State of New Hampshire

Department of Health and Human Services
Division of Public Health Services

Pease PFC Blood Testing Program: April 2015 – October 2015

Pease Tradeport
Portsmouth, NH

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SUMMARY

In May 2014, perfluorochemicals (PFCs) were detected in concentrations near or above the U.S. Environmental Protection Agency's (EPA's) short-term Provisional Health Advisory levels in one of three wells that supplied drinking water to the Pease Tradeport in Portsmouth, New Hampshire. Perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) were detected at concentrations of 2,500 parts per trillion (ppt) and 350 ppt, respectively, in the Haven well prompting the City of Portsmouth to shut down the well on May 12, 2014. Perfluorohexane sulfonic acid (PFHxS) was also found at concentrations of 830 ppt in the Haven well.

Due to concern about exposure, the New Hampshire Department of Health and Human Services (NH DHHS) implemented a PFC blood testing program that began in April 2015 and ran through October 2015. The serum blood testing was for any person who had worked on, lived on, or attended childcare on the Pease Tradeport or Pease Air Force Base ("Pease") and was exposed to contaminated drinking water, or who consumed water from a contaminated private well adjacent to Pease that was tested as part of the Pease Superfund Assessment and found to have levels of PFOA or PFOS above the EPA Provisional Health Advisory levels. The purpose of the blood testing program was to provide individuals with a serum PFC level to inform them about levels of exposure from all sources. This testing program was not intended to be a health effects study and did not collect information pertaining to health outcomes. Brief questionnaires were distributed that collected basic information about PFC exposure at Pease but did not assess other potential sources of exposure. This report summarizes the findings of the NH DHHS PFC blood testing program.

A total of 1,578 individuals submitted a blood sample for PFC testing. The majority of participants were adults 20 years of age or older, while almost one quarter of participants were children aged 11 years or younger. Due to the community's interest in PFC serum testing and limited testing capacity, serum samples were sent to three different laboratories. The majority of samples were sent to the Centers for Disease Control and Prevention (CDC) and AXYS Analytical Laboratories. The California State biomonitoring laboratory was also utilized.

Three perfluorochemicals, PFOS, PFOA, and PFHxS, were detected in more than 94% of participants' serum samples; perfluorononanoic acid (PFNA) was also detected in the majority of participants' serum samples. The geometric mean levels in the Pease population for PFOS, PFOA, and PFHxS were significantly higher than the general U.S adult and adolescent population tested in 2011–2012 as part of the CDC's National Health and Nutrition Examination Survey (NHANES) and reported in the *Fourth National Report on Human Exposure to Environmental Chemicals* (updated tables, February 2015). The geometric mean level for PFNA was significantly lower in the Pease population. Geometric mean represents a type of average

value of a set of numbers. Other PFCs were detected in a minority of serum samples and at much lower concentrations, preventing a valid summary analysis and comparison of results.

Demographic and exposure characteristics of the Pease testing population were analyzed and showed that age, male sex, and the cumulative number of years spent on Pease were most strongly associated with serum PFC levels. Because serum levels of PFCs represent exposure from all sources, including other exposures on or off Pease and in the home environments, there are likely many factors unaccounted for in this analysis which have contributed to a person's serum PFC levels. Certain actions, especially in children, such as hand-to-mouth behavior, can be a significant source of exposure to PFCs and other chemicals and may account for some differences found among age groups.

The absolute difference in the geometric mean PFOS, PFOA, and PFHxS levels in the Pease population compared with the general U.S. population is relatively small, and these small changes have unclear health implications. The levels of PFOA and PFOS were also more consistent with national average levels found a decade ago, and levels of these three PFCs are well below what has been found in other environmentally contaminated communities and occupationally exposed workers (**Appendix A**).

While a variety of health effects are currently being studied related to PFC exposure, the long-term health impact is still unclear, and it is unknown what an individual's risk may be for developing health problems after exposure. The serum PFC levels may cause concern and uncertainty, and anyone concerned about their health should share their test results and discuss their health concerns with their healthcare provider. The CDC's Agency for Toxic Substances Disease Registry (ATSDR) is also helping to address Pease community health concerns and has formed a Community Assistance Panel (CAP) to help plan for possible future health evaluation. NH DHHS will continue to work with ATSDR and review the latest science and recommendations related to PFC exposure to provide new information to the Pease community as it becomes available.

BACKGROUND

The Pease International Tradeport is a business and aviation community located in Portsmouth, New Hampshire, on the site of the former Pease Air Force Base. The Tradeport contains more than 250 businesses, public offices, restaurants, and childcare facilities employing more than 9,500 individuals.[1] It formerly operated from 1956–1991 as a United States Strategic Air Command Base before being the first major military installation to be closed in 1991 under the Base Realignment and Closure Act (BRAC).[2,3] Prior to the Air Force Base closure, it was added to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) National Priority List in 1990, identifying the former Air Force Base as a priority hazardous waste site requiring clean-up under the EPA's CERCLA program (commonly known as Superfund).[3] At closure, a Base Clean-up Team (BCT) was formed and led by the U.S. Air Force in coordination with the EPA and the New Hampshire Department of Environmental Services (NHDES).

Perfluorochemicals, also called perfluoroalkyls, are a group of man-made chemicals that have been used for decades to manufacture household and commercial products that resist heat, stains, grease, and water. Many PFCs, including PFOA, PFOS, and PFHxS are commonly found in our indoor and outdoor environments. PFCs are used in a variety of industrial applications and consumer products, including the manufacturing of nonstick cookware and for surface protection in stain-resistant carpets, clothing, furniture, and some paper and cardboard products used for food packaging (e.g., microwave popcorn bags, fast food wrappers, and pizza boxes). PFCs are also used in products as surfactants to help them flow freely, including paints, cleaning products, and certain firefighting foams called aqueous film-forming foams (AFFFs) that are used to fight fuel-based fires.

PFCs have been found in soil, air, and water and do not break down easily in the environment. PFCs in air emissions can remain in the air for days to weeks and can travel long distances before falling to the ground where they are able to move through soil and easily enter groundwater. PFCs can also travel long distances in groundwater. Over the past two decades, as techniques to test for PFC concentrations in water have improved, they have been found globally in many areas and bodies of water which previously were not known to contain PFCs.[4] Because of their widespread use, contamination of the environment, and concern for possible health impact, the EPA has classified PFCs as "contaminants of emerging concern," highlighting the need for further investigation of the health and environmental effects of PFCs.

PFCs are not currently regulated under the Safe Drinking Water Act (SDWA). The SDWA, however, requires the EPA to implement a national monitoring program for unregulated drinking water contaminants, and every five years the EPA publishes a list of unregulated contaminants to be monitored in public drinking water systems. In 2012, PFOA and PFOS were added to the

third Unregulated Contaminant Monitoring Rule (UCMR 3), which required all public drinking water systems serving more than 10,000 people to monitor for these contaminants by December 2015.[5,6] In April 2014, at the request of the EPA and NHDES under the Superfund program, the three wells supplying drinking water to Pease were tested by the U.S. Air Force for PFOA, PFOS, and a number of other PFCs. This was the first time these chemicals were tested for in the drinking water system at Pease.

On May 12, 2014, the U.S. Air Force notified NHDES that water samples collected from the Haven well in April 2014 showed levels of PFOS that were at 2,500 parts per trillion (ppt), which was above the Provisional Health Advisory (PHA) level in effect at that time. In 2009, the EPA had set a PHA of 200 ppt for PFOS and 400 ppt for PFOA based on short-term exposures to these contaminants in drinking water.[7] PFOA was also found in the Haven well at levels of 350 ppt, which was just below the PHA of 400 ppt.[7] Upon receipt of these test results, NHDES immediately notified the City of Portsmouth, which shut down the Haven well on May 12, 2014. PFOS and PFOA were also detected at the Smith and Harrison wells, the two other water supply wells located at Pease, but at levels well below the PHA. The water from all three wells was sampled at the well and not from the tap.

The levels of PFOS and PFOA in the Pease tap water were presumed to be lower than levels detected in the Haven well because water from the three wells was mixed together, diluting the PFOS and PFOA found in the Haven well. Additional PFCs, for which there were no PHA levels established, were also tested for and detected at the three wells, including perfluorohexane sulfonic acid (PFHxS), which was at 830 ppt in the Haven well. Private drinking water wells were also tested around Pease, and very few residences were identified as having PFOS or PFOA levels above advisory levels.

The EPA developed the Health Advisory Program in 1978 to provide information on pollutants found to contaminate drinking water that are not regulated under the SDWA. A Health Advisory level is not a federal standard that can be legally enforced, and it may change over time as new information becomes available. On May 19, 2016, the EPA published updated drinking water Health Advisories for PFOA and PFOS.[8,9] These Health Advisories recommend a drinking water level for PFOA and PFOS that is considered safe to drink without harming a person's health even if that person were to consume water at those PFOA and/or PFOS concentrations over a lifetime. These new EPA drinking water Health Advisories for PFOA and PFOS recommend that if a person's drinking water contains levels of PFOA or PFOS or both combined above 70 ppt they do not consume the water or use it in preparing food. The EPA reports that these recommended drinking water levels should be safe for all individuals, including babies exposed during pregnancy, nursing infants, and children, even if these water levels are consumed over a person's lifetime.

Currently, the two remaining wells on Pease (Smith and Harrison wells) are still in use and being supplemented with water from the Portsmouth water system. The PFOS and PFOA levels in the Smith and Harrison wells do not exceed these updated EPA Health Advisory levels for drinking water. Additionally, the U.S. Air Force under orders from the EPA is currently designing and implementing a drinking water treatment system for Pease. NHDES, the EPA, and the Air Force are also conducting ongoing water testing to ensure the water in these wells and surrounding private wells remains safe. All results of the drinking water testing, including the initial Haven Well test results, can be found on the Portsmouth City Department of Public Works website at http://www.cityofportsmouth.com/publicworks/phwn.html.

THE NH DHHS PFC BLOOD (SERUM) TESTING PROGRAM

In response to the 2014 well water contamination identified on Pease, the New Hampshire Department of Health and Human Services (NH DHHS) held a series of community meetings to discuss community concerns and planned to offer PFC blood testing on a limited scale to assess individual and community exposure to the PFCs. An initial testing protocol was released in March of 2015; however, with increased availability of serum testing offered by the Centers for Disease Control and Prevention (CDC), the scope was expanded to include any person who worked on, lived on, or attended childcare on Pease and consumed the contaminated water or who consumed water from a contaminated private drinking well in proximity to Pease that was tested as part of the Pease Superfund Assessment after the Haven well contamination was identified. The testing program allowed for children to be tested who were potentially exposed in utero. NH DHHS worked with the Portsmouth Regional Hospital laboratory to perform the blood draws, and serum samples were initially sent to the CDC laboratory for testing.

Blood sampling began in April 2015 and continued through June 2015. By the end of June, 471 individuals had provided a blood sample for PFC serum testing. A community meeting was held on June 17, 2015, to review the first 98 adult test results. Based on the preliminary test results, the amount of three PFCs (PFOA, PFOS, and PFHxS) were found in higher than average levels when compared with the general U.S. population. Another community meeting was held on September 9, 2015, to review the 108 test results for children 11 years of age and younger from the first round of testing, which showed similar findings. These results raised concern in the community, and additional individuals requested serum PFC testing.

The NH DHHS PFC blood testing program was re-opened for a second round of sampling from August through October 2015, during which time an additional 1,107 individuals had their blood drawn. Due to the volume, no single laboratory could accommodate all the samples. As a result, NH DHHS sent serum samples to two additional laboratories. Test results for the second round of testing were returned to NH DHHS in batches, subsequently sent to participants as they were received, and the last results were mailed to participants in April 2016.

The purpose of the PFC serum testing was to provide concerned community members with more information about their level of exposure to the PFCs. Since there is not an established PFC serum level at which a health effect is known to occur, it can be difficult for an individual and their healthcare provider to use the results as a guide for medical decision making.[10] The purpose of this report is to provide a final summary and analysis of all 1,578 individuals tested through NH DHHS as part of the PFC blood testing program.

METHODS

Individuals could request testing through the NH DHHS PFC blood testing program if they had, at any time, consumed contaminated drinking water while working on, living on, or attending childcare on Pease, or if they consumed water from a contaminated private drinking well in proximity to Pease that was tested as part of the Pease Superfund Assessment and found to have levels of PFCs above the EPA's Provisional Health Advisory levels. Infants or children who were exposed in utero through their mother's consumption of contaminated drinking water at Pease were also included in the testing at the parent's discretion.

To notify affected individuals about the PFC serum testing, the Pease Development Authority was asked to send information about the blood testing program to their business and childcare centers. Press releases were also issued, social media messages were sent, many news stories were published, and individuals with affected private drinking water wells were contacted directly. Individuals interested in participating in the PFC blood testing program were asked to call a NH DHHS public inquiry line to register for testing. Once participants were enrolled, they were sent educational material about PFCs and blood testing, a consent form, and a brief questionnaire asking about basic demographic information and a few questions about time spent on Pease and their water consumption. The questionnaire also asked about individual private well PFC testing, whether or not they ever worked as a firefighter, and whether or not they had abnormal kidney function, which could affect excretion of PFCs. The testing program was not intended to be a study of health effects and the questionnaire, therefore, did not collect health-related information for the purpose of assessing health outcomes from PFC exposure.

When the individuals returned their questionnaire and consent forms, they were mailed a laboratory form and instructions on where to go to have their blood drawn. Portsmouth Regional Hospital laboratory performed all blood draws with guidance from NH DHHS. Specimens were then transported to the NH DHHS Public Health Laboratories (PHL), where the specimens were processed, de-identified, and labeled with a unique patient identification number, and shipped in batches to a testing laboratory. Results were returned to the NH DHHS PHL where they were re-connected with a person's name, and individualized reports were then created and mailed to

participants with an attached cover letter including instructions on accessing additional resources. NH DHHS worked with the Northern New England Poison Center (NNEPC) to provide individuals with a phone number they could call with any questions or concerns about their individual test results.

Serum samples were sent to one of three out-of-state testing laboratories: the Centers for Disease Control and Prevention laboratory (CDC), AXYS Analytical Laboratory (AXYS), and a California State biomonitoring laboratory (CA State). Each laboratory tested for a different number of PFCs according to each laboratory's existing testing panel, but a common set of PFCs were tested for at all three laboratories. The CDC laboratory panel included testing for nine different PFCs. AXYS tested for seven PFCs that were included in the CDC panel. The CA State laboratory tested for 12 PFCs, including the nine tested at the CDC plus three additional PFCs. A list of the PFCs tested by each laboratory is given in **Table 1**.

Table 1. PFC panel by laboratory, Pease Tradeport, Portsmouth, NH, 2015–2016

PFC Name	PFC Abbreviation	CDC	AXYS	CA State
Perfluorooctane sulfonic acid	PFOS	X	X	X
Perfluorooctanoic acid	PFOA	X	X	X
Perfluorohexane sulfonic acid	PFHxS	X	X	X
Perfluorononanoic acid	PFNA	X	X	X
Perfluorodecanoic acid	PFDeA	X	X	X
Perfluoroundecanoic acid	PFUA	X	X	X
Perfluorooctane sulfonamide	PFOSA	X	X	X
2-(N-methyl-perfluorooctane sulfonamido) acetic acid	Me-PFOSA-AcOH	X		X
2-(N-ethyl-perfluorooctane sulfonamido) acetic acid	Et-PFOSA-AcOH	X		X
Perfluorobutane sulfonic acid	PFBS			X
Perfluorododecanoic acid	PFDoA			X
Perfluoroheptanoic acid	PFHpA			X

CA=California, CDC=Centers for Disease Control and Prevention, PFC=Perfluorochemical.
"X" indicates testing for the respective PFC by laboratory.

Serum samples were not randomly distributed to the three different laboratories; rather, the testing laboratory was determined based on laboratory capacity, the order of receipt of blood samples, and the completion of a contract with NH DHHS. The CDC laboratory, for example tested all 471 individuals from the first round of sampling and the first 300 serum samples from the second round of blood sampling. The majority of serum samples in the second round of sampling were sent to AXYS, and then the remaining serum samples were sent to the CA State laboratory. The limit of detection (LOD) for each PFC varied by testing laboratory; LODs are shown in **Table 3**.

The three laboratories used a similar testing methodology which separated, identified, and measured PFCs present in the serum specimens by high pressure liquid chromatography tandem mass spectroscopy (LC/MS/MS) following solid-phase extraction. Each laboratory had an approved quality management plan that included method validation, instrument calibration, quality indicators for acceptable performance, and successful participation in an external proficiency testing program.

Information collected from the participant questionnaire, which underwent further analysis, included the following demographic and exposure information:

- Age
- Sex
- Average water consumption in cups per day ("water consumption")
- Cumulative time (years) spent working on, living on, or attending childcare on Pease ("time spent on Pease")
- Time (years) since the participant last worked on, lived on, or attended childcare on Pease ("time since last on Pease")
- Whether the participant was currently or had ever been a professional or volunteer firefighter
- Whether the participant had abnormal kidney function, which might affect PFC serum levels

"Time spent on Pease" was the length of time the participant was employed on, lived on, or attended childcare on Pease summed across all employment or childcare periods. "Time since last on Pease" was calculated as the difference between the date of questionnaire completion and the most recent end of employment, residence, or childcare date. "Water consumption" was the amount of water, on average, the individual consumed per day. If the respondent provided a range for daily water consumption, the mid-point of the range was used; all values were converted to cups.

The questionnaire also asked about private drinking wells that tested positive for PFCs, but only two individuals reported private contaminated wells, and this variable was not analyzed further. Questionnaire data were entered into an Access database. PFC serum levels were reported to the NH DHHS PHL in Excel format. Prior to analysis, the two data sources were merged, and a quality review was performed for consistency. The questionnaire data required significant corrections before analysis could occur and many variables were incomplete due to responses not being provided on the questionnaire. All questionnaire data were self-reported and not validated against any other data sources.

