Second National Report on Human Exposure to Environmental Chemicals

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Contents

Introduction

The *National Report on Human Exposure to Environmental Chemicals* provides an ongoing assessment of the U.S. population's exposure to environmental chemicals using biomonitoring. The first *National Report on Human Exposure to Environmental Chemicals* (*First Report*) was issued in March 2001. This *Second Report,* released in January 2003, presents biomonitoring exposure data for 116 environmental chemicals for the noninstitutionalized, civilian U.S. population over the 2-year period 1999-2000.

Chemicals and their metabolites were measured in blood and urine samples from selected participants in the National Health and Nutrition Examination Survey (NHANES) conducted by CDC's National Center for Health Statistics. NHANES is a series of surveys designed to collect data on the health and nutritional status of the U.S. population.

For this *Report*, an environmental chemical means a chemical compound or chemical element present in air, water, food, soil, dust, or other environmental media (e.g., consumer products). Biomonitoring is the assessment of human exposure to chemicals by measuring the chemicals or their metabolites in human specimens such as blood or urine. A metabolite is the chemical alteration of the original compound by body tissues. Blood and urine levels reflect the amount of the chemical in the environment that actually gets into the body.

The first *Report* presented exposure data for 27 chemicals from NHANES 1999; this *Second Report* presents exposure data for 116 chemicals (including the 27 in the first *Report*) from NHANES 1999-2000. The *Second Report* also presents exposure data for the U.S. population divided into age, gender, and race/ethnicity groups.

The first *Report* measured lead, mercury, cadmium, and other metals; dialkyl phosphate metabolites of organophosphate pesticides; cotinine; and phthalates. The *Second Report* includes these chemicals and adds

- Polycyclic aromatic hydrocarbons (PAHs)
- Dioxins, furans, and coplanar polychlorinated biphenyls (PCBs)
- Non-coplanar PCBs
- Phytoestrogens
- Selected organophosphate pesticides
- Organochlorine pesticides
- Carbamate pesticides
- Herbicides
- Pest repellents and disinfectants

Public Health Uses of the *Report*

The overall purpose of the *Report* is to provide unique exposure information to scientists, physicians, and health officials to help prevent disease that results from exposure to environmental chemicals. Specific public health uses of the exposure information in the *Second Report* are:

- To determine which chemicals get into Americans and at what concentrations.
- For chemicals with a known toxicity level, to determine the prevalence of people with levels above those toxicity levels (e.g., a blood lead level [BLL] greater than or equal to 10 micrograms per deciliter [µg/dL]).
- To establish reference ranges that can be used by physicians and scientists to determine whether a person or group has an unusually high exposure.
- To assess the effectiveness of public health efforts to reduce exposure of Americans to specific chemicals.
- To determine whether exposure levels are higher among minorities, children, women of childbearing age, or other potentially vulnerable groups.
- To track, over time, trends in levels of exposure of the population.
- To set priorities for research on human health effects.

Data Presented for Each Environmental Chemical

The *Report* presents tables of descriptive statistics on the distribution of blood or urine levels for each environmental chemical. Statistics include geometric means and percentiles with confidence intervals.

Geometric means are calculated by taking the log of each concentration, then calculating the mean of those log values, and finally, taking the antilog of that mean (the calculation can be done using log base e or log base 10). A geometric mean provides a better estimate of central tendency for data that are distributed with a long tail at the upper end of the distribution. This type of distribution is common when measuring environmental chemicals in blood or urine. The geometric mean is influenced less by high values than is the arithmetic mean.

Percentiles (10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th}, and 95^{th}) are given to provide additional information about the shape of the distribution. For urine measurements, data are shown for both the concentration in urine and the concentration corrected for urine-creatinine level.

Interpreting *Report* Exposure Data: Important Factors

Research studies, separate from the Report*, are required to determine which blood or urine levels are safe and which cause disease.*

The measurement of an environmental chemical in a person's blood or urine does not by itself mean that the chemical causes disease. Advances in analytical methods allow us to measure low levels of environmental chemicals in people, but separate studies of varying exposure levels and health effects are needed to determine which blood or urine levels result in disease. These studies must also consider other factors such as duration of exposure. The *Report* does not present new data on health risks from different exposures.

For some environmental chemicals, such as lead, research studies have given us a good understanding of the health risks associated with different blood lead levels. However, for many environmental chemicals, we need more research to assess health risks from different blood or urine levels of a chemical. The results shown in the *Report* should help prioritize and foster research on human health risks that result from exposure to environmental chemicals.

For more health information about exposure to environmental chemicals, see the section titled "Toxicology and Health-Risk Information," which includes Internet reference sites. Each environmental chemical can be searched in databases at these Web sites using the chemical name or the chemical's Chemical Abstract Service (CAS) number, which is provided in the *Second Report*. If toxicology information is available for the chemical of interest, the Agency for Toxic Substances and Disease Registry (ATSDR) ToxFAQs and ToxProfiles provide good summaries as well as answers to common questions about exposure and health effects.

Blood and urine levels of a chemical should not be confused with levels of the chemical in air, water, food, soil, or dust.

Concentrations of environmental chemicals in blood or urine are not the same as those in air, water, food, soil, or dust. For example, a chemical concentration of 10 µg/L in water does not produce a level of 10 µg/L in blood or urine. Blood or urine levels may reflect exposure from multiple sources including air, water, food, soil, or dust. Levels of a chemical in blood and urine are determined by how much of the chemical has entered the body through ingestion, inhalation, or dermal absorption and the kinetics of the chemical's transformation into metabolites and elimination from the body. Except for metals, most measurements in urine quantify chemical metabolites.

The survey design provides estimates for the U.S. population.

NHANES is designed to provide estimates for the civilian, noninstitutionalized U.S. population. The current design does not permit estimates to be made on a state-by-state or city-by-city basis. For example, it is not possible to extract a subset of the data and examine levels of blood lead that represent a state population.

Data from the first Report *are updated in the larger* Second Report*. Future* Reports *will be released every two years.*

The first *Report* was based on data on 27 chemicals from 1999. The *Second Report* contains the data that were included in the first *Report* and adds new data for the year 2000 for these chemicals. It also contains data from these two years for an additional 89 chemicals. The S*econd Report* represents the U.S. population over the two year period, 1999-2000. Two years of data provide more stable estimates for the total population and are necessary for adequate sample sizes for some subgroup analyses. Current plans are to release future *Reports* of exposure of the U.S. population to cover 2-year periods (e.g., 2001-2002, 2003-2004, 2005-2006).

Future releases of the *Report* will also include findings from CDC studies of special-exposure populations. Groups of people in special-exposure situations (e.g., pesticide applicators, people living near hazardous waste sites, people working in lead smelters) are not targeted nor identified in this set of results. For example, people working in lead smelters probably have a distribution of BLLs different from that of people in the general population. A specific study of people working in lead smelters would be needed to describe the distribution of BLLs in that group.

Selection of Chemicals Included in the *Report*

Chemicals in the *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 some levels of 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 adequate blood or urine samples; and the incremental analytical cost to perform the biomonitoring analysis for the chemical. The availability of biomonitoring methods with adequate performance and acceptable cost was a major consideration.

CDC has solicited nominations for chemicals or categories of chemicals to include in future *Reports* (*Federal Register*, Vol. 67, No. 194, October 7, 2002, pages 62477-8). Selection criteria, similar to those above, are described in the *Federal Register* notice and will be used to prioritize nominated chemicals for inclusion in future *Reports*. Nominators should provide as much information as possible that would assist experts in evaluating the chemicals according to the listed criteria.

Biomonitoring Exposure Measurements

The blood and urine exposure measurements presented in the *Second Report* were made at CDC's Environmental Health Laboratory (Division of Laboratory Sciences, National Center for Environmental Health). The analytical methods used for measuring these environmental chemicals or their metabolites in blood and urine were isotope dilution mass spectrometry, inductively coupled plasma mass spectrometry, or graphite furnace atomic absorption spectrometry. References for the analytical methods used to measure the different chemicals are provided in Appendix A.

For chemicals measured in urine, levels are presented two ways: per volume of urine and per gram of creatinine. Levels per gram of creatinine (i.e., creatinine-corrected) adjust for urine dilution. For example, if one person has consumed more fluids than another person, his or her urine output is likely higher and the urine more dilute than that of the latter person. Creatinine is excreted from the body at a relatively constant rate over time, so expressing the result per gram of creatinine helps adjust for the effects of urinary dilution.

For dioxins, furans, PCBs, and organochlorine pesticides, serum levels are presented per gram of total lipid. These compounds are lipophilic and concentrate in the body's lipid stores including the lipid in the serum. Levels for these compounds are expressed as per gram of total lipid in the serum because the chemicals reside in this part of the serum.

Units of chemical measurements are important. Results are reported here using standard units, generally conforming to those most commonly used in biomonitoring measurements. Some conversions are presented in Table 1 as an aid.

Table 1. Units of measurement and conversions

Unit	Abbreviation	Value
liter	L	
deciliter	dL	10^{-1} liters
milliliter	mL	10^{-3} liters
gram	g	
milligram	mg	10^{-3} grams
microgram	µg	10^{-6} grams
nanogram	ng	10^{-9} grams
picogram	pg	10^{-12} grams
femtogram	fg	10^{-15} grams
parts-per-million	ppm	1 µg/g or 1 µg/mL or 1 mg/L
parts-per-billion	ppb	1 ng/g or 1 ng/mL or 1 µg/L
parts-per-trillion	ppt	1 pg/g or 1 pg/mL or 1 ng/L
parts-per-quadrillion	ppq	1 fg/g or 1 fg/mL or 1 pg/L

Data Sources

The National Health and Nutrition Examination Survey

The National Health and Nutrition Examination Survey (NHANES) is a series of surveys conducted by CDC's National Center for Health Statistics (NCHS) that is designed to collect data on the health and nutritional status of the U.S. population. NHANES is unique in its ability to examine public health issues that can best be addressed through physical and laboratory examinations of the U.S. population. NHANES collects information about a wide range of topics, from the prevalence of infectious diseases to risk factors for cardiovascular disease. Beginning in 1999, NHANES became a continuous and annual survey. The sampling plan follows a complex, stratified, multistage, probability-cluster design to select a representative sample of the civilian, noninstitutionalized population in the United States.

The current sample design includes targeted sampling of African Americans, Mexican Americans, adolescents (aged 12-19 years), older Americans (aged 60 years and older), and pregnant women to produce more reliable estimates for these groups. In 2000, targeted sampling of low-income whites was also included. The NHANES protocol includes a home interview followed by a standardized physical examination in a mobile examination center. As part of the examination component, blood is obtained by venipuncture for participants aged 1 year and older, and urine specimens are collected for people aged 6 years and older. Additional information on the NHANES survey is available online at http://www.cdc.gov/nchs/nhanes.htm.

Environmental chemicals were measured in either blood or urine specimens collected as part of the examination component of NHANES. The age range for which a chemical was measured varied. Most of the environmental chemicals were measured in randomly selected subsamples within specific age groups. This subsampling was needed to obtain an adequate quantity of sample for analysis and to accommodate the throughput of the mass-spectrometry analytical methods.

Age groups and sample sizes for each exposure measurement are provided in the tables of results. Blood lead and cadmium levels were measured in all people aged 1 year and older. Serum cotinine was measured in all people aged 3 years and older. Total blood mercury was measured in children aged 1-5 years and in women aged 16-49 years. Urine mercury was measured in women aged 16-49 years. Metals, phthalates, PAHs, and phytoestrogens were measured in urine from a random one-third sample of people aged 6 years and older. Urine organophosphate pesticide metabolites, selected pesticides, and herbicides were measured in a random one-half sample of children aged 6-11 years in 1999 and 2000, a random one-quarter sample of people aged 12-59 years in 1999, and a random one-third sample of people aged 12-59 years in 2000. Dioxins, furans, PCBs, and organochlorine pesticides were measured in serum from a random one-third sample of people aged 12 years and older.

Data Analysis

Because the NHANES sample design is complex, sample weights must be used to account for the unequal probability of selection into the survey. Sample weights also are used to adjust for possible bias resulting from nonresponse and are post-stratified to U.S. Census Bureau estimates of the U.S. population. Data were analyzed using and the statistical software package from Statistical Analysis System (SAS)® (SAS Institute Inc., 1999) and the statistical software package SUDAAN® (SUDAAN Release 8.0, 2001). SUDAAN uses sample weights and calculates variance estimates that account for the complex survey design.

Selected percentiles and geometric means of analyte concentrations are presented. For each estimate, 95% confidence intervals are shown. Percentile estimates were calculated using SAS Proc Univariate using weighted data. Confidence intervals for the percentiles were calculated using the method of Korn (1998). A more detailed explanation of this method used to calculate confidence intervals is provided in Appendix B. Reported geometric means, percentiles, and their confidence intervals are rounded to three significant figures consistent with the accuracy and precision of the analytical measurements (Taylor, 1987).

Results are shown for the total population and also by age group, gender, and race/ethnicity. For these analyses, race/ethnicity is categorized as Mexican American, non-Hispanic black, and non-Hispanic white. Other racial/ethnic groups are included in estimates that are based on the entire population sample.

