America's Children and the Environment, Third Edition

DRAFT Indicators

Biomonitoring: Perfluorochemicals (PFCs)

EPA is preparing the third edition of *America's Children and the Environment* (ACE3), following the previous editions published in December 2000 and February 2003. ACE is EPA's compilation of children's environmental health indicators and related information, drawing on the best national data sources available for characterizing important aspects of the relationship between environmental contaminants and children's health. ACE includes four sections: Environments and Contaminants, Biomonitoring, Health, and Special Features.

EPA has prepared draft indicator documents for ACE3 representing 23 children's environmental health topics and presenting a total of 42 proposed children's environmental health indicators. This document presents the draft text, indicator, and documentation for the PFCs topic in the Biomonitoring section.

THIS INFORMATION IS DISTRIBUTED SOLELY FOR THE PURPOSE OF PRE-DISSEMINATION PEER REVIEW UNDER APPLICABLE INFORMATION QUALITY GUIDELINES. IT HAS NOT BEEN FORMALLY DISSEMINATED BY EPA. IT DOES NOT REPRESENT AND SHOULD NOT BE CONSTRUED TO REPRESENT ANY AGENCY DETERMINATION OR POLICY.

For more information on America's Children and the Environment, please visit www.epa.gov/ace. For instructions on how to submit comments on the draft ACE3 indicators, please visit www.epa.gov/ace/ace3drafts/.

Perfluorochemicals (PFCs)

Perfluorochemicals (PFCs) are a group of manmade chemicals that have been used since the 1950s in many consumer products.[1] The structure of these chemicals makes them very stable, hydrophobic (water-repelling), and oleophobic (oil-repelling). These unique properties have led to extensive use of PFCs in surface coating and protectant formulations for paper and cardboard packaging products; carpets; leather products; and textiles that repel water, grease, and soil. PFCs have also been used in fire-fighting foams and in the production of nonstick coatings on cookware and some waterproof clothes.[2] PFCs are persistent in the environment, bioconcentrate in wildlife, and are persistent in humans, with most taking years to be cleared from the body.[3,4]

The PFCs with the highest production volume have been perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA). Other high-volume PFCs include perfluorohexane sulfonic acid (PFHxS), which is a member of the same chemical class as PFOS; and perfluorononanoic acid (PFNA), which is a member of the same chemical class as PFOA. Chemicals within a given PFC chemical family share similar properties, uses, and chemical functional groups.

Recent action to control PFCs has focused on decreasing production and emissions of PFOS, PFOA, and related compounds. A joint program between EPA and the chemical industry resulted in the phase-out of PFOS and PFHxS, which began in 2000 and was completed in 2002.[5] In 2006, EPA launched the 2010/15 PFOA Stewardship Program, with eight companies voluntarily agreeing to reduce emissions and product content of PFOA, PFNA, and related chemicals by 95% no later than 2010. The industry participants also committed to work toward eliminating emissions and product content of these chemicals by 2015, and have reported progress toward both the 2010 and 2015 goals.[6] However, the fact that these chemicals are persistent in the environment and have a long half-life in humans means that they will continue to persist in the environment and in people for many years, despite reductions in emissions. EPA is currently evaluating the potential need for regulation of PFCs using the authorities of the Toxic Substances Control Act.[7]

The major sources of human exposure to PFCs are poorly understood, but two recent studies identified food consumption as the primary pathway of exposure to PFOS and PFOA for Americans and Europeans.[8,9] Nonstick coatings on cookware and PFC-treated food-contact packaging, such as microwave popcorn bags, may be a source of PFC exposure. Meat and dairy products may also be contaminated with PFCs due to exposure of source animals to air, water, and feed contaminated with PFCs.[10-12] In some areas, such as those near industrial facilities that either make or use PFCs, these contaminants have been found in drinking water, groundwater, and/or surface water.[13-18] PFCs have also been detected in human breast milk, which represents a key source of exposure for breastfeeding infants.[19-21] PFCs have been measured in house dust as well, with the compounds found to be present in the majority of dust samples examined.[22-25] Infants and small children may be more highly exposed to certain PFCs in house dust than adults are, due to their frequent and extensive contact with floors, carpets, and other surfaces where dust gathers, as well as their frequent hand-to-mouth activity.[8,26-28] Children could have increased exposure to PFCs in carpet and carpet protectants, due to the amount of time they

spend lying, crawling, and playing on carpet.[7,27] There are limited data available on levels of PFCs in children's blood; however these data indicate that the blood serum levels of most PFCs are higher in children ages 3 to 11 years compared with other age groups.[29]

PFCs have been widely detected in umbilical cord blood, indicating that the developing fetus can be exposed to PFCs while in the womb. For example, PFOS and PFOA were detected in 99% and 100% of umbilical cord blood samples, respectively, collected from newborns in a recent study in Baltimore.[30] The level of PFOS circulating in a pregnant woman's blood is highly correlated with the level in umbilical cord blood,[31] so the widespread presence of PFOS in blood of women of child-bearing age suggests that fetal exposure is also widespread.[32]

A growing number of human health studies have found associations between prenatal exposure to PFOS or PFOA and a range of adverse birth outcomes, such as low birth weight, decreased head circumference, reduced birth length, and smaller abdominal circumference.[33-36] Two smaller studies, however, failed to find an association between prenatal PFC exposure and birth weight.[37,38] The participants in all of these studies had PFC blood serum levels comparable to levels in the general population. A recent study has also found a weak association between blood serum levels of PFOS and preeclampsia (pregnancy-induced high blood pressure), which can be dangerous for both the mother and developing fetus.[39] Animal studies echo these findings, though typically at levels much higher than what humans are normally exposed to. Developmental and reproductive effects, including reduced birth weight, decreased gestational length, structural defects, delays in postnatal growth and development, increased neonatal mortality, and pregnancy loss have all been associated with prenatal rodent exposure to PFOS and PFOA.[38,40-50]

Emerging evidence suggests that exposure to some PFCs can have negative impacts on human thyroid function. Alterations in thyroid hormone levels, as well as an increased risk of thyroid disease, have been associated with PFC levels in workers exposed on the job, and in the general population.[51-53] The health risks associated with maternal thyroid hormone disruption during pregnancy make this a cause for concern. Moderate deficits in maternal thyroid hormone levels during early pregnancy have been linked to reduced childhood IQ scores and other neurodevelopmental effects, as well as unsuccessful or complicated pregnancies.[54]

Both animal and human studies show a relationship between PFCs exposure and cholesterol and/or triglyceride levels, although the results are conflicting. Structurally, PFCs resemble fatty acids and can bind to receptors that play key roles in lipid metabolism and fat production.[55] In animal studies involving various species PFCs are associated with decreased serum levels of these lipids, while human studies often show an increase in blood lipid levels with increased presence of PFCs, including PFOS, PFOA, PFHxS, and PFNA.[46,47,55-63] This could be a concern for children because the developing fetus is likely to be sensitive to maternal levels of cholesterol and triglycerides, which support cellular growth, differentiation, and adipose accumulation during fetal development.[33,64] Finally, although human evidence is lacking, animal studies have demonstrated an association between PFOS and PFNA exposure (in utero and in adulthood) and immune suppression, including alterations in function and production of immune cells and decreased lymphoid organ weights.[65-67]

The following indicator presents median blood serum levels of PFOS, PFOA, PFHxS, and PFNA in women ages 16 to 49 years.

Indicator PFC1: Perfluorochemicals in women ages 16 to 49 years: Median concentrations in blood serum, 1999-2006

Overview

Indicator PFC1 presents concentrations of perfluorochemicals (PFCs) in blood of U.S. women ages 16 to 49 years. The data are from a national survey that collects blood specimens from a representative sample of the population, and then measures the concentration of PFCs in the blood. The indicator shows the change in blood PFC concentrations over time. The focus is on women of child-bearing age because blood levels of PFCs during pregnancy have been associated with adverse children's health outcomes.

NHANES

To examine trends in human levels of PFCs, this indicator presents data from the National Health and Nutrition Examination Survey (NHANES). NHANES is a nationally representative survey designed to assess the health and nutritional status of the civilian noninstitutionalized U.S. population, conducted by the Centers for Disease Control and Prevention (CDC). Interviews and physical examinations are conducted with approximately 5,000 people each year. CDC's National Center for Environmental Health measures concentrations of environmental chemicals in blood and urine samples collected from NHANES participants.[68] Concentrations of 12 different PFCs in blood serum have been measured in a representative subset of NHANES participants ages 12 years and older beginning with the 1999–2000 survey cycle, although data for the 2001–2002 cycle are not available. NHANES data from 1999–2006 (excluding the years 2001–2002) for women of child-bearing age are used for Indicator PFC1. The focus is on women of child-bearing age because much of the scientific research regarding outcomes of PFCs exposure found effects in infants and children who were exposed in the womb.

Perfluorinated Compounds

This indicator presents blood serum levels of four important PFCs: perfluorohexane sulfonic acid (PFHxS), perfluorononanoic acid (PFNA), perfluorooctane sulfonic acid (PFOS), and perfluorooctanoic acid (PFOA). These four PFCs were chosen because they are commonly detected in humans, and the bulk of human and animal health assessments have focused on these contaminants—especially PFOS and PFOA. These selected PFCs were detected in 92% to 100% of the women in the NHANES samples. Currently, NHANES measures eight other PFCs in blood serum samples, in addition to the four shown in this indicator.

PFCs bind to proteins in the serum of blood. Because PFCs remain in the human body for years, blood serum levels of PFCs are reflective of long-term exposures to these contaminants. Serum accounts for about half the weight of whole blood, so the blood serum concentration of PFCs is

about twice the concentration of PFCs in whole blood.[69] The blood serum PFC levels for this indicator are given in nanograms of PFC per milliliter of blood serum (ng/mL).[i]

Birthrate Adjustment

This indicator uses measurements of PFCs in blood serum of women ages 16 to 49 years to represent the distribution of PFCs exposures to women who are pregnant or may become pregnant. However, women of different ages have a different likelihood of giving birth. For example, in 2003–2004, women aged 27 years had a 12% annual probability of giving birth, and women aged 37 years had a 4% annual probability of giving birth.[70] A birthrate-adjusted distribution of women's blood serum levels is used in calculating this indicator, meaning that the data are weighted using the age-specific probability of a woman giving birth.[71]

Data Presented in the Indicator

This indicator presents median levels of selected PFCs in blood serum of women ages 16 to 49 years. The median is the value in the middle of the distribution of blood serum PFC levels: half of the women have levels greater than the median, and half have levels below the median. The median can be thought of as representing a typical exposure.

Additional information on the 95th percentile blood serum levels of PFOS, PFOA, PFNA, and PFHxS for women ages 16 to 49 years is presented in the supplemental data tables for this indicator, along with information showing how blood serum levels of PFCs in women of child-bearing age vary by race/ethnicity and family income.