Three different statistical analyses were performed using the above data:

1. Calculation of summary testing statistics (i.e., geometric mean, median, confidence intervals, etc.)
2. Assessment of relationships between each individual demographic and exposure characteristics and PFC serum concentration (non-parametric analysis of variance with post-hoc testing)
3. Assessment of the relationships between demographic and exposure characteristics and PFC serum concentrations, taking into account the various relationships that may exist between the different characteristics (multivariate linear regression analysis)

For all statistical analyses, test results that were below each laboratories LOD were assigned a value equal to the laboratory's respective LOD divided by the square root of two, which is consistent with methods used in the CDC's Fourth National Report on Human Exposure to Environmental Chemicals, 2009.[11] For the summary testing statistics, medians, geometric means, quartiles, maximums, and detection frequencies for each PFC were calculated. Geometric means were used primarily in the analysis and reporting since geometric means provide a better estimate of central tendency for data that are distributed with a long tail at the upper end of the distribution (i.e., not normally distributed); this is common in the measurement of environmental chemicals in humans, including with serum PFC levels. Summary statistics were compared with 2011–2012 National Health and Nutrition Examination Survey (NHANES) data as reported in the *Fourth National Report on Human Exposure to Environmental Chemicals*, updated February 2015.[12] Non-overlapping confidence intervals were considered statistically significantly different. The proportion of individuals with serum concentrations greater than the NHANES 95th percentile was also calculated.

Summary statistics and demographic characteristics were stratified by testing laboratory and compared with one another to identify differences. The Kruskal-Wallis test (a non-parametric analysis of variance) was used to assess significance of the non-normally distributed continuous variables, and the chi-square test was used for categorical variables. The Kruskal-Wallis test was used to assess individual relationships between PFC serum concentration and age, sex, water consumption, time spent on Pease, time since last on Pease, firefighter occupation, and abnormal kidney function. Where significant relationships existed, post-hoc analyses of ranked data were performed using a Bonferroni adjustment for multiple comparisons to identify which groups were significantly different from a reference group.

Multivariate linear regression analyses were performed to assess associations between PFC serum concentrations and age, sex, water consumption, time spent on Pease, time since last on Pease, and firefighter occupation, taking into account the various potential relationships between all these variables together. Natural log transformations of PFC serum concentrations were used, and independent variables (i.e., demographic and exposure variables) were categorized to reduce

interaction effects. Final models describing the relationship between PFC serum concentrations and exposure variables were developed using a backward elimination approach that included assessment of interaction between significant variables. SAS version 9.3 (SAS Institute Inc., Cary, NC) was used to analyze data; p-values less than 0.05 were considered statistically significant.

RESULTS

A total of 1,578 individuals submitted blood samples for testing from April to October 2015; 366 (23.2%) were children aged 11 years or younger, 31 (2.0%) were aged 12–19 years, and 1,181 (74.8%) were aged 20 years or older. The majority of individuals tested (n=856, 54.3%) were female. Other exposure characteristics are outlined in **Table 2** and are discussed further below.

Out of all participants, 1,171 (74%) reported at least one place of business where they worked or attended childcare on Pease (data not shown). There were approximately 218 different places of business represented in the testing population, and out of all participants, 404 (26%) identified as working at one of five companies. Out of the 218 companies reported on the questionnaire, 193 (88%) had fewer than 10 persons who participated in the testing program.

Out of all participants, 1,540 (98%) reported their town or city of residence (data not shown). There were 150 towns/cities represented in the testing population, and out of all participants, 691 (44%) reported living in one of five towns/cities. Out of the 150 different towns/cities reported on the questionnaire, 122 (81%) had fewer than 10 individuals per town/city participate in the testing program. There were also 12 different states represented; 1,328 (84.2%) reported residing in New Hampshire, 184 (11.7%) reported residing in Maine, and 42 (2.7%) reported residing in Massachusetts.

Table 2. Characteristics of individuals who participated in the NH DHHS PFC blood testing program, Pease Tradeport, Portsmouth, NH, 2015–2016 (n=1578)

Characteristics	n	%
Age Group (years)	(median= 40)	
0-2	75	4.8
3-5	164	10.4
6-8	91	5.8
9-11	36	2.3
12-19	31	2.0
20-39	369	23.4
40-59	611	38.7
60+	201	12.7
Sex		
Male	639	40.1
Female	856	54.3
Unknown	83	5.3
Water Consumption (cups per day)	(median= 4)	
<4	572	36.3
4-7	539	34.2
8+	227	14.4
Unknown	240	15.2
Time Spent on Pease (years)	(median=6.5)	
<1	75	4.8
1-4	429	27.2
5-9	378	24.0
10-19	318	20.2
20+	88	5.6
Unknown	290	18.4
Time Since Last on Pease (years)	(median=0.0)	
<1	948	60.1
1-4	144	9.1
5-9	88	5.6
10-19	74	4.7
20+	34	2.2
Unknown	290	18.4
Firefighter (yes)	98	6.2
Abnormal Kidney Function (yes)	22	1.4

Testing Laboratory

In total, 771 samples (49%) were tested at the CDC laboratory, 700 (44%) were tested at AXYS, and 107 (7%) were tested at the CA State laboratory. Serum specimens for children 11 years of age and younger (n=366) were tested at the CDC (n=164, 44.8%), AXYS (n=201, 54.9%), and CA State (n=1, 0.2%) laboratories. The LODs for each laboratory and PFC are listed

in **Table 3.** The number and percentage of serum specimens at each laboratory that tested above the LOD are listed along with the total number of serum specimens that contained detectable levels of each PFC. Most serum specimens had detectable levels of PFOS (99.8%), PFOA (99.2%), and PFHxS (94.2%). A majority of participants also had detectable levels of PFNA (85.2%). The remaining PFCs were found in much smaller amounts.

Because serum specimens were not randomly assigned to the three different laboratories, differences in the testing population between laboratories were expected. The various demographic and exposure characteristics of the testing population were evaluated, which showed significant differences between laboratories in age, time since last on Pease, and reported work as a firefighter (**Table 4**). AXYS tested a significantly younger population, and the CA State laboratory tested a significantly older population. Individuals tested at the CDC were more recently on Pease at the time of testing compared with the other two laboratories, which likely highlights selection bias between the first round of testing, when all samples went to the CDC laboratory, and the second round of testing, when samples were split among the three laboratories. The majority of firefighters were also tested at the CDC laboratory.

Table 3. PFC limits of detection (LOD) and detection frequency by laboratory, Pease Tradeport, Portsmouth, NH, 2015–2016 (n=1578)

PFC Abbreviation	CDC (n=771)		AXYS (n=700)		CA State (n=107)		Total Above LOD n (%)
	LOD (µg/L)	Detection Frequency n (%)	LOD (µg/L)	Detection Frequency n (%)	LOD (µg/L)	Detection Frequency n (%)	
PFOS	0.1	769 (99.7)	1.0	698 (99.7)	0.144	107 (100.0)	1574 (99.8)
PFOA	0.1	770 (99.9)	0.5	689 (98.4)	0.072	107 (100.0)	1566 (99.2)
PFHxS	0.1	770 (99.9)	1.0	610 (87.1)	0.019	107 (100.0)	1487 (94.2)
PFNA	0.1	767 (99.5)	0.5	478 (68.3)	0.045	100 (93.5)	1345 (85.2)
PFDeA	0.1	617 (80.0)	0.5	22 (3.1)	0.073	25 (23.4)	664 (42.1)
PFUA	0.1	356 (46.2)	0.5	30 (4.3)	0.030	88 (82.2)	474 (30.0)
PFOSA	0.1	1 (0.1)	0.5	0 (0.0)	0.016	30 (28.0)	31 (2.0)
Me-PFOSA-AcOH	0.1	215 (27.9)	NT	NT	0.020	102 (95.3)	317 (36.1)
Et-PFOSA-AcOH	0.1	6 (0.8)	NT	NT	0.028	17 (15.9)	23 (2.6)
PFBS	NT	NT	NT	NT	0.050	20 (18.7)	20 (18.7)
PFDoA	NT	NT	NT	NT	0.115	5 (4.7)	5 (4.7)
PFHpA	NT	NT	NT	NT	0.100	1 (0.9)	1 (0.9)

CA=California, CDC=Centers for Disease Control and Prevention, LOD=Limit of detection, NT=Not tested, PFC=Perfluorochemical

Table 4. Characteristics of individuals in the Pease testing population by testing laboratory, Pease Tradeport, Portsmouth, NH, 2015–2016 (n=1578)

	CDC (n=771)			AXYS (n=700)			CA State (n=107)			p-value
	n (%)	Geo Mean (µg/L)	95% CI	n (%)	Geo Mean (µg/L)	95% CI	n (%)	Geo Mean (µg/L)	95% CI	
Age (years)	771 (100.0)	38.2	36.8-39.7	700 (100.0)	32.8	31.2-34.4	107 (100.0)	46.5	44.1-48.9	<0.0001Ŧ*
Water Consumption (cups per day)	673 (87.3)	5.0	4.7-5.3	564 (80.6)	4.6	4.3-4.8	101 (94.4)	4.5	4.0-5.0	0.1732Ŧ
Time Spent on Pease (years)	653 (84.7)	8.6	8.1-9.2	530 (75.7)	7.8	7.2-8.3	105 (98.1)	8.2	6.9-9.4	0.3477Ŧ
Time Since Last on Pease (years)	654 (84.8)	1.6	1.2-1.9	529 (75.6)	2.9	2.4-3.5	105 (98.1)	3.0	1.5-4.4	<0.0001Ŧ*
Sex (male)	313 (42.9)	n/a	n/a	273 (41.4)	n/a	n/a	53 (50.5)	n/a	n/a	0.2139¥
Firefighter (yes)	64 (8.3)	n/a	n/a	25 (3.6)	n/a	n/a	9 (8.4)	n/a	n/a	0.0005¥*

CA=California, CDC=Centers for Disease Control and Prevention, CI=Confidence Interval, Geo Mean=Geometric Mean in µg/L, N/A=Not Applicable,
Ŧ Kruskal-Wallis test.
¥ Chi-square test.
***Denotes a statistically significant p-value.**

SUMMARY PFC ANALYSIS

Table 5 shows a summary of the serum PFC test results for all individuals and comparison with levels typically found in the general U.S. adolescent and adult population (age 12 years and older) through NHANES testing. For seven PFCs (PFUA, PFOSA, Me-PFOSA-AcOH, Et-PFOSA-AcOH, PFBS, PFDoA, and PFHpA), there is no geometric mean comparison calculated in the most recent 2011–2012 NHANES data because the proportion of results below the LOD was too great to provide a valid or reliable measure. Most of these seven PFCs were detected in small amounts in the Pease population, and while a geometric mean is provided for these PFCs, the estimates become unreliable due to the large percentage of individuals who tested below the LOD, requiring these individuals' test results to be replaced with an estimated number for analysis (described above in the Methods section).

PFOS, PFOA, and PFHxS, were found at significantly higher concentrations in the Pease testing population compared with the NHANES data; the geometric means were significantly higher, and there was a greater percentage of individuals who tested above the NHANES 95th percentile than would be expected. PFNA was found in statistically lower concentrations compared with NHANES. The distribution of serum levels for these four PFCs is shown in

Figure 1, which graphs serum PFC concentration by the number of individuals tested at each level. The distribution of levels is not shown for the other PFCs because the majority were below the LOD.

Table 5. Summary of PFC serum concentrations in the Pease testing population compared with NHANES, all individuals (n=1578), Pease Tradeport, Portsmouth, NH, 2015–2016

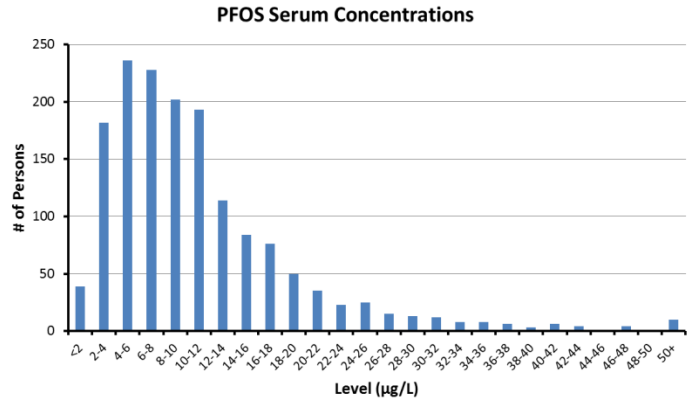
PFCs	Pease Testing Population (µg/L)						NHANES (2011-2012) Data (µg/L)			
	n	Median	Geometric Mean	95% CI	Max	Above NHANES 95th Percentile n (%)	n	Geometric Mean	95% CI	95th Percentile
PFOS	1578	8.90	8.59*	8.28-8.91	95.6	143 (9.1)	1904	6.31	5.84-6.82	21.7
PFOA	1578	3.20	3.09*	2.99-3.19	32	261 (16.5)	1904	2.08	1.95-2.22	5.68
PFHxS	1578	4.20	4.12*	3.92-4.33	116	628 (39.8)	1904	1.28	1.15-1.43	5.44
PFNA	1578	0.74	0.73¥	0.70-0.75	5.2	35 (2.2)	1904	0.88	0.80-0.97	2.54
PFDeA	1578	0.35	0.22	0.21-0.23	5.6	25 (1.6)	1904	0.20	0.18-0.22	0.69
PFUA	1578	0.30	0.19	0.18-0.19	1.6	19 (1.2)	1904	NC	NC	0.62
PFOSA	1578	0.07	0.13	0.12-0.14	0.4	N/A	1904	NC	NC	<0.1
Me-PFOSA	878	0.07	0.09	0.09-0.10	1.58	18 (2.1)	1904	NC	NC	0.69
Et-PFOSA	878	0.07	0.06	0.06-0.06	0.51	9 (1.0)	1904	NC	NC	0.11
PFBS	107	0.04	0.04	0.04-0.04	0.24	N/A	1904	NC	NC	<0.1
PFDoA	107	0.08	0.08	0.08-0.09	0.31	3 (2.8)	1904	NC	NC	0.14
PFHpA	107	0.07	0.07	0.07-0.07	0.39	NS	1904	NC	NC	0.22

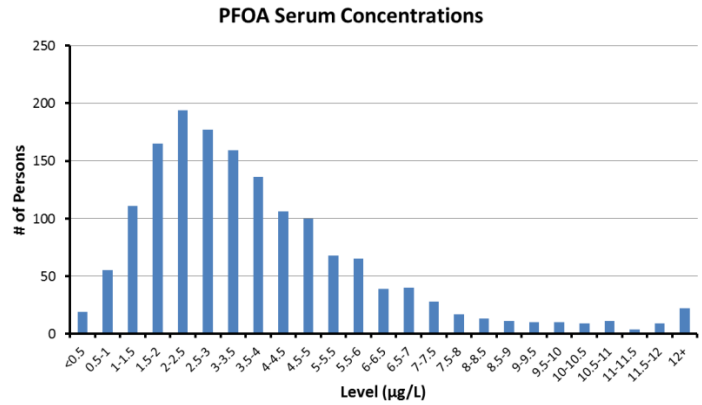
CI=confidence interval, N/A=not applicable because 95th percentile was the limit of detection, NHANES=National Health and Nutrition Examination Survey, NT=not tested, NC=not calculated, NS= not shown in order to protect confidentiality, PFC=Perfluorochemical

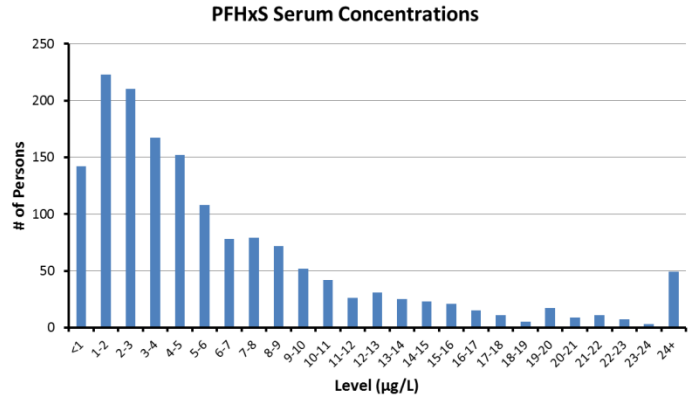
***Geometric mean is significantly higher than NHANES comparison data,**

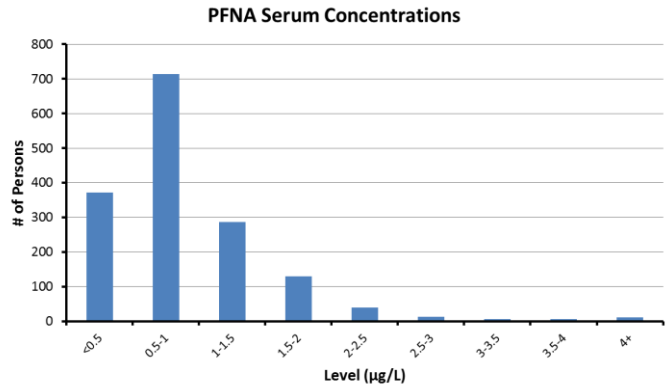
¥ Geometric mean is significantly lower than NHANES comparison data.

Figure 1. Distribution of serum PFC concentrations, Pease Tradeport, Portsmouth NH, 2015–2016









The data were separated and analyzed by age. For children (aged 11 years and younger) and adolescents and adults (aged 12 years and older), the results were similar to the combined data. **Table 6** shows a summary of the serum PFC results for all adolescents and adults aged 12 years and older. **Table 7** shows a summary of the serum PFC results for all children aged 11 years and younger. PFOS, PFOA, and PFHxS remained at significantly higher concentrations compared with NHANES in both groups (**Figure 2**). For adolescents and adults, PFNA remained significantly lower compared with NHANES, whereas for children there was no significant difference in PFNA levels compared with NHANES.

In comparing PFC levels within the Pease testing population, PFOS and PFHxs were not significantly different between children and adolescents/adults; PFOA and PFNA were both found to be slightly, but statistically, higher in children (**Figure 2**).

