


2009

Fourth National Report on Human Exposure to Environmental Chemicals



Executive Summary

Department of Health and Human Services
Centers for Disease Control and Prevention
National Center for Environmental Health

Background

The *National Report on Human Exposure to Environmental Chemicals (National Exposure Report)* is a series of ongoing assessments of the U.S. population's exposure to environmental chemicals by measuring chemicals in people's blood and urine, also called biomonitoring. The *Fourth National Report* on *Human Exposure to Environmental Chemicals* (*Fourth Report*) presents exposure data for 212 environmental chemicals for the civilian, noninstitutionalized U.S. population. This *Fourth Report* includes results from 2003–2004, as well as data from1999–2000 and 2001–2002 as reported in the *Second* and *Third National Report on Human Exposure to Environmental Chemicals.*

To obtain data for this *Fourth Report*, the Centers for Disease Control and Prevention (CDC)'s Environmental Health Laboratory at the National Center for Environmental Health measured chemicals or their metabolites in blood and urine from a random sample of participants from the National Health and Nutrition Examination Survey (NHANES). CDC's National Center for Health Statistics conducts NHANES, which is a series of surveys on the health status, health-related behaviors, and nutrition of the U.S. population. Since 1999, NHANES has been conducted in continuous two-year survey cycles.

For the *National Exposure Report*, an environmental chemical refers to a chemical compound or chemical element present in air, water, food, soil, dust, or other environmental media, such as consumer products. Blood and urine levels reflect the amount of the chemical that actually gets into the body from the environment. Either the chemical or its metabolite is measured. A metabolite is a substance produced when body tissues chemically alter the original compound.

The *Fourth Report* includes results for 75 chemicals measured for the first time in the U.S. population. These chemicals are in the following groups:

- acrylamide and glycidamide adducts;
- arsenic species and metabolites;
- environmental phenols, including bisphenol A and triclosan;
- perchlorate;
- perfluorinated chemicals;
- polybrominated diphenyl ethers;
- volatile organic compounds; and
- some additions to chemical groups previously measured.

A complete listing of the 75 new chemicals is given on page 10. A full listing of the chemicals included in the *Fourth Report* is available at http://www.cdc.gov/exposurereport/pdf/NER_Chemical_List.pdf.

Interpreting the Data

The presence of an environmental chemical in people's blood or urine does not mean that it will cause effects or disease. The toxicity of a chemical is related to its dose or concentration, in addition to a person's individual susceptibility. Small amounts may be of no health consequence, whereas larger amounts may cause adverse health effects. Research studies, separate from the *National Exposure Report*, are required to determine the levels of a chemical that may cause health effects and the levels that are not a significant health concern. For some chemicals, such as lead, research studies provide a good understanding of health risks associated with various blood levels. For most of the environmental chemicals included in the *Fourth Report*, more research is needed to determine whether exposure at the levels reported is a cause for health concern. CDC conducts and provides biomonitoring measurements for this type of research in collaboration with other agencies and institutions.

The *Fourth Report* presents data that provides estimates of exposure for the civilian, noninstitutionalized U.S. population. The current survey design does not permit CDC to estimate exposure on a state-by-state or city-by-city basis. For example, CDC cannot extract a subset of data and examine levels of blood lead that represent a state population.

Public Health Uses of *the Fourth Report*

The *Fourth Report* provides unique exposure information to scientists, physicians, and health officials to help prevent effects that may result from exposure to environmental chemicals. Specific public health uses of the exposure information in the *Fourth Report* are to:

- determine which chemicals get into Americans' bodies and at what concentrations;
- determine what proportion of the population has levels above those associated with adverse health effects for chemicals with a known toxicity level;
- establish reference values that can be used by physicians and scientists to determine whether a person or group has an unusually high exposure;
- assess the effectiveness of public health efforts to reduce exposure of Americans to track levels over time;
- determine whether exposure levels are higher among minorities, children, women of childbearing age, or other special groups; and
- direct priorities for research on human health effects from exposure.




First-Time Exposure Information for the U.S. Population Provided for 75 Chemicals

The *Fourth Report*, for the first time, provides population reference values in blood and urine, including 95th percentile levels, for 75 chemicals. The 95th percentile level means that 95% of the population has concentrations below that level. Public health officials use such reference values to determine whether groups of people are experiencing an exposure that is unusual compared with an exposure experienced by the rest of the population.