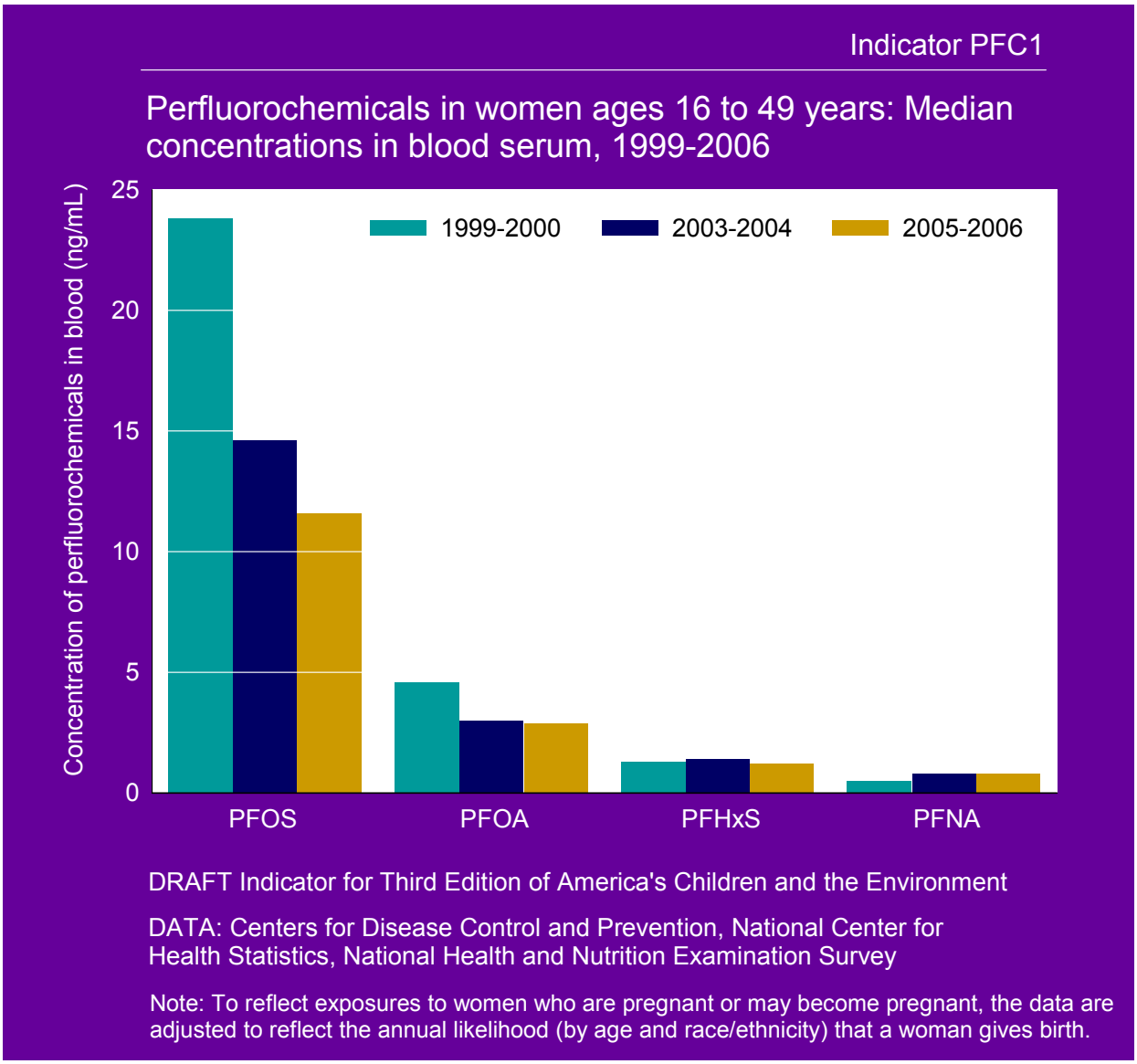
Statistical Testing

Statistical analysis has been applied to the biomonitoring indicators to determine whether any changes in chemical concentrations over time, or any differences in chemical concentrations between demographic groups, are statistically significant. These analyses use a 5% significance level ($p \leq 0.05$), meaning that a conclusion of statistical significance is made only when there is no more than a 5% chance that the observed change over time or difference between demographic groups occurred randomly. It should be noted that when statistical testing is conducted for differences among multiple demographic groups (e.g., considering both race/ethnicity and income level), the large number of comparisons involved increases the probability that some differences identified as statistically significant may actually have occurred randomly.

A finding of statistical significance for a biomonitoring indicator depends not only on the numerical difference in the value of a reported statistic between two groups, but also on the number of observations in the survey, the amount of variability among the observations, and various aspects of the survey design. For example, if two groups have different median levels of a chemical in blood or urine, the statistical test is more likely to detect a difference when samples have been obtained from a larger number of people in those groups. Similarly, if there is low

[i] Most persistent organic pollutants (POPs) are lipophilic, meaning that they accumulate in fatty tissues; however, this is not the case for PFCs, which are both hydrophobic (water-repelling), and oleophobic (oil-repelling). They instead bind to proteins in the serum of blood. While blood levels of lipophilic POPs are commonly lipid-adjusted, the PFC measurements in blood are not.

variability in levels of the chemical within each group, then a difference between groups is more likely to be detected. A finding that there is or is not a statistically significant difference in exposure levels between two groups or in exposure levels over time does not necessarily suggest any interpretation regarding the health implications of those differences.



- Median blood serum levels of PFOS in women of child-bearing age declined by 51% between 1999–2000 and 2005–2006. Median blood serum levels of PFOA in women of child-bearing age declined by 37% between 1999–2000 and 2005–2006. These declines were statistically significant.

- The median blood serum levels of PFHxS and PFNA are lower than those of PFOS and PFOA in women of child-bearing age. Median levels of PFHxS have remained relatively constant over time, while levels of PFNA have increased.
    - Statistical note: There was no statistically significant change in median levels of PFHxS. The increase in median PFNA levels was statistically significant.

- The concentration of PFOS in blood serum at the 95th percentile in women of child-bearing age declined by 45% between 1999–2000 and 2005–2006. The concentration of PFOA in

blood serum at the 95th percentile in women of child-bearing age declined by 24% between 1999–2000 and 2005–2006. (See Table PFC1a.)
  - Statistical note: The decline in 95th percentile PFOS levels was statistically significant, while the decline in 95th percentile PFOA levels was not.

- For the years 2003–2006, women of child-bearing age living at or above poverty level typically had higher median and 95th percentile concentrations of PFCs in their blood serum compared with women living below poverty level—sometimes up to 60% higher. (See Tables PFC1b and PFC1c.)
  - Statistical note: The differences in median levels between income groups were statistically significant for all PFCs studied, although the difference in PFNA levels appears to be attributable to other demographic characteristics (differences in race/ethnicity or age profile above and below poverty). The differences in 95th percentile levels between income groups were not statistically significant.

- For the years 2003–2006, White non-Hispanic women of child-bearing age had higher median and 95th percentile concentrations of PFOS and PFOA in their blood serum compared with Black non-Hispanic women, Mexican-American women, and women of other races/ethnicities, although these differences were not always statistically significant. (See Tables PFC1b and PFC1c.)

Data Tables

Table PFC1. Perfluorochemicals in women ages 16 to 49 years: Median concentrations in blood serum, 1999-2006

	Median concentration of PFCs in blood serum (ng/mL)			
Year	**PFOS**	**PFOA**	**PFHxS**	**PFNA**
1999-2000	23.8	4.6	1.3	0.5
2003-2004	14.6	3.0	1.4	0.8
2005-2006	11.6	2.9	1.2	0.8

DATA: Centers for Disease Control and Prevention, National Center for Health Statistics, National Health and Nutrition Examination Survey

NOTE: The distribution of the data for women ages 16 to 49 years is adjusted for the likelihood that a woman of a particular age and race/ethnicity gives birth in a particular year. The intent of this adjustment is to approximate the distribution of exposure to pregnant women. Results will therefore differ from a characterization of exposure to adult women without consideration of birthrates.

Table PFC1a. Perfluorochemicals in women ages 16 to 49 years: 95th percentile concentrations in blood serum, 1999-2006

	95th percentile concentration of PFCs in blood serum (ng/mL)			
Year	**PFOS**	**PFOA**	**PFHxS**	**PFNA**
1999-2000	50.1	8.4	4.9	1.3
2003-2004	42.2	8.4	7.1	2.4
2005-2006	27.8	6.4	5.4	2.2

DATA: Centers for Disease Control and Prevention, National Center for Health Statistics, National Health and Nutrition Examination Survey

NOTE: The distribution of the data for women ages 16 to 49 years is adjusted for the likelihood that a woman of a particular age and race/ethnicity gives birth in a particular year. The intent of this adjustment is to approximate the distribution of exposure to pregnant women. Results will therefore differ from a characterization of exposure to adult women without consideration of birthrates.

Table PFC1b. Perfluorochemicals in women ages 16 to 49 years: Median concentrations in blood serum, by race/ethnicity and family income, 2003-2006

PFC	Race / Ethnicity	Median concentration of PFCs in blood serum (ng/mL)					
		All Incomes	< Poverty Level	≥ Poverty Level	≥Poverty (Detail)		Unknown Income
					100-200% of Poverty Level	> 200% of Poverty Level	
PFOS	All Races/ Ethnicities	12.9	10.8	13.5	12.1	14.6	17.4
	White non-Hispanic	14.6	12.0	14.8	13.9	14.8	NA**
	Black non-Hispanic	12.9	12.6	13.7	14.1	12.7	15.8
	Mexican-American	9.5	8.7	9.9	9.5	10.8	NA**
	Other†	11.1	6.0	13.0	13.0	13.2	NA**
PFOA	All Races/ Ethnicities	2.9	2.4	3.1	2.7	3.2	4.8
	White non-Hispanic	3.3	3.0	3.3	3.5	3.2	NA**
	Black non-Hispanic	2.4	2.4	2.4	2.1	2.5	3.0
	Mexican-American	2.3	1.7	2.6	2.3	3.4	3.2
	Other†	2.3	2.1	2.4	1.8*	3.0	NA**
PFHxS	All Races/ Ethnicities	1.3	0.9	1.4	1.4	1.3	1.4
	White non-Hispanic	1.4	0.9	1.5	2.2	1.4	NA**
	Black non-Hispanic	1.2	1.0	1.2	1.1*	1.2	2.1
	Mexican-American	1.0	1.0	1.0*	1.1*	NA**	NA**
	Other†	1.3	NA**	1.4	1.1	1.4*	NA**
PFNA	All Races/ Ethnicities	0.8	0.7	0.8	0.7	0.9	NA**
	White non-Hispanic	0.8	0.7	0.8	0.7	0.9	NA**
	Black non-Hispanic	0.9	0.9	0.8	0.8	0.9	1.2

		Median concentration of PFCs in blood serum (ng/mL)					
	Mexican-American	0.6	0.6	0.6	0.6	0.9	0.7
	Other†	0.7	0.6*	0.8	0.7	0.9	NA**

DATA: Centers for Disease Control and Prevention, National Center for Health Statistics, National Health and Nutrition Examination Survey

NOTE: The distribution of the data for women ages 16 to 49 years is adjusted for the likelihood that a woman of a particular age and race/ethnicity gives birth in a particular year. The intent of this adjustment is to approximate the distribution of exposure to pregnant women. Results will therefore differ from a characterization of exposure to adult women without consideration of birthrates.

† "Other" includes Asian non-Hispanic; Native American non-Hispanic; Hispanic other than Mexican-American; those reporting multi-racial; and those with a missing value for race/ethnicity.

* The estimate should be interpreted with caution because the standard error of the estimate is relatively large: the relative standard error, RSE, is at least 30% but is less than 40% (RSE = standard error divided by the estimate).

** The estimate is not reported because it has large uncertainty: the relative standard error, RSE, is at least 40% (RSE = standard error divided by the estimate).

Table PFC1c. Perfluorochemicals in women ages 16 to 49 years: 95th percentile concentrations in blood serum, by race/ethnicity and family income, 2003-2006

PFC		95th percentile concentration of PFCs in blood serum (ng/mL)					
	Race / Ethnicity	All Incomes	< Poverty Level	≥ Poverty Level	≥Poverty (Detail)		Unknown Income
					100-200% of Poverty Level	> 200% of Poverty Level	
PFOS	All Races/ Ethnicities	32.2	24.2	33.1	30.6	33.4	32.2
	White non-Hispanic	33.4	38.8	33.4	43.7	33.4	NA**
	Black non-Hispanic	29.7	23.1	33.4	39.0	33.4	21.6
	Mexican-American	20.0	17.4	21.7	21.7	22.2	28.2
	Other†	31.0	44.6	31.0	31.0	31.0	NA**
PFOA	All Races/ Ethnicities	7.4	5.6	7.5	7.7	7.5	10.3
	White non-Hispanic	8.6	7.4	8.6	9.9	8.2	NA**
	Black non-Hispanic	5.8	5.6	5.8	6.7	5.8	6.6
	Mexican-American	5.8	4.9	6.6	4.9	6.6	4.9
	Other†	5.6*	5.4	5.6	3.4	5.6	NA**
PFHxS	All Races/ Ethnicities	5.9	5.4	6.1	7.8*	6.1	4.6*
	White non-Hispanic	6.5*	6.0*	7.1*	10.0	6.1	NA**
	Black non-Hispanic	5.9	NA**	6.5	NA**	6.5	8.8
	Mexican-American	4.8	4.0	5.3	4.8	NA**	4.6*
	Other†	3.2	NA**	3.2	2.1*	NA**	NA**
PFNA	All Races/ Ethnicities	2.4	2.3	2.2	2.1	2.2	6.1
	White non-Hispanic	2.4	1.7	2.4	2.4	2.4	NA**
	Black non-Hispanic	2.5	3.4	2.1	2.5	1.8	1.9
	Mexican-	1.8	2.3	1.6	1.5	1.6	1.4

		95th percentile concentration of PFCs in blood serum (ng/mL)					
	American						
	Other†	1.7*	1.9	NA**	3.5	1.5	NA**

DATA: Centers for Disease Control and Prevention, National Center for Health Statistics, National Health and Nutrition Examination Survey

NOTE: The distribution of the data for women ages 16 to 49 years is adjusted for the likelihood that a woman of a particular age and race/ethnicity gives birth in a particular year. The intent of this adjustment is to approximate the distribution of exposure to pregnant women. Results will therefore differ from a characterization of exposure to adult women without consideration of birthrates.