Table 6. Serum PFC concentrations in the Pease testing population compared to NHANES, individuals 12 years of age and older (n=1212), Pease Tradeport, Portsmouth, NH, 2015–2016

PFCs	Pease Testing Population (µg/L)						NHANES (2011–2012) Data (µg/L)			
	n	Median	Geometric Mean	95% CI	Max	Above NHANES 95th Percentile n (%)	n	Geometric Mean	95% CI	95th Percentile
PFOS	1212	9.17	8.74*	8.37-9.13	95.60	124 (10.2)	1904	6.31	5.84-6.82	21.7
PFOA	1212	3.10	2.99*	2.87-3.11	32.0	190 (15.7)	1904	2.08	1.95-2.22	5.68
PFHxS	1212	4.16	4.21*	3.98-4.46	116.0	477 (39.4)	1904	1.28	1.15-1.43	5.44
PFNA	1212	0.70	0.68¥	0.65-0.70	4.90	13 (1.1)	1904	0.88	0.80-0.97	2.54
PFDeA	1212	0.30	0.22	0.21-0.23	5.60	23 (1.9)	1904	0.20	0.18-0.22	0.69
PFUA	1212	0.30	0.19	0.18-0.20	1.60	19 (1.6)	1904	NC	NC	0.62
PFOSA	1212	0.07	0.12	0.11-0.13	0.35	N/A	1904	NC	NC	<0.1
Me-PFOSA	713	0.07	0.09	0.09-0.10	1.58	9 (1.3)	1904	NC	NC	0.69
Et-PFOSA	713	0.07	0.06	0.06-0.06	0.40	7 (1.0)	1904	NC	NC	0.11
PFBS	106	NC	NC	NC	NS	N/A	1904	NC	NC	<0.1
PFDoA	106	NC	NC	NC	NS	NS	1904	NC	NC	0.14
PFHpA	106	NC	NC	NC	NS	NS	1904	NC	NC	0.22

CI=confidence interval, N/A=not applicable because 95th percentile was the limit of detection, NHANES=National Health and Nutrition Examination Survey, NT=not tested, NC=not calculated, NS= not shown in order to protect confidentiality, PFC=Perfluorochemical

***Geometric mean is significantly higher than NHANES comparison data**

¥ Geometric mean is significantly lower than NHANES comparison data.

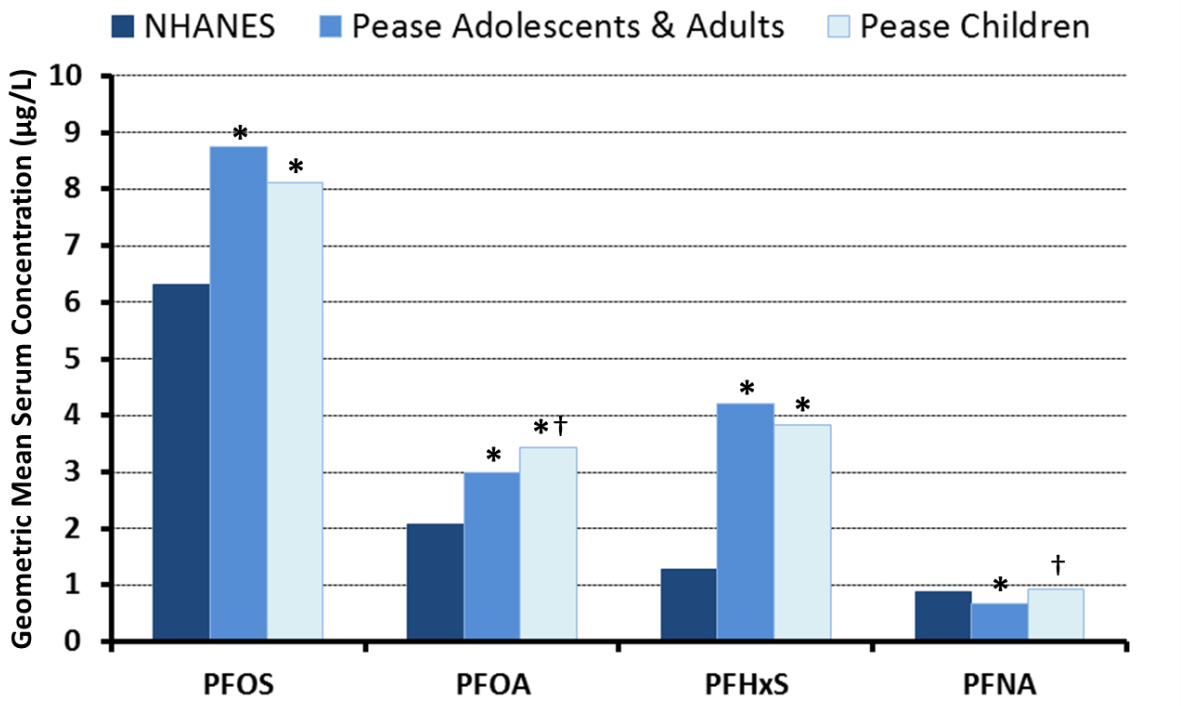
Table 7. Serum PFC concentrations in the Pease testing population compared with NHANES, children 11 years of age and younger (n=366), Pease Tradeport, Portsmouth, NH, 2015–2016

PFCs	Pease Testing Population (µg/L)						NHANES (2011–2012) Data (µg/L)			
	n	Median	Geo Mean	95% CI	Max	Above NHANES 95th Percentile n (%)	n	Geo Mean	95% CI	95th Percentile
PFOS	366	8.27	8.11*	7.59-8.67	30.80	19 (5.2)	1904	6.31	5.84-6.82	21.7
PFOA	366	3.63	3.43*	3.23-3.64	12.00	71 (19.4)	1904	2.08	1.95-2.22	5.68
PFHxS	366	4.24	3.83*	3.48-4.22	31.70	151 (41.3)	1904	1.28	1.15-1.43	5.44
PFNA	366	0.90	0.92	0.86-0.98	5.20	22 (6.0)	1904	0.88	0.80-0.97	2.54
PFDeA	366	0.35	0.23	0.22-0.25	0.70	2 (0.6)	1904	0.20	0.18-0.22	0.69
PFUA	366	0.35	0.18	0.16-0.19	0.50	0 (0.0)	1904	NC	NC	0.62
PFOSA	366	0.35	0.17	0.16-0.19	0.40	N/A	1904	NC	NC	<0.1
Me-PFOSA	165	0.07	0.10	0.09-0.12	1.30	9 (5.5)	1904	NC	NC	0.69
Et-PFOSA	165	0.07	0.07	0.07-0.07	0.51	2 (1.2)	1904	NC	NC	0.11
PFBS	1	NC	NC	NC	NS	N/A	1904	NC	NC	<0.1
PFDoA	1	NC	NC	NC	NS	NS	1904	NC	NC	0.14
PFHpA	1	NC	NC	NC	NS	NS	1904	NC	NC	0.22

CI=confidence interval, N/A=not applicable because 95th percentile was the limit of detection, NHANES=National Health and Nutrition Examination Survey, NT=not tested, NC=not calculated, NS= not shown in order to protect confidentiality, PFC=Perfluorochemical

***Geometric mean is significantly higher than NHANES comparison data,**

Figure 2. Comparison of geometric means by serum PFC concentrations, Pease Tradeport, Portsmouth, NH, 2015–2016



NHANES=National Health and Nutrition Examination Survey, 2011-2012 data
*** Indicates a statistically significant difference compared with NHANES**
† Indicates a statistically significant difference comparing Pease children with Pease adolescents and adults

DEMOGRAPHIC AND EXPOSURE ANALYSIS

Because PFOS, PFOA, and PFHxS were the only three PFCs that were found in significantly higher amounts compared with the general U.S. population, the additional analysis outlined below focuses on these three compounds. PFNA is also included in the analysis because it was detected in the majority of individual serum samples, even though it was detected in only trace quantities in the Haven well (20 ppt) and was not detected in either the Smith or Harrison wells.

Demographics: Age and Sex

The age of individuals tested showed a bimodal distribution with a peak of individuals in the 3–5 year old and 40–60 year old age ranges. For each PFC, the geometric mean levels for each age group was compared with the youngest age group (0–2 year olds), which served as a reference population for the statistical comparison (**Appendix B, Figure 3**). For both PFOS and PFHxS, there were significantly higher geometric mean levels found in the 3–5, 40–59, and 60+ year old age groups compared with the youngest age group. For PFOA, The 3–5, 40–59, and 60+ year old age groups were similar to the youngest age group; however, the 9–11, 12–19, and 20–39 year old groups all had statistically lower levels. PFNA also showed significantly lower levels in the 12–19 and 20–39 year old age groups; however, the 3–5 year olds were significantly

higher. All PFC levels declined in later childhood and adolescence before beginning to increase starting in the 20–39 year old age group (**Figure 3**).

The majority of individuals tested were female (54.3%). With PFOS, PFOA, PFHxS, and PFNA, males were found to have significantly higher geometric mean PFC serum concentrations (**Appendix B**, **Figure 4**).

Figure 3. Distribution of geometric mean serum PFC concentrations by age group and individual PFC analyte, Pease Tradeport, Portsmouth, NH, 2015–2016

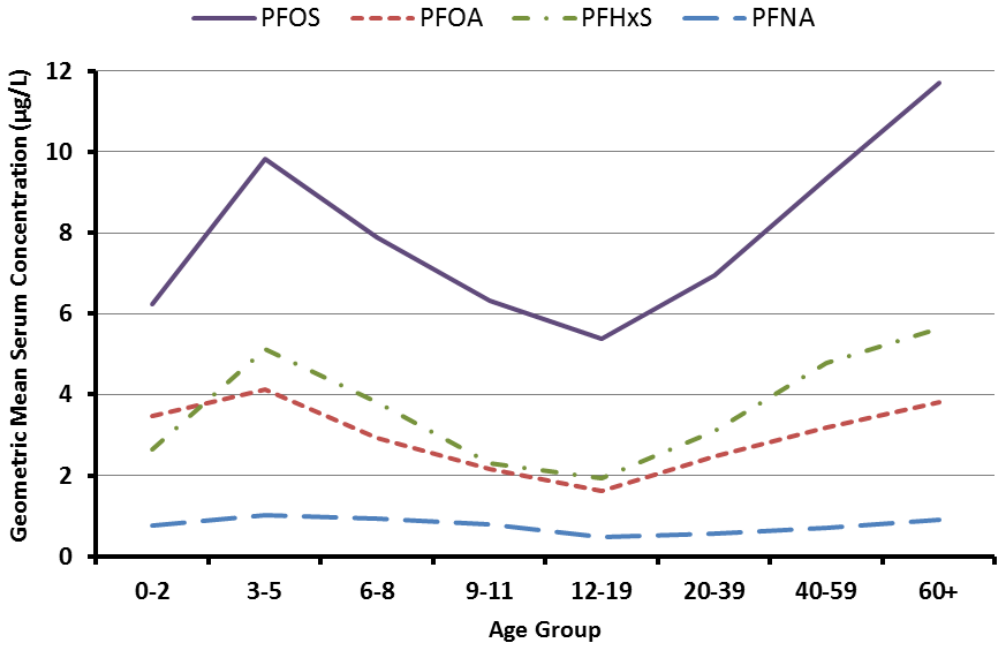
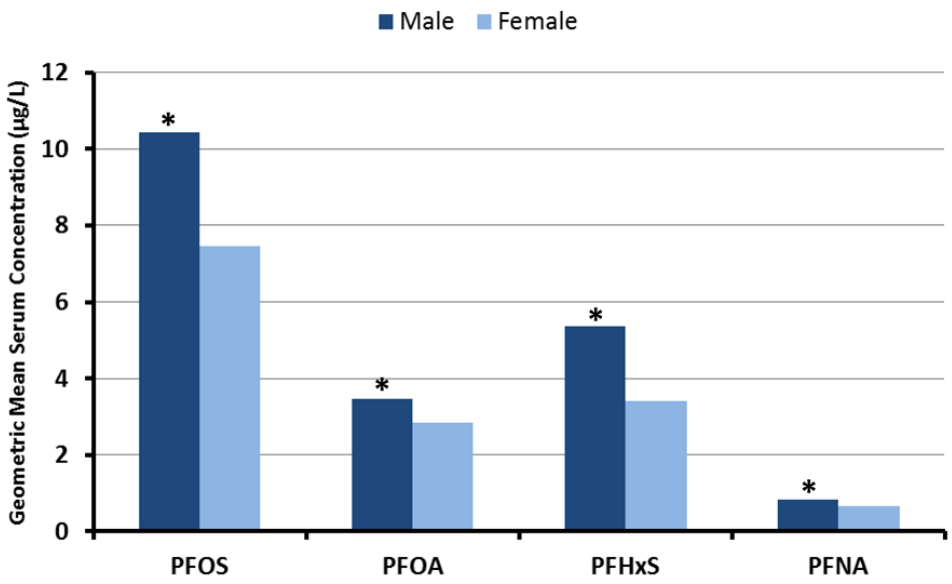


Figure 4. Geometric mean serum PFC concentrations by sex, Pease Tradeport, Portsmouth, NH, 2015–2016

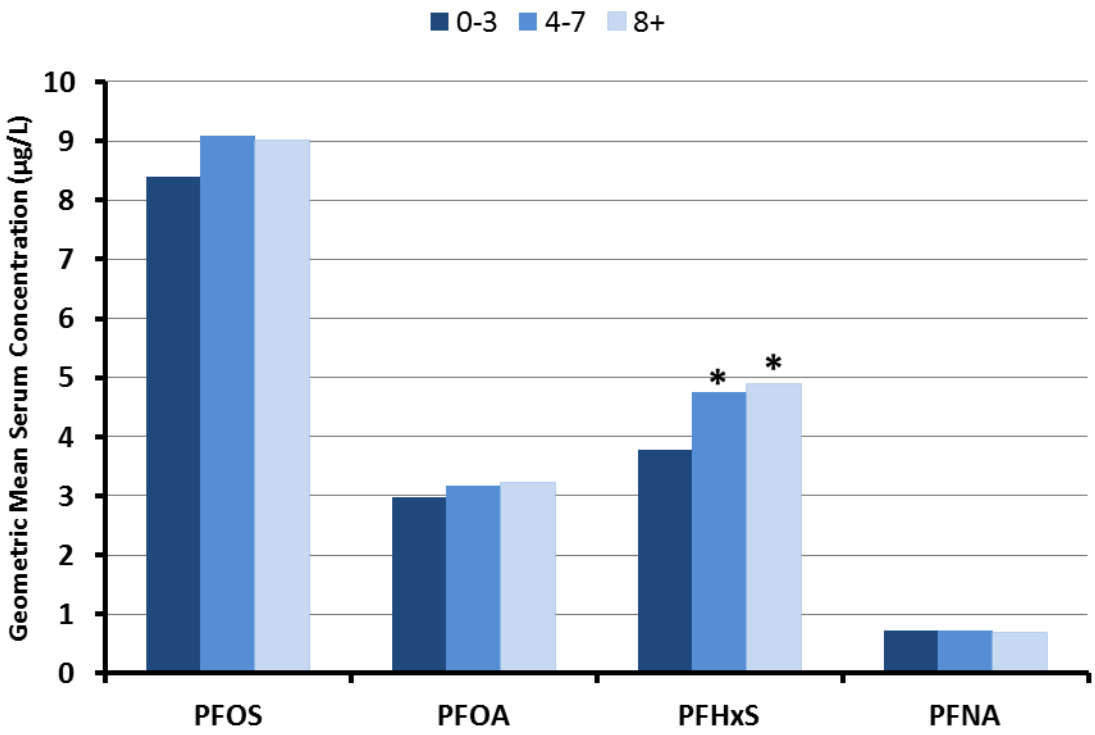


***Indicates a statistically higher concentration compared with females.**

Average Daily Water Consumption

The data collected by questionnaire about average daily water consumption on Pease required significant data correction. Many individuals (n=549, 34.8%) reported a range of average daily water consumption which required the reported range to be averaged in order to create a single analyzable number. The median water consumption was four cups per day. The majority of individuals reported drinking on average fewer than eight cups of water per day, with about a third drinking fewer than four cups per day (**Table 2**). When comparing geometric mean PFC serum levels by water consumption, the lowest water consumption group (0–3 cups per day) was used as a reference population (**Appendix B**). Out of the four PFCs, only PFHxS showed statistically higher geometric mean serum concentrations for the groups that drank 4–7 or 8+ cups of water per day on Pease, compared with those who drank only 0–3 cups per day (**Figure 5**).

Figure 5. Geometric mean serum PFC concentrations by water consumption group (cups per day), Pease Tradeport, Portsmouth, NH, 2015–2016

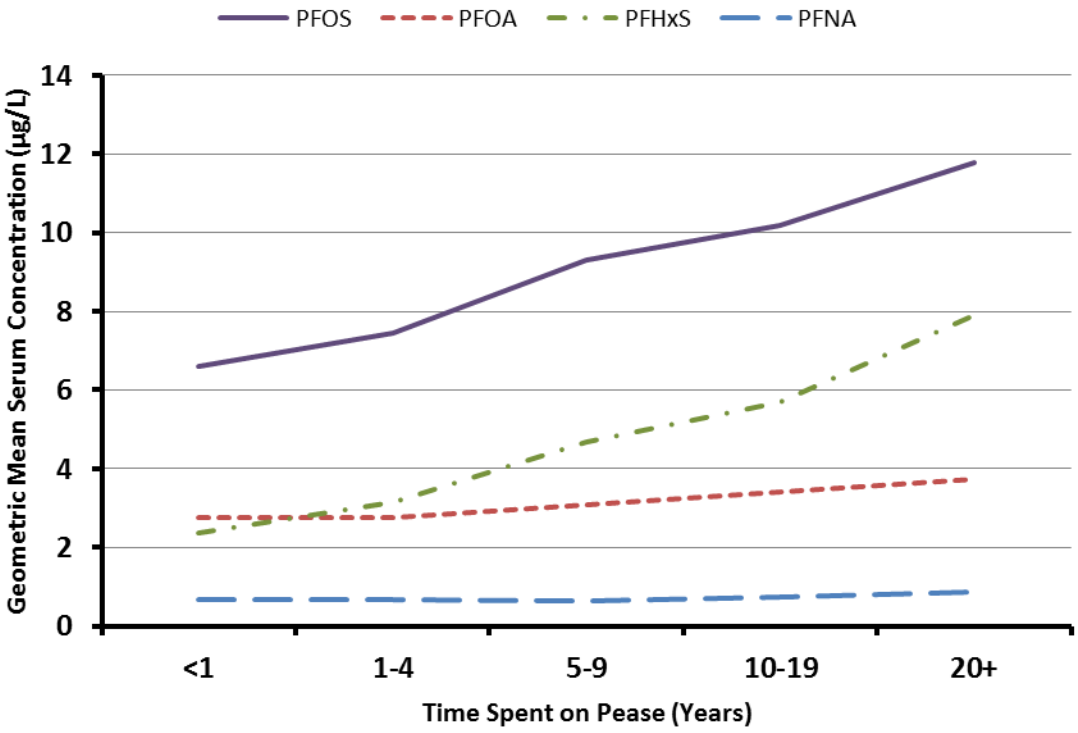


***Indicates a statistically higher concentration compared with lowest water consumption group.**

Cumulative Time Spent on Pease

More than half of individuals spent fewer than 10 years working on, living on, or attending childcare on Pease, with a median of 6.5 years (**Table 2**). When comparing geometric mean serum PFC levels by cumulative time spent on Pease, the lowest number of years spent on Pease (<1 year) was used as a reference population (**Appendix B**). PFOS, PFOA, PFHxS, and PFNA all showed significant differences in serum PFC concentration based on cumulative years spent on Pease. For PFOS, groups that spent 5–9, 10–19, or 20+ years on Pease had significantly higher geometric mean PFOS levels. For PFOA, groups that spent 10–19 or 20+ years on Pease had a significantly higher geometric mean PFOA level. For PFHxS, groups who spent 1–4, 5–9, 10–19, or 20+ years on Pease had significantly higher serum levels. For PFNA, only the group that spent 20+ years on Pease had significantly higher PFNA levels. Trends were most pronounced with PFOS and PFHxS (**Figure 6**).