In the text accompanying the tables with descriptive statistics, results are presented for analysis of covariance (ANCOVA) tests using SUDAAN to compare mean levels among demographic groups. All ANCOVA comparisons were made after adjustment for covariates of age, gender, and race/ethnicity. Urine creatinine is also included as a continuous variable in the ANCOVA for chemicals measured in urine. Cotinine is a major metabolite of nicotine, and log cotinine is also included as a continuous variable in ANCOVA analyses of dioxins, furans, PAHs, lead, and cadmium to adjust for known or probable effects of smoking on the blood or urine levels of these chemicals. Age groups are shown for each chemical in the results table. Gender is coded as male or female, and race/ethnicity is categorized as Mexican American, non-Hispanic black, and non-Hispanic white.

Concentrations less than the limit of detection (LOD) were assigned a value equal to the LOD divided by the square root of 2 for calculation of geometric means. The LOD is the level at which the measurement has a 95% probability of being greater than zero (Taylor, 1987). Assigning a value of the LOD divided by 2 made little difference in geometric mean estimates. Percentile estimates that are less than the LOD for the chemical analysis are reported as < LOD. If the proportion of results below the LOD was greater than 40%, geometric means were not calculated. Every table with a < LOD entry includes the LOD in the table footnotes.

For most chemicals, the LOD is constant for each sample analyzed. For dioxins, furans, PCBs, organochlorine pesticides, and a few other pesticides, each individual sample has its own LOD. These analyses have an individual LOD for each sample, mostly because the sample volume used for analysis differed for each sample. A higher sample volume results in a lower LOD and a better ability to detect lower levels. Tables for these chemicals include in the footnotes the mean LOD with a standard deviation (SD) and a maximum LOD. The maximum LOD was the highest LOD among all the individual samples analyzed.

The same procedure for imputing values below the LOD in calculations of geometric means was used for chemicals with individual LODs for each sample. That is, concentrations less than the individual LOD were assigned a value equal to the individual LOD divided by the square root of 2. For chemicals that had individual sample LODs, a conservative rule was used for reporting percentiles: if any individual sample LOD was above a percentile estimate, the percentile estimate was not reported.

Toxicology and Health-Risk Information

The *Report* presents new data on the exposure of the U.S. population to environmental chemicals. The measurement of an environmental chemical in a person's blood or urine does not by itself mean that the chemical causes disease. Advances in analytical methods allow us to measure lower and lower levels of environmental chemicals in people. Separate studies of varying exposure levels and health effects are required to determine which blood and urine levels are safe and which result in disease.

If available, generally recognized guidelines for blood or urine levels for each chemical are presented in the *Second Report.* These guidelines are usually from federal agencies. One exception is the American Conference of Governmental Industrial Hygienists (ACGIH), a private organization. ACGIH publishes biological exposure indices (BEIs) which "generally indicate a concentration below which nearly all workers should not experience adverse health effects" (ACGIH, 2000). The BEIs are blood or urine levels of a chemical that correspond to air-exposure limits for workers set by ACGIH. This organization notes that these values are for workers and that it is not appropriate to apply them to the general population. Information about the BEI level is provided here for comparison, not to imply that the BEI is a safety level for general population exposure.

For most chemicals reported here, these guidelines are not available. The *Report* also references selected studies of other population groups that have had biomonitoring measurements for comparison to the levels reported here for the U.S. population. The exposure information in the *Second Report* should help prioritize research on the relation between exposure and health effects and identify population groups with unusually high exposure for health effects evaluation.

Information Available on the Internet

Links to nonfederal organizations are provided solely as a service to our readers. These links do not constitute an endorsement of these organizations or their programs by CDC or the federal government, and none should be inferred. CDC is not responsible for the content of an individual organization's Web pages found at these links. For information about toxicology and health risks, see the following sites:

Federal and Nonfederal Internet Links

- ATSDR ToxFAQs: www.atsdr.cdc.gov/toxfaq.html or www.atsdr.cdc.gov/toxprofiles
- National Institute for Occupational Safety and Health (NIOSH), Occupational Health and Safety Guidelines for Chemical Hazards: www.cdc.gov/niosh/81-123.html
- National Toxicology Program (NTP) Report on Carcinogens: http://ehis.niehs.nih.gov/roc
- EPA Integrated Risk-Information System (IRIS): www.epa.gov/iris
- International Programme on Chemical Safety (IPCS): www.who.int/pcs
- Chemfinder: www.chemfinder.com
- Material Safety Data Sheets (MSDS): www.hazard.com/msds

U.S. Government-Related Internet Links

Centers for Disease Control and Prevention (CDC)

- NIOSH Pocket Guide to Chemical Hazards: www.cdc.gov/niosh/npg/npgd0000.html
- Registry of Toxic Effects of Chemical Substances (RTECS): www.cdc.gov/niosh/rtecs.html
- Tobacco Information and Prevention Source: www.cdc.gov/tobacco
- National Center for Health Statistics: www.cdc.gov/nchs
- National Health and Nutrition Examination Survey: www.cdc.gov/nchs/nhanes.htm
- Childhood Lead Poisoning Prevention Program: www.cdc.gov/nceh/lead/lead.htm
- Pesticides and Public Health: Integrated Methods of Mosquito Management: www.cdc.gov/ncidod/eid/vol7no1/rose.htm

U.S. Department of Health and Human Services (HHS)

- Environmental Health Policy Committee: http://web.health.gov/environment

U.S. Food and Drug Administration (FDA)

- Center for Devices and Radiological Health: www.fda.gov/cdrh
- Center for Food Safety and Applied Nutrition: www.cfsan.fda.gov
- National Center for Toxicological Research: www.fda.gov/nctr

National Institutes of Health (NIH)

- National Cancer Institute (NCI): www.nci.nih.gov
- National Institute of Child Health and Human Development: www.nichd.nih.gov
- National Institute for Environmental Health Sciences: www.niehs.nih.gov
- National Toxicology Program (NTP) Chemical Health and Safety Data: http://ntp-server.niehs.nih.gov/Main_Pages/Chem-HS.html
- NTP Report on Carcinogens: http://ntp-server.niehs.nih.gov/NewHomeRoc/AboutRoC.html
- Chemical Carcinogenesis Research Information System: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?CCRIS
- Hazardous Susbstances Data Bank (HSDB®): http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB

U.S. Environmental Protection Agency (U.S. EPA)

- Office of Air and Radiation (OAR): www.epa.gov/oar
- Office of Environmental Information (OEI): www.epa.gov/oei
- Office of Prevention, Pesticides, and Toxic Substances (OPPTS): www.epa.gov/opptsmnt/index.htm
- Office of Research and Development (ORD): www.epa.gov/ORD
- Office of Water (OW): www.epa.gov/OW
- Office of Pesticide Programs: www.epa.gov/pesticides
- EPA Integrated Risk-Information System (IRIS): www.epa.gov/iris
- EPA Envirofacts: www.epa.gov/enviro/index_java.html
- Lead: www.epa.gov/OGWDW/dwh/c-ioc/lead.html

U.S. Department of Agriculture (USDA)

- Food Safety and Inspection Service: http://www.fsis.usda.gov
- USDA, Forest Service Pesticide Fact Sheets: http://svinet2.fs.fed.us/foresthealth/pesticide

U.S. Department of Energy (DOE)

- Office of Environment, Safety and Health: http://tis.eh.doe.gov/portal/home.htm

U.S. Department of Housing and Urban Development (HUD)

- Office of Healthy Homes and Lead-Hazard Control: www.hud.gov/offices/lead

U.S. Consumer Product Safety Commission (CPSC)

- www.cpsc.gov

U.S. Department of Transportation (DOT)

- Hazardous Materials Emergency-Response Guidebook: http://hazmat.dot.gov/erg2000/psnsort.htm

U.S. Department of Labor, Occupational Safety and Health Administration (OSHA)

- http://www.osha.gov/index.html

Other Related Internet Sites

- American College of Occupational and Environmental Medicine: http://www.acoem.org
- Association of Occupational and Environmental Clinics: http://www.aoec.org
- Association of Public Health Laboratories: http://www.aphl.org
- International Chemical Safety Cards: http://www.ilo.org/public/english/protection/safework/cis/products/icsc/dtasht/index.htm
- National Researc Council (NRC) Toxicological Effects of Methylmercury: http://books.nap.edu/books/0309071402/html/index.html

Results by Chemical Group

Metals

Lead

CAS No. 7439-92-1

General Information

Elemental lead is a malleable, dense, blue-gray metal. It can be combined to form inorganic and organic molecules. Lead is a naturally occurring element found in soils and rocks. It has a variety of uses in manufacturing ammunition, solders, metal alloys, ceramic glazes, antique-molded or casted ornaments, storage batteries, and shielding from radiation sources. In the past, lead was added to paints and gasoline, and it has been used in plumbing for centuries. Small amounts of lead also may be produced from the burning of fossil fuels.

Since the elimination of leaded gasoline in the United States, general lead exposures for adults have resulted from occupational and recreational sources. For children, the major sources of exposure are from deteriorated

Table 2. Lead

Geometric mean and selected percentiles of blood concentrations (in µg/dL) for the U.S. population aged 1 year and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 1 and older	1.66 (1.58-1.73)	.800 (.700-.800)	1.00 (1.00-1.10)	1.60 (1.50-1.60)	2.40 (2.30-2.60)	3.80 (3.50-4.00)	4.90 (4.50-5.50)	7970
Age group								
1-5 years	2.23 (1.99-2.49)	1.00 (.800-1.10)	1.40 (1.10-1.50)	2.20 (1.90-2.50)	3.30 (2.80-3.90)	4.80 (4.00-6.60)	7.00 (5.20-9.90)	723
6-11 years	1.51 (1.35-1.69)	.700 (.600-.900)	.900 (.800-1.10)	1.30 (1.20-1.60)	2.00 (1.70-2.40)	3.30 (2.60-3.90)	4.50 (3.30-6.30)	905
12-19 years	1.10 (1.03-1.18)	.400 (.400-.500)	.800 (.700-.800)	1.00 (1.00-1.10)	1.40 (1.30-1.60)	2.30 (2.10-2.40)	2.80 (2.50-3.00)	2135
20 years and older	1.75 (1.67-1.83)	.700 (.700-.800)	1.00 (1.00-1.10)	1.70 (1.60-1.70)	2.50 (2.40-2.70)	3.90 (3.60-4.10)	5.20 (4.70-5.70)	4207
Gender								
Males	2.01 (1.92-2.10)	.800 (.800-.900)	1.30 (1.20-1.30)	1.80 (1.80-1.90)	2.90 (2.70-3.00)	4.40 (4.00-4.80)	6.00 (5.40-6.50)	3913
Females	1.37 (1.30-1.45)	.600 (.500-.600)	.800 (.800-.900)	1.30 (1.20-1.30)	1.90 (1.80-2.10)	3.00 (2.80-3.30)	4.00 (3.60-4.40)	4057
Race/ethnicity								
Mexican Americans	1.83 (1.71-1.95)	.800 (.700-.800)	1.20 (1.10-1.20)	1.80 (1.60-1.90)	2.70 (2.50-3.00)	4.20 (3.80-4.60)	5.80 (5.10-6.60)	2743
Non-Hispanic blacks	1.87 (1.73-2.02)	.700 (.700-.800)	1.10 (1.00-1.30)	1.70 (1.60-1.90)	2.80 (2.50-2.90)	4.20 (3.90-4.70)	5.70 (5.00-6.30)	1842
Non-Hispanic whites	1.62 (1.53-1.71)	.600 (.600-.700)	1.00 (1.00-1.10)	1.60 (1.40-1.60)	2.40 (2.20-2.50)	3.60 (3.30-3.90)	5.00 (4.30-5.90)	2715

lead-based paint and the resulting dust and soil contamination. Other sources of exposure, such as the use of lead solder in canned foods and in leaded water pipes, have also been eliminated. However, uncommon sources of exposure still exist, including unglazed low-temperature-fired ceramic pottery, pewter drinking vessels, plumbing systems with lead-soldered joints, old paint removal, indoor firing ranges, and nearby mining and smelting operations.