† "Other" includes Asian non-Hispanic; Native American non-Hispanic; Hispanic other than Mexican-American; those reporting multi-racial; and those with a missing value for race/ethnicity.

* The estimate should be interpreted with caution because the standard error of the estimate is relatively large: the relative standard error, RSE, is at least 30% but is less than 40% (RSE = standard error divided by the estimate).

** The estimate is not reported because it has large uncertainty: the relative standard error, RSE, is at least 40% (RSE = standard error divided by the estimate).

References

1. Calafat, A.M., L.Y. Wong, Z. Kuklenyik, J.A. Reidy, and L.L. Needham. 2007. Polyfluoroalkyl chemicals in the U.S. population: data from the National Health and Nutrition Examination Survey (NHANES) 2003-2004 and comparisons with NHANES 1999-2000. *Environmental Health Perspectives* 115 (11):1596-602.

2. Agency for Toxic Substances and Disease Registry (ATSDR). 2009. *Toxicological profile for Perfluoroalkyls. (Draft for Public Comment).* Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. http://www.atsdr.cdc.gov/toxprofiles/tp200.html#bookmark08.

3. Harada, K., N. Saito, K. Inoue, T. Yoshinaga, T. Watanabe, S. Sasaki, S. Kamiyama, and A. Koizumi. 2004. The influence of time, sex and geographic factors on levels of perfluorooctane sulfonate and perfluorooctanoate in human serum over the last 25 years. *Journal of Occupational Health* 46 (2):141-7.

4. Olsen, G.W., J.M. Burris, D.J. Ehresman, J.W. Froehlich, A.M. Seacat, J.L. Butenhoff, and L.R. Zobel. 2007. Half-life of serum elimination of perfluorooctanesulfonate, perfluorohexanesulfonate, and perfluorooctanoate in retired fluorochemical production workers. *Environmental Health Perspectives* 115 (9):1298-305.

5. 3M. 2010. *What is 3M Doing?* Retrieved January 18, 2010 from http://solutions.3m.com/wps/portal/3M/en_US/PFOS/PFOA/Information/Action/.

6. U.S. Environmental Protection Agency. 2010. *News Release: EPA Announces Substantial Decrease of PFOA* Retrieved January 20, 2010 from http://yosemite.epa.gov/opa/admpress.nsf/68b5f2d54f3eefd28525701500517fbf/8f9dbdd044050f71852573e50064439f!OpenDocument.

7. U.S. Environmental Protection Agency. 2009. *Long-Chain Perfluorinated Chemicals (PFCs) Action Plan.* Washington, DC: U.S. EPA, Office of Pollution Prevention and Toxics. http://www.epa.gov/oppt/existingchemicals/pubs/pfcs_action_plan1230_09.pdf.

8. Trudel, D., L. Horowitz, M. Wormuth, M. Scheringer, I.T. Cousins, and K. Hungerbuhler. 2008. Estimating consumer exposure to PFOS and PFOA. *Risk Analysis* 28 (2):251-69.

9. Egeghy, P.P., and M. Lorber. An assessment of the exposure of Americans to perfluorooctane sulfonate: A comparison of estimated intake with values inferred from NHANES data. *J Expo Sci Environ Epidemiol*.

10. Tittlemier, S.A., K. Pepper, C. Seymour, J. Moisey, R. Bronson, X.L. Cao, and R.W. Dabeka. 2007. Dietary exposure of Canadians to perfluorinated carboxylates and perfluorooctane sulfonate via consumption of meat, fish, fast foods, and food items prepared in their packaging. *Journal of Agricultural and Food Chemistry* 55 (8):3203-10.

11. Ericson, I., R. Marti-Cid, M. Nadal, B. Van Bavel, G. Lindstrom, and J.L. Domingo. 2008. Human exposure to perfluorinated chemicals through the diet: intake of perfluorinated compounds in foods from the Catalan (Spain) market. *Journal of Agricultural and Food Chemistry* 56 (5):1787-94.

12. Schecter, A., J. Colacino, D. Haffner, K. Patel, M. Opel, O. Papke, and L. Birnbaum. 2010. Perfluorinated Compounds, Polychlorinated Biphenyl, and Organochlorine Pesticide Contamination in Composite Food Samples from Dallas, Texas. *Environmental Health Perspectives* 118:796-802.

13. Post, G.B., J.B. Louis, K.R. Cooper, B.J. Boros-Russo, and R.L. Lippincott. 2009. Occurrence and potential significance of perfluorooctanoic acid (PFOA) detected in New Jersey public drinking water systems. *Environmental Science and Technology* 43 (12):4547-54.

14. Steenland, K., C. Jin, J. MacNeil, C. Lally, A. Ducatman, V. Vieira, and T. Fletcher. 2009. Predictors of PFOA Levels in a Community Surrounding a Chemical Plant *Environmental Health Perspectives* 117 (7):1083-1088.

15. Konwick, B.J., G.T. Tomy, N. Ismail, J.T. Peterson, R.J. Fauver, D. Higginbotham, and A.T. Fisk. 2008. Concentrations and patterns of perfluoroalkyl acids in Georgia, USA surface waters near and distant to a major use source. *Environmental Toxicology and Chemistry* 27 (10):2011-8.

16. Moody, C.A., G.N. Hebert, S.H. Strauss, and J.A. Field. 2003. Occurrence and persistence of perfluorooctanesulfonate and other perfluorinated surfactants in groundwater at a fire-training area at Wurtsmith Air Force Base, Michigan, USA. *Journal of Environmental Monitoring* 5 (2):341-5.

17. Sinclair, E., D.T. Mayack, K. Roblee, N. Yamashita, and K. Kannan. 2006. Occurrence of perfluoroalkyl surfactants in water, fish, and birds from New York State. *Archives of Environmental Contamination and Toxicology* 50 (3):398-410.

18. Skutlarek, D., M. Exner, and H. Farber. 2006. Perfluorinated surfactants in surface and drinking waters. *Environmental Science and Pollution Research International* 13 (5):299-307.

19. Karrman, A., I. Ericson, B. van Bavel, P.O. Darnerud, M. Aune, A. Glynn, S. Lignell, and G. Lindstrom. 2007. Exposure of perfluorinated chemicals through lactation: levels of matched human milk and serum and a temporal trend, 1996-2004, in Sweden. *Environmental Health Perspectives* 115 (2):226-30.

20. Tao, L., K. Kannan, C.M. Wong, K.F. Arcaro, and J.L. Butenhoff. 2008. Perfluorinated compounds in human milk from Massachusetts, U.S.A. *Environmental Science and Technology* 42 (8):3096-101.

21. Volkel, W., O. Genzel-Boroviczeny, H. Demmelmair, C. Gebauer, B. Koletzko, D. Twardella, U. Raab, and H. Fromme. 2008. Perfluorooctane sulphonate (PFOS) and perfluorooctanoic acid (PFOA) in human breast milk: results of a pilot study. *International Journal of Hygiene and Environmental Health* 211 (3-4):440-6.

22. Bjorklund, J.A., K. Thuresson, and C.A. De Wit. 2009. Perfluoroalkyl compounds (PFCs) in indoor dust: concentrations, human exposure estimates, and sources. *Environmental Science and Technology* 43 (7):2276-81.

23. Strynar, M.J., and A.B. Lindstrom. 2008. Perfluorinated compounds in house dust from Ohio and North Carolina, USA. *Environmental Science and Technology* 42 (10):3751-6.

24. Kato, K., A.M. Calafat, and L.L. Needham. 2009. Polyfluoroalkyl chemicals in house dust. *Environmental Research* 109 (5):518-23.

25. Kubwabo, C., B. Stewart, J. Zhu, and L. Marro. 2005. Occurrence of perfluorosulfonates and other perfluorochemicals in dust from selected homes in the city of Ottawa, Canada. *Journal of Environmental Monitoring* 7 (11):1074-8.

26. Egeghy, P.P., and M. Lorber. 2010. An assessment of the exposure of Americans to perfluorooctane sulfonate: A comparison of estimated intake with values inferred from NHANES data. *Journal of Exposure Science and Environmental Epidemiology* doi:10.1038/jes.2009.73.

27. Harrad, S., C.A. de Wit, M.A. Abdallah, C. Bergh, J.A. Bjorklund, A. Covaci, P.O. Darnerud, J. de Boer, M. Diamond, S. Huber, P. Leonards, M. Mandalakis, C. Ostman, L.S. Haug, C. Thomsen, and T.F. Webster. 2010. Indoor contamination with hexabromocyclododecanes, polybrominated diphenyl ethers, and perfluoroalkyl compounds: an important exposure pathway for people? *Environmental Science and Technology* 44 (9):3221-31.

28. U.S. Environmental Protection Agency. 2008. *Child-Specific Exposure Factors Handbook (Final Report).* Washington, DC. EPA/600/R-06/096F. http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=199243#Download.

29. Kato, K., A.M. Calafat, L.Y. Wong, A.A. Wanigatunga, S.P. Caudill, and L.L. Needham. 2009. Polyfluoroalkyl compounds in pooled sera from children participating in the National Health and Nutrition Examination Survey 2001-2002. *Environmental Science and Technology* 43 (7):2641-7.

30. Apelberg, B.J., L.R. Goldman, A.M. Calafat, J.B. Herbstman, Z. Kuklenyik, J. Heidler, L.L. Needham, R.U. Halden, and F.R. Witter. 2007. Determinants of fetal exposure to polyfluoroalkyl compounds in Baltimore, Maryland. *Environmental Science and Technology* 41 (11):3891-7.

31. Inoue, K., F. Okada, R. Ito, S. Kato, S. Sasaki, S. Nakajima, A. Uno, Y. Saijo, F. Sata, Y. Yoshimura, R. Kishi, and H. Nakazawa. 2004. Perfluorooctane sulfonate (PFOS) and related perfluorinated compounds in human maternal and cord blood samples: assessment of PFOS exposure in a susceptible population during pregnancy. *Environmental Health Perspectives* 112 (11):1204-7.

32. Calafat, A.M., Z. Kuklenyik, J.A. Reidy, S.P. Caudill, J.S. Tully, and L.L. Needham. 2007. Serum concentrations of 11 polyfluoroalkyl compounds in the U.S. population: data from the national health and nutrition examination survey (NHANES). *Environmental Science and Technology* 41 (7):2237-42.

33. Apelberg, B.J., F.R. Witter, J.B. Herbstman, A.M. Calafat, R.U. Halden, L.L. Needham, and L.R. Goldman. 2007. Cord serum concentrations of perfluorooctane sulfonate (PFOS) and perfluorooctanoate (PFOA) in relation to weight and size at birth. *Environmental Health Perspectives* 115 (11):1670-6.

34. Fei, C., J.K. McLaughlin, R.E. Tarone, and J. Olsen. 2007. Perfluorinated chemicals and fetal growth: a study within the Danish National Birth Cohort. *Environmental Health Perspectives* 115 (11):1677-82.

35. Fei, C., J.K. McLaughlin, R.E. Tarone, and J. Olsen. 2008. Fetal growth indicators and perfluorinated chemicals: a study in the Danish National Birth Cohort. *American Journal of Epidemiology* 168 (1):66-72.

36. Washino, N., Y. Saijo, S. Sasaki, S. Kato, S. Ban, K. Konishi, R. Ito, A. Nakata, Y. Iwasaki, K. Saito, H. Nakazawa, and R. Kishi. 2009. Correlations between prenatal exposure to perfluorinated chemicals and reduced fetal growth. *Environmental Health Perspectives* 117 (4):660-7.

37. Hamm, M.P., N.M. Cherry, E. Chan, J.W. Martin, and I. Burstyn. 2009. Maternal exposure to perfluorinated acids and fetal growth. *Journal of Exposure Science and Environmental Epidemiology* doi:10.1038/jes.2009.57.