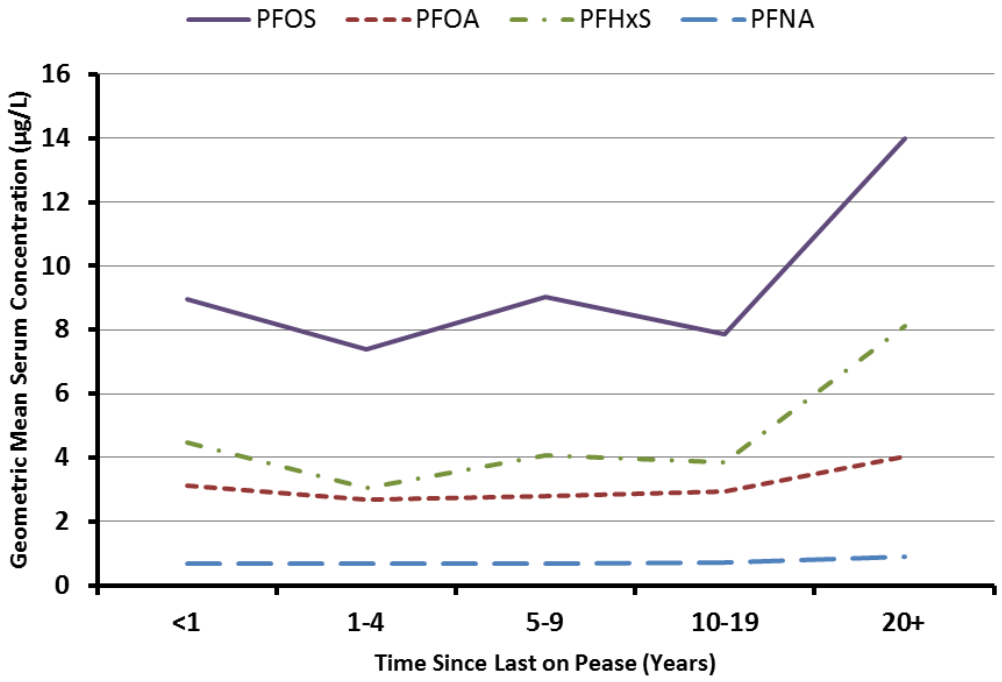
Figure 6. Geometric mean serum PFC concentrations by time spent on Pease and PFC analyte, Pease Tradeport, Portsmouth, NH, 2015–2016



Time Since Last on Pease

The majority of individuals (60%) who participated in the blood testing program reported currently or recently (within the last year) working on Pease at the time of the blood sampling (**Table 2**). Longer times off Pease could equate to lower PFC levels, depending on the level of initial exposure and whether the main source of a person's exposure was on Pease. When comparing geometric mean PFC serum concentrations by time since last on Pease, the greatest number of years since last on Pease (20+) was used as a reference population (**Appendix B**). All groups that had been on Pease within the past 20 years had significantly lower levels of PFOS and PFHxS compared with the group that had been away from Pease for 20+ years, although the sample size was small for the 20+ years group. There was a similar trend for PFOA and PFNA, although for PFOA, only those groups that had been on Pease 1–4 or 5–9 years prior had significantly lower PFOA levels. For PFNA, only those groups that had been on Pease <1, 1–4, and 5–9 years prior had significantly lower PFNA levels. Trends are shown in **Figure 7**.

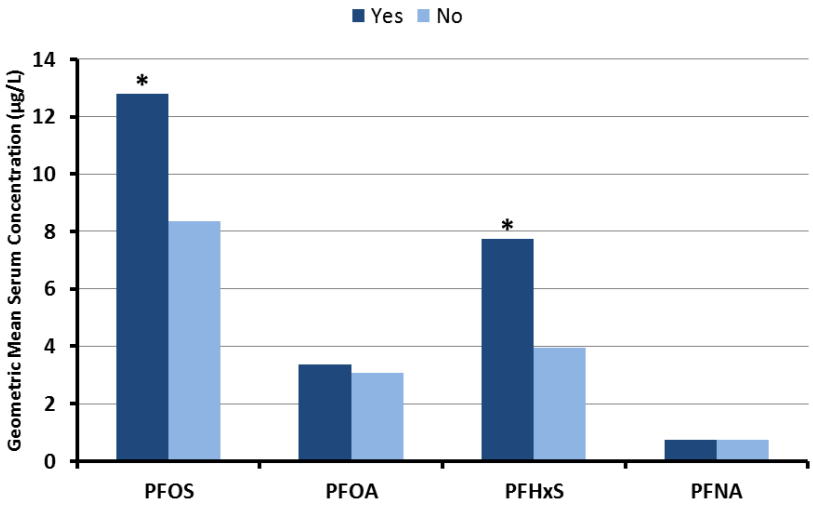
Figure 7. Geometric mean serum PFC concentrations by time since last on Pease and PFC analyte, Pease Tradeport, Portsmouth, NH, 2015–2016



Firefighter

Ninety-eight individuals (6%) reported current or past work as a firefighter (**Table 2**). Firefighters were found to have significantly higher geometric mean PFOS and PFHxS serum concentrations compared with those who did not indicate working as a firefighter (**Appendix B**, **Figure 8**). Levels of PFOA and PFNA did not show any significant differences.

Figure 8. Geometric mean serum PFC concentrations by reported past or current work as a firefighter ("yes" on questionnaire), Pease Tradeport, Portsmouth, NH, 2015–2016

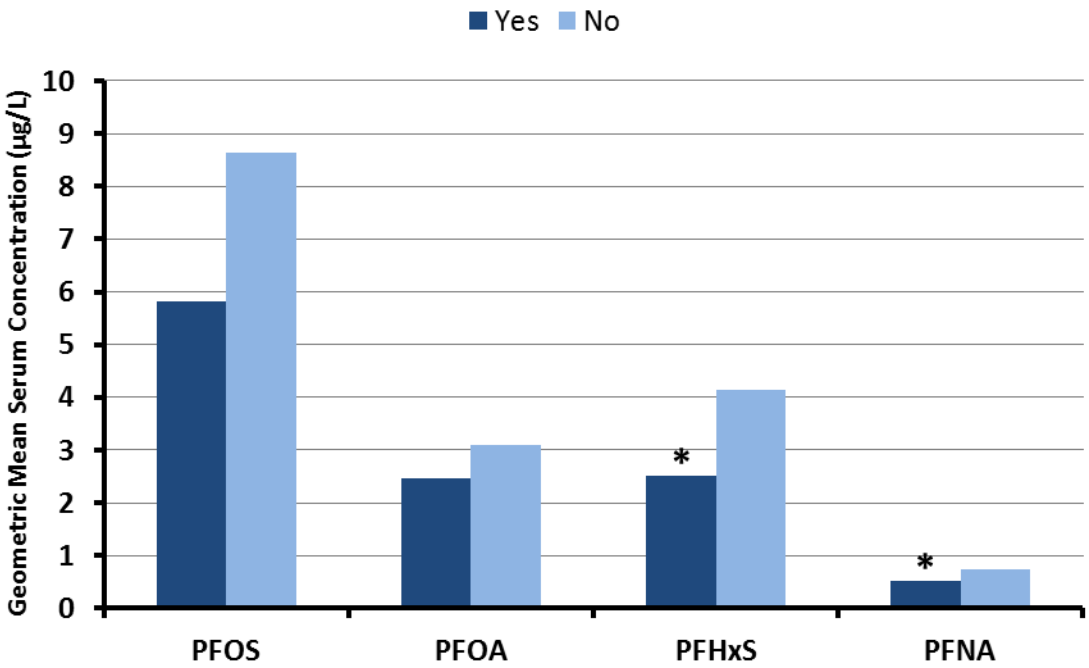


***Indicates a statistically higher concentration in firefighters compared with those who did not report firefighting work.**

Abnormal Kidney Function

Only 22 individuals (1%) reported having abnormal kidney function (**Table 2**). This question was asked in order to assess whether impairment of kidney function (impaired excretion) might affect PFC levels and lead to higher serum concentrations. Individuals who reported having abnormal kidney function were found to have significantly lower geometric mean serum concentrations for PFHxS and PFNA and borderline significantly lower geometric mean serum concentration for PFOS compared with those who did not report abnormal kidney function (**Appendix B, Figure 9**). The reason for this finding is unclear.

Figure 9. Geometric mean serum PFC concentrations for those who reported abnormal kidney function ("yes") compared with those who did not report abnormal kidney function ("no"), Pease Tradeport, Portsmouth, NH, 2015–2016



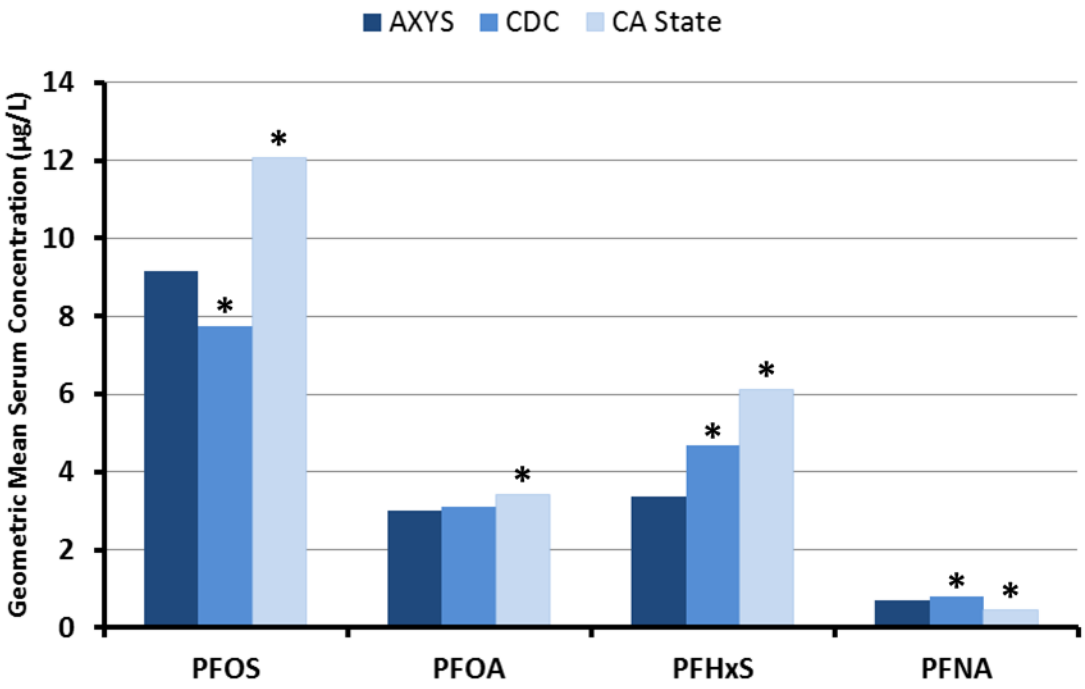
***Indicates a statistically lower concentration in those who reported abnormal kidney function compared with those who did not report abnormal kidney function.**

Analytical Testing

The CDC, AXYS and CA State laboratories used the same testing methodology, although each had a different limit of detection (LOD). Using AXYS as a reference, the geometric mean PFC levels among laboratories was compared (**Appendix B**). The CDC laboratory showed significantly lower levels of PFOS, and significantly higher levels of PFHxS and PFNA compared with AXYS; PFOA levels were no different. The CA State laboratory showed significantly higher levels of PFOS, PFOA, and PFHxS, but significantly lower levels of PFNA compared with AXYS. A single pattern across all PFCs was not identified (**Figure 10**). As a sensitivity analysis, the same LOD was applied to all the laboratories, and the analysis was

repeated with the same results (data not shown). Differences in demographic and exposure characteristics were found among the laboratories (**Table 4**), likely accounting for the differences in geometric mean PFC levels among laboratories.

Figure 10. Geometric mean serum PFC concentrations by laboratory, Pease Tradeport, Portsmouth, NH, 2015–2016



***Indicates a statistically different geometric mean serum concentration compared with AXYS laboratory.**

Multivariate Linear Regression Analysis

While significant differences were found in the analyses above among the multiple demographic and exposure characteristics and the various serum PFC levels, each of these analyses only evaluate one characteristic, or variable, at a time. Sometimes multiple characteristics can interact or have an effect, or one characteristic might appear to have an effect on PFC serum level when another variable not taken into consideration is actually causing the effect. Because multiple demographic and exposure characteristics can influence a person's PFC level, it can be difficult to know which characteristics truly are associated with serum PFC levels, or have more of an effect on serum PFC levels, without performing an analysis that takes into account all factors simultaneously. This type of analysis is called a multivariate (or multiple variable) analysis. Linear regression refers to a type of statistical analysis that attempts to model and find a linear relationship, or pattern, among the various characteristics and serum PFC levels.

In the multivariate linear regression analysis, the following variables were factored in for simultaneous analysis: age, sex, average daily water consumption, cumulative time spent on

Pease, time since last on Pease, and whether or not an individual reported working as a firefighter. Abnormal kidney function was not included in this analysis because of the very low numbers. As mentioned in the Methods section, the PFC levels were log-transformed for the analysis, but the exposure and demographic variables were grouped and analyzed as categories (i.e., ordinal data). For each PFC, the regression analysis was run with all the above mentioned variables included, and then a simplified model was run with only those significant variables identified in the first analysis. On some analyses, there was a significant "interaction" found among different characteristics. An "interaction" is a statistical term meaning that the relationship between one variable and PFC level is different depending on the value of another variable. For example, the relationship between sex and PFC level may be different in one age group versus another age group. With the PFCs for which a significant interaction was found, the analysis was stratified by one of those characteristics to eliminate the interaction. This occurred for the PFOA and PFHxS analysis, which required the analysis to be stratified by age categories. The results of this multivariate regression analysis are found in **Appendix C**, but are summarized here.

In the multivariate linear regression analysis for PFOS, age, sex, and time on Pease were significantly associated with PFOS serum concentrations. For PFNA, only sex was found to be significantly associated with PFNA level. PFOA was stratified by age group due to an interaction with age and another variable. When stratified by age, no characteristics were found to be significantly associated with serum PFOA concentrations for the 0–19 and 60+ age groups, but sex and time spent on Pease both showed a significant association for the 20–39 and 40–59 year old age groups. PFHxS was also stratified by age due to a significant interaction: for the 0–19 age group, average daily water consumption and time since last on Pease showed a significant association with PFHxS level; for the 20–39 year old age group, sex, average daily water consumption, time spent on Pease, and time since last on Pease all showed a significant association with PFHxS serum levels; for the 40–59 year old age group, sex, average daily water consumption, and time spent on Pease were significantly associated; and for the 60+ age group, only time spent on Pease was significantly associated with PFHxS serum levels. More details, including the estimated marginal effect of each of these statistically significant associations, can be found in the tables in **Appendix C**.

DISCUSSION

There was a significant interest in serum PFC testing after identification of contaminated drinking water on the Pease Tradeport in Portsmouth, New Hampshire. Ultimately, 1,578 individuals had their blood tested for PFCs. The testing population included 366 children (23%) aged 11 years or younger. Overall, more than 94% of individuals who participated in the NH DHHS PFC blood testing program were found to have PFOS, PFOA, and PFHxS detectable in their serum, which is consistent with other studies of children, adolescents, and adults tested for

PFCs.[13-16] PFNA was also detected in 85% of serum samples submitted during the Pease testing, which is also one of the more commonly found PFCs in the general U.S. population. The other PFCs were found in much lower quantities.

In the Pease population, PFOS, PFOA, and PFHxS were found in significantly higher amounts compared with the general U.S. adolescent and adult population as tested by NHANES in 2011–2012. These three PFCs were also found in higher levels in the contaminated Haven well on Pease. Typically, PFOS levels in the general U.S. population are 3–10 times higher than PFOA.[13-15,17] The results from the Pease testing show similar trends, with the geometric mean serum PFOS level approximately three times higher compared with the geometric mean serum PFOA level. Normally PFHxS is found at lower levels than either PFOS or PFOA,[13-15] but the results from the Pease testing show that the geometric mean PFHxS level is higher than PFOA and lower than PFOS. Comparing Pease adolescents and adults (age 12 and older) with Pease children (age 11 and younger), serum levels of PFOS and PFHxS were not found to be significantly different. Serum levels of PFOA did show slight but significantly higher mean levels in children compared with adolescents and adults.

Despite finding significantly higher levels of PFOS, PFOA, and PFHxS when compared with the most recent NHANES data, when evaluated against other populations (**Appendix A**), the average serum PFOS and PFOA levels in the Pease testing population are similar, if not lower, than levels found in the general U.S. population without a known exposure tested through NHANES a decade ago in 2005–2006. Levels of PFHxS are higher than the general U.S. population, even compared with 2005–2006 NHANES data. The mean levels of all three PFCs are substantially lower than those found in other occupationally and environmentally exposed populations. **Appendix A** shows graphs of mean serum PFC levels by testing population comparing the Pease population with the general U.S. population, environmentally exposed communities, and occupationally exposed workers.