To provide scientists and public health officials these new data quickly, CDC published much of this exposure information on new chemicals in separate scientific peer-reviewed publications before the *Fourth Report* was released. Abstracts and links to full-text articles are available at http://www.cdc.gov/exposurereport/.

Widespread Exposure to Some Industrial Chemicals

Findings in the *Fourth Report* indicate widespread exposure to some commonly used industrial chemicals.

- Polybrominated diphenyl ethers are fire retardants used in certain manufactured products. These accumulate in the environment and in human fat tissue. One type of polybrominated diphenyl ether, BDE-47, was found in the serum of nearly all of the NHANES participants.
- Bisphenol A (BPA), a component of epoxy resins and polycarbonates, may have potential reproductive toxicity. General population exposure to BPA may occur through ingestion of foods in contact with BPA-containing materials. CDC scientists found bisphenol A in more than 90% of the urine samples representative of the U.S. population.
- Another example of widespread human exposure included several of the perfluorinated chemicals. One of these chemicals, perfluorooctanoic acid (PFOA), was a byproduct of the synthesis of other perfluorinated chemicals and was a synthesis aid in the manufacture of a commonly used polymer, polytetrafluoroethylene, which is used to create heat-resistant non-stick coatings in cookware. Most participants had measurable levels of this environmental contaminant.

Ongoing Progress in Reducing Blood Lead Levels in Children

Progress is being made in reducing children's blood lead levels. New data on blood lead levels in children aged 1 to 5 years enable estimates of the number of children with elevated levels (that is, levels greater than or equal to 10 micrograms per deciliter [µg/dL]). Figure 1 shows how the percentage of blood lead levels in children has declined since the late 1970s. For example, for the period 1999–2004, 1.4% of children aged 1 to 5 years had elevated blood lead levels, the smallest percentage of any of the prior survey periods.

These data document that public health efforts to reduce the number of children with elevated blood lead levels in the general population continue to be successful. However, the *Fourth Report* also notes that other data sources show that special populations of children at high risk for lead exposure (for example, children living in homes containing lead-based paint or lead-contaminated dust) have higher rates of elevated blood lead levels and remain a major public health concern.

First-Time Assessment of Acrylamide Exposure in the U.S. Population

Acrylamide is formed when foods containing carbohydrates are cooked at high temperatures (e.g., French fries) and as a byproduct of tobacco smoke. Most people are exposed to acrylamide through the diet and from smoking. Because acrylamide is a reactive chemical, it can bind to proteins. These reaction products are called adducts. CDC's Environmental Health Laboratory developed a new method to measure acrylamide and its metabolite, glycidamide, as adducts of hemoglobin, a major blood protein. This measure reflects the dose of acrylamide and glycidamide over the previous several months of intake. The data in the *Fourth Report* show that acrylamide exposure is extremely common in the U.S. population.

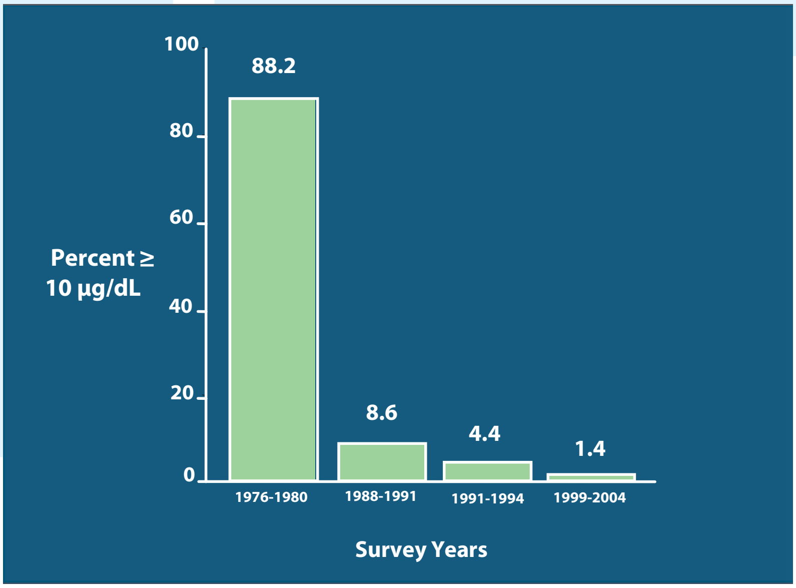

Figure 1. Percentage of children 1-5 years old in the U.S. population with elevated blood lead levels (≥ 10 µg/dL).[1]