Increasing amounts of lead in the body, as benchmarked by blood lead levels (BLLs), can cause impaired neurobehavioral development in children, increased blood pressure, kidney injury, and anemia (CDC, 2002). Neurophysiologic decrements can occur in adults as a result of workplace exposure to lead (Araki et al., 2000). At extremely high levels, lead will produce severe central nervous system injury and paralysis. The potential adverse effects of lead on reproduction are areas of ongoing research and may include miscarriage in women with high BLLs and problems with sperm formation in men with high BLLs (Borja-Aburto et al., 1999). The International Agency for Research on Cancer (IARC) has determined on the basis of animal studies that lead is a probable human carcinogen, but more study is needed on the relation of lead exposure to cancer in people (Jemal et al., 2002). Information about external exposure (environmental levels) and health effects is

Table 3. Lead

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	.758 (.711-.808)	.200 (.100-.200)	.500 (.400-.500)	.800 (.700-.800)	1.30 (1.30-1.40)	2.10 (1.90-2.30)	2.90 (2.50-3.20)	2465
Age group								
6-11 years	1.07 (.952-1.20)	.500 (.400-.600)	.700 (.500-.800)	1.00 (.900-1.20)	1.50 (1.30-1.70)	2.40 (1.80-3.00)	3.40 (2.40-5.10)	340
12-19 years	.656 (.585-.735)	.100 (.100-.200)	.300 (.300-.400)	.600 (.600-.700)	1.10 (.900-1.20)	1.70 (1.40-2.00)	2.20 (1.90-2.50)	719
20 years and older	.743 (.689-.801)	.200 (.100-.200)	.400 (.300-.400)	.700 (.700-.800)	1.40 (1.20-1.50)	2.10 (1.90-2.30)	2.90 (2.50-3.20)	1406
Gender								
Males	.920 (.848-.998)	.200 (.200-.300)	.500 (.500-.600)	.900 (.800-.900)	1.60 (1.40-1.70)	2.40 (2.20-2.90)	3.40 (2.90-3.90)	1227
Females	.632 (.577-.692)	.200 (<LOD-.200)	.300 (.300-.400)	.600 (.600-.700)	1.20 (1.10-1.30)	1.90 (1.60-2.10)	2.40 (2.10-2.80)	1238
Race/ethnicity								
Mexican Americans	1.02 (.916-1.13)	.200 (.200-.300)	.600 (.400-.600)	1.00 (.900-1.20)	1.70 (1.50-2.00)	2.80 (2.30-3.40)	4.10 (3.10-6.20)	884
Non-Hispanic blacks	1.11 (.983-1.25)	.300 (.300-.400)	.700 (.600-.800)	1.10 (1.00-1.20)	1.90 (1.50-2.10)	2.90 (2.40-3.50)	4.20 (3.20-5.70)	568
Non-Hispanic whites	.686 (.632-.745)	.100 (<LOD-.200)	.300 (.300-.400)	.700 (.600-.700)	1.30 (1.10-1.40)	1.90 (1.70-2.20)	2.60 (2.30-3.10)	822

< LOD means less than the limit of detection, which is 0.07 µg/L.

available from the EPA IRIS Web site at http://www.epa.gov/iris and from ATSDR at http://www.atsdr.cdc.gov/toxprofiles.

Interpreting Blood and Urine Lead Levels Reported in the Tables

In this NHANES 1999-2000 sample, BLLs were measured in all participants aged 1 year and older, and urine lead levels were measured in a sample of people aged 6 years and older. Blood lead measurement is the preferred method of evaluating lead exposure and its health effects in people. BLLs are contributed to by both recent intake and an equilibration with stored lead in other tissues. Urinary lead measurements tend to reflect mostly recent exposure and are therefore more variable than blood lead levels for a given individual. Urinary levels of lead above 20 µg/L should be evaluated by blood lead analysis, if such analyses have not already been conducted.

The U.S. Department of Labor, Occupational Safety and Health Administration (OSHA), requires monitoring of blood lead and reduction of exposure to lead when worker BLLs are higher than 40 µg/dL of whole blood [CFR 1910.1025(j)(2)(i)]. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends that BLLs in workers not exceed 30 µg/dL. The

Table 4. Lead (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	.714 (.671-.759)	.294 (.259-.313)	.444 (.412-.476)	.699 (.655-.745)	1.11 (1.03-1.19)	1.70 (1.55-1.91)	2.37 (2.15-2.86)	2465
Age group								
6-11 years	1.17 (.967-1.42)	.533 (.450-.625)	.746 (.639-.870)	1.06 (.899-1.22)	1.55 (1.25-1.90)	2.71 (1.63-4.71)	4.66 (2.03-18.0)	340
12-19 years	.494 (.457-.535)	.216 (.190-.267)	.328 (.296-.354)	.469 (.415-.494)	.702 (.632-.833)	1.10 (.968-1.33)	1.65 (1.21-2.78)	719
20 years and older	.711 (.665-.760)	.294 (.256-.333)	.452 (.419-.489)	.709 (.652-.750)	1.10 (1.02-1.19)	1.69 (1.50-1.91)	2.31 (2.00-2.74)	1406
Gender								
Males	.718 (.669-.771)	.302 (.258-.343)	.446 (.408-.489)	.693 (.639-.745)	1.10 (.997-1.22)	1.68 (1.50-2.00)	2.43 (2.04-3.33)	1227
Females	.710 (.658-.767)	.290 (.246-.320)	.442 (.392-.481)	.701 (.655-.762)	1.11 (1.04-1.20)	1.74 (1.50-2.02)	2.38 (2.02-2.88)	1238
Race/ethnicity								
Mexican Americans	.939 (.868-1.02)	.367 (.333-.446)	.593 (.516-.667)	.882 (.800-1.02)	1.43 (1.33-1.58)	2.38 (2.05-2.83)	3.31 (2.78-4.18)	884
Non-Hispanic blacks	.720 (.643-.807)	.290 (.258-.351)	.455 (.392-.491)	.667 (.579-.757)	1.11 (.973-1.20)	1.98 (1.52-2.52)	2.83 (2.25-3.70)	568
Non-Hispanic whites	.687 (.630-.749)	.289 (.245-.317)	.423 (.387-.461)	.673 (.619-.732)	1.07 (.987-1.15)	1.66 (1.48-1.86)	2.31 (1.89-2.88)	822

Deutsche Forschungsgemeinschaft provides a Biological Tolerance Level (BAT) of 40 µg/dL for workers. The World Health Organization (WHO) level of concern is 20 µg/dL. CDC recommends that children's levels not exceed 10 µg/dL.

Data from NHANES III, phase 2 (1991-1994) showed that 4.4% of children aged 1-5 years had BLLs greater than or equal to 10 µg/dL, and the geometric mean BLL for children 1-5 years old was 2.7 µg/dL (Pirkle et al., 1998). For the current NHANES 1999-2000 sample, 2.2% of children aged 1-5 years had BLLs greater than or equal to 10 µg/dL, with a geometric mean BLL of 2.23 µg/dL. Higher prevalences of elevated BLLs in U.S. children occur in urban settings, lower socioeconomic groups, immigrants, and refugees (Geltman et al., 2001). Children with BLLs greater than or equal to 10 µg/dL are at increased risk for neurocognitive decrements. Pronounced health effects from lead exposure, namely anemia, kidney injury, nerve injury, and overt brain dysfunction, occur at higher levels. In places where leaded gasoline is still used, such as Bangladesh, BLLs are similar to those in the United States before the removal of lead from gasoline (e.g., a mean BLL of 15.0 µg/dL and 87.4% with levels in excess of 10 µg/dL [Kaiser et al., 2001]).

Geometric mean BLLs of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, and log serum cotinine. Adjusted geometric mean BLLs were higher in children aged 1-5 years than in children aged 6-11 years, and both these age groups had higher levels than did those aged 12-19 years. BLLs in adults aged 20 years and older were higher than those in the group aged 12-19 years but lower than in children aged 1-5 years. BLLs for males were higher than those for females. Mexican Americans and non-Hispanic blacks had higher levels than did non-Hispanic whites. Similar demographic differences were observed for urine lead levels. It is unknown whether differences between ages or races/ethnicities represent differences in exposure, body-size relationships, or metabolism. For instance, to account for the decreasing BLLs observed with increasing childhood ages, several explanations are possible, including decreasing exposure, dilution of lead by growth of body mass, or changing equilibria with bone turnover. Among adults, BLLs increase slowly with age.

Cadmium

CAS No. 7440-43-9

General Information

Elemental cadmium is a silver-white metal. In nature, it usually is found combined with other elements such as oxygen (cadmium oxide), chlorine (cadmium chloride), or sulfur (cadmium sulfate, cadmium sulfide). Cadmium does not corrode easily and has many uses. In industry and consumer products, it is used in batteries, pigments, metal coatings, and plastics. Cadmium enters the environment from the weathering and mining of rocks and minerals that contain cadmium. Contaminated water sources, foods, and combustion sources may also result in human exposure. Cadmium exposure occurs from inhalation of cigarette smoke. Cadmium can be absorbed by inhalation or ingestion. Exposure to cadmium may occur in industries, such as mining or electroplating, which use or produce the chemical.

Cadmium and its compounds are toxic. Once absorbed into the body, cadmium may remain for decades. Low-level chronic exposures over many years may result in

Table 5. Cadmium

Geometric mean and selected percentiles of blood concentrations (in µg/L) for the U.S. population aged 1 year and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 1 and older	.412 (.386-.439)	< LOD	< LOD	.300 (.300-.400)	.600 (.500-.600)	1.00 (.900-1.00)	1.30 (1.20-1.40)	7970
Age group								
1-5 years	*	< LOD	< LOD	< LOD	.300 (<LOD-.300)	.400 (.300-.400)	.400 (.300-.400)	723
6-11 years	*	< LOD	< LOD	< LOD	.300 (<LOD-.300)	.400 (.300-.400)	.400 (.400-.500)	905
12-19 years	.333 (.309-.360)	< LOD	< LOD	.300 (<LOD-.300)	.300 (.300-.400)	.800 (.600-.900)	1.10 (.900-1.10)	2135
20 years and older	.468 (.436-.502)	< LOD	< LOD	.400 (.300-.400)	.600 (.600-.700)	1.00 (1.00-1.10)	1.50 (1.40-1.60)	4207
Gender								
Males	.403 (.376-.431)	< LOD	< LOD	.400 (.300-.400)	.600 (.500-.600)	1.00 (.900-1.00)	1.30 (1.20-1.50)	3913
Females	.421 (.394-.451)	< LOD	< LOD	.300 (.300-.400)	.600 (.500-.600)	1.00 (.800-1.00)	1.30 (1.10-1.40)	4057
Race/ethnicity								
Mexican Americans	.395 (.368-.423)	< LOD	< LOD	.400 (.300-.400)	.400 (.400-.500)	.700 (.700-.900)	1.10 (.900-1.30)	2743
Non-Hispanic blacks	.393 (.367-.421)	< LOD	< LOD	.300 (.300-.400)	.600 (.500-.600)	1.00 (.800-1.00)	1.40 (1.20-1.50)	1842
Non-Hispanic whites	.420 (.388-.456)	< LOD	< LOD	.400 (.300-.400)	.500 (.500-.600)	1.00 (.900-1.10)	1.30 (1.20-1.40)	2715

< LOD means less than the limit of detection, which is 0.3 µg/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

accumulation of cadmium in the kidneys. When the amount of cadmium exceeds the ability of the kidney cells to produce a binding protein that keeps the cadmium biologically inactive, serious kidney damage may occur. Chronic ingestion also has produced painful osteomalacia, a bone disorder similar to rickets in children. Large, acute airborne exposures to dusts and fumes, as occurs for example from welding on cadmium-alloyed metals, may result in severe swelling of the lungs (edema) and subsequent scarring (fibrosis). Other cadmium toxicity, as seen in animal studies, includes reproductive and teratogenic effects. IARC has determined that cadmium is a known human carcinogen. Information about external exposure (environmental levels) and health effects is available from the EPA IRIS Web site at http://www.epa.gov/iris and from ATSDR at http://www.atsdr.cdc.gov/toxprofiles.

Interpreting Blood and Urine Cadmium Levels Reported in the Tables

In the NHANES 1999-2000 sample, blood cadmium levels were measured in all participants aged 1 year and older, and urine cadmium levels were measured in a sample of people aged 6 years and older. Finding a measurable amount of cadmium in the blood or urine does not mean that the level of cadmium causes an adverse health effect. OSHA (1998) has developed criteria for evaluating occupational exposures. These occupational criteria are to be used to assess chronic

Table 6. Cadmium

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	.326 (.306-.347)	.110 (.090-.110)	.190 (.170-.200)	.330 (.310-.350)	.590 (.550-.640)	1.01 (.910-1.11)	1.36 (1.21-1.53)	2465
Age group								
6-11 years	.211 (.180-.248)	.080 (<LOD-.110)	.120 (.100-.160)	.210 (.170-.260)	.340 (.290-.380)	.460 (.380-.900)	.760 (.400-1.61)	340
12-19 years	.218 (.197-.242)	.070 (<LOD-.100)	.140 (.120-.160)	.240 (.210-.270)	.360 (.330-.420)	.510 (.440-.550)	.630 (.520-.780)	719
20 years and older	.368 (.344-.394)	.110 (.110-.130)	.200 (.180-.220)	.390 (.360-.420)	.670 (.620-.740)	1.11 (1.00-1.25)	1.51 (1.33-1.69)	1406
Gender								
Males	.347 (.316-.381)	.110 (.100-.130)	.190 (.170-.220)	.360 (.320-.380)	.620 (.540-.710)	1.03 (.920-1.30)	1.61 (1.21-1.89)	1227
Females	.307 (.282-.334)	.080 (.060-.110)	.170 (.140-.190)	.340 (.300-.350)	.590 (.540-.630)	.960 (.840-1.05)	1.25 (1.13-1.37)	1238
Race/ethnicity								
Mexican Americans	.310 (.280-.344)	.110 (.090-.130)	.170 (.150-.200)	.290 (.270-.320)	.600 (.500-.670)	.950 (.820-1.06)	1.24 (1.06-1.45)	884
Non-Hispanic blacks	.441 (.386-.504)	.160 (.130-.170)	.250 (.200-.300)	.440 (.390-.530)	.750 (.670-.890)	1.36 (1.13-1.48)	1.72 (1.44-2.00)	568
Non-Hispanic whites	.311 (.285-.338)	.100 (.080-.110)	.160 (.140-.190)	.330 (.300-.350)	.560 (.510-.620)	.980 (.830-1.12)	1.33 (1.13-1.61)	822

< LOD means less than the limit of detection, which is 0.04 µg/L.

workplace exposure. For blood cadmium, the criterion is 5 µg/L of blood; for urine cadmium, the criterion is 3 µg/gram of creatinine. Occupational criteria are provided here for comparison only, not to imply a safety level for general population exposure. The 95th percentile for blood cadmium reported in Table 5 is less than the OSHA criterion for blood cadmium, and the 95th percentile for urine cadmium shown in Table 7 is less than the OSHA criterion for urine cadmium.