Demographic Characteristics and PFC Concentrations

When evaluating differences in demographic factors by PFC levels, males were found to have higher geometric mean serum levels of PFOS, PFOA, PFHxS, and PFNA compared with females. This finding is consistent with other U.S. studies of PFC levels and may represent differences in exposure between the sexes.[13–18] There were also significant differences in PFC levels by age found in the Pease testing population, although the different PFCs showed mixed patterns related to age and PFC concentration. The two PFCs that were found in the highest levels in the Haven Well (PFOS and PFHxS) were found to be in significantly higher concentrations in the 3–5 and 40+ year old age groups compared with the youngest age group. PFOA was also found elevated in the Haven well, but showed a reverse pattern; the older children, adolescents, and young adults (aged 9–39 year olds) showed statistically lower PFOA levels, whereas the other age groups were similar when compared with the youngest age group.

PFNA, which was not detected in significant quantities in any of the Pease drinking wells, showed a mixed pattern with elevated levels in the 3–5 year old age group, similar to PFOS and PFHxS, but lower levels in the adolescents and young adults (12–39 year olds), similar to PFOA. With all PFCs, the levels declined in late childhood and adolescence, but then increased after age 20.

Studies of the general U.S. adolescent and adult population have shown conflicting results when assessing differences in PFC levels by age. Some studies have found no difference in PFC levels by age,[14,15] but a more recent study found significant increases in PFOS, PFOA, and PFNA with increasing age.[13] Studies of children have also shown conflicting results.[16,18] The differences likely illustrate the complex pattern of age, behavior, and PFC exposure. Children, for example, exhibit more frequent hand-to-mouth behavior at younger, ages which is a known factor for chemical exposures, including PFCs.[19,20] The elevation of PFC levels in the 3–5 year old age group at Pease may represent not only exposure from contaminated drinking water but also hand-to-mouth exposure in toddlers and children, which is considered to be a significant source of PFC exposure.[19] The fact that PFNA levels are also significantly higher in this 3–5 year old age group also supports the idea that behavioral factors and other sources of exposure are likely contributing to differences seen among age groups, since PFNA was not found in significant quantities in any of the drinking water on Pease.

Exposure Characteristics and PFC Concentrations

When evaluating differences in exposure characteristics compared with PFC levels, several relationships were found. With average daily water consumption, serum PFHxS levels were found to be significantly higher with greater daily water consumption. PFOS trended towards higher levels with more water consumption, but it did not reach statistical significance. The data collected by questionnaire about daily water consumption on Pease, however, were likely not of sufficient quality or precision to capture effects of changes in water consumption on PFC levels.

There were clearer trends, however, between increasing geometric mean serum PFOS, PFOA, and PFHxS levels and increasing time spent on Pease. PFOS, PFOA, and PFHxS all showed clear linear trends for increased PFC levels when more time was spent on Pease. This trend was most pronounced with PFOS and PFHxS, which have longer half-lives and were found in higher levels on Pease. For PFNA, only those who spent more than 20 years on Pease had significantly higher PFNA levels compared with those who spent less than one year; however, this may be confounded by other factors, such as age.

When evaluating the time since last on Pease, longer times off Pease were expected to equate to lower serum PFC levels. For all PFCs, however, those who had been away from Pease for 20+ years had higher serum concentrations. This trend was most pronounced for PFOS and PFHxS. The reason for this is unclear, but likely is explained by other unaccounted for factors, such as

age. This exposure variable fell out of most of the multivariate linear regression models as not significant when factoring in other demographic and exposure characteristics.

There were a total of 98 individuals (6%) who reported current or past work as a firefighter. Firefighters were found to have significantly higher geometric mean PFOS and PFHxS serum concentrations compared with those who did not indicate working as a firefighter, but the levels of PFOA and PFNA did not show any significant differences among the groups. While it is plausible that firefighters could have higher PFC levels due to more exposure to chemicals through their work, being a firefighter also fell out of the multivariate regression as a non-significant factor in predicting serum PFC concentrations either due to the very small numbers, or because other characteristics (i.e., age, sex, time spent on Pease) explain the differences in levels seen between those who identified as firefighters and those who did not.

When factoring variables into the multivariate linear regression model, the demographic or exposure characteristics most likely to contribute to changes in PFC levels among individuals were included. The regression model included the variables age, sex, daily water consumption, time spent on Pease, time since last on Pease, and firefighter occupation. The model assessed for significant associations among serum levels of each PFC and characteristics when taking into account all variables simultaneously. As previously mentioned, firefighter occupation and time since last on Pease fell out of most models as non-significant contributors to PFC levels. Daily water consumption also fell out of most models as a non-significant contributor to PFC levels, with the exception of PFHxS, when stratified by age group.

Age, sex, and time spent on Pease appeared to be more consistently associated with PFC level, especially for PFOS, PFOA, and PFHxS, although inconsistencies still exist among PFCs. Quantitative assessments of the associations can be found in **Appendix C**. Male sex appears to be most highly associated with PFOS, PFOA (certain age groups), PFHxS (certain age groups), and PFNA. Age also appeared to be significantly associated with PFC levels, although a quantitative analysis was unable to be performed analyzing the relationship between age and PFOA or PFHxS levels due to the need to stratify by age with these PFCs; age was not significantly associated with PFNA levels. Finally, time spent on Pease was found to be associated with PFOS, PFOA, and PFHxS levels.

In summary, the Pease serum PFC test results likely represent exposure from multiple sources, including drinking water contamination on Pease. Age may play a significant role in exposure because childhood behaviors can pre-dispose to PFC exposure, including hand-to-mouth behavior, which is most prominent in younger children and decreases with age.[19,20] Additionally, certain PFCs, such as PFOS and PFOA, have been phased out of use over the last 10–15 years, making childhood exposure to these specific PFCs in the home and work environments less likely.[21] Children, therefore, may have lower levels of these PFCs compared

with adults based on the fact that their lifetime exposure is likely lower. Other sources of exposure aside from the contaminated water at Pease should also be considered.

Differences Among Testing Laboratories

Due to the demand for serum PFC testing, no single laboratory could accommodate all the testing in a timely manner. The CDC laboratory performed testing on the first 771 serum samples submitted (471 from the first round and 300 from the second round of testing). The majority of the remaining serum specimens were sent to AXYS Analytical Laboratory (n=700), and the remainder were sent to the California State biomonitoring (CA State) laboratory (n=107). Testing of pediatric serum samples was prioritized to the CDC and AXYS laboratories. Because serum specimens were not randomly distributed, differences were expected to be found when comparing PFC levels by laboratory. Geometric mean serum levels were found to be different among the laboratories, but there was no pattern identified where a single laboratory consistently tested either higher or lower across the different PFCs compared with the other laboratories.

When comparing demographic and exposure characteristics among the three different laboratories, there were significant differences in the populations tested at the different laboratories. Individuals tested at AXYS were significantly younger, and individuals tested at the CA State laboratory were significantly older. Additionally, individuals tested at the CDC laboratory were more recently on Pease at the time of testing compared with the other two laboratories, which likely highlights a selection bias between the first round of testing, when all samples went to the CDC laboratory, and the second round of testing, when samples were split among the three laboratories. The majority of firefighters were also tested at the CDC laboratory. Differences in serum PFC levels among testing laboratories likely is due largely to differences in the population tested at each laboratory.

All laboratories used similar methodology (liquid chromatography/tandem mass spectrometry). The CA State laboratory also used the same process developed by the CDC. Each of the laboratories had a quality management plan which enabled them to appropriately analyze human clinical specimens (serum) for PFCs. This included validation of their testing method, quality control testing with each batch of specimens to ensure the instrument and laboratory scientist were detecting accurate serum concentrations, and successful participation in an external proficiency testing program. All three laboratories participated and performed well in the same external proficiency testing program, the Arctic Monitoring and Assessment Program (AMAP), administered by the Centre de Toxicologie du Quebec. Participating laboratories receive proficiency test challenges three times per year, consisting of three serum samples of unknown composition and concentration. Since all laboratories have performed well on these external proficiency challenges, it is an indicator of laboratory proficiency and data comparability. With these quality control processes, the different laboratories are able to reliably detect accurate concentrations of PFCs.

CONCLUSION

This report summarizes the final results from the Pease PFC blood testing program conducted by the NH DHHS in response to community concerns about exposure to contaminated drinking water which contained elevated levels of PFOS, PFOA, and PFHxS. Serum levels of PFOS, PFOA, and PFHxS were found at higher levels in the Pease population compared with the general U.S. adolescent and adult population, but the absolute difference in the mean PFC levels is small, and on a population level these small changes have unclear health implications. The levels of PFOA and PFOS, however, were more consistent with national average levels found a decade ago, and levels of these three PFCs are still well below what has been found in other environmentally contaminated communities and occupationally exposed workers (**Appendix A**). There are individuals who tested significantly higher than the national average, or who were above the NHANES 95th percentile. The long-term health implications of PFC exposure, however, are not fully understood, and individuals concerned about their health should discuss these concerns with their healthcare provider.

Additionally, while age, male sex, and cumulative number of years spent on Pease were found to be most strongly associated with increased serum PFC levels, it should be noted that the serum testing for PFCs represents exposure from all sources, including other exposures on or off Pease and in the home environments. Therefore, there are likely other significant sources of PFCs a person is exposed to that were not evaluated in this report.

Finally, the Pease PFC blood testing program was not intended to be a health effects study, and health-related information was not collected for the purpose of assessing health outcomes from PFC exposure. While a variety of health effects are currently being studied related to PFC exposure, the long-term health impact is still unclear, and it is unknown what an individual's risk may be for developing health problems after exposure; there is currently no serum PFC level of concern at which health effects are expected to occur.[10] However, the CDC's Agency for Toxic Substances Disease Registry (ATSDR) is helping to address the Pease community's health concerns and has formed a Community Assistance Panel (CAP) to help plan for possible future health evaluation. NH DHHS will continue to work with ATSDR and review the latest science and recommendations related to PFC exposure to provide new information to the Pease community as it becomes available.

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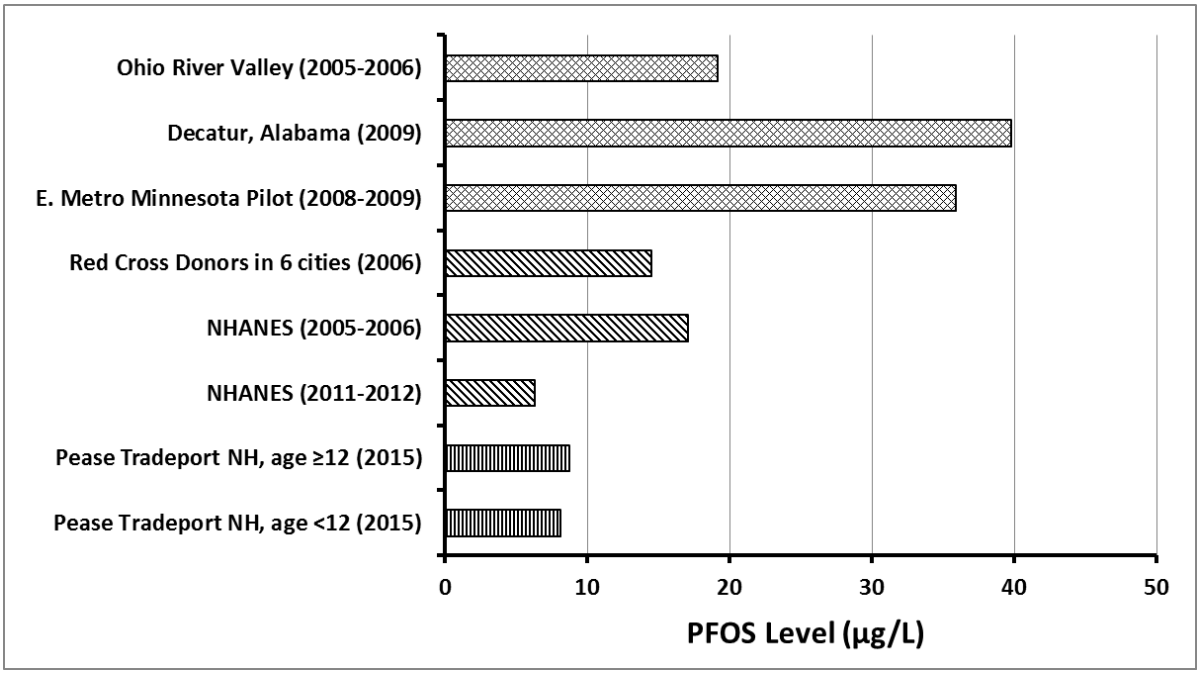
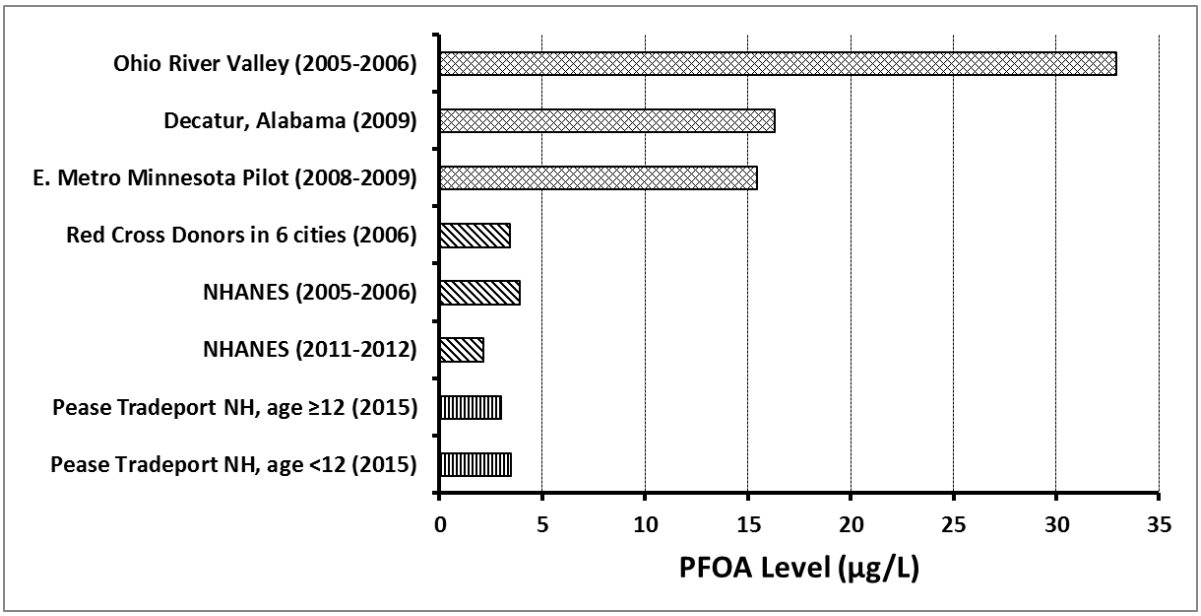
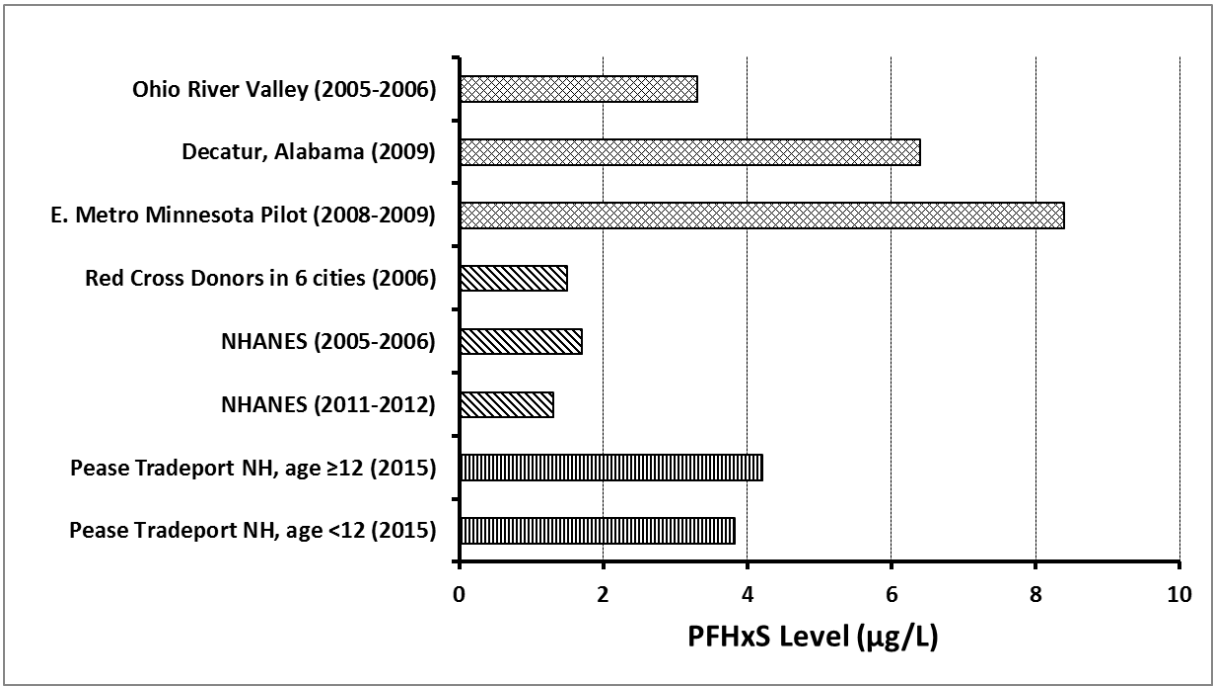
APPENDIX A
Comparison of Geometric Mean (Unless Otherwise Noted*) PFC Serum Levels Among Populations

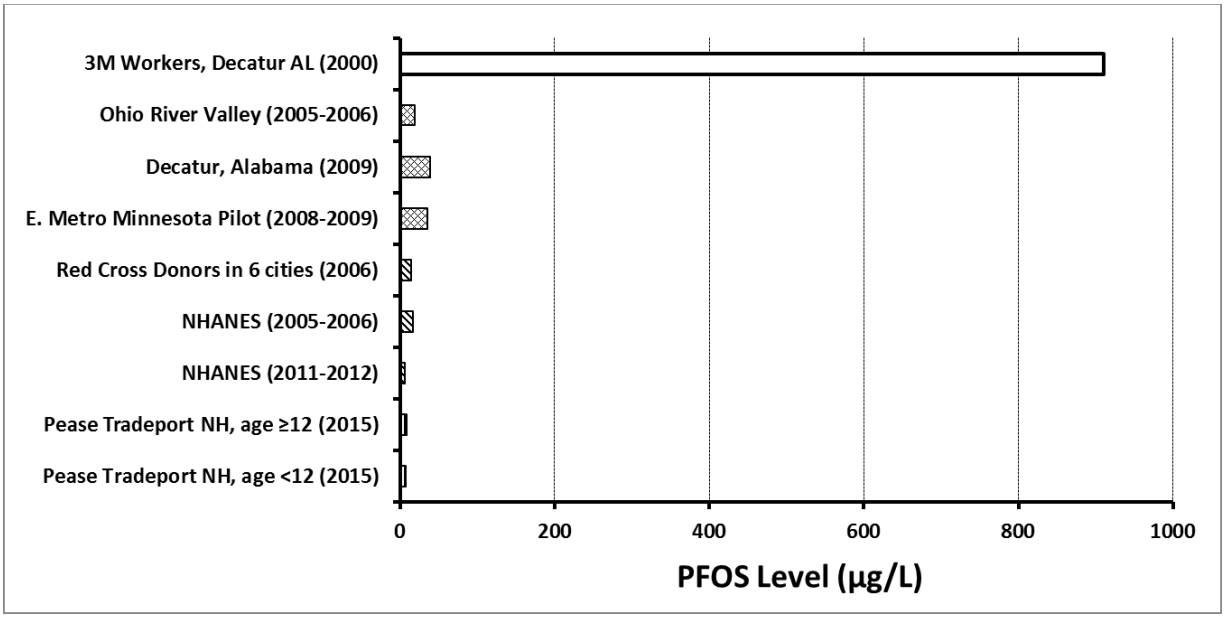
The following three graphs compare average levels of PFOS, PFOA, and PFHxS found in the Pease community (vertical line pattern) with other tested populations that represent the general U.S. population with no known PFC exposure (diagonal line pattern) or environmentally exposed U.S. communities (diamond pattern).