[1]Jones RL, Homa DM, Meyer PA, Brody DJ, Caldwell KL, Pirkle JL, Brown MJ. Trends in blood lead levels and blood lead testing among U.S. children aged 1 to 5 years, 1988–2004. Pediatrics 2009;123(3):e376-e385.

First Available Exposure Data on Mercury in the U.S. Population

For the first time, the *Fourth Report* characterizes mercury exposure of the U.S. population aged 1 year and older. Previous *National Exposure Reports* presented mercury levels for children 1–5 years old and women 16–49 years old. Total blood mercury levels are primarily composed of one type of mercury, methyl mercury, which enters the body mainly from dietary seafood sources. Findings in the *Fourth Report* show that total blood mercury levels increase with age for all groups and begin to decline after the fifth decade of life. Compared to older women of childbearing age, younger women have higher birth rates and lower mercury levels (see Figure 2).

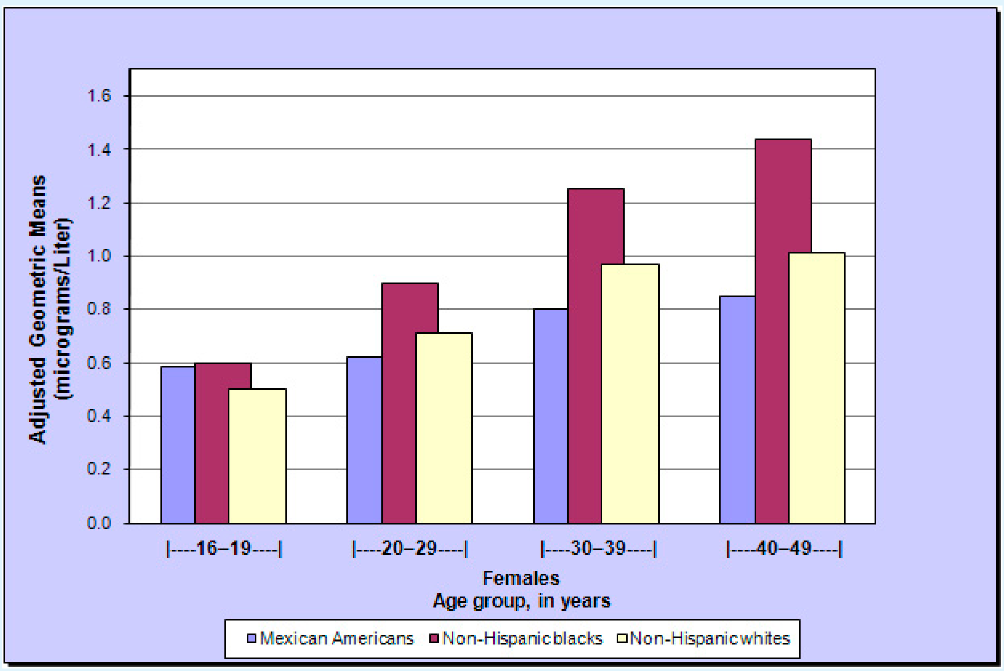

Figure 2. Age-related changes in total blood mercury levels for females aged16-49 by race/ethnicity, 1999-2006.[2]

Eight Different Species and Metabolites of Arsenic Measured

By using special laboratory methods, CDC researchers measured total arsenic and seven other forms of arsenic in the urine of NHANES participants for the first time. Some of the forms of arsenic measured are metabolites of inorganic arsenic and others are less toxic species that are formed in the environment. By differentiating these types of arsenic exposure, the *Fourth Report* helps scientists understand which forms of arsenic are important to human health.

[2] Caldwell KL, Mortensen ME, Jones RL, Caudill SP, Osterloh JD. Total blood mercury concentrations in the U.S. population: 1999-2006. Int J Hyg Environ Health 2009;212:588-598.