In a previous study of a non-random subsample from NHANES III (Paschal et al., 2000), levels of cadmium were similar to levels in this NHANES 1999-2000 sample. In this *Report*, geometric mean levels of blood cadmium for the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, log serum cotinine, and urinary creatinine. Females had slightly higher levels than males. Mexican Americans had higher blood cadmium levels than non-Hispanic whites or non-Hispanic blacks. Similar relationships for age, gender, and smoking were found in the study of NHANES III participants (Paschal et al., 2000). It is unknown whether differences between ages, genders, or races/ethnicities represent differences in exposure, body-size relationships, or metabolism.

Blood cadmium reflects recent and cumulative exposures, whereas urinary cadmium reflects losses from the kidney as protein binding is exceeded (Lauwerys and Hoet, 2001; Satarug et al. 2002). In occupational studies

Table 7. Cadmium (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	.307 (.290-.324)	.122 (.115-.134)	.188 (.174-.200)	.296 (.274-.315)	.496 (.466-.527)	.797 (.743-.850)	1.03 (.916-1.14)	2465
Age group								
6-11 years	.232 (.202-.265)	.120 (.113-.145)	.170 (.145-.191)	.221 (.200-.242)	.299 (.268-.342)	.414 (.321-.700)	.569 (.342-1.99)	340
12-19 years	.164 (.151-.179)	.088 (.070-.106)	.121 (.113-.130)	.160 (.152-.173)	.230 (.198-.258)	.315 (.267-.364)	.376 (.321-.500)	719
20 years and older	.353 (.333-.373)	.145 (.122-.163)	.220 (.200-.240)	.351 (.332-.375)	.581 (.534-.617)	.852 (.798-.947)	1.13 (.977-1.24)	1406
Gender								
Males	.271 (.252-.291)	.112 (.101-.128)	.164 (.153-.183)	.255 (.240-.271)	.421 (.385-.457)	.720 (.636-.785)	.890 (.794-1.13)	1227
Females	.345 (.322-.370)	.143 (.121-.161)	.213 (.195-.232)	.344 (.319-.364)	.566 (.509-.614)	.857 (.786-.953)	1.13 (.966-1.31)	1238
Race/ethnicity								
Mexican Americans	.286 (.264-.311)	.135 (.120-.145)	.176 (.161-.188)	.265 (.246-.289)	.432 (.377-.483)	.759 (.588-.899)	.968 (.787-1.13)	884
Non-Hispanic blacks	.287 (.256-.321)	.115 (.096-.142)	.171 (.161-.186)	.274 (.249-.313)	.500 (.420-.556)	.740 (.659-.841)	.929 (.782-1.06)	568
Non-Hispanic whites	.311 (.288-.336)	.120 (.108-.140)	.187 (.170-.205)	.302 (.271-.333)	.509 (.457-.570)	.817 (.751-.912)	1.12 (.916-1.33)	822

of exposed males, urinary cadmium thresholds corresponding to significant increased excretion of renal protein markers have ranged from 2.4 µg/gram to 11.5 µg/gram of creatinine. A threshold of 10 µg/gram of creatinine has been suggested for the occurrence of reversible low-molecular mass proteinuria (functional effect) and subsequent loss of renal filtration reserve capacity (Roels et al., 1999). This threshold also approximates the critical cadmium concentration in the renal cortex of 200 µg of cadmium per gram of tissue. In this *Report*, geometric mean levels of urinary cadmium for the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, log serum cotinine, and urinary creatinine. There were no differences in the adjusted geometric means of urine cadmium for the race/ethnicity categories. People aged 12-19 years had lower urinary cadmium levels than either children aged 6-11 years or adults aged 20 years and older. Urinary cadmium levels in males were lower than in females. It is unknown whether differences between ages or genders represent differences in exposure, body-size relationships, or metabolism.

Whether cadmium at the levels reported here is a cause for health concern is not yet known; more research is needed. Measuring cadmium at these levels in blood and urine is possible because of advances in analytical chemistry. These data provide physicians with a reference range so they can determine whether people have been exposed to higher levels of cadmium than those found in the general population. These data also will help scientists plan and conduct research about cadmium exposure and health effects.

Mercury

CAS No. 7439-97-6

General Information

Mercury is a naturally occurring metal that has metallic, inorganic, and organic forms. Metallic mercury (quicksilver) is a shiny, silver-white liquid. Metallic elemental mercury is used to produce chlorine gas and caustic soda. It also can be used in detonating devices, cosmetics, pharmaceuticals, pesticides, blood pressure devices, electrical equipment (e.g., thermostats and switches), thermometers, dental fillings, and batteries. Spills of metallic mercury can volatilize into the air and be inhaled. Elemental mercury is poorly absorbed from the gastrointestinal tract. Vaporization of mercury from dental amalgams also contributes to exposure (Ritchie et al., 2002).

Inorganic mercury exists in two oxidative states (mercurous and mercuric) and combines with other elements, such as chlorine (e.g., mercuric chloride), sulfur, or oxygen, to form inorganic mercury compounds or salts. Inorganic mercury enters the air from the mining of ore deposits, the burning of coal, and the incineration of waste. It also enters the water or soil from natural deposits, disposal of wastes, and volcanic activity.

Mercury can combine with organic compounds (e.g., methyl mercury, phenyl mercury, merthiolate). In mercury-contaminated water or soil, microorganisms can organify mercury into methyl mercury, which concentrates in the food chain. Fish consumption is the primary source of methyl mercury exposure in people.

The health effects of mercury are diverse and can depend on the form of the mercury encountered and the severity and length of exposure. With large acute exposures to elemental mercury vapor, the lungs may be injured. At levels below those that cause lung injury, low-dose or

Table 8. Mercury

Geometric mean and selected percentiles of blood concentrations (in µg/L) for males and females aged 1 to 5 years and females aged 16 to 49 years in the U.S. population, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Age group								
1-5 years (males and females)	.343 (.299-.393)	< LOD	< LOD	.300 (.200-.300)	.500 (.500-.600)	1.40 (1.10-2.00)	2.30 (1.40-3.20)	705
Males	.317 (.270-.372)	< LOD	< LOD	.200 (.200-.300)	.500 (.500-.600)	1.10 (.800-1.50)	2.10 (1.10-3.50)	387
Females	.377 (.311-.457)	< LOD	< LOD	.200 (.200-.300)	.800 (.500-1.00)	1.60 (1.20-2.30)	2.70 (1.80-4.80)	318
16-49 years (females)	1.02 (.860-1.22)	.200 (<LOD-.200)	.400 (.400-.600)	.900 (.800-1.20)	2.00 (1.60-2.70)	4.90 (4.00-6.10)	7.10 (5.60-9.90)	1709
Race/ethnicity (females,16-49 years)								
Mexican Americans	.820 (.691-.974)	.200 (<LOD-.200)	.400 (.300-.500)	.900 (.700-1.00)	1.40 (1.20-1.90)	2.60 (2.10-3.40)	4.00 (2.70-5.50)	579
Non-Hispanic blacks	1.35 (1.11-1.64)	.300 (.200-.500)	.600 (.500-.900)	1.30 (1.10-1.60)	2.60 (1.90-3.30)	4.80 (3.30-6.60)	5.90 (4.40-10.9)	370
Non-Hispanic whites	.944 (.765-1.17)	< LOD	.400 (.300-.400)	.900 (.700-1.10)	1.90 (1.40-2.90)	5.00 (3.40-6.50)	6.90 (5.40-10.6)	588

< LOD means less than the limit of detection, which is 0.14 µg/L.

chronic inhalation may affect the nervous system. Symptoms include weakness; fatigue; loss of weight (with anorexia); gastrointestinal disturbances; salivation; tremors; and behavioral and personality changes, including depression and emotional instability.

Exposure to inorganic mercury usually occurs by ingestion. The most prominent effect is on the kidneys, where mercury accumulates, leading to tubular necrosis. In addition, there may be an irritant or corrosive effect on the gastrointestinal tract involving stomatitis, ulceration, diarrhea, vomiting, and bleeding. Psychomotor and neuromuscular effects also may occur.

Organic mercury is more toxic than inorganic mercury. The effects of organic mercury include changes in vision, sensory disturbances in the arms and legs, cognitive disturbances, dermatitis, and muscle wasting. The developing nervous systems of the fetus and infants are considered to be susceptible to the effects of methyl mercury as measured by neurobehavioral testing in population studies (National Academy of Sciences, 2000). Information about external exposure (environmental levels) and health effects is available at the EPA IRIS Web site at http://www.epa.gov/iris and from ATSDR at http://www.atsdr.cdc.gov/toxprofiles.

Interpreting Blood and Urine Mercury Levels Reported in the Tables

Blood mercury levels were measured in a subsample of NHANES participants aged 1-5 years and in females aged 16-49 years. Urine mercury levels were measured in a subsample of females aged 16-49 years. Subsamples were randomly selected within the specified age ranges to be a representative sample of the U.S. population. The measurement of total blood mercury includes both inorganic and organic forms. In the general population, total blood mercury is due mostly to the dietary intake of organic forms, particularly methyl mercury. Urinary mercury mostly comprises inorganic mercury, since little organic mercury is excreted in the urine. These distinctions can assist in the interpretation of the meaning of elevated mercury blood levels in people. Finding a measurable amount of mercury in blood or urine does not mean that the level of mercury causes an adverse health effect.

Total blood mercury levels in this *Report* were well below occupational thresholds of concern. ACGIH recommends that the blood inorganic mercury of workers not exceed 15 µg/L and that urine values not exceed 35 µg/gram of creatinine. Information about the biological exposure indices (BEI) is provided here for comparison,

Table 9. Mercury

Geometric mean and selected percentiles of urine concentrations (in µg/L) for females aged 16 to 49 years in the U.S. population, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Age group (females)								
16-49 years	.720 (.642-.808)	< LOD	.310 (.260-.370)	.770 (.650-.880)	1.62 (1.46-1.84)	3.15 (2.68-3.58)	5.00 (3.86-5.55)	1748
Race/ethnicity (females,16-49 years)								
Mexican Americans	.724 (.607-.864)	< LOD	.280 (.240-.350)	.650 (.520-.890)	1.69 (1.33-2.35)	3.68 (3.10-4.45)	5.62 (4.68-7.51)	595
Non-Hispanic blacks	1.07 (.888-1.29)	< LOD	.450 (.360-.650)	1.03 (.870-1.34)	2.30 (1.85-2.89)	4.81 (3.41-6.08)	6.98 (5.13-9.64)	381
Non-Hispanic whites	.657 (.576-.748)	< LOD	.280 (.210-.340)	.710 (.560-.810)	1.50 (1.31-1.77)	2.84 (2.35-3.32)	4.05 (3.26-5.24)	594

< LOD means less than the limit of detection, which is 0.14 µg/L.

not to imply that the BEI is a safety level for general population exposure. The measurement of urinary protein excretion for assessment of early kidney tubular damage is also recommended. Roels et al. (1999) evaluated the utility of urinary mercury concentrations in assessing renal injury. They concluded that, to prevent cytotoxic and functional renal effects, urinary mercury levels should not exceed 50 µg/gram of creatinine.

Blood mercury levels in this NHANES 1999-2000 subsample are consistent with levels found in other population studies. In Germany, the geometric mean for blood mercury was 0.58 µg/L in all 4,645 participants and was 0.33 µg/L for children 6-14 years old (Becker et al., 1998). During the years 1996 through 1998, Benes et al. (2000) studied 1,216 blood donors (896 males and 320 females; average age 33 years) and 758 children (average age 9.9 years). They found median concentrations of mercury in blood for adults (medians) of 0.78 µg/L and in the juvenile population of 0.46 µg/L. Total blood mercury is known to increase with greater fish consumption (Grandjean et al., 1995; Mahaffey and Mergler 1998; Sanzo et al., 2001; Dewailly et al., 2001) and with the number of teeth filled with mercury-containing amalgams (Becker et al., 1998). The levels reported in this NHANES 1999-2000 subsample for maternal-aged females were below levels associated with *in utero* effects on the fetus, or with effects in children and adults (National Academy of Sciences, 2000).

Geometric mean blood mercury levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, log serum cotinine, and urinary creatinine. Females aged 16-49 years had blood mercury levels that were more than double those of children aged 1-5 years. Among children 1-5 years old, girls had higher values than boys. In addition, non-Hispanic whites had lower blood mercury levels than either non-Hispanic blacks or Mexican Americans. Among maternal-aged women (16-49 years old), blood mercury levels in non-Hispanic blacks were higher than levels in non-Hispanic whites and Mexican Americans.

In this *Report*, no differences existed between racial/ethnic groups for urinary mercury levels. Use of certain mercury-containing cosmetic creams can increase urine mercury levels slightly (McRill et al., 2000).