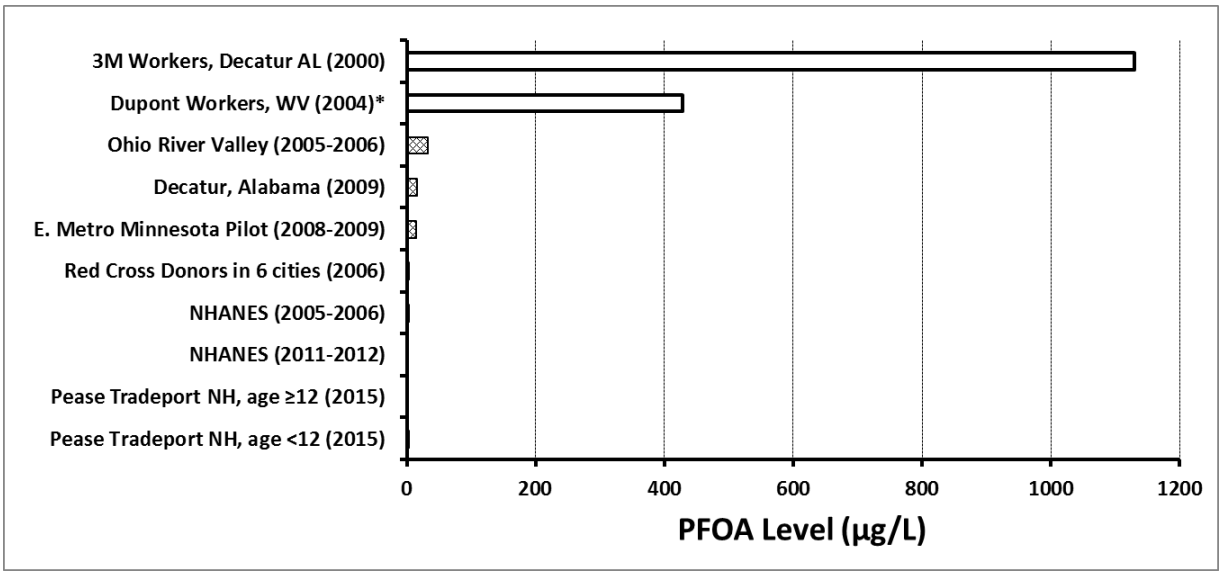


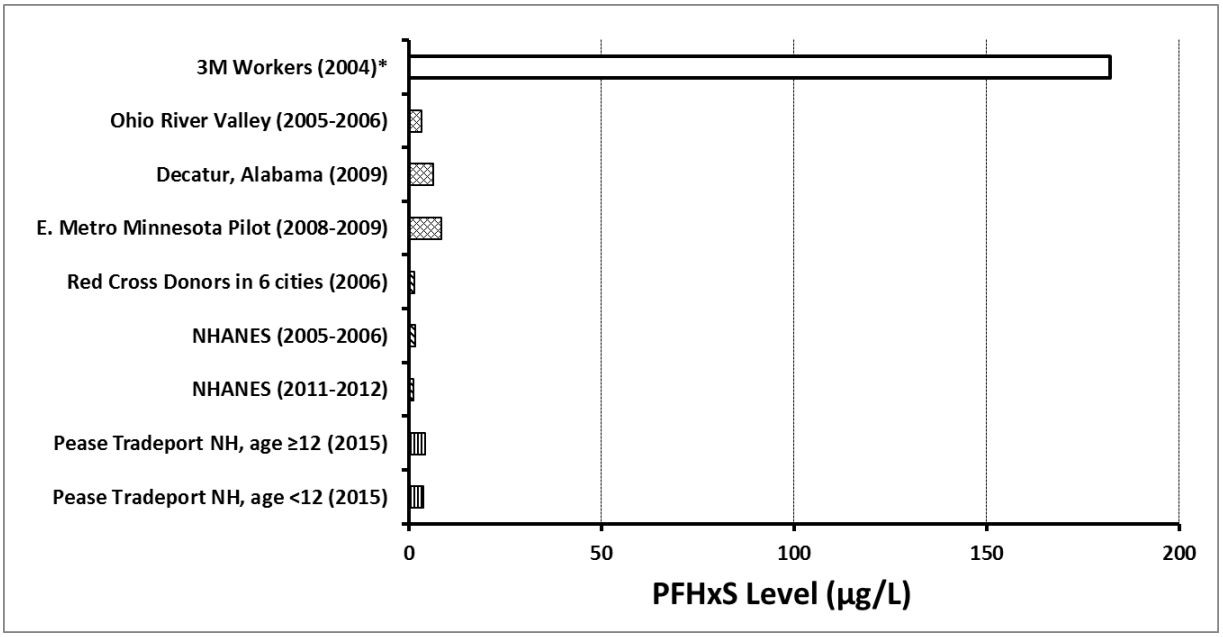




The following three graphs again compare average levels of PFOS, PFOA, and PFHxS found in the Pease community (vertical line pattern) with other tested populations including the general U.S. population with no known PFC exposure (diagonal line pattern) and environmentally exposed U.S. communities (diamond pattern). They also include comparison with average levels found in chemical plant workers (no pattern), where individuals are exposed to much higher levels of PFCs in occupation settings.







***Indicates arithmetic mean is reported instead of geometric mean. Arithmetic mean is usually higher than the geometric mean**

References:

Study Population	Years Blood Tested	# Participants	Reference
3M workers	2000	263	Olsen GW, et al. Epidemiologic assessment of worker serum perfluorooctanesulfonate (PFOS) and perfluorooctanoate (PFOA) concentrations and medical surveillance examinations. J Occup Environ Med. 2003;45(3):260-270.
3M workers*	2004	26	Olsen GW, et al. Half-life of serum elimination of perfluorooctanesulfonate,perfluorohexanesulfonate, and perfluorooctanoate in retired fluorochemical production workers. Environ Health Perspect. 2007;115(9):1298-1305.
Dupont workers*	2004	1025	Sakr CJ, et al. Cross-sectional study of lipids and liver enzymes related to a serum biomarker of exposure (ammonium perfluorooctanoate or APFO) as part of a general health survey in a cohort of occupationally exposed workers. J Occup Environ Med. Oct 2007;49(10):1086-1096.
Ohio River Valley	2005-2006	69,030	Frisbee et al. The C8 Health Project: Design, methods, and participants. Env Health Persp 2009;117(12):1873-82.
Decatur, Alabama	2009	153	ATSDR. Exposure Investigation Report: PFC serum sampling in the vicinity of Decatur, AL Morgan, Lawrence, and Limestone Counties. Apr 2013. Accessed at: http://www.atsdr.cdc.gov/HAC/pha/Decatur/Perfluorochemical_Serum%20
East Metro Minnesota pilot	2008-2009	196	Minnesota Dept of Health. East Metro PFC biomonitoring pilot project. Jul 2009. Accessed at: http://www.health.state.mn.us/divs/hpcd/tracking/biomonitoring/projects/pfcfinalrpt2009.pdf
Red Cross donors	2006	600	Olsen GW, et al. Decline in PFOS and other PFCs in American Red Cross adult blood donors, 2000-2006. Enciron Sci Technol. 2008;42:4989-4995.
NHANES	2005-2006 2011-2012	2120 1904	CDC. Fourth National report on human exposure to environmental chemicals. Feb 2015. Accessed at: http://www.cdc.gov/exposurereport/

***Reports on arithmetic mean instead of geometric mean**

APPENDIX B
Comparison of Demographic and Exposure Characteristics with PFOS, PFOA, PFHxS, and PFNA Serum Levels

Association between characteristics of the Pease testing population and serum PFOS concentrations (µg/L), Pease Tradeport, Portsmouth, NH, 2015–2016

Characteristics	PFOS							
	n	Median	Geometric Mean	25% Quartile 1	75% Quartile 3	Max	p-value ₸	Post-Hoc Multiple Comparison Testing¥
Age Group	(median= 40)						<0.0001	
0-2	75	6.47	6.25	3.50	10.40	28.50		ref
3-5	164	10.10	9.81	7.00	14.75	30.80		<0.0001
6-8	91	8.00	7.89	5.50	12.90	29.30		0.3406
9-11	36	6.13	6.31	4.95	8.73	11.50		1.0000
12-19	31	5.20	5.39	4.20	7.38	18.10		1.0000
20-39	369	7.18	6.94	4.40	11.20	43.70		1.0000
40-59	611	9.77	9.35	5.88	15.30	95.60		<0.0001
60+	201	11.20	11.72	8.10	17.40	62.30		<0.0001
Sex (n=1495)							<0.0001	N/A
Female	856	7.70	7.46	4.70	11.65	78.00		
Male	639	10.60	10.45	6.90	16.80	95.60		
Water Consumption (cups per day) (n=1338)	(median= 4)						0.1115	N/A
0-3	572	8.88	8.40	5.30	13.20	75.20		
4-7	539	9.46	9.10	5.80	15.20	75.10		
8+	227	9.01	9.01	5.50	14.20	95.60		
Time Spent on Pease (years) (n=1288)	(median=6.5)						<0.0001	
<1	75	6.30	6.61	3.94	10.70	60.10		ref
1-4	429	7.40	7.45	4.70	11.50	60.20		0.7065
5-9	378	10.00	9.30	6.07	14.20	95.60		0.0003
10-19	318	10.55	10.18	6.90	16.80	62.00		<0.0001
20+	88	11.55	11.79	7.75	19.50	75.20		<0.0001
Time Since Last on Pease (years) (n=1288)	(median=0.0)						<0.0001	

Characteristics	PFOS							
	n	Median	Geometric Mean	25% Quartile 1	75% Quartile 3	Max	p-value ₸	Post-Hoc Multiple Comparison Testing¥
<1	948	9.40	8.94	5.80	14.20	95.60		0.0043
1-4	144	7.40	7.40	4.52	11.60	46.70		<0.0001
5-9	88	9.24	9.03	5.55	15.45	47.70		0.0210
10-19	74	8.51	7.87	4.70	13.10	60.10		0.0013
20+	34	12.25	13.99	8.20	34.10	78.00		ref
Firefighter							<0.0001	N/A
No	1480	8.70	8.37	5.36	13.40	78.00		
Yes	98	11.75	12.80	8.40	23.10	95.60		
Abnormal Kidney Function							0.0500	N/A
No	1556	8.90	8.64	5.50	13.80	95.60		
Yes	22	6.34	5.82	3.90	10.50	43.20		
Laboratory							<0.0001	
Axys	700	9.40	9.15	5.96	14.85	95.60		ref
CDC	771	8.00	7.74	4.90	12.30	75.20		<0.0001
California PHL	107	11.90	12.06	8.26	19.30	47.70		<0.0001
Laboratory (applying same LOD to all samples)							<0.0001	
Axys	700	9.40	9.15	5.96	14.85	95.60		ref
CDC	771	8.00	7.80	4.90	12.30	75.20		<0.0001
California PHL	107	11.90	12.06	8.26	19.30	47.70		<0.0001

₸ Kruskal-Wallis test.

¥ Comparing ranked data using Bonferroni adjustment.

N/A: Not applicable because post-hoc testing wasn't performed. Multiple comparison testing is only performed for statistically significant variables in the Kruskal-Wallis analysis with more than two categories.

Association between characteristics of the Pease testing population and serum PFOA concentrations (µg/L), Pease Tradeport, Portsmouth, NH, 2015–2016

Characteristics	PFOA							
	n	Median	Geometric Mean	25% Quartile 1	75% Quartile 3	Max	p-value ₸	Post-Hoc Multiple Comparison Testing¥
Age Group	(median= 40)						<0.0001	
0-2	75	3.83	3.47	2.10	5.83	12.00		ref
3-5	164	4.31	4.12	3.14	5.52	11.60		0.1652
6-8	91	2.90	2.94	2.21	4.37	9.29		0.4975
9-11	36	2.05	2.16	1.62	2.63	6.23		<0.0001
12-19	31	1.60	1.62	1.27	2.30	5.73		<0.0001
20-39	369	2.51	2.47	1.68	3.79	16.80		<0.0001
40-59	611	3.20	3.20	2.20	4.90	32.00		1.0
60+	201	3.80	3.80	2.60	5.31	18.90		1.0
Sex (n=1495)							<0.0001	N/A
Female	856	2.95	2.85	1.90	4.50	32.00		
Male	639	3.50	3.45	2.42	5.00	18.40		
Water Consumption (cups per day) (n=1338)	(median= 4)						0.1102	N/A
0-3	572	3.01	2.98	2.06	4.51	32.00		
4-7	539	3.24	3.17	2.10	4.90	18.90		
8+	227	3.30	3.22	2.20	4.90	16.30		
Time Spent on Pease (years) (n=1288)	(median=6.5)						<0.0001	
<1	75	2.63	2.75	1.90	3.90	18.90		ref
1-4	429	2.88	2.75	1.90	4.36	32.00		1.0000
5-9	378	3.12	3.08	2.10	4.71	19.00		0.5582
10-19	318	3.50	3.42	2.33	5.09	16.30		0.0212
20+	88	3.69	3.75	2.55	5.45	18.40		0.0094
Time Since Last on Pease (n=1288)	(median=0.0)						0.0014	
<1	948	3.24	3.14	2.18	4.86	32.00		0.2279
1-4	144	2.71	2.68	1.77	3.94	16.80		0.0051
5-9	88	2.73	2.80	1.76	4.60	11.50		0.0225
10-19	74	3.20	2.93	1.90	4.67	18.90		0.1525

Characteristics	PFOA							
	n	Median	Geometric Mean	25% Quartile 1	75% Quartile 3	Max	p-value ₸	Post-Hoc Multiple Comparison Testing¥
20+	34	3.98	4.04	2.50	6.59	19.00		ref
Firefighter							0.1023	N/A
No	1480	3.20	3.07	2.04	4.80	32.00		
Yes	98	3.40	3.37	2.50	5.26	12.10		
Abnormal Kidney Function							0.2644	N/A
No	1556	3.20	3.10	2.10	4.80	32.00		
Yes	22	2.93	2.46	1.70	3.90	8.35		
Laboratory							0.1384	N/A
Axys	700	3.10	3.02	2.01	4.68	19.00		
CDC	771	3.20	3.10	2.10	4.90	32.00		
California PHL	107	3.50	3.42	2.45	4.98	11.90		
Laboratory (applying same LOD to all samples)							0.1380	N/A
Axys	700	3.10	3.02	2.01	4.68	19.00		
CDC	771	3.20	3.11	2.10	4.90	32.00		
California PHL	107	3.50	3.42	2.45	4.98	11.90		

₸ Kruskal-Wallis test.

¥ Comparing ranked data using Bonferroni adjustment.

N/A: Not applicable because post-hoc testing wasn't performed. Multiple comparison testing is only performed for statistically significant variables in the Kruskal-Wallis analysis with more than two categories.