Perchlorate and Thyroid Function

The chemical perchlorate is both naturally occurring and manmade and is used to manufacture fireworks, explosives, flares, and rocket propellant. For decades, scientists have known that large medical doses of perchlorate affect thyroid function. Low-level exposure to perchlorate from the environment has been under investigation by many scientists in recent years. The *Fourth Report* shows that all NHANES participants have detectable perchlorate in their urine and provides reference values for urinary perchlorate levels (see Table 1). This knowledge helps scientists target the levels of human exposure for future study.

Urinary Perchlorate

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population from the National Health and Nutrition Examination Survey.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total	01-02	**3.54** (3.29-3.81)	**3.70** (3.50-4.00)	**6.30** (5.80-6.90)	**10.0** (9.10-11.0)	**14.0** (11.0-17.0)	2820
	03-04	**3.22** (2.93-3.55)	**3.30** (2.90-3.80)	**5.50** (5.00-6.40)	**9.50** (8.40-11.0)	**13.0** (12.0-15.0)	2522
Age group							
6-11 years	01-02	**4.93** (4.22-5.76)	**5.20** (4.40-6.40)	**8.10** (6.90-9.80)	**12.0** (9.30-19.0)	**19.0** (12.0-23.0)	374
	03-04	**4.32** (3.67-5.09)	**4.60** (4.00-5.20)	**7.90** (5.70-9.50)	**13.0** (8.81-16.0)	**16.0** (11.0-29.0)	314
12-19 years	01-02	**3.80** (3.44-4.20)	**4.40** (3.80-4.80)	**6.80** (6.30-7.30)	**10.0** (8.90-11.0)	**13.0** (11.0-17.0)	828
	03-04	**3.62** (3.19-4.12)	**3.80** (3.20-4.40)	**6.40** (5.50-7.10)	**9.80** (7.90-12.0)	**13.0** (10.0-18.0)	721
20 years and older	01-02	**3.35** (3.08-3.65)	**3.50** (3.20-3.70)	**5.90** (5.30-6.60)	**10.0** (8.70-11.0)	**13.0** (11.0-17.0)	1618
	03-04	**3.05** (2.75-3.38)	**3.20** (2.70-3.60)	**5.20** (4.70-6.10)	**9.10** (7.90-10.0)	**12.0** (11.0-14.0)	1487
Gender							
Males	01-02	**4.19** (3.93-4.46)	**4.40** (4.20-4.60)	**7.10** (6.40-7.90)	**11.0** (9.70-12.0)	**14.0** (11.0-19.0)	1335
	03-04	**3.75** (3.39-4.16)	**3.90** (3.40-4.40)	**6.40** (5.60-7.50)	**11.0** (9.20-12.0)	**14.0** (13.0-17.0)	1229
Females	01-02	**3.01** (2.74-3.31)	**3.10** (2.70-3.40)	**5.40** (5.00-6.00)	**9.20** (8.20-11.0)	**13.0** (11.0-17.0)	1485
	03-04	**2.79** (2.49-3.11)	**2.90** (2.50-3.20)	**4.90** (4.40-5.50)	**8.20** (6.90-9.84)	**11.0** (8.80-15.0)	1293
Race/ethnicity							
Mexican Americans	01-02	**4.02** (3.47-4.66)	**4.40** (3.70-5.00)	**7.10** (5.80-8.40)	**12.0** (9.40-13.0)	**14.0** (12.0-18.0)	708
	03-04	**3.76** (3.45-4.11)	**3.96** (3.50-4.40)	**6.20** (5.30-7.50)	**11.0** (9.10-12.0)	**15.0** (12.0-17.0)	617
Non-Hispanic blacks	01-02	**3.51** (3.07-4.03)	**3.70** (3.10-4.10)	**5.90** (5.10-7.00)	**9.20** (7.80-12.0)	**15.0** (11.0-20.0)	681
	03-04	**3.21** (2.90-3.56)	**3.20** (2.87-3.50)	**5.40** (4.60-6.30)	**8.60** (7.50-11.0)	**13.0** (9.30-17.0)	652
Non-Hispanic whites	01-02	**3.51** (3.18-3.88)	**3.70** (3.40-4.10)	**6.30** (5.70-7.10)	**10.0** (8.90-11.0)	**14.0** (11.0-18.0)	1228
	03-04	**3.26** (2.89-3.68)	**3.30** (2.80-4.00)	**5.60** (4.90-6.80)	**9.40** (8.10-11.0)	**13.0** (11.0-15.0)	1092

Limit of detection (LOD, see Data Analysis section in full *Report*) for Survey years 01-02 and 03-04 are 0.05 and 0.05. For the 2001-2002 Survey period, surplus samples were used, and data are unavailable at NHANES website.