38. Monroy, R., K. Morrison, K. Teo, S. Atkinson, C. Kubwabo, B. Stewart, and W.G. Foster. 2008. Serum levels of perfluoroalkyl compounds in human maternal and umbilical cord blood samples. *Environmental Research* 108 (1):56-62.

39. Stein, C.R., D.A. Savitz, and M. Dougan. 2009. Serum levels of perfluorooctanoic acid and perfluorooctane sulfonate and pregnancy outcome. *American Journal of Epidemiology* 170 (7):837-46.

40. Lau, C., J.R. Thibodeaux, R.G. Hanson, J.M. Rogers, B.E. Grey, M.E. Stanton, J.L. Butenhoff, and L.A. Stevenson. 2003. Exposure to perfluorooctane sulfonate during pregnancy in rat and mouse. II: postnatal evaluation. *Toxicological Sciences* 74 (2):382-92.

41. Era, S., K.H. Harada, M. Toyoshima, K. Inoue, M. Minata, N. Saito, T. Takigawa, K. Shiota, and A. Koizumi. 2009. Cleft palate caused by perfluorooctane sulfonate is caused mainly by extrinsic factors. *Toxicology* 256 (1-2):42-7.

42. Hines, E.P., S.S. White, J.P. Stanko, E.A. Gibbs-Flournoy, C. Lau, and S.E. Fenton. 2009. Phenotypic dichotomy following developmental exposure to perfluorooctanoic acid (PFOA) in female CD-1 mice: Low doses induce elevated serum leptin and insulin, and overweight in mid-life. *Molecular and Cellular Endocrinology* 304 (1-2):97-105.

43. Fuentes, S., M.T. Colomina, J. Rodriguez, P. Vicens, and J.L. Domingo. 2006. Interactions in developmental toxicology: concurrent exposure to perfluorooctane sulfonate (PFOS) and stress in pregnant mice. *Toxicology Letters* 164 (1):81-9.

44. Grasty, R.C., D.C. Wolf, B.E. Grey, C.S. Lau, and J.M. Rogers. 2003. Prenatal window of susceptibility to perfluorooctane sulfonate-induced neonatal mortality in the Sprague-Dawley rat. *Birth Defects Research Part B: Developmental and Reproductive Toxicology* 68 (6):465-71.

45. Luebker, D.J., M.T. Case, R.G. York, J.A. Moore, K.J. Hansen, and J.L. Butenhoff. 2005. Two-generation reproduction and cross-foster studies of perfluorooctanesulfonate (PFOS) in rats. *Toxicology* 215 (1-2):126-48.

46. Luebker, D.J., R.G. York, K.J. Hansen, J.A. Moore, and J.L. Butenhoff. 2005. Neonatal mortality from in utero exposure to perfluorooctanesulfonate (PFOS) in Sprague-Dawley rats: dose-response, and biochemical and pharamacokinetic parameters. *Toxicology* 215 (1-2):149-69.

47. Thibodeaux, J.R., R.G. Hanson, J.M. Rogers, B.E. Grey, B.D. Barbee, J.H. Richards, J.L. Butenhoff, L.A. Stevenson, and C. Lau. 2003. Exposure to perfluorooctane sulfonate during pregnancy in rat and mouse. I: maternal and prenatal evaluations. *Toxicological Sciences* 74 (2):369-81.

48. Butenhoff, J.L., G.L. Kennedy, Jr., S.R. Frame, J.C. O'Connor, and R.G. York. 2004. The reproductive toxicology of ammonium perfluorooctanoate (APFO) in the rat. *Toxicology* 196 (1-2):95-116.

49. Lau, C., J.L. Butenhoff, and J.M. Rogers. 2004. The developmental toxicity of perfluoroalkyl acids and their derivatives. *Toxicology and Applied Pharmacology* 198 (2):231-41.

50. Lau, C., J.R. Thibodeaux, R.G. Hanson, M.G. Narotsky, J.M. Rogers, A.B. Lindstrom, and M.J. Strynar. 2006. Effects of perfluorooctanoic acid exposure during pregnancy in the mouse. *Toxicological Sciences* 90 (2):510-8.

51. Olsen, G.W., and L.R. Zobel. 2007. Assessment of lipid, hepatic, and thyroid parameters with serum perfluorooctanoate (PFOA) concentrations in fluorochemical production workers. *International Archives of Occupational and Environmental Health* 81 (2):231-46.

52. Dallaire, R., E. Dewailly, D. Pereg, S. Dery, and P. Ayotte. 2009. Thyroid function and plasma concentrations of polyhalogenated compounds in Inuit adults. *Environmental Health Perspectives* 117 (9):1380-6.

53. Melzer, D., N. Rice, M.H. Depledge, W.E. Henley, and T.S. Galloway. 2010. Association Between Serum Perfluorooctanoic Acid (PFOA) and Thyroid Disease in the NHANES Study. *Environmental Health Perspectives*.

54. Morreale de Escobar, G., M.J. Obregon, and F. Escobar del Rey. 2000. Is neuropsychological development related to maternal hypothyroidism or to maternal hypothyroxinemia? *The Journal of Clinical Endocrinology and Metabolism* 85 (11):3975-87.

55. Nelson, J.W., E.E. Hatch, and T.F. Webster. 2009. Exposure to Polyfluoroalkyl Chemicals and Cholesterol, Body Weight, and Insulin Resistance in the General U.S. Population. *Environmental Health Perspectives* 118 (2).

56. Haughom, B., and O. Spydevold. 1992. The mechanism underlying the hypolipemic effect of perfluorooctanoic acid (PFOA), perfluorooctane sulphonic acid (PFOSA) and clofibric acid. *Biochimica et Biophysica Acta* 1128 (1):65-72.

57. Seacat, A.M., P.J. Thomford, K.J. Hansen, G.W. Olsen, M.T. Case, and J.L. Butenhoff. 2002. Subchronic toxicity studies on perfluorooctanesulfonate potassium salt in cynomolgus monkeys. *Toxicological Sciences* 68 (1):249-64.

58. Gilliland, F.D., and J.S. Mandel. 1996. Serum perfluorooctanoic acid and hepatic enzymes, lipoproteins, and cholesterol: a study of occupationally exposed men. *American Journal of Industrial Medicine* 29 (5):560-8.

59. Olsen, G.W., J.M. Burris, J.H. Mandel, and L.R. Zobel. 1999. Serum perfluorooctane sulfonate and hepatic and lipid clinical chemistry tests in fluorochemical production employees. *Journal of Occupational and Environmental Medicine* 41 (9):799-806.

60. Olsen, G.W., J.M. Burris, M.M. Burlew, and J.H. Mandel. 2003. Epidemiologic assessment of worker serum perfluorooctanesulfonate (PFOS) and perfluorooctanoate (PFOA) concentrations and medical surveillance examinations. *Journal of Occupational and Environmental Medicine* 45 (3):260-70.

61. Costa, G., S. Sartori, and D. Consonni. 2009. Thirty years of medical surveillance in perfluooctanoic acid production workers. *Journal of Occupational and Environmental Medicine* 51 (3):364-72.

62. Sakr, C.J., K.H. Kreckmann, J.W. Green, P.J. Gillies, J.L. Reynolds, and R.C. Leonard. 2007. 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. *Journal of Occupational and Environmental Medicine* 49 (10):1086-96.

63. Lin, C.Y., P.C. Chen, Y.C. Lin, and L.Y. Lin. 2009. Association among serum perfluoroalkyl chemicals, glucose homeostasis, and metabolic syndrome in adolescents and adults. *Diabetes Care* 32 (4):702-7.

64. Woollett, L.A. 2001. The origins and roles of cholesterol and fatty acids in the fetus. *Current Opinion in Lipidology* 12 (3):305-12.

65. Keil, D.E., T. Mehlmann, L. Butterworth, and M.M. Peden-Adams. 2008. Gestational exposure to perfluorooctane sulfonate suppresses immune function in B6C3F1 mice. *Toxicological Sciences* 103 (1):77-85.

66. Fang, X., L. Zhang, Y. Feng, Y. Zhao, and J. Dai. 2008. Immunotoxic effects of perfluorononanoic acid on BALB/c mice. *Toxicological Sciences* 105 (2):312-21.

67. Peden-Adams, M.M., J.M. Keller, J.G. Eudaly, J. Berger, G.S. Gilkeson, and D.E. Keil. 2008. Suppression of humoral immunity in mice following exposure to perfluorooctane sulfonate. *Toxicological Sciences* 104 (1):144-54.

68. Centers for Disease Control and Prevention. 2010. *Fourth National Report on Human Exposure to Environmental Chemicals*. Atlanta, GA: CDC. http://www.cdc.gov/exposurereport/.

69. Ehresman, D.J., J.W. Froehlich, G.W. Olsen, S.C. Chang, and J.L. Butenhoff. 2007. Comparison of human whole blood, plasma, and serum matrices for the determination of perfluorooctanesulfonate (PFOS), perfluorooctanoate (PFOA), and other fluorochemicals. *Environ Res* 103 (2):176-84.

70. National Center for Health Statistics. *Vital Statistics Natality Birth Data, 2003-2004*. Retrieved June 15, 2009 from http://www.cdc.gov/nchs/data_access/Vitalstatsonline.htm. .

71. Axelrad, D.A., and J. Cohen. 2011. Calculating summary statistics for population chemical biomonitoring in women of childbearing age with adjustment for age-specific natality. *Environmental Research* 111 (1):149-155.

Metadata

Metadata for	National Health and Nutrition Examination Survey (NHANES)
Brief description of the data set	The National Health and Nutrition Examination Survey (NHANES) is a program of studies designed to assess the health and nutritional status of adults and children in the United States, using a combination of interviews, physical examinations, and laboratory analysis of biological specimens.
Who provides the data set?	Centers for Disease Control and Prevention, National Center for Health Statistics.
How are the data gathered?	Laboratory data are obtained by analysis of blood and urine samples collected from survey participants at NHANES Mobile Examination Centers. Health status is assessed by physical examination. Demographic and other survey data regarding health status, nutrition and health-related behaviors are collected by personal interview, either by self-reporting or, for children under 16 and some others, as reported by an informant.
What documentation is available describing data collection procedures?	See http://www.cdc.gov/nchs/nhanes.htm for detailed survey and laboratory documentation by survey period.
What types of data relevant for children's environmental health indicators are available from this database?	Concentrations of environmental chemicals in urine, blood, and serum. Body measurements. Health status, as assessed by physical examination, laboratory measurements and interview responses. Demographic information.
What is the spatial representation of the database (national or other)?	NHANES sampling procedures provide nationally-representative data. Analysis of data for any other geographic area (region, state, etc.) is possible only by special arrangement with the NCHS Research Data Center, and such analyses may not be representative of the specified area.
Are raw data (individual measurements or survey responses) available?	Individual laboratory measurements and survey responses are generally available. Individual survey responses for some questions are not publicly released.
How are database files obtained?	http://www.cdc.gov/nchs/nhanes.htm
Are there any known data quality or data analysis concerns?	Some environmental chemicals have large percentages of values below the detection limit. Data gathered by interview, including demographic information, and responses regarding health status, nutrition and health-related behaviors are self-

Metadata for	**National Health and Nutrition Examination Survey (NHANES)**
	reported, or (for individuals age 16 years and younger) reported by an adult informant.
What documentation is available describing QA procedures?	http://www.cdc.gov/nchs/nhanes.htm includes detailed documentation on laboratory and other QA procedures. Data quality information is available at http://www.cdc.gov/nchs/about/policy/quality.htm.
For what years are data available?	Some data elements were collected in predecessors to NHANES beginning in 1959; collection of data on environmental chemicals began with measurement of blood lead in NHANES II, 1976-1980. The range of years for measurement of environmental chemicals varies; apart from lead and cotinine (initiated in NHANES III), measurement of environmental chemicals began with 1999-2000 or later NHANES.
What is the frequency of data collection?	Data are collected on continuous basis, but are grouped into NHANES cycles: NHANES II (1976-1980); NHANES III phase 1 (1988-1991); NHANES III phase 2 (1991-1994); and continuous two-year cycles beginning with 1999-2000 and continuing to the present.
What is the frequency of data release?	Data are released in two-year cycles (e.g. 1999-2000); particular data sets from a two-year NHANES cycle are released as available.
Are the data comparable across time and space?	Detection limits can vary across time, affecting some comparisons. Some contaminants are not measured in every NHANES cycle. Within any NHANES two-year cycle, data are generally collected and analyzed in the same manner for all sampling locations.
Can the data be stratified by race/ethnicity, income, and location (region, state, county or other geographic unit)?	Data are collected to be representative of the U.S. population based on age, sex, and race/ethnicity. The public release files allow stratification by these and other demographic variables, including family income range and poverty income ratio. Data cannot be stratified geographically except by special arrangement with the NCHS Research Data Center.