These data provide physicians with a reference range so that they can determine whether people have been exposed to higher levels of mercury than those found in the general population. These data will also help scientists plan and conduct research about mercury exposure and health effects.

Table 10. Mercury (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for females aged 16 to 49 years in the U.S. population, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 10th	25th	50th	75th	90th	95th	Sample size
Age group (females)								
16-49 years	.711 (.638-.792)	< LOD	.354 (.294-.422)	.723 (.640-.832)	1.41 (1.28-1.59)	2.48 (2.21-2.79)	3.27 (2.94-3.70)	1748
Race/ethnicity (females,16-49 years)								
Mexican Americans	.685 (.555-.846)	< LOD	.312 (.244-.400)	.639 (.487-.836)	1.45 (1.12-1.88)	2.89 (2.01-3.70)	4.51 (3.20-5.48)	595
Non-Hispanic blacks	.666 (.558-.796)	< LOD	.335 (.266-.414)	.615 (.503-.837)	1.22 (1.01-1.63)	2.56 (1.90-3.65)	3.99 (2.90-4.70)	381
Non-Hispanic whites	.706 (.621-.803)	< LOD	.368 (.289-.455)	.721 (.632-.846)	1.41 (1.26-1.64)	2.46 (2.16-2.78)	3.05 (2.56-3.76)	594

< LOD means less than the limit of detection (see previous table).

Cobalt

CAS No. 7440-48-4

General Information

Cobalt is a magnetic element that occurs in nature either as a steel-gray, shiny, hard metal or in combination with other elements. The cobalt used in U.S. industry is imported or obtained by recycling scrap metal that contains cobalt. Among its many uses are in the manufacture of hard-metal alloys (in combination with tungsten carbide), blue-colored pigments, and fertilizers. Cobalt is added to some paints and to porcelain enamel for use on steel bathroom fixtures, large appliances, and kitchenware. Cobalt carbonyls are used as catalysts in the synthesis of polyester and other materials. Small amounts of cobalt naturally occur in food; vitamin B_{12} is a cobalt-containing compound that is essential to good health.

Cobalt occurs naturally in dust, seawater, and many types of soil. It is also emitted into the environment from burning coal and oil and from car and truck exhaust. Usual human exposure is from food sources. Exposure in the workplace may come from electroplating, the processing of alloys, or the grinding of tungsten carbide-type metal-cutting tools. Workplace standards for external air exposure to cobalt and several of its compounds have been established (OSHA, ACGIH). Pneumoconiosis, asthma, contact dermatitis, and cardiomyopathy have occurred following chronic, high-level

Table 11. Cobalt

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	.372 (.347-.399)	.130 (.110-.140)	.220 (.200-.250)	.400 (.370-.420)	.630 (.580-.660)	.940 (.880-1.06)	1.32 (1.16-1.45)	2465
Age group								
6-11 years	.498 (.438-.565)	.220 (.150-.320)	.350 (.280-.430)	.520 (.450-.580)	.740 (.640-.850)	1.03 (.860-1.12)	1.22 (1.03-1.50)	340
12-19 years	.517 (.466-.574)	.200 (.170-.250)	.350 (.290-.390)	.520 (.490-.540)	.810 (.670-.870)	1.16 (1.01-1.47)	1.52 (1.24-2.57)	719
20 years and older	.339 (.313-.368)	.120 (.100-.130)	.200 (.180-.230)	.360 (.330-.400)	.560 (.520-.630)	.880 (.790-.970)	1.28 (1.06-1.45)	1406
Gender								
Males	.369 (.342-.398)	.150 (.120-.170)	.230 (.210-.280)	.400 (.380-.420)	.580 (.540-.630)	.810 (.750-.880)	1.01 (.910-1.12)	1227
Females	.375 (.340-.415)	.120 (.100-.140)	.220 (.180-.240)	.410 (.350-.440)	.670 (.600-.750)	1.17 (.970-1.34)	1.49 (1.28-1.98)	1238
Race/ethnicity								
Mexican Americans	.415 (.370-.466)	.130 (.100-.180)	.250 (.220-.310)	.470 (.400-.510)	.660 (.630-.740)	1.05 (.930-1.22)	1.47 (1.25-1.61)	884
Non-Hispanic blacks	.433 (.401-.467)	.160 (.140-.190)	.270 (.240-.290)	.420 (.390-.470)	.680 (.610-.780)	1.15 (1.02-1.25)	1.45 (1.22-2.04)	568
Non-Hispanic whites	.365 (.332-.402)	.120 (.090-.130)	.220 (.190-.260)	.400 (.350-.430)	.620 (.560-.670)	.930 (.840-1.06)	1.29 (1.06-1.49)	822

exposures in the workplace or as a result of chronic unintentional exposures. A mild reduction in thyroid function was noted in one worker study (Swennen et al., 1993). Cobalt is considered an animal carcinogen, but evidence of its carcinogenicity in people is inadequate (IARC). Information about external exposure (environmental levels) and health effects is available from ATSDR at http://www.atsdr.cdc.gov/toxprofiles.

Interpreting Urine Cobalt Levels Reported in the Tables

Urine cobalt levels were measured in a subsample of NHANES participants aged 6 years and older. Subsamples were randomly selected within the specified age range to be a representative sample of the U.S. population. Measuring cobalt at these levels in urine is possible because of advances in analytical chemistry. Finding a measurable amount of cobalt in urine does not mean that the level of cobalt causes an adverse health effect.

For workers exposed to cobalt in the air, the distinction between soluble cobalt and insoluble (oxides and metallic) cobalt should be made (Christensen and Poulsen, 1994; Lison et al., 1994). Exposure to soluble cobalt salts will produce proportionately higher urinary levels because of better absorption. The ACGIH BEI is 15 µg/L at a threshold limit value (as a time-weighted average) of air exposure at 20 µg/m^3 and applies only to exposures from soluble forms of cobalt. Correlations between air-exposure levels and urinary cobalt levels in

Table 12. Cobalt (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	.350 (.328-.374)	.162 (.147-.175)	.224 (.210-.236)	.326 (.307-.355)	.507 (.471-.561)	.821 (.723-.913)	1.16 (.955-1.41)	2465
Age group								
6-11 years	.546 (.487-.611)	.287 (.256-.322)	.391 (.338-.436)	.548 (.471-.625)	.774 (.629-.938)	1.00 (.833-1.48)	1.23 (.895-1.50)	340
12-19 years	.390 (.353-.430)	.176 (.165-.189)	.259 (.227-.284)	.374 (.330-.397)	.535 (.469-.586)	.824 (.640-1.10)	1.44 (.805-3.54)	719
20 years and older	.325 (.302-.350)	.152 (.138-.170)	.211 (.193-.226)	.302 (.278-.324)	.465 (.431-.500)	.727 (.667-.861)	1.12 (.913-1.30)	1406
Gender								
Males	.288 (.268-.309)	.139 (.120-.156)	.191 (.176-.214)	.277 (.256-.294)	.400 (.375-.436)	.608 (.545-.706)	.833 (.679-1.05)	1227
Females	.422 (.389-.457)	.190 (.180-.211)	.262 (.238-.289)	.405 (.366-.443)	.605 (.561-.667)	.955 (.861-1.16)	1.50 (1.14-1.64)	1238
Race/ethnicity								
Mexican Americans	.383 (.346-.424)	.163 (.134-.205)	.246 (.212-.280)	.376 (.342-.409)	.598 (.510-.656)	.898 (.786-1.01)	1.23 (1.11-1.35)	884
Non-Hispanic blacks	.281 (.265-.299)	.122 (.113-.139)	.174 (.163-.201)	.254 (.238-.280)	.417 (.375-.467)	.707 (.604-.774)	.975 (.757-1.45)	568
Non-Hispanic whites	.366 (.335-.399)	.172 (.150-.187)	.234 (.211-.256)	.344 (.314-.378)	.520 (.468-.586)	.861 (.721-.972)	1.25 (.957-1.50)	822

hard-metal fabricators are well documented (Ichikawa et al., 1985; Linnainmaa and Kiilunen, 1997; ACGIH 2001; Kraus et al., 2001; Lauwerys and Hoet, 2001). Air and urine cobalt levels for the workplace have been set as parallel standards in Germany. For instance, a urinary level of 30 µg/L can result from exposure to 0.05 mg/m^3 in the air. Generally, workers have urinary concentrations several to many times higher than general populations. Swennen et al. (1993) reported a median value of 44 µg/gram of creatinine and a maximum value of 2,245 µg/gram of creatinine in cobalt workers. The 95th percentiles of urinary cobalt levels reported for this NHANES 1999-2000 subsample are much less than levels observed during occupational exposures or established occupational levels of concern.

Previous studies reporting urinary levels for general populations in other developed countries have found values roughly similar to those reported in Tables 11 and 12 (White et al., 1998; Minoia, 1990; Lauwerys and Hoet 2001). In addition, levels measured in clinically submitted specimens are also broadly similar (Komaromy-Hiller et al., 2000) to levels documented in this *Report*. A previous study of urinary metals in a non-random subsample from NHANES III participants found several-fold higher values of cobalt, which are likely due to methodologic differences (Paschal et al., 1998). Because concentrations of cobalt in the urine decline rapidly within 24 hours after an exposure ceases (Alexandersson et al., 1988), such measurements reflect recent exposure. Taking multivitamins, tobacco smoking, and the presence of metal joint prostheses may increase cobalt excretion in the urine.

Geometric mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, and urinary creatinine. Urinary cobalt levels were slightly higher for ages 6-11 years than for ages 12-19 years, with both age groups having higher levels than people in the 20 years and older age group. Urinary cobalt levels in females were higher than in males, and levels in non-Hispanic blacks were lower than in either Mexican Americans or non-Hispanic whites. It is unknown whether differences between ages, genders, or races/ethnicities represent differences in exposure, body-size relationships, or metabolism.

Whether cobalt at the levels reported here is a cause for health concern is not yet known; more research is needed. These data provide physicians with a reference range so that they can determine whether people have been exposed to higher levels of cobalt than those found in the general population. These data will also help scientists plan and conduct research about cobalt exposure and health effects.

Uranium

CAS No. 7440-61-1

General Information

Uranium is a silver-white, extremely dense, and weakly radioactive metal. It usually occurs as an inorganic compound with oxygen, chlorine, or fluorine. Uranium has many commercial uses, including its use in nuclear weapons, nuclear fuel, armor-piercing shells, in some ceramics, and as an aid in electron microscopy.

Human exposure to uranium occurs primarily in the workplace by inhaling dust and other small particles. Exposure to insoluble uranium oxides and uranium metal via inhalation results in retention of these forms of uranium in the lungs and other tissues with little excreted in the urine. Soluble forms of uranium salts are poorly absorbed in the gastrointestinal tract, but these small amounts can be reflected in urinary measurements. Some uranium can be absorbed from food and water, especially in areas where large amounts of uranium occur naturally.

Workplace air standards for external exposure to soluble and insoluble uranium compounds have been established (OSHA, ACGIH). Although older evaluations suggested the carcinogenicity of uranium among smokers, the U.S. EPA has withdrawn its classification; IARC and the National Toxicology Program (NTP) have no ratings,

Table 13. Uranium

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	.007 (.006-.008)	< LOD	< LOD	.007 (.006-.007)	.013 (.011-.015)	.026 (.022-.036)	.046 (.036-.054)	2464
Age group								
6-11 years	.008 (.006-.010)	< LOD	< LOD	.007 (.005-.007)	.013 (.009-.019)	.032 (.019-.046)	.046 (.032-.066)	340
12-19 years	.009 (.007-.010)	< LOD	< LOD	.009 (.008-.009)	.014 (.012-.017)	.025 (.021-.036)	.043 (.029-.066)	719
20 years and older	.007 (.006-.008)	< LOD	< LOD	.007 (.006-.007)	.012 (.010-.015)	.026 (.021-.036)	.045 (.035-.054)	1405
Gender								
Males	.008 (.007-.010)	< LOD	< LOD	.007 (.007-.009)	.015 (.012-.019)	.036 (.024-.044)	.053 (.043-.065)	1227
Females	.006 (.005-.007)	< LOD	< LOD	.006 (.005-.007)	.011 (.009-.013)	.023 (.017-.028)	.035 (.027-.049)	1237
Race/ethnicity								
Mexican Americans	.016 (.012-.022)	< LOD	< LOD	.015 (.011-.021)	.032 (.021-.049)	.059 (.040-.127)	.113 (.054-.298)	883
Non-Hispanic blacks	.008 (.007-.010)	< LOD	< LOD	.007 (.007-.010)	.013 (.011-.018)	.028 (.019-.040)	.049 (.031-.066)	568
Non-Hispanic whites	.007 (.006-.008)	< LOD	< LOD	.007 (.006-.007)	.012 (.009-.013)	.023 (.017-.030)	.041 (.028-.050)	822

< LOD means less than the limit of detection, which is 0.003 µg/L.

and CDC's National Institute for Occupational Safety and Health (NIOSH) classifies uranium as carcinogenic. Information about external exposure and health effects is available from the EPA IRIS Web site at http://www.epa.gov/iris and from ATSDR at http://www.atsdr.cdc.gov/toxprofiles.