***Table 1. Urinary Perchlorate as provided in the* Fourth Report.**

Reduced Exposure to Environmental Tobacco Smoke

Environmental tobacco smoke (ETS) has significant health effects on cardiovascular and respiratory disease. Cotinine is a metabolite of nicotine, and for nonsmokers, levels of cotinine in people's blood tracks exposure to ETS. In the past 15 years, data show that blood cotinine levels for nonsmokers in the U.S. population have decreased about 70%, indicating that public health interventions to reduce ETS exposure have been successful.

U.S. Population's Exposure to Volatile Organic Compounds

People are exposed every day to volatile chemicals in the air we breathe. The *Fourth Report* provides measurements on 33 of these hydrocarbon and halohydrocarbon-type chemicals. One example is the gasoline additive methyl *tert*-butyl ether (MTBE). Exposure to this chemical can occur through the air we breathe or from contaminated water sources. A high percentage of the NHANES participants representing the U.S. population showed detectable levels of MTBE.

Exposure to Cadmium

Recent research studies show that urine cadmium levels as low as 1 microgram per gram of creatinine in people may be associated with subtle markers of effects on the kidney and with an increased risk for low bone-mineral density. The *Fourth Report* shows that about 5% of the U.S. population aged 20 years and older has urinary cadmium levels at or near these levels. Cigarette smoking is the most likely source for these higher cadmium levels. These findings should promote further research on the public health consequences of cadmium in people.

Selection of Chemicals for the *Fourth Report*

Chemicals presented in the *Fourth Report* were selected on the basis of scientific data that suggested exposure in the U.S. population; the seriousness of health effects known or suspected to result from exposure; the need to assess the efficacy of public health actions to reduce exposure to a chemical; the availability of a biomonitoring analytical method with adequate accuracy, precision, sensitivity, specificity, and speed; the availability of sufficient quantity of blood or urine samples; and the incremental analytical cost to perform the analyses. More information is available at http://www.cdc.gov/exposurereport/chemical_selection.htm.

Plans for Future *National Exposure Reports*

CDC's goal is to make new biomonitoring exposure information available as soon as possible to the public and scientific community. To meet this goal, CDC periodically releases the *National Exposure Report* and also publishes biomonitoring exposure information in peer-reviewed publications. The *National Exposure Report* is cumulative, providing biomonitoring exposure data starting in 1999 through the latest available data at the time of the report release. Future plans include releasing data on additional chemicals and providing more information on exposure in population groups defined by age, sex, and race or ethnicity. Peer-reviewed journal articles published since the latest release of the *National Exposure Report* provide more recent and supplementary biomonitoring data for the U.S. population. These peer-reviewed publications typically also contain more extensive data analysis than that provided in the *National Exposure Report*.

About CDC's Environmental Health Laboratory

By using advanced laboratory science and innovative techniques, CDC's Environmental Health Laboratory at the National Center for Environmental Health has been at the forefront of efforts to assess people's exposure to environmental chemicals. CDC's laboratory scientists have built on more than three decades of experience in measuring chemicals directly in people's blood or urine, a process known as biomonitoring. Biomonitoring measurements are the most health-relevant assessments of exposure because they measure the total amount of the chemical that actually gets into people from all environmental sources (e.g., air, soil, water, dust, or food). With a few exceptions, the concentration of the chemical in people provides the best exposure information for public health officials to evaluate the potential for adverse health effects.