1

Methods

Indicator

PFC1. Perfluorochemicals in women ages 16 to 49 years: Median concentrations in blood serum, 1999-2006.

Summary

Since the 1970s, the National Center for Health Statistics, a division of the Centers for Disease Control and Prevention, has conducted the National Health and Nutrition Examination Surveys (NHANES), a series of U.S. national surveys of the health and nutrition status of the noninstitutionalized civilian population. The National Center for Environmental Health at CDC measures environmental chemicals in blood and urine samples collected from NHANES participants.[ii] This indicator uses blood serum perfluorochemical (PFC) measurements of the four PFCs, perfluorohexane sulfonic acid (PFHxS), perfluorononanoic acid (PFNA), perfluorooctane sulfonic acid (PFOS), and perfluorooctanoic acid (PFOA). The NHANES 1999-2000, 2003-2004, and 2005-2006 surveys included blood serum PFC data for children and adults ages 12 years and over.[iii] Indicator PFC1 gives the median concentrations of each of these PFCs for women ages 16 to 49 years, stratified by survey period. The median is the estimated concentration such that 50 percent of all noninstitutionalized civilian women ages 16 to 49 years during the survey period have a PFC concentration below this level; the population distribution was adjusted by age-specific birthrates to estimate the median pre-natal exposure to PFCs. Table PFC1a gives the 95th percentile concentrations of each of these PFCs for women ages 16 to 49 years, stratified by survey period. The 95th percentile is the estimated concentration such that 95 percent of all noninstitutionalized civilian women ages 16 to 49 years during the survey period have a PFC concentration below this level. Table PFC1b gives the median concentrations of each of these PFCs for women ages 16 to 49 years for 2003-2006, stratified by race/ethnicity and family income. Table PFC1c gives the 95th percentile concentrations of each of these PFCs for women ages 16 to 49 years for 2003-2006, stratified by race/ethnicity and family income. The survey data were weighted to account for the complex multi-stage, stratified, clustered sampling design.

[ii] Centers for Disease Control and Prevention. 2009. Fourth National Report on Human Exposure to Environmental Chemicals. Atlanta, GA. Available at: www.cdc.gov/exposurereport.

[iii] Blood serum data from NHANES 2001-2002 are not included in Indicator PFC1 because the data were pooled and thus not comparable to data from other years.

1
2
3 **Data Summary**
4

Indicator		PFC1. Perfluorochemicals in women ages 16 to 49 years: Median concentrations in blood serum, 1999-2006.		
Time Period		1999-2000 and 2003-2006		
Data		Blood Serum PFC for four PFCs.		
PFOS	Years	1999-2000	2003-2004	2005-2006
	Limits of Detection (ng/mL)*	0.2	0.4	0.2
	Number of Non-missing Values**	444	504	626
	Number of Missing Values	0	73	58
	Percentage Below Limit of Detection***	0	0	0
PFOA	Years	1999-2000	2003-2004	2005-2006
	Limits of Detection (ng/mL)*	0.2	0.1	0.1
	Number of Non-missing Values**	444	504	626
	Number of Missing Values	0	73	58
	Percentage Below Limit of Detection***	0	1	0
PFHxS	Years	1999-2000	2003-2004	2005-2006
	Limits of Detection (ng/mL)*	0.1	0.3	0.1
	Number of Non-missing Values**	444	504	626
	Number of Missing	0	73	58

Indicator		PFC1. Perfluorochemicals in women ages 16 to 49 years: Median concentrations in blood serum, 1999-2006.		
	Values			
	Percentage Below Limit of Detection***	0	4	7
PFNA	Years	1999-2000	2003-2004	2005-2006
	Limits of Detection (ng/mL)*	0.2	0.1	0.1
	Number of Non-missing Values**	444	504	626
	Number of Missing Values	0	73	58
	Percentage Below Limit of Detection***	8	2	1

* The Limit of Detection (LOD) is defined as the level at which the measurement has a 95% probability of being greater than zero..

**Non-missing values include those below the analytical LOD, which are reported as LOD/√2.

***This percentage is survey-weighted using the NHANES survey weights for the given period and is weighted by age-specific birthrates.

Overview of Data Files

The following files are needed to calculate this indicator. The files together with the survey documentation and SAS programs for reading in the data are available at the NHANES website: http://www.cdc.gov/nchs/nhanes.htm.

- NHANES 1999-2000: Demographic file demo.xpt. Surplus Specimen Laboratory Component: Polyfluorinated Chemicals (Surplus Sera) Laboratory file sspfc_a.xpt. The demographic file demo.xpt is a SAS transport file that contains the subject identifier (SEQN), age (RIDAGEYR), gender (RIAGENDR), pseudo-stratum (SDMVSTRA), pseudo-PSU (SDMVPSU), and laboratory survey weight (WTMEC2YR). The Polyfluorinated Chemicals laboratory file sspfc_a.xpt contains SEQN and the PFCs PFOS, PFOA, PFHxS and PFNA (SPFOS, SPFOA, SPFHS, SPFNA). The two files are merged using the common variable SEQN.

- NHANES 2003-2004: Demographic file demo_c.xpt. Polyfluorinated Compounds Laboratory file l24pfc_c.xpt. The demographic file demo_c.xpt is a SAS transport file that contains the subject identifier (SEQN), age (RIDAGEYR), gender (RIAGENDR), race/ethnicity (RIDRETH1), poverty income ratio (INDFMPIR), pseudo-stratum

(SDMVSTRA) and the pseudo-PSU (SDMVPSU). The Polyfluorinated Compounds laboratory file l24pfc_c.xpt contains SEQN, the PFCs PFOS, PFOA, PFHxS and PFNA (LBXPFOS, LBXPFOA, LBXPFHS, LBXPFNA), the PFC non-detect comment codes (LBDPFOSL, LBDPFOAL, LBDPFHSL, LBDPFNAL), and the sub-sample A laboratory survey weight (WTSA2YR). The two files are merged using the common variable SEQN.

- NHANES 2005-2006: Demographic file demo_d.xpt. Polyfluorinated Compounds Laboratory file pfc_d.xpt. The demographic file demo_d.xpt is a SAS transport file that contains the subject identifier (SEQN), age (RIDAGEYR), gender (RIAGENDR), race/ethnicity (RIDRETH1), poverty income ratio (INDFMPIR), pseudo-stratum (SDMVSTRA) and the pseudo-PSU (SDMVPSU). The Polyfluorinated Compounds laboratory file pfc_d.xpt contains SEQN, the PFCs PFOS, PFOA, PFHxS and PFNA (LBXPFOS, LBXPFOA, LBXPFHS, LBXPFNA), the PFC non-detect comment codes (LBDPFOSL, LBDPFOAL, LBDPFHSL, LBDPFNAL), and the sub-sample A laboratory survey weight (WTSA2YR). The two files are merged using the common variable SEQN.

National Health and Nutrition Examination Surveys (NHANES)

Since the 1970s, the National Center for Health Statistics, a division of the Centers for Disease Control and Prevention, has conducted the National Health and Nutrition Examination Surveys (NHANES), a series of U.S. national surveys of the health and nutrition status of the noninstitutionalized civilian population. The National Center for Environmental Health at CDC measures environmental chemicals in blood and urine samples collected from NHANES participants. This indicator uses blood serum PFC measurements of four PFCs from NHANES 1999-2000, 2003-2004 and 2005-2006 in women ages 16 to 49. The NHANES data were obtained from the NHANES website: http://www.cdc.gov/nchs/nhanes.htm. Following the CDC recommended approach, values below the analytical limit of detection (LOD) were replaced by LOD/√2.[iv]

This analysis uses the four PFCs listed in the following table.

PFC Abbreviation	Full name	SAS name (1999-2000)	SAS name (2003-2006)	SAS name for non-detect comment code (2003-2006)*
PFOS	Perfluorooctane sulfonic acid	SPFOS	LBXPFOS	LBDPFOSL
PFOA	Perfluorooctanoic acid	SPFOA	LBXPFOA	LBDPFOAL
PFHxS	Perfluorohexane sulfonic acid	SPFHS	LBXPFHS	LBSPFHSL

[iv] See Hornung RW, Reed LD. 1990. Estimation of average concentration in the presence of nondetectable values. *Applied Occupational and Environmental Hygiene* 5:46–51.

PFC Abbreviation	Full name	SAS name (1999-2000)	SAS name (2003-2006)	SAS name for non-detect comment code (2003-2006)*
PFNA	Perfluorononanoic acid	SPFNA	LBXPFNA	LBDPFNAL

*The non-detect comment code equals 1 if the measurement is below the analytical limit of detection, and equals 0 if the measurement is at or above the analytical limit of detection.

The NHANES use a complex multi-stage, stratified, clustered sampling design. Certain demographic groups were deliberately over-sampled, including Mexican-Americans and Blacks. Oversampling is performed to increase the reliability and precision of estimates of health status indicators for these population subgroups. The publicly released data includes survey weights to adjust for the over-sampling, non-response, and non-coverage. The statistical analyses used the applicable laboratory survey weights (WTMEC2YR for 2001-2002 and WTSA2YR for 2003-2006) to re-adjust the blood serum PFC data to represent the national population.

Age-Specific Birthrates

In addition to the NHANES survey weights, the data for women of child-bearing age (ages 16 to 49) were also weighted by the birthrate for women of the given age and race/ethnicity to estimate pre-natal exposures. Thus the overall weight in each two year period is the product of the NHANES survey weight and the total number of births in the two calendar years for the given age and race/ethnicity, divided by twice the corresponding population of women at the midpoint of the two year period.[v]

Race/Ethnicity and Family Income

For the tables PFC1b and PFC1c the percentiles were calculated for demographic strata defined by the combination of race/ethnicity and family income.

The family income was characterized based on the INDFMPIR variable, which is the ratio of the family income to the poverty level. The National Center for Health Statistics used the U.S. Census Bureau Current Population Survey to define the family units, and the family income for the respondent was obtained during the interview. The U.S. Census Bureau defines annual poverty level money thresholds varying by family size and composition. The poverty income ratio (PIR) is the family income divided by the poverty level for that family. Family income was stratified into the following groups:

- Below Poverty Level: PIR < 1
- Between 100% and 200% of Poverty Level: $1 \leq PIR \leq 2$
- Above 200% of Poverty level: PIR > 2
- Above Poverty Level: $PIR \geq 1$ (combines the previous two groups)

[v] Axelrad, D.A., Cohen, J. 2010. Calculating summary statistics for population chemical biomonitoring in women of childbearing age with adjustment for age-specific natality. *Environmental Research* 111 (1) 149-155.

- Unknown Income: PIR is missing

Race/ethnicity was characterized using the RIDRETH1 variable. The possible values of this variable are:

- 1. Mexican American
- 2. Other Hispanic
- 3. Non-Hispanic White
- 4. Non-Hispanic Black
- 5. Other Race – Including Multi-racial
- "." Missing

Category 5 includes: all non-Hispanic single race responses other than White or Black; and multi-racial responses.

For this indicator, the RIDRETH1 categories 2, 5, and missing were combined into a single "Other" category. This produced the following categories:

- White non-Hispanic: RIDRETH1 = 3
- Black non-Hispanic: RIDRETH1 = 4
- Mexican-American: RIDRETH1 = 1
- Other: RIDRETH1 = 2 or 5 or missing

The "Other" category includes Asian non-Hispanic; Native American non-Hispanic; Hispanic other than Mexican-American; those reporting multi-racial; and those with a missing value for race/ethnicity.

Calculation of Indicator

Indicator PFC1 is the median for blood serum PFC in women of ages 16 to 49 years, stratified by survey period. The median is the estimated concentration such that 50 percent of all noninstitutionalized civilian women ages 16 to 49 years during the survey period have blood serum PFC concentrations below this level. To adjust the NHANES data to represent pre-natal exposures, the data for each woman surveyed was multiplied by the estimated number of births per woman of the given age and race/ethnicity. Table PCB1a is the 95th percentile for blood serum PFC in women of ages 16 to 49 years, stratified by survey period. The 95th percentile is the estimated concentration such that 95 percent of all noninstitutionalized civilian women ages 16 to 49 years during the survey period have blood serum PFC concentrations below this level. Table PCB1b is the median for blood serum PFC in women of ages 16 to 49 years, stratified both by race/ethnicity and family income. Table PCB1c is the 95th percentile for blood serum PFC in women of ages 16 to 49 years, stratified both by race/ethnicity and family income.