Interpreting Urine Uranium Levels Reported in the Tables

Urine uranium levels were measured in a subsample of NHANES participants aged 6 years old and older. Subsamples were randomly selected within the specified age range to be a representative sample of the U.S. population. The analytical method measures only levels of the ^{238}U isotope and not levels of the ^{235}U isotope (higher in enriched uranium used as nuclear fuel). More than 99% of naturally occurring uranium is ^{238}U. Measuring uranium at these levels in urine is possible because of advances in analytical chemistry. Finding a measurable amount of uranium in urine does not mean that the level of uranium causes an adverse health effect.

Uranium may produce renal injury through its chemical effect. The U.S. Nuclear Regulatory Commission (NRC) has set an action level of 15 µg/L for uranium in urine to protect people who are occupationally exposed to uranium (NRC, 1978). Six workers in a depleted uranium program had concentrations of 0.110 to 45 µg/L (Ejnik et al., 2000). In people who drank well water with high

Table 14. Uranium (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	.007 (.006-.008)	< LOD	< LOD	.006 (.005-.007)	.011 (.010-.014)	.023 (.019-.027)	.034 (.026-.049)	2464
Age group								
6-11 years	.009 (.007-.010)	< LOD	< LOD	.008 (.006-.010)	.015 (.010-.020)	.026 (.020-.035)	.037 (.026-.077)	340
12-19 years	.006 (.005-.008)	< LOD	< LOD	.006 (.005-.007)	.010 (.008-.014)	.019 (.013-.025)	.030 (.021-.061)	719
20 years and older	.007 (.006-.007)	< LOD	< LOD	.006 (.005-.007)	.011 (.010-.014)	.023 (.019-.027)	.034 (.025-.050)	1405
Gender								
Males	.006 (.006-.007)	< LOD	< LOD	.006 (.005-.007)	.011 (.009-.014)	.021 (.017-.026)	.035 (.024-.054)	1227
Females	.007 (.006-.008)	< LOD	< LOD	.007 (.006-.008)	.012 (.010-.014)	.024 (.020-.027)	.034 (.025-.050)	1237
Race/ethnicity								
Mexican Americans	.015 (.011-.020)	< LOD	< LOD	.014 (.011-.019)	.029 (.019-.048)	.058 (.029-.127)	.100 (.044-.270)	883
Non-Hispanic blacks	.005 (.004-.006)	< LOD	< LOD	.005 (.004-.006)	.008 (.006-.011)	.017 (.011-.027)	.028 (.019-.039)	568
Non-Hispanic whites	.007 (.006-.008)	< LOD	< LOD	.006 (.005-.008)	.011 (.009-.013)	.020 (.015-.024)	.028 (.022-.050)	822

< LOD means less than the limit of detection (see previous table for LOD).

natural uranium concentrations, the median urinary concentration was 0.078 µg/L (ranging up to 5.65 µg/L), and a subtle effect of uranium on calcium and phosphate fractional clearance was indicated (within the normal range of these measures) but without effects on other biochemical or traditional markers of renal function (Kurttio et al., 2002). The urine uranium levels in Table 13 for the NHANES 1999-2000 subsample are well below any of the aforementioned levels.

Dang et al. (1993) and Karpas et al. (1996) reported values for small groups of normal individuals in a range similar to those values seen in this NHANES 1999-2000 subsample. In addition, other studies have demonstrated urinary uranium concentrations that are consistent with levels documented in this *Report*, in that the reported levels were below their respective detection limits (Hamilton et al., 1994; Komaromy-Hiller et al., 2000; Byrne et al., 1991). A previous non-random subsample from NHANES III (n = 499) showed concentrations that are essentially similar to those in Table 13 (Ting et al., 1999). In the current NHANES 1999-2000 subsample, geometric mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, and urinary creatinine. Urinary uranium levels tended to be slightly higher for children aged 6-11 years than for people in the other two age groups. Urinary uranium levels in Mexican Americans were more than twice the levels of either non-Hispanic blacks or non-Hispanic whites. It is unknown whether differences between ages or races/ethnicities represent differences in exposure, body-size relationships, or metabolism.

Whether uranium at the levels reported here is cause for health concern is unknown; more research is needed. These urine uranium data provide physicians with a reference range so that they can determine whether people have been exposed to higher levels of uranium than those found in the general population. These data will also help scientists plan and conduct research about uranium exposure and health effects.

Antimony

CAS No. 7440-36-0

General Information

Elemental antimony is a silver-white metal. In nature, antimony can be found in ores or other minerals, usually combined with oxygen to form antimony oxide. Antimony is used in metal alloys, storage batteries, solder, sheet and pipe metal, bearings, castings, and pewter. Antimony oxide is used as a fire-retardant in textiles and plastics. It is also used in paints, ceramics, fireworks, enamels, and glass. One organic antimony compound is still used as an antiparasitic medication.

Antimony gets into the environment from natural sources and from industry. People are exposed to antimony primarily from food and to a lesser extent from drinking water and air. Workplace exposures occur as a result of breathing the air near industries such as smelters, coal-fired plants, and refuse incinerators that process or release antimony. Workplace standards for air exposure to antimony have been established (OSHA, ACGIH). Antimony is considered an animal carcinogen, but evidence of its carcinogenicity in people is inadequate (IARC). Information about external exposure (environmental levels) and health effects is available from the EPA IRIS Web site at http://www.epa.gov/iris and from ATSDR at http://www.atsdr.cdc.gov/toxprofiles.

Table 15. Antimony

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	.128 (.116-.140)	.050 (<LOD-.060)	.070 (.070-.090)	.130 (.120-.140)	.210 (.200-.230)	.330 (.290-.350)	.420 (.390-.470)	2276
Age group								
6-11 years	.173 (.152-.197)	.090 (.050-.110)	.130 (.110-.150)	.190 (.160-.210)	.260 (.230-.280)	.350 (.290-.440)	.400 (.320-.600)	316
12-19 years	.156 (.140-.174)	.060 (.050-.080)	.100 (.090-.120)	.170 (.150-.180)	.230 (.210-.260)	.340 (.300-.390)	.460 (.360-.510)	663
20 years and older	.119 (.107-.132)	< LOD	.070 (.060-.090)	.110 (.100-.120)	.190 (.180-.220)	.310 (.280-.350)	.420 (.390-.470)	1297
Gender								
Males	.139 (.127-.153)	.040 (<LOD-.060)	.090 (.070-.100)	.140 (.130-.150)	.240 (.220-.250)	.350 (.310-.380)	.470 (.390-.530)	1132
Females	.118 (.105-.133)	.040 (<LOD-.060)	.080 (.060-.090)	.120 (.100-.130)	.190 (.180-.220)	.300 (.260-.340)	.390 (.340-.470)	1144
Race/ethnicity								
Mexican Americans	.127 (.111-.145)	.040 (<LOD-.060)	.080 (.060-.100)	.130 (.120-.150)	.200 (.180-.230)	.300 (.260-.340)	.410 (.340-.500)	787
Non-Hispanic blacks	.173 (.149-.201)	.070 (.050-.080)	.110 (.090-.140)	.180 (.150-.200)	.260 (.220-.290)	.390 (.310-.470)	.490 (.400-.580)	554
Non-Hispanic whites	.124 (.112-.138)	.040 (<LOD-.060)	.080 (.060-.080)	.120 (.120-.140)	.210 (.180-.220)	.320 (.280-.360)	.400 (.360-.500)	768

< LOD means less than the limit of detection, which is 0.03 µg/L.

Interpreting Urine Antimony Levels Reported in the Tables

Urine antimony levels were measured in a subsample of NHANES participants aged 6 years and older. Subsamples were randomly selected within the specified age range to be a representative sample of the U.S. population. Measuring antimony at these levels in urine is possible because of advances in analytical chemistry. Finding a measurable amount of antimony in urine does not mean that the level of antimony causes an adverse health effect. Several investigations of airborne exposures to antimony in workers show urinary levels that are many times higher than those seen in Table 15, even when exposure levels were below workplace air standards (Kentner et al., 1995; Ludersdorf et al., 1987; Bailly et al., 1991). Kentner et al. proposed a urinary limit of 260 µg/gram of creatinine for workplace air exposures equivalent to an air concentration of 500 µg/m^3 of antimony hydride. Previous studies reporting measurements on normal populations (Minoia et al., 1990; Paschal et al., 1998) or compiled reference ranges (Hamilton et al., 1994) have found values slightly higher than those reported in Table 15, some of which may be due to methodologic differences, although population and exposure differences may exist. The variation of urinary antimony levels across this NHANES 1999-2000 subsample was narrow, possibly indicating limited opportunities for exposure.

Table 16. Antimony (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 10th	25th	50th	75th	90th	95th	Sample size
Total, age 6 and older	.120 (.107-.135)	.053 (.045-.063)	.078 (.067-.090)	.117 (.106-.133)	.184 (.164-.208)	.272 (.236-.320)	.382 (.320-.438)	2276
Age group								
6-11 years	.188 (.151-.235)	.086 (.053-.108)	.135 (.106-.158)	.185 (.159-.208)	.250 (.200-.382)	.439 (.263-.741)	.537 (.303-1.30)	316
12-19 years	.119 (.105-.136)	.059 (.041-.073)	.083 (.070-.095)	.119 (.104-.134)	.176 (.150-.199)	.259 (.207-.310)	.310 (.231-.421)	663
20 years and older	.114 (.101-.128)	< LOD	.074 (.063-.087)	.110 (.099-.126)	.171 (.152-.202)	.257 (.229-.318)	.352 (.318-.400)	1297
Gender								
Males	.109 (.099-.121)	.052 (.041-.060)	.072 (.064-.084)	.108 (.100-.121)	.164 (.149-.178)	.224 (.209-.250)	.298 (.241-.382)	1132
Females	.132 (.115-.152)	.056 (.047-.069)	.083 (.070-.099)	.129 (.111-.148)	.210 (.182-.235)	.320 (.265-.361)	.425 (.339-.531)	1144
Race/ethnicity								
Mexican Americans	.116 (.105-.128)	.056 (.041-.071)	.082 (.074-.095)	.113 (.105-.126)	.166 (.148-.197)	.247 (.215-.280)	.327 (.280-.357)	787
Non-Hispanic blacks	.113 (.098-.131)	.053 (.045-.061)	.075 (.065-.087)	.111 (.097-.129)	.159 (.143-.184)	.236 (.195-.338)	.339 (.236-.450)	554
Non-Hispanic whites	.125 (.109-.143)	.054 (.045-.066)	.080 (.067-.095)	.121 (.106-.143)	.194 (.169-.218)	.296 (.239-.347)	.400 (.318-.476)	768

< LOD means less than the limit of detection (see previous table).

Geometric mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, and urinary creatinine. Urinary antimony levels were slightly higher for children aged 6-11 years than for either people aged 12-19 years or 20 years and older. Urinary antimony levels in females were slightly higher than in males. It is unknown whether differences between ages or genders represent differences in exposure, body-size relationships, or metabolism.

Whether antimony at the levels reported here is a cause for health concern is not yet known; more research is needed. These urine antimony data provide physicians with a reference range so that they can determine whether people have been exposed to higher levels of antimony than those found in the general population. These data will also help scientists plan and conduct research about exposure to antimony and health effects.

Barium

CAS No. 7440-39-3

General Information

Elemental barium is a silver-white metal. In nature, it combines with other chemicals such as sulfur or carbon and oxygen. Barium compounds are used by the oil and gas industries to make drilling muds. These compounds are also produced commercially for use in paint, bricks, tiles, glass, rubber, depilatories, fireworks, and ceramics. Medically, barium sulfate is used as a contrast medium for taking X-rays of the gastrointestinal tract. Barium sulfate is insoluble and not absorbed.

People can be exposed to barium in air, water, and food. The health effects of exposure to barium compounds depend on the dose, chemical form, and water solubility. Workers employed by industries that make or use barium compounds are exposed to barium dust. Chronic accumulation of inhaled barium dust in the lung tissue may cause baritosis, a benign condition that may occur among barite ore miners. Workplace standards for external air exposure to various barium salts have been established (OSHA). Barium is considered unlikely to be carcinogenic (U.S. EPA, NTP). Information about external exposure (environmental levels) and health effects is available from the EPA IRIS Web site at http://www.epa.gov/iris and from ATSDR at http://www.atsdr.cdc.gov/toxprofiles.