New Chemicals in the *Fourth Report*

Acrylamide
Acrylamide hemoglobin adducts
Glycidamide hemoglobin adducts

Perchlorate

Total and Speciated Arsenic
Arsenic, Total
Arsenic (V) acid
Arsenobetaine
Arsenocholine
Arsenous (III) acid
Dimethylarsinic acid
Monomethylarsonic acid
Trimethylarsine oxide

Environmental Phenols
Benzophenone-3 (2-Hydroxy-4-methoxybenzophenone)
Bisphenol A (2,2-*bis* [4-Hydroxyphenyl] propane)
4-*tert* -Octylphenol (4-[1,1,3,3-Tetramethylbutyl] phenol)
Triclosan (2,4,4′-Trichloro-2′-hydroxyphenyl ether)

Phthalate Metabolite
Mono-(2-ethyl-5-carboxypentyl) phthalate (MECPP)

Perfluorochemicals
Perfluorobutane sulfonic acid (PFBuS)
Perfluorodecanoic acid (PFDeA)
Perfluorododecanoic acid (PFDoA)
Perfluoroheptanoic acid (PFHpA)
Perfluorohexane sulfonic acid (PFHxS)
Perfluorononanoic acid (PFNA)
Perfluorooctane sulfonamide (PFOSA)
Perfluorooctane sulfonic acid (PFOS)
2-(N-Ethyl-perfluorooctane sulfonamido) acetic acid (Et-PFOSA-AcOH)
2-(N-Methyl-perfluorooctane sulfonamido) acetic acid (Me-PFOSA-AcOH)
Perfluorooctanoic acid (PFOA)
Perfluoroundecanoic acid (PFUA)

Non-Dioxin-Like Polychlorinated Biphenyls
2,2′,3,5′-Tetrachlorobiphenyl (PCB 44)
2,2′,4,5′-Tetrachlorobiphenyl (PCB 49)
2,2′,3,3′,4,4′,5,5′,6,6′-Decachlorobiphenyl (PCB 209)

Brominated Fire Retardants
2,2′,4-Tribromodiphenyl ether (BDE 17)
2,4,4′-Tribromodiphenyl ether (BDE 28)
2,2′,4,4′-Tetrabromodiphenyl ether (BDE 47)
2,3′,4,4′-Tetrabromodiphenyl ether (BDE 66)
2,2′,3,4,4′-Pentabromodiphenyl ether (BDE 85)
2,2′,4,4′,5-Pentabromodiphenyl ether (BDE 99)
2,2′,4,4′,6-Pentabromodiphenyl ether (BDE 100)
2,2′,4,4′,5,5′-Hexabromodiphenyl ether (BDE 153)
2,2′,4,4′,5,6′-Hexabromodiphenyl ether (BDE 154)
2,2′,3,4,4′,5′,6-Heptabromodiphenyl ether (BDE 183)
2,2′,4,4′,5,5′-Hexabromobiphenyl (BB 153)

Disinfection By-Products (Trihalomethanes)
Bromodichloromethane
Dibromochloromethane (Chlorodibromomethane)
Tribromomethane (Bromoform)
Trichloromethane (Chloroform)

Volatile Organic Compounds
Benzene
Chlorobenzene (Monochlorobenzene)
1,2-Dibromo-3-chloropropane (DBCP)
Dibromomethane
1,2-Dichlorobenzene (*ortho*-Dichlorobenzene)
1,3-Dichlorobenzene (*meta*-Dichlorobenzene)
1,4-Dichlorobenzene (*para*-Dichlorobenzene)
1,1-Dichloroethane
1,2-Dichloroethane (Ethylene dichloride)
1,1-Dichloroethene (Vinylidene chloride)
cis-1,2-Dichloroethene
trans-1,2-Dichloroethene
Dichloromethane (Methylene chloride)
1,2-Dichloropropane
2,5-Dimethylfuran (DMF)
Ethylbenzene
Hexachloroethane
Methyl *tert*-butyl ether (MTBE)
Nitrobenzene
Styrene
1,1,2,2-Tetrachloroethane
Tetrachloroethene (Perchloroethylene)
Tetrachloromethane (Carbon tetrachloride)
Toluene
1,1,1-Trichloroethane (Methyl chloroform)
1,1,2-Trichloroethane
Trichloroethene (Trichloroethylene, TCE)
meta- and *para*-Xylene
ortho-Xylene







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