To simply demonstrate the calculations, we will use the NHANES 2005-2006 blood serum PFOS values for women ages 16 to 49 years of all race/ethnicities and all incomes as an example. We have rounded all the numbers to make the calculations easier:

We begin with all the non-missing NHANES 2005-2006 blood serum PFOS values for women ages 16 to 49 years. Assume for the sake of simplicity that valid data on blood serum PFOS were available for every sampled woman. Each sampled woman has an associated annual survey weight, WTSA2YR, that estimates the annual number of U.S. women represented by that sampled woman. Each sampled woman also has an associated birthrate giving the numbers of annual births per woman of the given age, race, and ethnicity. The product of the annual survey weight and the birthrate estimates the annual number of U.S. births represented by that sampled woman, which we will refer to as the adjusted survey weight. For example, the lowest blood serum PFOS measurement for a woman between 16 and 49 years of age is 0.14 ng/mL with an annual survey weight of 110,000, a birthrate of 0.0006, and thus an adjusted survey weight of 70, and so represents 70 births. The total of the adjusted survey weights for the sampled women equals 4 million, the total number of annual U.S. births to women ages 16 to 49 years. The second-lowest measurement is 0.5 ng/mL with an adjusted survey weight of 2,400, and so represents another 2,400 U.S. births. The highest measurement was 175 ng/mL, with an adjusted survey weight of 40, and so represents another 40 U.S. births.

To calculate the median, we can use the adjusted survey weights to expand the data to the entire U.S. population of births to women ages 16 to 49. We have 70 values of 0.14 ng/mL from the lowest measurement, 2,400 values of 0.50 ng/mL from the second lowest measurement, and so on, up to 40 values of 175 ng/mL from the highest measurement. Arranging these 4 million values in increasing order, the 2 millionth value is 11.6 ng/mL. Since half of the values are below 11.6 and half of the values are above 11.6, the median equals 11.6 ng/mL. To calculate the 95th percentile, as in Table PFC1a, note that 95 percent of 4 million equals 3.8 million. The 3.8 millionth value is 27.8 ng/mL. Since 95 percent of the values are below 27.8, the 95th percentile equals 27.8 ng/mL.

In reality, the calculations need to take into account that blood serum PFOS measurements were not available for every respondent, and to use exact rather than rounded numbers. There were blood serum PFOS measurements for only 626 of the 684 sampled women ages 16 to 49 years. The adjusted survey weights for all 684 sampled women add up to 4.2 million, the U.S. population of births to women ages 16 to 49. The adjusted survey weights for the 626 sampled women with blood serum PFOS data add up to 3.9 million. Thus the available data represent 3.9 million values and so represent only 91% of the U.S. population of births. The median and 95th percentiles are given by the 1.95 millionth (50% of 3.9 million) and 3.71 millionth (95% of 3.9 million) U.S. birth's value. These calculations assume that the sampled women with valid blood serum PFOS data are representative of women giving birth without valid blood serum PFOS data. The calculations also assume that the sampled women are representative of women that actually gave birth in 2005-2006, since NHANES information on pregnancy and births was not incorporated into the analysis.

Equations

These percentile calculations can also be given as the following mathematical equations, which are based on the default percentile calculation formulas from Statistical Analysis System (SAS) software. Exclude all missing blood serum PFOS values. Suppose there are n women of ages 16

to 49 years with valid blood serum PFOS values. Arrange the blood serum PFC concentrations in increasing order (including tied values) so that the lowest concentration is x(1) with an adjusted survey weight of w(1), the second lowest concentration is x(2) with an adjusted survey weight of w(2), …, and the highest concentration is x(n) with an adjusted survey weight of w(n).

1. Sum all the adjusted survey weights to get the total weight W:

$$W = \Sigma[1 \leq i \leq n]\ w(i)$$

2. Find the largest number i so that the total of the weights for the i lowest values is less than or equal to W/2.

$$\Sigma[j \leq i]\ w(j) \leq W/2 < \Sigma[j \leq i + 1]\ w(j)$$

3. Calculate the median using the results of the second step. We either have

$$\Sigma[j \leq i]\ w(j) = W/2 < \Sigma[j \leq i + 1]\ w(j)$$

or

$$\Sigma[j \leq i]\ w(j) < W/2 < \Sigma[j \leq i + 1]\ w(j)$$

In the first case we define the median as the average of the i'th and i + 1'th values:

$$\text{Median} = [x(i) + x(i + 1)]/2 \text{ if } \Sigma[j \leq i]\ w(j) = W/2$$

In the second case we define the median as the i + 1'th value:

$$\text{Median} = x(i + 1) \text{ if } \Sigma[j \leq i]\ w(j) < W/2$$

(The estimated median does not depend upon how the tied values of x(j) are ordered).

A similar calculation applies to the 95th percentile. The first step to calculate the sum of the weights, W, is the same. In the second step, find the largest number i so that the total of the weights for the i lowest values is less than or equal to 0.95W.

$$\Sigma[j \leq i]\ w(j) \leq 0.95W < \Sigma[j \leq i + 1]\ w(j)$$

In the third step we calculate the 95th percentile using the results of the second step. We either have

$$\Sigma[j \leq i]\ w(j) = 0.95W < \Sigma[j \leq i + 1]\ w(j)$$

or

$$\Sigma[j \leq i]\ w(j) < 0.95W < \Sigma[j \leq i + 1]\ w(j)$$

In the first case we define the 95th percentile as the average of the i'th and i + 1'th values:

$$95^{th}\ \text{Percentile} = [x(i) + x(i+1)]/2 \text{ if } \Sigma[j \le i]\ w(j) = 0.95W$$

In the second case we define the 95th percentile as the i + 1'th value:

$$95^{th}\ \text{Percentile} = x(i+1) \text{ if } \Sigma[j \le i]\ w(j) < 0.95W$$

Relative Standard Error

The uncertainties of the median and 95th percentile values were calculated using a revised version of the CDC method given in CDC 2005,[vi] Appendix C, and the SAS® program provided by CDC. The method uses the Clopper-Pearson binomial confidence intervals adapted for complex surveys by Korn and Graubard (see Korn and Graubard, 1999,[vii] p. 65). The following text is a revised version of the Appendix C. For the birthrate adjusted calculations for women ages 16 to 49, the sample weight is adjusted by multiplying by the age-specific birthrate.

Step 1: Use SAS® Proc Univariate to obtain a point estimate P_{SAS} of the percentile value. Use the Weight option to assign the exact correct sample weight for each chemical result.

Step 2: Use SUDAAN® Proc Descript with Taylor Linearization DESIGN = WR (i.e., sampling with replacement) and the proper sampling weight to estimate the proportion (p) of subjects with results less than and not equal to the percentile estimate P_{SAS} obtained in Step 1 and to obtain the standard error (se_p) associated with this proportion estimate. Compute the degrees-of-freedom adjusted effective sample size

$$n_{df} = (t_{num}/t_{denom})^2\, p(1 - p)/(se_p{}^2)$$

where t_{num} and t_{denom} are 0.975 critical values of the Student's t distribution with degrees of freedom equal to the sample size minus 1 and the number of PSUs minus the number of strata, respectively. Note: the degrees of freedom for t_{denom} can vary with the demographic sub-group of interest.

Step 3: After obtaining an estimate of p (i.e., the proportion obtained in Step 2), compute the Clopper-Pearson 95% confidence interval ($P_L(x,n_{df})$, $P_U(x,n_{df})$) as follows:

$$P_L(x,n_{df}) = v_1F_{v1,v2}\,(0.025)/(v_2 + v_1F_{v1,v2}(0.025))$$
$$P_U(x,n_{df}) = v_3F_{v3,v4}\,(0.975)/(v_4 + v_3F_{v3,v4}(0.975))$$

where x is equal to p times n_{df}, $v_1 = 2x$, $v_2 = 2(n_{df} - x + 1)$, $v_3 = 2(x + 1)$, $v_4 = 2(n_{df} - x)$, and $F_{d1,d2}(\beta)$ is the β quantile of an F distribution with d1 and d2 degrees of freedom. (Note: If n_{df} is greater than the actual sample size or if p is equal to zero, then the actual sample size should be used.) This step will produce a lower and an upper limit for the estimated proportion obtained in Step 2.

Step 4: Use SAS Proc Univariate (again using the Weight option to assign weights) to determine the chemical percentile values P_{CDC}, L_{CDC} and U_{CDC} that correspond to the proportion p obtained in Step 2 and its lower and upper limits obtained in Step 3. Do not round the values of p and the lower and upper limits.

[vi] CDC Third National Report on Human Exposure to Environmental Chemicals. 2005
[vii] Korn E. L., Graubard B. I. 1999. *Analysis of Health Surveys.* Wiley.

For example, if p = 0.4832, then P_{CDC} is the 48.32'th percentile value of the chemical. The alternative percentile estimates P_{CDC} and P_{SAS} are not necessarily equal.

Step 5: Use the confidence interval from Step 4 to estimate the standard error of the estimated percentile P_{CDC}:

$$\text{Standard Error } (P_{CDC}) = (U_{CDC} - L_{CDC}) / (2t_{denom})$$

Step 6: Use the estimated percentile P_{CDC} and the standard error from Step 4 to estimate the relative standard error of the estimated percentile P_{CDC}:

$$\text{Relative Standard Error (\%)} = [\text{Standard Error } (P_{CDC}) / P_{CDC}] \times 100\ \%$$

The tabulated estimated percentile is the value of P_{SAS} given in Step 1. The relative standard error is given in Step 6, using P_{CDC} and its standard error.

The relative standard error depends upon the survey design. For this purpose, the public release version of NHANES includes the variables SDMVSTRA and SDMVPSU, which are the Masked Variance Unit pseudo-stratum and pseudo-primary sampling unit (pseudo-PSU). For approximate variance estimation, the survey design can be approximated as being a stratified random sample with replacement of the pseudo-PSUs from each pseudo-stratum; the true stratum and PSU variables are not provided in the public release version to protect confidentiality.

Percentiles with a relative standard error less than 30% were treated as being reliable and were tabulated. Percentiles with a relative standard error greater than or equal to 30% but less than 40% were treated as being unstable; these values were tabulated but were flagged to be interpreted with caution. Percentiles with a relative standard error greater than or equal to 40%, or without an estimated relative standard error, were treated as being unreliable; these values were not tabulated and were flagged as having a large uncertainty.

Questions and Comments

Questions regarding these methods, and suggestions to improve the description of the methods, are welcome. Please use the "Contact Us" link at the bottom of any page in the America's Children and the Environment website.

Statistical Comparisons

Statistical analyses of the percentiles were used to determine whether the differences between percentiles for different demographic groups were statistically significant. For these analyses, the percentiles and their standard errors were calculated for each combination of age group, income group (below poverty, at or above poverty, unknown income), and race/ethnicity group using the method described in the "Relative Standard Error" section. In the notation of that section, the percentile and standard error are the values of P_{CDC} and Standard Error (P_{CDC}), respectively. These calculated standard errors account for the survey weighting and design and, for women, for the age-specific birthrate.

Using a weighted linear regression model, the percentile was assumed to be the sum of explanatory terms for age, income and/or race/ethnicity and a random error term; the error terms were assumed to be approximately independent and normally distributed with a mean of zero and a variance equal to the square of the standard error. Using this model, the difference in the value of a percentile between different demographic groups is statistically significant if the difference between the corresponding sums of explanatory terms is statistically significantly different from zero. A p-value at or below 0.05 implies that the difference is statistically significant at the five percent significance level. No adjustment is made for multiple comparisons.

For each type of comparison, we present unadjusted and adjusted analyses. The unadjusted analyses directly compare a percentile between different demographic groups. The adjusted analyses add other demographic explanatory variables to the statistical model and use the statistical model to account for the possible confounding effects of these other demographic variables. For example, the unadjusted race/ethnicity comparisons use and compare the percentiles between different race/ethnicity pairs. The adjusted race/ethnicity comparisons use the percentiles for each age/ income/race/ethnicity combination. The adjusted analyses add age, and income terms to the statistical model and compare the percentiles between different race/ethnicity pairs after accounting for the effects of the other demographic variables. For example, if White non-Hispanics tend to have higher family incomes than Black non-Hispanics, and if the body burden strongly depends on family income only, then the unadjusted differences between these two race/ethnicity groups would be significant but the adjusted difference (taking into account income) would not be significant.