Table 17. Barium

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	1.48 (1.36-1.61)	.200 (.200-.300)	.800 (.700-.900)	1.50 (1.40-1.70)	3.00 (2.80-3.30)	5.40 (4.70-6.00)	6.80 (6.20-8.40)	2180
Age group								
6-11 years	2.13 (1.77-2.56)	.800 (.600-.900)	1.20 (1.00-1.50)	2.20 (1.80-2.30)	3.90 (2.90-5.90)	6.40 (5.40-8.30)	8.30 (5.60-40.8)	297
12-19 years	1.97 (1.76-2.21)	.600 (.500-.800)	1.10 (.800-1.30)	2.00 (1.60-2.30)	3.50 (3.00-4.10)	5.90 (4.80-6.70)	9.70 (6.10-13.1)	621
20 years and older	1.35 (1.24-1.48)	.200 (.200-.300)	.700 (.500-.700)	1.40 (1.30-1.60)	2.70 (2.50-3.00)	5.00 (4.20-5.50)	6.40 (5.80-7.70)	1262
Gender								
Males	1.69 (1.50-1.89)	.300 (.200-.500)	1.00 (.800-1.10)	1.80 (1.60-2.00)	3.10 (2.80-3.40)	5.50 (4.50-6.20)	7.50 (6.20-9.40)	1083
Females	1.31 (1.19-1.45)	.300 (.200-.300)	.600 (.500-.700)	1.50 (1.20-1.60)	2.80 (2.40-3.00)	5.10 (4.20-5.80)	6.80 (5.80-10.2)	1097
Race/ethnicity								
Mexican Americans	1.34 (1.18-1.52)	.400 (.300-.400)	.600 (.500-.800)	1.30 (1.20-1.60)	2.60 (2.30-2.90)	4.50 (3.90-5.30)	6.30 (5.40-7.20)	692
Non-Hispanic blacks	1.33 (1.11-1.59)	.200 (.200-.400)	.700 (.500-.700)	1.30 (1.10-1.50)	2.50 (2.10-2.80)	5.10 (3.80-6.20)	7.40 (5.40-13.9)	540
Non-Hispanic whites	1.55 (1.40-1.72)	.300 (.300-.400)	.700 (.600-.900)	1.70 (1.60-2.00)	3.30 (3.00-3.50)	5.40 (4.60-6.20)	7.20 (6.20-9.40)	765

< LOD means less than the limit of detection, which is 0.08 µg/L.

Interpreting Urine Barium Levels Reported in the Tables

Urine barium levels were measured in a subsample of NHANES participants aged 6 years and older. Subsamples were randomly selected within the specified age range to be a representative sample of the U.S. population. Measuring barium at these levels in urine is possible because of advances in analytical chemistry. Finding a measurable amount of barium in urine does not mean that the level of barium causes an adverse health effect. Previous studies reporting urinary levels of barium in normal populations have found values roughly similar to those documented in this *Report* (Minoia et al., 1990; Paschal et al., 1998). In addition, levels determined in clinically submitted specimens are broadly similiar (Komaromy-Hiller et al., 2000). Median urinary levels of barium found in welders of barium-containing electrodes were 60 times higher than the median levels reported below (Zschiesche et al., 1992) without obvious health effects.

In the current NHANES 1999-2000 subsample, geometric mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, and urinary creatinine. Urinary barium levels were higher for children aged 6-11 years than for either people aged 12-19 years or 20 years and older, and levels in people aged 12-19 years were higher than people aged 20 years and older. Urinary barium levels in females were higher than in males, and

Table 18. Barium (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	1.39 (1.29-1.50)	.410 (.345-.500)	.790 (.741-.863)	1.41 (1.32-1.49)	2.54 (2.25-2.80)	4.68 (4.09-5.25)	6.27 (5.47-8.09)	2180
Age group								
6-11 years	2.34 (1.86-2.95)	.651 (.502-.879)	1.41 (1.11-1.66)	2.35 (1.85-2.92)	4.46 (3.04-5.45)	8.77 (4.28-22.0)	11.4 (5.60-22.0)	297
12-19 years	1.50 (1.34-1.69)	.556 (.483-.631)	.863 (.743-1.06)	1.39 (1.26-1.60)	2.48 (2.00-3.04)	4.36 (3.26-5.33)	6.95 (4.24-11.4)	621
20 years and older	1.28 (1.19-1.38)	.374 (.298-.458)	.744 (.690-.817)	1.33 (1.22-1.42)	2.32 (2.11-2.57)	4.29 (3.69-4.84)	5.65 (5.28-6.33)	1262
Gender								
Males	1.30 (1.19-1.43)	.400 (.298-.500)	.762 (.690-.848)	1.36 (1.23-1.47)	2.39 (2.08-2.64)	4.24 (3.58-5.00)	5.61 (4.61-6.76)	1083
Females	1.48 (1.34-1.63)	.429 (.329-.526)	.846 (.741-.926)	1.46 (1.33-1.61)	2.65 (2.23-3.17)	4.86 (4.26-6.00)	7.36 (5.41-10.0)	1097
Race/ethnicity								
Mexican Americans	1.20 (1.05-1.37)	.370 (.265-.455)	.640 (.556-.744)	1.17 (.968-1.46)	2.39 (2.00-2.68)	4.00 (3.22-4.80)	5.31 (4.71-6.67)	692
Non-Hispanic blacks	.869 (.719-1.05)	.244 (.134-.316)	.469 (.361-.559)	.904 (.714-1.05)	1.64 (1.42-1.92)	3.27 (2.48-4.04)	4.84 (3.62-10.8)	540
Non-Hispanic whites	1.55 (1.40-1.72)	.500 (.367-.603)	.917 (.817-1.01)	1.55 (1.40-1.68)	2.72 (2.39-3.16)	5.00 (4.26-5.60)	6.60 (5.56-10.0)	765

< LOD means less than the limit of detection (see previous table).

levels in non-Hispanic whites were higher than in non-Hispanic blacks or Mexican Americans. It is unknown whether differences between ages, genders, or races/ethnicities represent differences in exposure, body-size relationships, or metabolism.

Whether barium at the levels reported here is a cause for health concern is not yet known; more research is needed. These urine barium data provide physicians with a reference range so that they can determine whether people have been exposed to higher levels of barium than those found in the general population. These data will also help scientists plan and conduct research about exposure to barium and health effects.

Beryllium

CAS No. 7440-41-7

General Information

Pure beryllium is a hard, gray metal. In nature, beryllium can be found in mineral rocks, coal, soil, and volcanic dust. Beryllium compounds are commercially mined, and the beryllium is purified for use in mirrors and in special metal alloys in the nuclear, electrical, aircraft, and machine-parts industries. Small amounts of beryllium dust can enter air from burning coal and oil. Exposure to beryllium occurs mostly in the workplace, near some hazardous waste sites, and from breathing tobacco smoke.

In the workplace, beryllium dust enters the body primarily through the lungs, where it remains for years, but there are little data available on how the metal accumulates in the lungs. Berylliosis, a granulomatous interstitial lung disease that results from chronic beryllium inhalation, is rarely seen today. Skin contact with beryllium may also produce dermatitis, and some people demonstrate a hypersensitivity reaction to beryllium. Workplace air standards for external exposure have been established (OSHA, ACGIH). Beryllium is an animal carcinogen, and it is reasonably anticipated to be a human lung carcinogen (IARC). NTP considers beryllium to be a known carcinogen. Information about external exposure (environmental levels) and health effects is available

Table 19. Beryllium

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	2465
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	340
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	719
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1406
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1227
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1238
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	884
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	568
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	822

< LOD means less than the limit of detection, which is 0.09 µg/L.

* Not calculated. Proportion of results below the limit of detection was too high to provide a valid result.

from the EPA IRIS Web site at http://www.epa.gov/iris and from ATSDR at http://www.atsdr.cdc.gov/toxprofiles.

Interpreting Urine Beryllium Results Reported in the Tables

Urine beryllium levels were measured in a subsample of NHANES participants aged 6 years old and older. Subsamples were randomly selected within the specified age range to be a representative sample of the U.S. population. Previous studies reporting urinary levels for normal populations either have reported undetectable concentrations or have not had comparable detection limits (White et al., 1998; Komaromy-Hiller et al., 2000; Minoia et al., 1990; Paschal et al., 1998). A summary of reference ranges taken from previous studies suggested that a true reference range for urinary beryllium is below many current detection limits (< 1 µg/L) (Hamilton et al., 1994). Apostoli and Schaller (2001) suggest that previous detection limits are inadequate to quantitate normal human exposure. In that study, urinary beryllium in workers correlated with air exposure measures. When air levels were below the recommended threshold limit value, urinary beryllium concentrations ranged from 0.12 to 0.15 µg/L. Because the detection limit documented in this *Report* was 0.09 µg/L and because 99.8% of values were undetectable, these NHANES 1999-2000 levels are likely to be lower than levels considered safe for workers.

Table 20. Beryllium (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	2465
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	340
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	719
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1406
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1227
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1238
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	884
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	568
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	822

< LOD means less than the limit of detection (see previous table for LOD).

* Not calculated. Proportion of results below the limit of detection was too high to provide a valid result.

Cesium

CAS No. 7440-46-2

General Information

Cesium is a silver-white metal that ignites on contact with air and reacts explosively with water. Cesium compounds can be found naturally in rock, soil, and clay. Cesium inorganic compounds are commonly used in photomultiplier tubes, vacuum tubes, scintillation counters, infrared lamps, semiconductors, high-power gas-ion devices, and as polymerization catalysts and photographic emulsions. Radioactive cesium-137 has been used medically to treat cancer.

Most human exposure to cesium occurs through diet. Little is known about the health effects of this metal. Cesium hydroxide is a corrosive and an irritant. Workplace air standards for external exposure are recommended on the basis of these irritant effects but only for certain salts (NIOSH). It is not known whether cesium compounds are carcinogenic. National agencies (ATSDR, U.S. EPA, NTP) have not reviewed exposure or health effects related to this element.

Interpreting Urine Cesium Levels Reported in the Tables

Urine cesium levels were measured in a subsample of NHANES participants aged 6 years and older. Subsamples were randomly selected within the specified age

Table 21. Cesium

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 10th	25th	50th	75th	90th	95th	Sample size
Total, age 6 and older	4.35 (4.08-4.64)	1.60 (1.30-1.80)	2.90 (2.70-3.30)	4.80 (4.50-5.30)	7.10 (6.80-7.40)	9.60 (8.90-10.2)	11.4 (10.3-12.5)	2464
Age group								
6-11 years	4.87 (4.19-5.65)	2.10 (1.00-2.90)	3.80 (2.80-3.90)	5.60 (4.40-6.70)	7.30 (6.80-7.90)	9.00 (7.90-9.70)	9.70 (8.80-10.8)	340
12-19 years	4.54 (4.14-4.99)	1.80 (1.40-2.30)	3.40 (2.80-3.80)	5.10 (4.50-5.50)	6.80 (6.20-7.70)	8.80 (8.00-9.40)	10.4 (9.00-12.2)	718
20 years and older	4.26 (3.99-4.55)	1.50 (1.20-1.70)	2.80 (2.50-3.00)	4.80 (4.40-5.10)	7.10 (6.70-7.50)	9.80 (8.90-10.5)	11.6 (10.3-13.0)	1406
Gender								
Males	4.83 (4.48-5.21)	1.90 (1.70-2.40)	3.50 (3.00-3.70)	5.50 (4.90-5.80)	7.50 (7.00-8.00)	9.70 (8.90-10.3)	11.6 (10.3-13.0)	1226
Females	3.94 (3.61-4.31)	1.10 (1.00-1.30)	2.60 (2.30-2.80)	4.50 (4.00-4.80)	6.60 (6.20-7.10)	9.10 (8.20-10.0)	11.1 (9.90-12.9)	1238
Race/ethnicity								
Mexican Americans	4.31 (3.92-4.75)	1.50 (1.20-2.00)	3.00 (2.50-3.40)	4.70 (4.20-5.00)	6.60 (6.30-7.00)	9.10 (8.00-9.80)	10.9 (9.70-12.5)	884
Non-Hispanic blacks	4.93 (4.44-5.47)	2.10 (1.90-2.70)	3.70 (3.10-4.00)	5.40 (4.90-6.10)	7.40 (6.90-8.20)	9.80 (8.80-10.8)	11.5 (10.0-12.8)	568
Non-Hispanic whites	4.25 (3.91-4.62)	1.50 (1.20-1.80)	2.70 (2.40-3.00)	4.70 (4.30-5.30)	7.10 (6.70-7.70)	9.60 (8.80-10.5)	11.7 (10.3-13.1)	821

range to be a representative sample of the U.S. population. Finding a measurable amount of cesium in urine does not mean that the level of cesium causes an adverse health effect. For one small population study (Minoia et al., 1990) and one study of clinically submitted specimens (Komaromy-Hiller et al., 2000), urinary cesium levels were slightly higher than levels reported in Tables 21 and 22. Median values in this current NHANES 1999-2000 subsample are more than twice the median values reported in a non-random subsample from NHANES III (1988-1994) (Paschal et al., 1998). The cause of these differences in the aforementioned studies is not known but may be due to methodologic differences at these low levels.

In the current NHANES 1999-2000 subsample, geometric mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, and urinary creatinine. Urinary cesium levels were higher for children aged 6-11 years than for people aged 12-19 years, with both age groups having higher levels than people aged 20 years and older. Non-Hispanic whites had higher levels than non-Hispanic blacks. It is unknown whether differences between ages, genders, or races/ethnicities represent differences in exposure, body-size relationships, or metabolism.