Association between characteristics of the Pease testing population and serum PFHxS concentrations (µg/L), Pease Tradeport, Portsmouth, NH, 2015–2016

Characteristics	PFHxS							
	n	Median	Geometric Mean	25% Quartile 1	75% Quartile 3	Max	p-value ₸	Post-Hoc Multiple Comparison Testing¥
Age Group	(median= 40)						<0.0001	
0-2	75	2.60	2.63	1.17	6.20	19.70		ref
3-5	164	6.06	5.11	3.05	9.30	31.70		<0.0001
6-8	91	4.20	3.80	2.22	7.20	19.50		0.1048
9-11	36	2.46	2.31	1.44	3.90	7.50		1.0000
12-19	31	2.30	1.92	0.92	3.50	7.50		0.4365
20-39	369	3.10	3.10	1.69	5.80	37.10		1.0000
40-59	611	4.90	4.79	2.40	9.42	116.00		<0.0001
60+	201	5.30	5.64	3.18	11.00	56.20		<0.0001
Sex (n=1495)							<0.0001	N/A
Female	856	3.50	3.41	1.70	7.10	61.40		
Male	639	5.44	5.36	2.90	10.10	116.00		
Water Consumption (cups per day) (n=1338)	(median= 4)						<0.0001	
0-3	572	3.72	3.77	2.04	7.20	68.10		ref
4-7	539	4.95	4.76	2.40	9.04	56.20		<0.0001
8+	227	5.00	4.90	2.50	10.30	116.00		0.0023
Time Spent on Pease (years) (n=1288)	(median=6.5)						<0.0001	
<1	75	2.20	2.37	1.34	5.13	32.50		ref
1-4	429	3.20	3.16	1.80	6.00	40.80		0.0466
5-9	378	4.65	4.66	2.40	8.69	61.40		<0.0001
10-19	318	5.94	5.68	3.18	11.30	116.00		<0.0001
20+	88	8.21	7.91	3.60	16.35	68.70		<0.0001
Time Since Last on Pease (n=1288)	(median=0.0)						<0.0001	
<1	948	4.50	4.47	2.32	8.69	68.10		0.0041
1-4	144	2.99	3.07	1.54	5.28	56.20		<0.0001
5-9	88	3.60	4.09	2.10	8.32	116.00		0.0018

Characteristics	PFHxS							
	n	Median	Geometric Mean	25% Quartile 1	75% Quartile 3	Max	p-value ₸	Post-Hoc Multiple Comparison Testing¥
10-19	74	3.97	3.86	2.05	8.80	32.50		0.0028
20+	34	8.97	8.11	4.00	19.70	68.70		ref
Firefighter							<0.0001	N/A
No	1480	4.08	3.95	2.04	7.96	61.40		
Yes	98	8.14	7.74	4.00	14.70	116.00		
Abnormal Kidney Function							0.0214	N/A
No	1556	4.20	4.15	2.10	8.36	116.00		
Yes	22	2.60	2.52	1.59	3.74	36.80		
Laboratory							<0.0001	
Axys	700	3.39	3.36	1.68	6.92	61.40		ref
CDC	771	4.70	4.69	2.40	9.40	116.00		<0.0001
California PHL	107	6.70	6.13	3.72	10.20	40.60		<0.0001
Laboratory (applying same LOD to all samples)							<0.0001	
Axys	700	3.39	3.36	1.68	6.92	61.40		ref
CDC	771	4.70	4.75	2.40	9.40	116.00		<0.0001
California PHL	107	6.70	6.08	3.72	10.20	40.60		<0.0001

₸ Kruskal-Wallis test.

¥ Comparing ranked data using Bonferroni adjustment

N/A: Not applicable because post-hoc testing wasn't performed. Multiple comparison testing is only performed for statistically significant variables in the Kruskal-Wallis analysis with more than two categories.

Association between characteristics of the Pease testing population and serum PFNA concentrations (µg/L), Pease Tradeport, Portsmouth, NH, 2015–2016

Characteristics	PFNA							
	n	Median	Geometric Mean	25% Quartile 1	75% Quartile 3	Max	p-value ₸	Post-Hoc Multiple Comparison Testing¥
Age Group	(median= 40)						<0.0001	
0-2	75	0.74	0.76	0.35	1.20	5.16		Ref
3-5	164	1.03	1.01	0.68	1.63	5.20		0.0018
6-8	91	0.96	0.95	0.63	1.42	4.46		0.0617
9-11	36	0.80	0.79	0.47	1.40	3.70		1.0000
12-19	31	0.40	0.49	0.35	0.71	1.98		0.0069
20-39	369	0.60	0.56	0.35	0.80	2.34		0.0006
40-59	611	0.71	0.70	0.50	1.01	4.90		1.0000
60+	201	1.00	0.90	0.60	1.30	4.60		0.0539
Sex (n=1495)							<0.0001	N/A
Female	856	0.68	0.66	0.40	1.00	4.90		
Male	639	0.84	0.82	0.60	1.13	5.20		
Water Consumption (cups per day) (n=1338)	(median= 4)						0.6537	N/A
0-3	572	0.70	0.72	0.50	1.05	4.00		
4-7	539	0.79	0.73	0.50	1.10	5.20		
8+	227	0.70	0.69	0.50	1.00	4.60		
Time Spent on Pease (years) (n=1288)	(median=6.5)						0.0002	
<1	75	0.80	0.67	0.40	0.95	2.70		ref
1-4	429	0.70	0.68	0.40	1.03	4.90		1.0000
5-9	378	0.70	0.64	0.40	0.94	4.00		1.0000
10-19	318	0.80	0.75	0.51	1.10	4.60		0.5334
20+	88	0.87	0.85	0.60	1.21	3.16		0.0223
Time Since Last on Pease (n=1288)	(median=0.0)						0.0570	N/A
<1	948	0.70	0.69	0.50	1.00	4.90		
1-4	144	0.70	0.69	0.35	1.04	3.60		
5-9	88	0.65	0.66	0.400	0.94	3.10		

Characteristics	PFNA							
	n	Median	Geometric Mean	25% Quartile 1	75% Quartile 3	Max	p-value ₸	Post-Hoc Multiple Comparison Testing¥
10-19	74	0.72	0.72	0.50	1.10	4.12		
20+	34	0.99	0.89	0.67	1.47	1.91		
Firefighter							0.6252	N/A
No	1480	0.72	0.73	0.50	1.10	5.20		
Yes	98	0.80	0.73	0.60	1.00	1.90		
Abnormal Kidney Function							0.0088	N/A
No	1556	0.75	0.73	0.50	1.10	5.20		
Yes	22	0.54	0.52	0.35	0.65	1.60		
Laboratory							<0.0001	
Axys	700	0.70	0.71	0.35	1.08	5.16		ref
CDC	771	0.80	0.79	0.60	1.10	5.20		<0.0001
California PHL	107	0.60	0.46	0.34	0.93	1.96		<0.0001
Laboratory (applying same LOD to all samples)							<0.0001	
Axys	700	0.70	0.71	0.35	1.08	5.16		ref
CDC	771	0.80	0.81	0.60	1.10	5.20		<0.0001
California PHL	107	0.60	0.61	0.35	0.93	1.96		0.0005

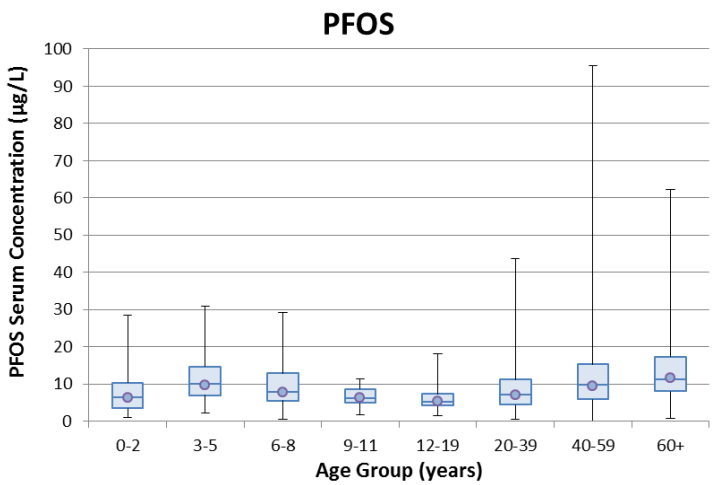
₸ Kruskal-Wallis test.

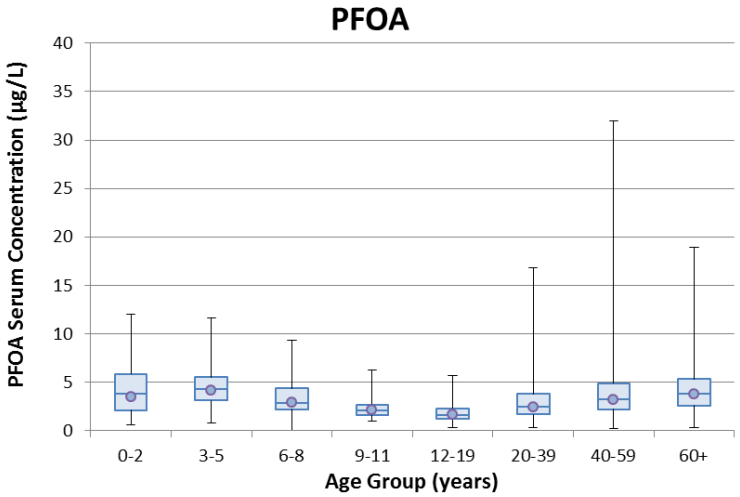
¥ Comparing ranked data using Bonferroni adjustment.

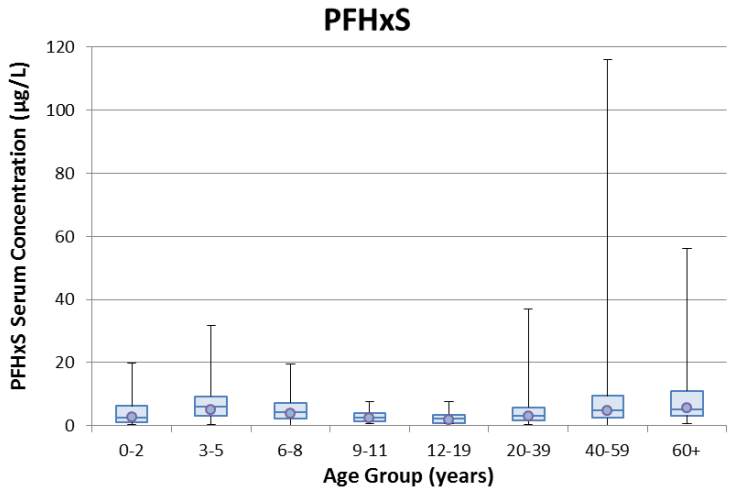
N/A: Not applicable because post-hoc testing wasn't performed. Multiple comparison testing is only performed for statistically significant variables in the Kruskal-Wallis analysis with more than two categories.

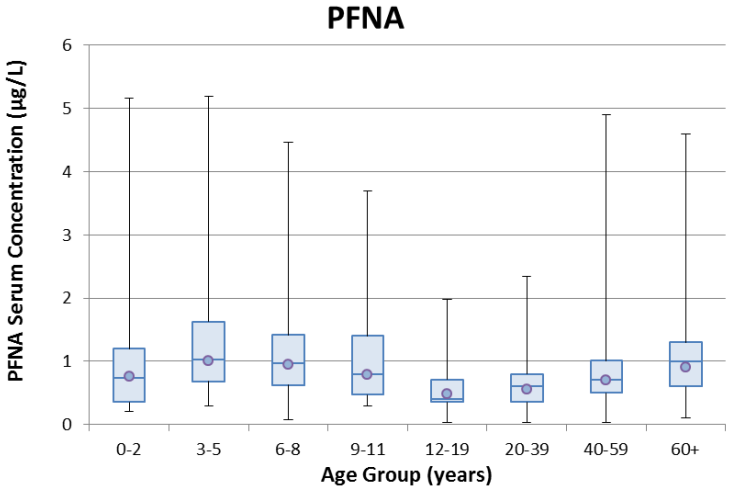
Box Plots Comparing Serum PFC Concentrations by Age Group

The blue box represents the interquartile range crossed by a line in the middle, which is the median. This box represents the test results for half (50%) of the people tested. Test results for the bottom 25% of people are below this box, and test results for the top 25% of people are above this box. The circle represents the geometric mean. The "whiskers" (lines extending above and below the box) represent the minimum and maximum values.



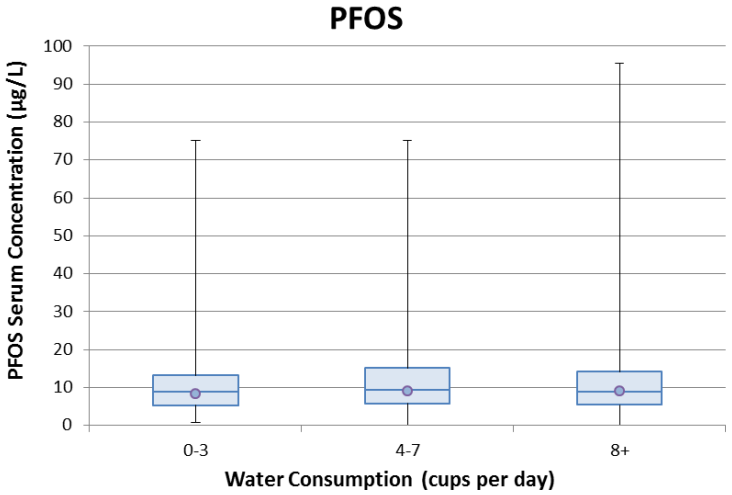


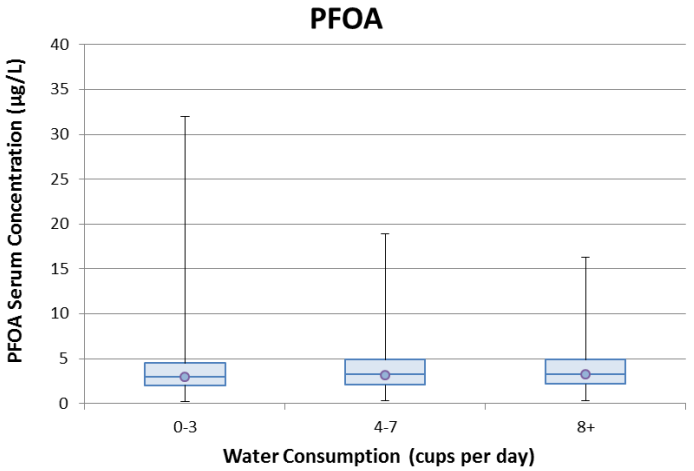


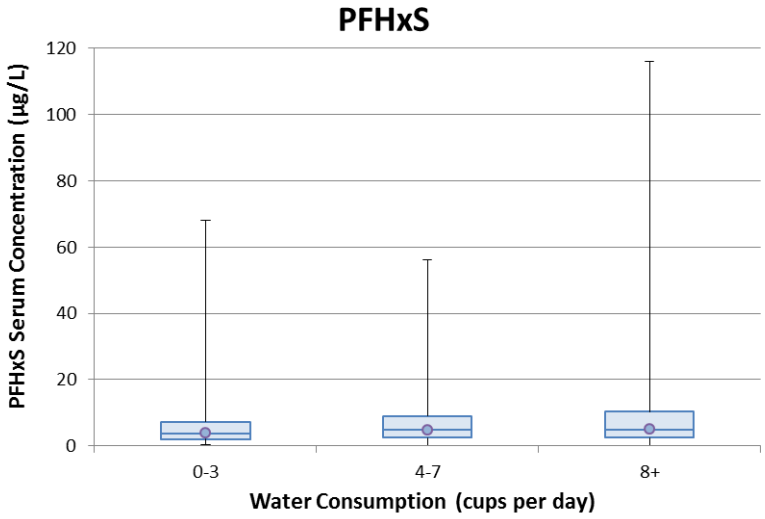


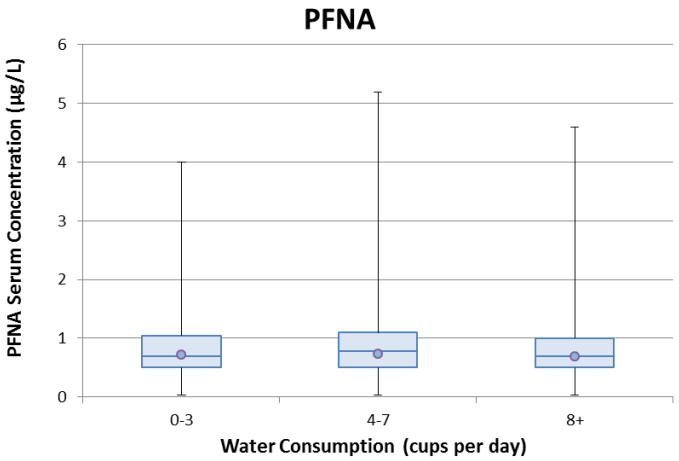
Box Plots Comparing Serum PFC Concentrations by Daily Water Consumption

The blue box represents the interquartile range crossed by a line in the middle, which is the median. This box represents the test results for half (50%) of the people tested. Test results for the bottom 25% of people are below this box, and test results for the top 25% of people are above this box. The circle represents the geometric mean. The "whiskers" (lines extending above and below the box) represent the minimum and maximum values.