Comparisons between pairs of race/ethnicity groups are shown in Tables 1 and 2 for women ages 16 to 49 years. In Table 1, for the unadjusted "All incomes" comparisons, the only explanatory variables are terms for each race/ethnicity group. For these unadjusted comparisons, the statistical tests compare the percentiles for each pair of race/ethnicity groups. For the adjusted "All incomes (adjusted for age, income)" comparisons, the explanatory variables are terms for each race/ethnicity group, together with terms for each age and income group. For these adjusted comparisons, the statistical test compares the pair of race/ethnicity groups after accounting for any differences in the age and income distributions between the race/ethnicity groups.

In Table 1, for the unadjusted "Below Poverty Level" and "At or Above Poverty Level" comparisons, the only explanatory variables are terms for each of the twelve race/ethnicity/income combinations (combinations of four race/ethnicity groups and three

income groups). For example, in row 1, the p-value for "Below Poverty Level" compares White non-Hispanics below the poverty level with Black non-Hispanics below the poverty level. The same set of explanatory variables are used in Table 2 for the unadjusted comparisons between one race/ethnicity group below the poverty level and the same or another race/ethnicity group at or above the poverty level. The corresponding adjusted analyses include extra explanatory variables for age, so that race/ethnicity/income groups are compared after accounting for any differences due to age.

Additional comparisons are shown in Table 3 for women ages 16 to 49 years. The AGAINST = "income" unadjusted p-value compares the body burdens for those below poverty level with those at or above poverty level, using the explanatory variables for the three income groups (below poverty, at or above poverty, unknown income). The adjusted p-value includes adjustment terms for age and race/ethnicity in the model. The AGAINST = "yearnum" p-value examines whether the linear trend in the body burden is statistically significant (using the percentiles for each NHANES period regressed against the midpoint of that period); the adjusted model for trend adjusts for demographic changes in the populations from year to year by including terms for age, income, and race/ethnicity.

For women, the age groups used were 16-19, 20-24, 25-29, 30-39, and 40-49.

For more details on these statistical analyses, see the memorandum by Cohen (2010).[viii]

Table 1. Statistical significance tests comparing the percentiles of PFCs in women ages 16 to 49 years, between pairs of race/ethnicity groups, for 2003-2006.

				P-VALUES					
Variable	Percentile	RACE1	RACE2	All incomes	All incomes (adjusted for age, income)	Below Poverty Level	Below Poverty Level (adjusted for age)	At or Above Poverty Level	At or Above Poverty Level (adjusted for age)
PFOS	50	White non-Hispanic	Black non-Hispanic	0.151	0.321	0.745	0.622	0.498	0.139
PFOS	50	White non-Hispanic	Mexican-American	< 0.0005	< 0.0005	0.048	0.005	0.001	< 0.0005
PFOS	50	White non-Hispanic	Other	0.013	< 0.0005	0.008	0.003	0.173	< 0.0005
PFOS	50	Black non-Hispanic	Mexican-American	< 0.0005	< 0.0005	< 0.0005	0.020	0.011	0.001
PFOS	50	Black non-Hispanic	Other	0.149	< 0.0005	< 0.0005	0.006	0.564	< 0.0005
PFOS	50	Mexican-American	Other	0.195	0.069	0.103	0.105	0.025	0.297
PFOA	50	White non-Hispanic	Black non-Hispanic	0.001	0.035	0.303	0.005	0.002	0.007
PFOA	50	White non-Hispanic	Mexican-American	< 0.0005	< 0.0005	0.004	< 0.0005	0.010	0.005
PFOA	50	White non-Hispanic	Other	0.001	< 0.0005	0.022	< 0.0005	0.037	< 0.0005
PFOA	50	Black non-	Mexican-	1.000	0.001	0.069	0.359	0.526	0.963

[viii] Cohen, J. 2010. *Selected statistical methods for testing for trends and comparing years or demographic groups in ACE NHIS and NHANES indicators.* Memorandum submitted to Dan Axelrad, EPA, 21 March, 2010.

				P-VALUES					
Variable	**Percentile**	**RACE1**	**RACE2**	**All incomes**	**All incomes (adjusted for age, income)**	**Below Poverty Level**	**Below Poverty Level (adjusted for age)**	**At or Above Poverty Level**	**At or Above Poverty Level (adjusted for age)**
		Hispanic	American						
PFOA	50	Black non-Hispanic	Other	0.767	< 0.0005	0.165	0.098	1.000	0.026
PFOA	50	Mexican-American	Other	0.736	0.191	1.000	0.328	0.656	0.027
PFHxS	50	White non-Hispanic	Black non-Hispanic	0.111	0.009	0.454	0.072	0.037	0.299
PFHxS	50	White non-Hispanic	Mexican-American	0.094	< 0.0005	0.427	< 0.0005	0.195	0.117
PFHxS	50	White non-Hispanic	Other	0.566	0.340	1.000	0.073	0.429	0.770
PFHxS	50	Black non-Hispanic	Mexican-American	0.485	< 0.0005	1.000	0.007	0.806	0.672
PFHxS	50	Black non-Hispanic	Other	0.188	0.039	0.737	0.155	0.484	0.345
PFHxS	50	Mexican-American	Other	0.149	0.228	0.734	0.408	0.495	0.178
PFNA	50	White non-Hispanic	Black non-Hispanic	0.246	0.557	0.089	0.222	1.000	0.498
PFNA	50	White non-Hispanic	Mexican-American	< 0.0005	< 0.0005	0.298	0.002	0.048	0.246
PFNA	50	White non-Hispanic	Other	0.020	0.738	0.335	0.013	1.000	0.753
PFNA	50	Black non-Hispanic	Mexican-American	< 0.0005	0.006	0.001	0.677	0.044	0.567
PFNA	50	Black non-Hispanic	Other	0.003	0.434	0.053	0.004	1.000	0.846
PFNA	50	Mexican-American	Other	0.182	0.008	0.608	< 0.0005	0.201	0.527
PFOS	95	White non-Hispanic	Black non-Hispanic	0.444	< 0.0005	0.047	< 0.0005	0.967	0.938
PFOS	95	White non-Hispanic	Mexican-American	0.001	< 0.0005	0.002	< 0.0005	0.024	< 0.0005
PFOS	95	White non-Hispanic	Other	0.432	< 0.0005	0.574	< 0.0005	0.675	< 0.0005
PFOS	95	Black non-Hispanic	Mexican-American	0.015	< 0.0005	0.175	< 0.0005	0.026	< 0.0005
PFOS	95	Black non-Hispanic	Other	0.952	< 0.0005	0.015	< 0.0005	0.702	< 0.0005
PFOS	95	Mexican-American	Other	0.028	0.054	0.001	0.687	0.093	0.001
PFOA	95	White non-Hispanic	Black non-Hispanic	0.002	< 0.0005	0.550	0.108	0.002	< 0.0005
PFOA	95	White non-Hispanic	Mexican-American	0.004	< 0.0005	0.235	< 0.0005	0.053	< 0.0005
PFOA	95	White non-Hispanic	Other	0.163	< 0.0005	0.193	< 0.0005	< 0.0005	< 0.0005
PFOA	95	Black non-Hispanic	Mexican-American	0.862	< 0.0005	0.622	< 0.0005	0.385	0.831
PFOA	95	Black non-Hispanic	Other	0.958	0.001	0.477	0.002	0.478	0.084
PFOA	95	Mexican-American	Other	0.916	0.685	0.706	0.247	0.171	0.141
PFHxS	95	White non-Hispanic	Black non-Hispanic	0.762	< 0.0005	0.951	< 0.0005	0.867	0.212
PFHxS	95	White non-Hispanic	Mexican-American	0.366	0.961	0.272	0.400	0.556	0.015
PFHxS	95	White non-Hispanic	Other	0.110	< 0.0005	0.172	0.001	0.171	< 0.0005

				P-VALUES					
Variable	Percentile	RACE1	RACE2	All incomes	All incomes (adjusted for age, income)	Below Poverty Level	Below Poverty Level (adjusted for age)	At or Above Poverty Level	At or Above Poverty Level (adjusted for age)
PFHxS	95	Black non-Hispanic	Mexican-American	0.337	< 0.0005	0.338	< 0.0005	0.405	0.053
PFHxS	95	Black non-Hispanic	Other	0.028	< 0.0005	0.209	< 0.0005	0.006	< 0.0005
PFHxS	95	Mexican-American	Other	0.045	< 0.0005	0.446	0.002	0.024	< 0.0005
PFNA	95	White non-Hispanic	Black non-Hispanic	0.710	< 0.0005	0.005	< 0.0005	0.334	0.673
PFNA	95	White non-Hispanic	Mexican-American	0.175	0.079	0.336	0.465	< 0.0005	0.003
PFNA	95	White non-Hispanic	Other	0.258	< 0.0005	0.523	0.003	0.070	< 0.0005
PFNA	95	Black non-Hispanic	Mexican-American	0.153	< 0.0005	0.223	< 0.0005	0.060	< 0.0005
PFNA	95	Black non-Hispanic	Other	0.203	< 0.0005	0.035	< 0.0005	0.210	< 0.0005
PFNA	95	Mexican-American	Other	0.875	< 0.0005	0.612	0.014	0.744	< 0.0005

Table 2. Statistical significance tests comparing the percentiles of PFCs in women ages 16 to 49 years, between pairs of race/ethnicity/income groups at different income levels, for 2003-2006.

				P-VALUES	
Variable	Percentile	RACEINC1	RACEINC2	Unadjusted	Adjusted (for age)
PFOS	50	White non-Hispanic, < PL	White non-Hispanic, ≥ PL	0.154	< 0.0005
PFOS	50	White non-Hispanic, < PL	Black non-Hispanic, ≥ PL	0.381	0.002
PFOS	50	White non-Hispanic, < PL	Mexican-American, ≥ PL	0.271	0.892
PFOS	50	White non-Hispanic, < PL	Other, ≥ PL	0.622	0.260
PFOS	50	Black non-Hispanic, < PL	White non-Hispanic, ≥ PL	0.118	< 0.0005
PFOS	50	Black non-Hispanic, < PL	Black non-Hispanic, ≥ PL	0.435	0.001
PFOS	50	Black non-Hispanic, < PL	Mexican-American, ≥ PL	0.048	0.702
PFOS	50	Black non-Hispanic, < PL	Other, ≥ PL	0.810	0.463
PFOS	50	Mexican-American, < PL	White non-Hispanic, ≥ PL	< 0.0005	< 0.0005
PFOS	50	Mexican-American, < PL	Black non-Hispanic, ≥ PL	< 0.0005	< 0.0005
PFOS	50	Mexican-American, < PL	Mexican-American, ≥ PL	0.285	0.004
PFOS	50	Mexican-American, < PL	Other, ≥ PL	< 0.0005	0.259
PFOS	50	Other, < PL	White non-Hispanic, ≥ PL	< 0.0005	< 0.0005
PFOS	50	Other, < PL	Black non-Hispanic, ≥ PL	< 0.0005	< 0.0005
PFOS	50	Other, < PL	Mexican-American, ≥ PL	0.039	0.004
PFOS	50	Other, < PL	Other, ≥ PL	< 0.0005	0.032
PFOA	50	White non-Hispanic, < PL	White non-Hispanic, ≥ PL	0.451	0.125
PFOA	50	White non-Hispanic, < PL	Black non-Hispanic, ≥ PL	0.163	0.172
PFOA	50	White non-Hispanic, < PL	Mexican-American, ≥ PL	0.337	0.151
PFOA	50	White non-Hispanic, < PL	Other, ≥ PL	0.262	< 0.0005
PFOA	50	Black non-Hispanic, < PL	White non-Hispanic, ≥ PL	0.030	< 0.0005
PFOA	50	Black non-Hispanic, < PL	Black non-Hispanic, ≥ PL	0.804	0.116

