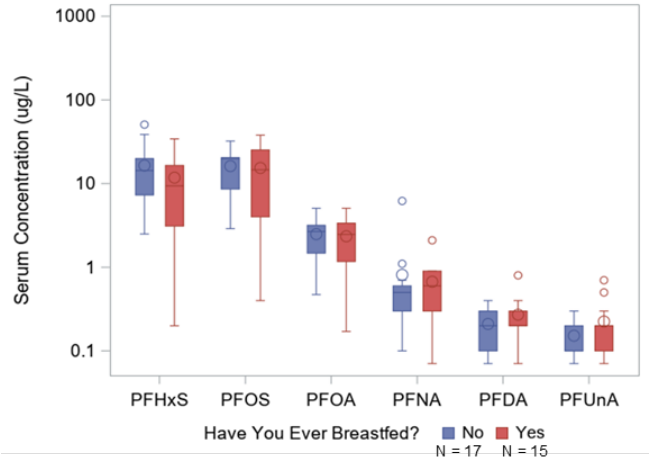

Figure C20. Boxplot of adult female blood (serum) PFAS concentrations by breastfeeding duration

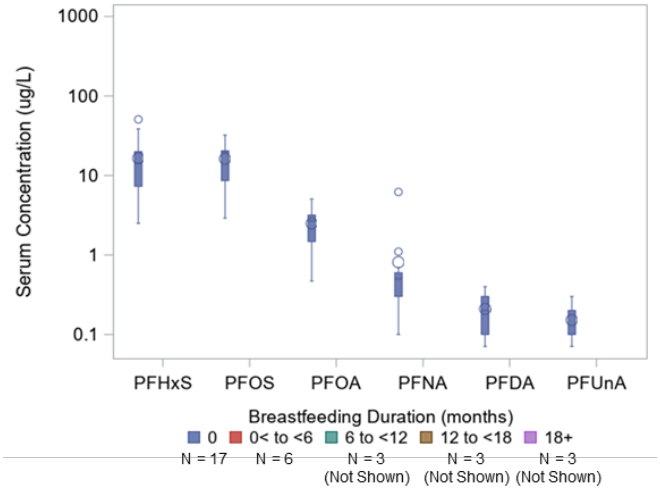

Figure C21. Boxplot of adult female blood (serum) PFAS concentrations by biological children variable