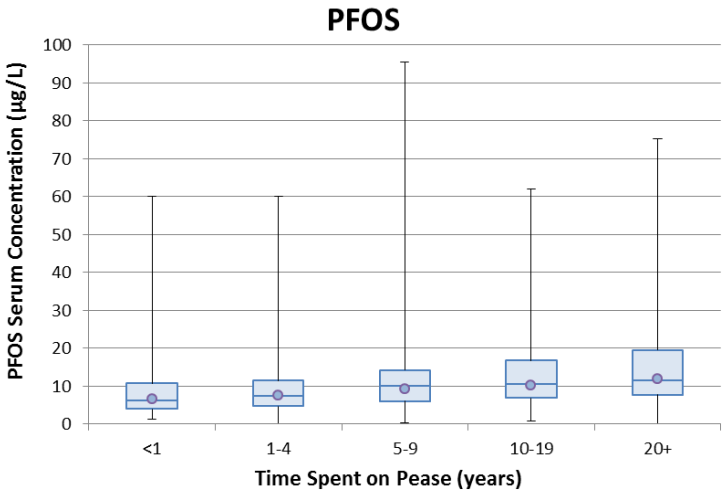


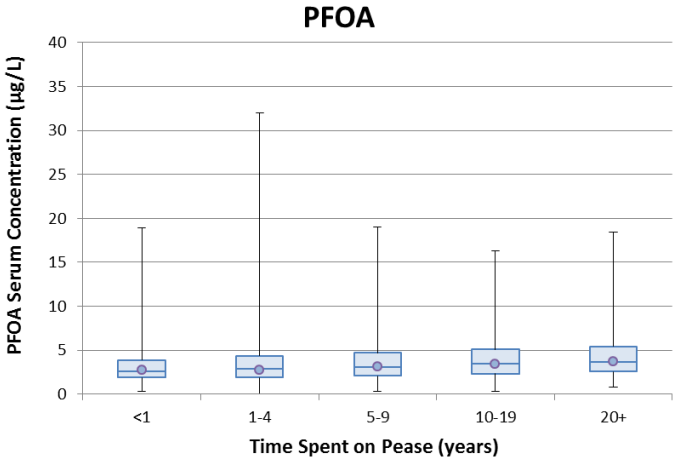


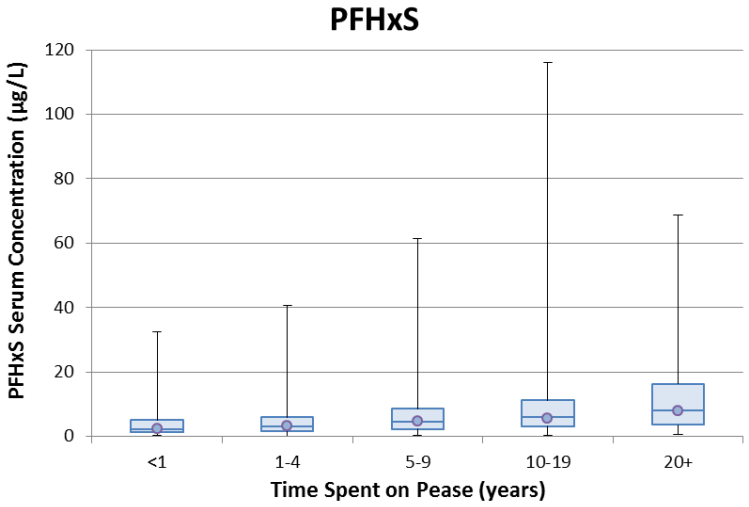


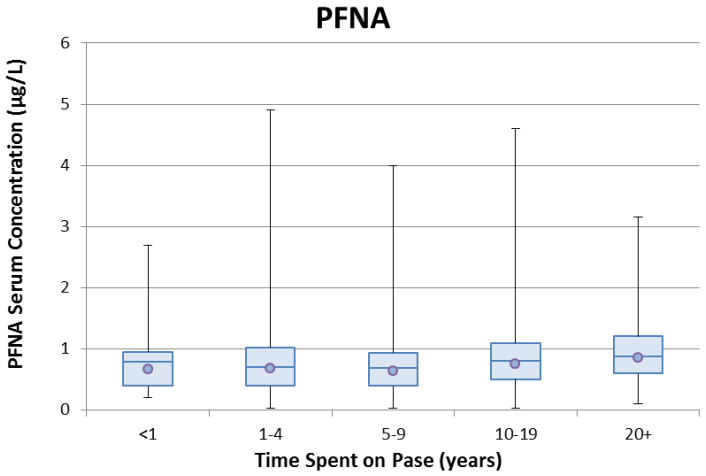
Box Plots Comparing Serum PFC Concentrations by Time Spent on Pease

The blue box represents the interquartile range crossed by a line in the middle, which is the median. This box represents the test results for half (50%) of the people tested. Test results for the bottom 25% of people are below this box, and test results for the top 25% of people are above this box. The circle represents the geometric mean. The "whiskers" (lines extending above and below the box) represent the minimum and maximum values.



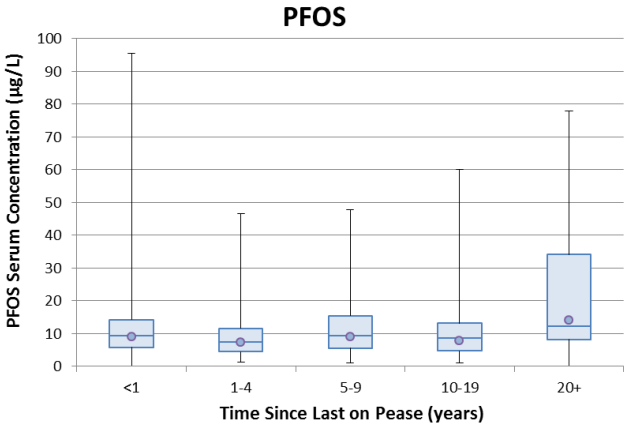


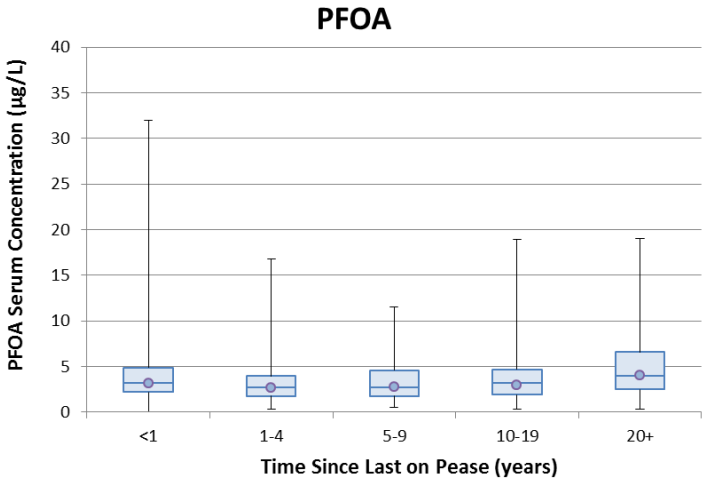


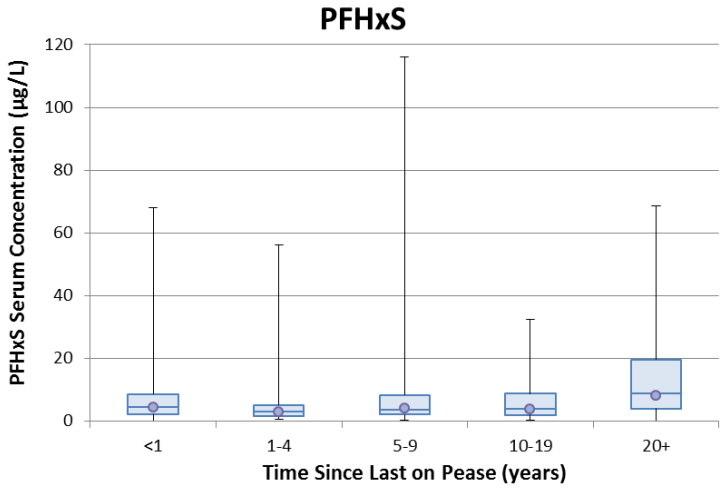


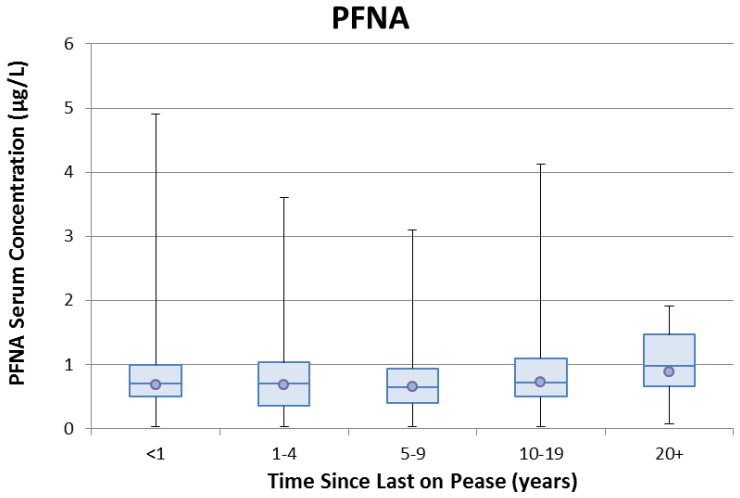
Box Plots Comparing Serum PFC Concentrations by Time Since Last on Pease

The blue box represents the interquartile range crossed by a line in the middle, which is the median. This box represents the test results for half (50%) of the people tested. Test results for the bottom 25% of people are below this box, and test results for the top 25% of people are above this box. The circle represents the geometric mean. The "whiskers" (lines extending above and below the box) represent the minimum and maximum values.









APPENDIX C
Multivariate Linear Regression Analysis Tables for PFOS, PFOA, PFHxS, and PFNA
(Includes both the full model and the model with only significant variables retained)

Association between characteristics of the Pease testing population and serum PFOS concentrations, model with all characteristics, Pease Tradeport, Portsmouth, NH, 2015–2016

Characteristics	PFOS β			
	Coefficient	Standard Error	Test statistic	Prob
Age Group	0.14737	0.02731	5.40	<0.0001*
Sex (male)	0.43059	0.04499	9.57	<0.0001*
Water Consumption Group	0.01103	0.02836	0.39	0.6974
Time Spent on Pease Group	0.09035	0.02216	4.08	<0.0001*
Time Since Last on Pease Group	-0.03297	0.02167	-1.52	0.1284
Firefighter (yes)	0.04190	0.08670	0.48	0.6290

β: Data for variable was log-transformed because data are not normally distributed.
***Denotes statistical significance**
Age Groups: 0–19, 20–39, 40–59, 60+. Groupings for water consumption, time spent on Pease, and time since last on Pease are as listed in the individual characteristics table.
Model statistics: n= 1133, F=31.42, df=6, p<0.0001, R^2= 0.1434, Intercept=1.36524

Associations between characteristics of the Pease testing population and serum PFOS concentrations, model with only significant characteristics retained, Pease Tradeport, Portsmouth, NH, 2015–2016

Characteristics	PFOS β				
	Coefficient	Standard Error	Test statistic	Prob	Marginal Effect
Age Group	0.15474	0.02589	5.98	<0.0001*	↑ 16.74%
Sex (male)	0.40817	0.04125	9.89	<0.0001*	↑ 50.41%
Time Spent on Pease Group	0.08681	0.02113	4.11	<0.0001*	↑ 9.07%

β: Data for variable was log-transformed because data are not normally distributed.
***Denotes statistical significance**
Age Groups: 0–19, 20–39, 40–59, 60+. Groupings for water consumption, time spent on Pease, and time since last on Pease are as listed in the individual characteristics table.
Model statistics: n= 1225, F=63.24, df=3, p<0.0001, R2= 0.1345, Intercept=1.33911

Association between characteristics in the Pease testing population and serum PFOA concentrations, model with all characteristics, Pease Tradeport, Portsmouth, NH, 2015–2016

Characteristics	PFOA β			
	Coefficient	Standard Error	Test statistic	Prob
Age Group	0.09192	0.02534	3.63	0.0003*
Sex (male)	0.27042	0.04175	6.48	<0.0001*
Water Consumption Group	0.04618	0.02631	1.76	0.0795
Time Spent on Pease Group	0.06680	0.02056	3.25	0.0012*
Time Since Last on Pease Group	-0.04295	0.02010	-2.14	0.0329*
Firefighter (yes)	-0.12757	0.08044	-1.59	0.1130

β: Data for variable was log-transformed because data are not normally distributed.
***Denotes statistical significance**
Age Groups: 0–19, 20–39, 40–59, 60+. Groupings for water consumption, time spent on Pease, and time since last on Pease are as listed in the individual characteristics table.
Model statistics: n= 1133, F=14.53, df=6, p<0.0001, R2= 0.0719, Intercept=0.55831

Associations between characteristics of the Pease testing population and serum PFOA concentrations, model with only significant characteristics retained, Pease Tradeport, Portsmouth, NH, 2015–2016

Characteristics	PFOA β				
	Coefficient	Standard Error	Test statistic	Prob	Marginal Effect
Age: 0-19 years					
Sex (male)	0.12301	0.13487	0.91	0.3637	none
Time Spent on Pease Group	-0.21384	0.12094	-1.77	0.0798	none
Age: 20-39 years					
Sex (male)	0.50631	0.07055	7.18	<0.0001*	↑ 65.92%
Time Spent on Pease Group	0.12451	0.04135	3.01	0.0028*	↑ 13.26%
Age: 40-59 years					
Sex (male)	0.16889	0.05714	2.96	0.0032*	↑ 18.40%
Time Spent on Pease Group	0.06880	0.02815	2.44	0.0148*	↑ 7.12%
Age: 60+ years					
Sex (male)	-0.08870	0.08931	-0.99	0.3219	none
Time Spent on Pease Group	0.06008	0.03770	1.59	0.1127	none

β: Data for variable was log-transformed because data are not normally distributed.
***Denotes statistical significance**
Groupings for water consumption, time spent on Pease, and time since last on Pease are as listed in the individual characteristics table.
Model statistics (Age: 0–19 years): n= 115, F=1.70, df=2, p=0.1866, R^2= 0.0295, Intercept=1.53930
Model statistics (Age: 20–39 years): n= 348, F=29.47, df=2, p<0.0001, R^2= 0.1459, Intercept=0.40335
Model statistics (Age: 40–59 years): n= 576, F= 9.55, df=2, p<0.0001, R^2= 0.0323, Intercept= 0.87268
Model statistics (Age: 60+ years): n= 186, F=1.70, df=2, p=0.1857, R^2= 0.0182, Intercept=1.19326

Association between characteristics of the Pease testing population and serum PFHxS concentrations, model with all characteristics, Pease Tradeport, Portsmouth, NH, 2015–2016

Characteristics	PFHxS β			
	Coefficient	Standard Error	Test statistic	Prob
Age Group	0.09221	0.03545	2.60	0.0094*
Sex (male)	0.50626	0.05842	8.67	<0.0001*
Water Consumption Group	0.12860	0.03682	3.49	0.0005*
Time Spent on Pease Group	0.25406	0.02876	8.83	<0.0001*
Time Since Last on Pease Group	-0.05881	0.02813	-2.09	0.0368*
Firefighter (yes)	0.05493	0.11256	0.49	0.6257

β: Data for variable was log-transformed because data are not normally distributed.
***Denotes statistical significance**
Age Groups: 0-19, 20-39, 40-59, 60+. Groupings for water consumption, time spent on Pease, and time since last on Pease are as listed in the individual characteristics table.
Model statistics: n= 1133, F=41.66, df=6, p<0.0001, R^2= 0.1817, Intercept=0.13130

Associations between characteristics of the Pease testing population and serum PFHxS concentrations, model with only significant characteristics retained, Pease Tradeport, Portsmouth, NH, 2015–2016

Characteristics	PFHxS β				
	Coefficient	Standard Error	Test statistic	Prob	Marginal Effect
Age: 0-19 years					
Sex (male)	0.12251	0.15171	0.81	0.4215	none
Water Consumption Group	0.3103	0.14923	2.08	0.0405*	↑ 36.38%
Time Spent on Pease Group	0.17336	0.1332	1.30	0.1965	none
Time Since Last on Pease Group	-0.67623	0.09424	-7.18	<0.0001*	↓ 49.15%
Age: 20-39 years					
Sex (male)	0.70984	0.09265	7.66	<0.0001*	↑ 103.37%
Water Consumption Group	0.17948	0.05688	3.16	0.0018*	↑ 19.66%
Time Spent on Pease Group	0.29606	0.05452	5.43	<0.0001*	↑ 34.46%
Time Since Last on Pease Group	-0.18067	0.06315	-2.86	0.0045*	↓ 16.53%
Age: 40-59 years					
Sex (male)	0.49837	0.08425	5.92	<0.0001*	↑ 64.60%
Water Consumption Group	0.15525	0.05419	2.87	0.0043*	↑ 16.80%
Time Spent on Pease Group	0.28985	0.04100	7.07	<0.0001*	↑ 33.62%
Time Since Last on Pease Group	0.01391	0.04194	0.33	0.7403	none
Age: 60+ years					
Sex (male)	0.08593	0.14975	0.57	0.5668	none
Water Consumption Group	0.15289	0.10823	1.41	0.1596	none
Time Spent on Pease Group	0.23821	0.06276	3.80	0.0002*	↑ 26.90%
Time Since Last on Pease Group	-0.04301	0.05516	-0.78	0.4367	none

β: Data for variable was log-transformed because data are not normally distributed.
***Denotes statistical significance**
Groupings for water consumption, time spent on Pease, and time since last on Pease are as listed in the individual characteristics table.
Model statistics (Age: 0–19 years): n= 93, F=16.11, df=4, p<0.0001, R^2= 0.4227, Intercept=1.70974
Model statistics (Age: 20–39 years): n= 327, F=27.91, df=4, p<0.0001, R^2= 0.2575, Intercept=0.02592
Model statistics (Age: 40–59 years): n= 537, F= 30.90, df=4, p<0.0001, R^2= 0.1885, Intercept= 0.14669
Model statistics (Age: 60+ years): n= 176, F=4.20, df=4, p=0.0029, R^2= 0.0895, Intercept=0.76193

Association between characteristics of the Pease testing population and serum PFNA concentrations, model with all characteristics, Pease Tradeport, Portsmouth, NH, 2015–2016

Characteristics	PFNA β			
	Coefficient	Standard Error	Test statistic	Prob
Age Group	0.10357	0.02401	4.31	<0.0001*
Sex (male)	0.26547	0.03956	6.71	<0.0001*
Water Consumption Group	-0.01749	0.02493	-0.70	0.4831
Time Spent on Pease Group	0.01116	0.01948	0.57	0.5667
Time Since Last on Pease Group	0.00852	0.01905	0.45	0.6549
Firefighter (yes)	-0.11576	0.07622	-1.52	0.1291

β: Data for variable was log-transformed because data are not normally distributed.
***Denotes statistical significance**
Age Groups: 0–19, 20–39, 40–59, 60+. Groupings for water consumption, time spent on Pease, and time since last on Pease are as listed in the individual characteristics table.
Model statistics: n= 1133, F=11.43, df=6, p<0.0001, R2= 0.0574, Intercept=-0.76661

Associations between characteristics of the Pease testing population and serum PFNA concentrations, model with only significant characteristics retained, Pease Tradeport, Portsmouth, NH, 2015–2016

Characteristics	PFNA β				
	Coefficient	Standard Error	Test statistic	Prob	Marginal Effect
Sex (male)	0.21686	0.03348	6.48	<0.0001	↑ 24.22%

β: Data for variable was log-transformed because data are not normally distributed.
***Denotes statistical significance**
Age Groups: 0–19, 20–39, 40–59, 60+. Groupings for water consumption, time spent on Pease, and time since last on Pease are as listed in the individual characteristics table.
Model statistics: n= 1495, F=41.95, df=1, p<0.0001, R2= 0.0273, Intercept=-0.41423