				P-VALUES	
Variable	Percentile	RACEINC1	RACEINC2	Unadjusted	Adjusted (for age)
PFOA	50	Black non-Hispanic, < PL	Mexican-American, ≥ PL	0.797	0.111
PFOA	50	Black non-Hispanic, < PL	Other, ≥ PL	0.846	0.659
PFOA	50	Mexican-American, < PL	White non-Hispanic, ≥ PL	< 0.0005	< 0.0005
PFOA	50	Mexican-American, < PL	Black non-Hispanic, ≥ PL	0.055	0.002
PFOA	50	Mexican-American, < PL	Mexican-American, ≥ PL	0.006	0.001
PFOA	50	Mexican-American, < PL	Other, ≥ PL	0.178	0.593
PFOA	50	Other, < PL	White non-Hispanic, ≥ PL	< 0.0005	< 0.0005
PFOA	50	Other, < PL	Black non-Hispanic, ≥ PL	0.183	0.001
PFOA	50	Other, < PL	Mexican-American, ≥ PL	0.067	0.001
PFOA	50	Other, < PL	Other, ≥ PL	0.277	0.109
PFHxS	50	White non-Hispanic, < PL	White non-Hispanic, ≥ PL	0.003	0.122
PFHxS	50	White non-Hispanic, < PL	Black non-Hispanic, ≥ PL	0.263	0.951
PFHxS	50	White non-Hispanic, < PL	Mexican-American, ≥ PL	0.641	0.649
PFHxS	50	White non-Hispanic, < PL	Other, ≥ PL	0.112	0.265
PFHxS	50	Black non-Hispanic, < PL	White non-Hispanic, ≥ PL	0.009	0.003
PFHxS	50	Black non-Hispanic, < PL	Black non-Hispanic, ≥ PL	0.667	0.163
PFHxS	50	Black non-Hispanic, < PL	Mexican-American, ≥ PL	1.000	0.283
PFHxS	50	Black non-Hispanic, < PL	Other, ≥ PL	0.292	0.039
PFHxS	50	Mexican-American, < PL	White non-Hispanic, ≥ PL	0.003	< 0.0005
PFHxS	50	Mexican-American, < PL	Black non-Hispanic, ≥ PL	0.640	< 0.0005
PFHxS	50	Mexican-American, < PL	Mexican-American, ≥ PL	1.000	0.001
PFHxS	50	Mexican-American, < PL	Other, ≥ PL	0.267	< 0.0005
PFHxS	50	Other, < PL	White non-Hispanic, ≥ PL	0.228	0.037
PFHxS	50	Other, < PL	Black non-Hispanic, ≥ PL	0.615	0.075
PFHxS	50	Other, < PL	Mexican-American, ≥ PL	0.770	0.089
PFHxS	50	Other, < PL	Other, ≥ PL	0.419	0.035
PFNA	50	White non-Hispanic, < PL	White non-Hispanic, ≥ PL	1.000	0.671
PFNA	50	White non-Hispanic, < PL	Black non-Hispanic, ≥ PL	1.000	0.793
PFNA	50	White non-Hispanic, < PL	Mexican-American, ≥ PL	0.068	0.441
PFNA	50	White non-Hispanic, < PL	Other, ≥ PL	1.000	0.980
PFNA	50	Black non-Hispanic, < PL	White non-Hispanic, ≥ PL	0.068	0.143
PFNA	50	Black non-Hispanic, < PL	Black non-Hispanic, ≥ PL	0.064	0.268
PFNA	50	Black non-Hispanic, < PL	Mexican-American, ≥ PL	< 0.0005	0.445
PFNA	50	Black non-Hispanic, < PL	Other, ≥ PL	0.217	0.257
PFNA	50	Mexican-American, < PL	White non-Hispanic, ≥ PL	0.245	< 0.0005
PFNA	50	Mexican-American, < PL	Black non-Hispanic, ≥ PL	0.234	0.004
PFNA	50	Mexican-American, < PL	Mexican-American, ≥ PL	0.231	0.063
PFNA	50	Mexican-American, < PL	Other, ≥ PL	0.497	0.015
PFNA	50	Other, < PL	White non-Hispanic, ≥ PL	0.325	0.018
PFNA	50	Other, < PL	Black non-Hispanic, ≥ PL	0.323	0.008
PFNA	50	Other, < PL	Mexican-American, ≥ PL	1.000	0.006
PFNA	50	Other, < PL	Other, ≥ PL	0.396	0.013
PFOS	95	White non-Hispanic, < PL	White non-Hispanic, ≥ PL	0.467	0.236
PFOS	95	White non-Hispanic, < PL	Black non-Hispanic, ≥ PL	0.451	0.039
PFOS	95	White non-Hispanic, < PL	Mexican-American, ≥ PL	0.024	< 0.0005

				P-VALUES	
Variable	**Percentile**	**RACEINC1**	**RACEINC2**	**Unadjusted**	**Adjusted (for age)**
PFOS	95	White non-Hispanic, < PL	Other, ≥ PL	0.327	< 0.0005
PFOS	95	Black non-Hispanic, < PL	White non-Hispanic, ≥ PL	0.059	< 0.0005
PFOS	95	Black non-Hispanic, < PL	Black non-Hispanic, ≥ PL	0.064	< 0.0005
PFOS	95	Black non-Hispanic, < PL	Mexican-American, ≥ PL	0.711	0.013
PFOS	95	Black non-Hispanic, < PL	Other, ≥ PL	0.184	0.203
PFOS	95	Mexican-American, < PL	White non-Hispanic, ≥ PL	< 0.0005	< 0.0005
PFOS	95	Mexican-American, < PL	Black non-Hispanic, ≥ PL	< 0.0005	< 0.0005
PFOS	95	Mexican-American, < PL	Mexican-American, ≥ PL	0.415	< 0.0005
PFOS	95	Mexican-American, < PL	Other, ≥ PL	0.002	< 0.0005
PFOS	95	Other, < PL	White non-Hispanic, ≥ PL	0.186	< 0.0005
PFOS	95	Other, < PL	Black non-Hispanic, ≥ PL	0.178	< 0.0005
PFOS	95	Other, < PL	Mexican-American, ≥ PL	0.008	0.025
PFOS	95	Other, < PL	Other, ≥ PL	0.126	< 0.0005
PFOA	95	White non-Hispanic, < PL	White non-Hispanic, ≥ PL	0.208	< 0.0005
PFOA	95	White non-Hispanic, < PL	Black non-Hispanic, ≥ PL	0.571	< 0.0005
PFOA	95	White non-Hispanic, < PL	Mexican-American, ≥ PL	0.948	< 0.0005
PFOA	95	White non-Hispanic, < PL	Other, ≥ PL	0.395	< 0.0005
PFOA	95	Black non-Hispanic, < PL	White non-Hispanic, ≥ PL	0.038	< 0.0005
PFOA	95	Black non-Hispanic, < PL	Black non-Hispanic, ≥ PL	0.819	0.018
PFOA	95	Black non-Hispanic, < PL	Mexican-American, ≥ PL	0.484	0.054
PFOA	95	Black non-Hispanic, < PL	Other, ≥ PL	0.939	< 0.0005
PFOA	95	Mexican-American, < PL	White non-Hispanic, ≥ PL	< 0.0005	< 0.0005
PFOA	95	Mexican-American, < PL	Black non-Hispanic, ≥ PL	0.206	0.013
PFOA	95	Mexican-American, < PL	Mexican-American, ≥ PL	0.082	0.011
PFOA	95	Mexican-American, < PL	Other, ≥ PL	0.447	0.394
PFOA	95	Other, < PL	White non-Hispanic, ≥ PL	0.002	< 0.0005
PFOA	95	Other, < PL	Black non-Hispanic, ≥ PL	0.214	0.254
PFOA	95	Other, < PL	Mexican-American, ≥ PL	0.100	0.298
PFOA	95	Other, < PL	Other, ≥ PL	0.362	0.580
PFHxS	95	White non-Hispanic, < PL	White non-Hispanic, ≥ PL	0.777	< 0.0005
PFHxS	95	White non-Hispanic, < PL	Black non-Hispanic, ≥ PL	0.842	< 0.0005
PFHxS	95	White non-Hispanic, < PL	Mexican-American, ≥ PL	0.769	< 0.0005
PFHxS	95	White non-Hispanic, < PL	Other, ≥ PL	0.213	0.008
PFHxS	95	Black non-Hispanic, < PL	White non-Hispanic, ≥ PL	0.740	0.072
PFHxS	95	Black non-Hispanic, < PL	Black non-Hispanic, ≥ PL	0.789	0.406
PFHxS	95	Black non-Hispanic, < PL	Mexican-American, ≥ PL	0.842	0.263
PFHxS	95	Black non-Hispanic, < PL	Other, ≥ PL	0.274	< 0.0005
PFHxS	95	Mexican-American, < PL	White non-Hispanic, ≥ PL	0.211	< 0.0005
PFHxS	95	Mexican-American, < PL	Black non-Hispanic, ≥ PL	0.017	< 0.0005
PFHxS	95	Mexican-American, < PL	Mexican-American, ≥ PL	0.071	< 0.0005
PFHxS	95	Mexican-American, < PL	Other, ≥ PL	0.623	0.044
PFHxS	95	Other, < PL	White non-Hispanic, ≥ PL	0.135	< 0.0005
PFHxS	95	Other, < PL	Black non-Hispanic, ≥ PL	0.043	< 0.0005
PFHxS	95	Other, < PL	Mexican-American, ≥ PL	0.115	< 0.0005
PFHxS	95	Other, < PL	Other, ≥ PL	0.536	0.015

				P-VALUES	
Variable	Percentile	RACEINC1	RACEINC2	Unadjusted	Adjusted (for age)
PFNA	95	White non-Hispanic, < PL	White non-Hispanic, ≥ PL	0.009	< 0.0005
PFNA	95	White non-Hispanic, < PL	Black non-Hispanic, ≥ PL	0.168	< 0.0005
PFNA	95	White non-Hispanic, < PL	Mexican-American, ≥ PL	0.751	0.004
PFNA	95	White non-Hispanic, < PL	Other, ≥ PL	0.637	< 0.0005
PFNA	95	Black non-Hispanic, < PL	White non-Hispanic, ≥ PL	0.105	0.574
PFNA	95	Black non-Hispanic, < PL	Black non-Hispanic, ≥ PL	0.044	0.781
PFNA	95	Black non-Hispanic, < PL	Mexican-American, ≥ PL	0.002	< 0.0005
PFNA	95	Black non-Hispanic, < PL	Other, ≥ PL	0.012	< 0.0005
PFNA	95	Mexican-American, < PL	White non-Hispanic, ≥ PL	0.887	< 0.0005
PFNA	95	Mexican-American, < PL	Black non-Hispanic, ≥ PL	0.784	< 0.0005
PFNA	95	Mexican-American, < PL	Mexican-American, ≥ PL	0.258	0.001
PFNA	95	Mexican-American, < PL	Other, ≥ PL	0.265	0.009
PFNA	95	Other, < PL	White non-Hispanic, ≥ PL	0.245	< 0.0005
PFNA	95	Other, < PL	Black non-Hispanic, ≥ PL	0.672	< 0.0005
PFNA	95	Other, < PL	Mexican-American, ≥ PL	0.360	< 0.0005
PFNA	95	Other, < PL	Other, ≥ PL	0.394	0.323

Table 3. Other statistical significance tests comparing the percentiles of PFCs in women ages 16 to 49 years, for 2003-2006 (trends for 1999-2006).

					P-VALUES	
Variable	Percentile	From	To	Against	Unadjusted	Adjusted*
PFOS	50	2003	2006	income	0.003	< 0.0005
PFOS	50	1999	2006	yearnum	< 0.0005	< 0.0005
PFOA	50	2003	2006	income	0.031	< 0.0005
PFOA	50	1999	2006	yearnum	< 0.0005	< 0.0005
PFHxS	50	2003	2006	income	< 0.0005	< 0.0005
PFHxS	50	1999	2006	yearnum	0.626	< 0.0005
PFNA	50	2003	2006	income	< 0.0005	0.216
PFNA	50	1999	2006	yearnum	0.001	< 0.0005
PFOS	95	2003	2006	income	0.237	< 0.0005
PFOS	95	1999	2006	yearnum	< 0.0005	< 0.0005
PFOA	95	2003	2006	income	0.077	0.354
PFOA	95	1999	2006	yearnum	0.072	< 0.0005
PFHxS	95	2003	2006	income	0.485	< 0.0005
PFHxS	95	1999	2006	yearnum	0.837	< 0.0005
PFNA	95	2003	2006	income	1.000	< 0.0005
PFNA	95	1999	2006	yearnum	0.028	< 0.0005

*For AGAINST = "income," the p-values are adjusted for age and race/ethnicity.
For AGAINST = "yearnum," the p-values are adjusted for age, race/ethnicity, and income.