Whether cesium at the levels reported here is cause for health concern is not yet known; more research is

Table 22. Cesium (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	4.10 (3.89-4.31)	2.39 (2.22-2.61)	3.14 (3.04-3.26)	4.12 (3.96-4.28)	5.41 (5.21-5.71)	7.14 (6.73-7.64)	8.64 (7.78-9.76)	2464
Age group								
6-11 years	5.34 (4.94-5.77)	3.68 (3.04-3.99)	4.46 (4.17-4.69)	5.42 (5.00-6.05)	6.63 (6.09-7.18)	8.23 (6.83-9.90)	9.89 (7.57-10.7)	340
12-19 years	3.43 (3.23-3.65)	2.02 (1.87-2.22)	2.63 (2.42-2.89)	3.52 (3.24-3.73)	4.35 (4.17-4.56)	5.31 (4.85-5.99)	6.56 (5.21-10.4)	718
20 years and older	4.08 (3.86-4.31)	2.40 (2.22-2.65)	3.14 (3.01-3.27)	4.06 (3.87-4.27)	5.38 (5.07-5.71)	7.17 (6.73-7.65)	8.60 (7.77-9.76)	1406
Gender								
Males	3.78 (3.58-3.98)	2.12 (1.90-2.38)	2.97 (2.76-3.12)	3.78 (3.55-4.02)	4.96 (4.69-5.24)	6.45 (6.04-6.90)	7.71 (6.90-8.83)	1226
Females	4.43 (4.16-4.71)	2.63 (2.40-2.86)	3.36 (3.16-3.61)	4.44 (4.20-4.68)	5.92 (5.40-6.40)	7.70 (7.12-8.40)	9.38 (8.00-10.5)	1238
Race/ethnicity								
Mexican Americans	3.98 (3.71-4.27)	2.41 (2.16-2.58)	3.04 (2.86-3.23)	3.95 (3.65-4.12)	5.09 (4.66-5.44)	6.64 (6.00-7.21)	7.96 (7.20-8.95)	884
Non-Hispanic blacks	3.21 (2.88-3.56)	2.01 (1.69-2.29)	2.56 (2.27-2.77)	3.26 (3.05-3.45)	4.30 (3.99-4.55)	5.49 (5.08-5.97)	6.33 (5.90-7.08)	568
Non-Hispanic whites	4.26 (3.99-4.54)	2.54 (2.26-2.85)	3.33 (3.15-3.53)	4.28 (4.05-4.52)	5.63 (5.25-6.06)	7.27 (6.80-7.91)	8.68 (7.65-10.0)	821

needed. No relation has been established between urinary levels of cesium and health effects. These urine cesium data provide physicians with a reference range so that they can determine whether people have been exposed to higher levels of cesium than those found in the general population. These data will also help scientists plan and conduct research about exposure to cesium and health effects.

Molybdenum

CAS No. 7439-98-7

General Information

Elemental molybdenum is a silver-white, hard metal with many commercial uses, including the production of metal alloys. Compounds of molybdenum are used as corrosion inhibitors, hydrogenation catalysts, lubricants, alloys in steel, chemical reagents in hospital laboratories, and in pigments for ceramics and paints.

Molybdenum is a nutritionally essential trace element and enters the body primarily from dietary sources. Molybdenum enters the environment from the weathering of ores that contain it and from water containing the metal in its soluble forms (e.g., molybdates). In industry, dust and other fine particles produced during the refining or shaping of molybdenum are the most important sources of exposure. Workplace air standards for external exposure are generally established (OSHA, ACGIH). Generally, molybdenum has low or unknown toxicity. Some molybdenum compounds (e.g., molybdenum trioxide) may be animal carcinogens (NTP), but human carcinogenic risk is unknown (U.S. EPA). Information about external exposure (environmental levels) and health effects is available from the EPA IRIS Web site at http://www.epa.gov/iris.

Table 23. Molybdenum

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	45.9 (42.0-50.1)	12.6 (11.3-15.0)	26.7 (22.4-30.8)	50.7 (46.5-56.7)	84.9 (79.8-91.2)	134 (126-145)	178 (157-216)	2257
Age group								
6-11 years	78.2 (65.1-93.8)	31.1 (13.1-43.2)	48.9 (39.4-66.3)	83.4 (71.0-98.5)	126 (108-145)	174 (145-259)	267 (159-840)	310
12-19 years	54.3 (48.3-61.1)	16.9 (14.6-21.0)	32.6 (24.9-42.8)	60.6 (52.1-70.4)	93.3 (81.3-108)	146 (113-169)	183 (146-216)	648
20 years and older	41.7 (38.1-45.5)	11.5 (9.80-13.3)	23.3 (20.1-27.7)	46.5 (41.6-49.8)	76.7 (73.7-81.8)	125 (114-134)	167 (145-198)	1299
Gender								
Males	52.6 (47.1-58.7)	15.8 (13.2-20.1)	30.7 (25.9-34.7)	57.4 (50.1-66.2)	93.2 (83.8-106)	150 (133-175)	213 (169-252)	1121
Females	40.4 (36.4-44.7)	11.2 (8.70-12.6)	21.9 (18.1-26.9)	45.5 (40.7-50.7)	77.2 (72.7-83.8)	118 (108-132)	154 (138-175)	1136
Race/ethnicity								
Mexican Americans	47.0 (42.8-51.6)	12.8 (11.3-15.5)	29.6 (23.1-34.9)	53.2 (49.0-59.0)	80.3 (74.2-91.7)	120 (109-134)	152 (126-208)	780
Non-Hispanic blacks	57.6 (52.4-63.3)	18.6 (14.6-23.0)	34.5 (30.7-39.4)	61.8 (56.4-70.3)	97.7 (85.0-110)	151 (133-175)	202 (160-269)	546
Non-Hispanic whites	44.4 (39.2-50.4)	12.2 (9.10-15.0)	24.9 (20.0-31.1)	48.5 (42.4-56.6)	85.0 (77.2-93.9)	135 (123-152)	178 (153-221)	760

< LOD means less than the limit of detection, which is 0.6 µg/L.

Interpreting Urine Molybdenum Levels Reported in the Tables

Urine molybdenum levels were measured in a subsample of NHANES participants aged 6 years and older. Subsamples were randomly selected within the specified age range to be a representative sample of the U.S. population. Finding a measurable amount of molybdenum in urine does not mean that the level of molybdenum causes an adverse health effect. Because molybdenum is an essential element for good health, intake and loss in the urine is expected. One study of a small number of college students found that high molybdenum intakes were associated with high urinary levels (mean 187 ± 34 µg/24 hr) without apparent health effects (Tsongas et al., 1980). Molybdenum is conserved at low intakes, and urinary losses are greater with high intake (Turnlund et al., 1995). Copper intake can alter the absorption, excretion, and effects of molybdenum. Among infants, urinary molybdenum concentrations may be slightly lower (Sievers et al., 2001). Other factors (e.g., dietary composition) that may increase or decrease molybdenum excretion are unknown.

Levels documented in this *Report* are similar to levels found in a previous non-random subsample of the U.S. population from NHANES III (1988-1994) (Paschal et al., 1998) and roughly similar to levels in several different populations (White et al., 1998; Komaromy-Hiller et al., 2000). Also, urinary molybdenum levels of

Table 24. Molybdenum (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	43.1 (40.5-46.0)	19.4 (17.1-21.7)	28.3 (27.2-29.7)	41.5 (39.1-44.5)	63.5 (59.1-69.3)	108 (95.5-116)	144 (123-172)	2257
Age group								
6-11 years	85.8 (73.2-101)	43.1 (31.4-54.7)	60.3 (53.4-66.6)	78.9 (71.7-88.4)	122 (95.1-137)	173 (130-217)	213 (156-1040)	310
12-19 years	41.9 (38.4-45.7)	22.1 (18.6-24.5)	29.3 (26.7-33.1)	40.5 (35.9-46.2)	57.3 (50.5-65.8)	85.0 (68.4-103)	109 (83.1-185)	648
20 years and older	39.6 (37.2-42.2)	17.9 (15.5-20.7)	27.2 (25.7-28.4)	38.5 (36.5-40.7)	56.4 (53.5-60.7)	92.5 (80.7-107)	120 (112-152)	1299
Gender								
Males	40.7 (37.4-44.3)	16.9 (15.4-20.0)	26.6 (24.9-27.9)	38.5 (36.4-41.6)	62.4 (55.6-70.5)	101 (85.4-116)	131 (118-168)	1121
Females	45.5 (42.6-48.6)	22.1 (19.0-24.4)	30.7 (29.1-32.4)	43.7 (41.3-47.6)	64.4 (59.3-70.5)	111 (95.5-120)	149 (122-181)	1136
Race/ethnicity								
Mexican Americans	42.9 (40.5-45.5)	20.4 (16.4-23.9)	30.8 (28.1-32.8)	43.2 (40.9-45.6)	61.6 (57.0-66.2)	89.0 (80.2-102)	115 (97.8-132)	780
Non-Hispanic blacks	37.2 (34.3-40.3)	16.7 (14.5-20.3)	25.2 (23.5-26.8)	37.0 (34.2-40.6)	55.9 (51.6-62.4)	88.2 (73.3-109)	117 (88.4-141)	546
Non-Hispanic whites	44.4 (40.7-48.5)	19.6 (16.7-23.3)	28.8 (27.1-31.1)	42.1 (38.8-47.0)	65.3 (57.6-72.7)	116 (101-126)	172 (131-191)	760

< LOD means less than the limit of detection (see previous table).

adults in two smaller studies (Iversen et al., 1998; Allain et al., 1991) generally corresponded to the concentrations in this *Report*. In the current NHANES 1999-2000 subsample, geometric mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, and urinary creatinine. Urinary molybdenum levels were higher for 6-11 year olds than for people aged 12-19 years, with both age groups having higher levels than people in the 20 years and older group. Non-Hispanic blacks had slightly lower levels than non-Hispanic whites. It is unknown whether differences between ages or races/ethnicities represent differences in exposure, body-size relationships, or metabolism.

These urine molybdenum data provide physicians with a reference range so that they can determine whether people have been exposed to higher levels of molybdenum than those found in the general population. These data will also help scientists plan and conduct research about molybdenum exposure and health effects.

Platinum

CAS No. 7440-06-4

General Information

Platinum is a silver-gray, lustrous metal found naturally in extremely low amounts in the earth's crust and typically is associated with sulfide-ore bodies of nickel, copper, and iron. Important properties of platinum are resistance to corrosion, strength at high temperatures, and high catalytic activity. Platinum-rhodium compounds are used in glass and glass-fiber manufacture and in high-temperature thermocouples. Platinum compounds are also used in electrodes and jewelry, as oxidation catalysts in chemical manufacturing, and in thick-film circuits printed on ceramic substrates. Platinum-rhodium and platinum-palladium crystals are used as catalysts in petroleum refining and to control automobile-exhaust emissions.

Higher environmental soil concentrations of platinum have been associated with nearby roadways (Farago et al., 1998). Workplace air standards for external exposure are generally established for soluble salts (OSHA, ACGIH) or recommended for the metal form (NIOSH). The pharmaceutical, cisplatin, is an animal carcinogen (NTP) and a possible human carcinogen. The carcinogenicity of other platinum compounds is unknown. Information about external exposure (environmental levels) and health effects is available (NRC/NAS, 1977).

Table 25. Platinum

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	2465
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	340
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	719
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1406
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1227
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1238
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	884
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	568
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	822

< LOD means less than the limit of detection, which is 0.03 µg/L.

* Not calculated. Proportion of results below the limit of detection was too high to provide a valid result.

Interpreting Urine Platinum Levels Reported in the Tables

Urine platinum levels were measured in a subsample of NHANES participants aged 6 years and older. Subsamples were randomly selected within the specified age range to be a representative sample of the U.S. population. In the current NHANES 1999-2000 subsample, urinary platinum levels were not detectable in 98.8% of the sample (detection limit was 0.03 µg/L). Previous studies reporting measurements in normal populations have found detectable and higher values than those reported in Table 25 (Vaughan et al., 1992; Paschal et al., 1998) and are possibly due to methodologic differences, although population differences may exist. Platinum-industry and precious-metal workers can have urinary concentrations 1,000 times higher than unexposed populations (Schierl et al., 1998). Gold-platinum alloys used for dental fillings also may contribute to urinary platinum concentrations (Schierl et al., 2001).

Table 26. Platinum (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	2465
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	340
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	719
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1406
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1227
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1238
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	884
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	568
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	822

< LOD means less than the limit of detection (see previous table for LOD).

* Not calculated. Proportion of results below the limit of detection was too high to provide a valid result.

Thallium

CAS No. 7440-28-0

General Information

Elemental thallium is a blue-white metal found in small amounts in soil and in sulfide-based minerals. In the past, thallium was obtained as a byproduct of the smelting of other metals; however, it has not been produced in the United States since 1984. It is still used in small amounts in the electronics industry.

Thallium exposure occurs primarily from commercial processes such as coal-burning and smelting. In these and other sources, thallium is produced in fine particles that can be absorbed by inhalation. Thallium is toxic in small amounts and may cause peripheral neuropathy and alopecia following chronic exposures. Intentional or accidental overdoses result in multiorgan failure, neurologic injury, and death. Accidental ingestion of thallium can occur by eating rat poison that contains water-soluble thallium salts. In the United States, thallium has been banned for use in rat poisons. Other abandoned uses have included thallium as a component of cosmetic depilatories and antifungal agents.

Workplace air standards for external exposure are generally established (OSHA, ACGIH). Chronic high-level exposures can cause gastrointestinal and neurologic symptoms. Evidence for the carcinogenicity of thallium

Table 27. Thallium

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	.176 (.167-.186)	.060 (.060-.070)	.110 (.110-.130)	.200 (.180-.200)	.280 (.270-.300)	.400 (.380-.420)	.450 (.420-.470)	2413
Age group								
6-11 years	.201 (.177-.228)	.090 (.060-.110)	.150 (.110-.160)	.200 (.160-.250)	.300 (.260-.340)	.410 (.340-.430)	.440 (.390-.500)	336
12-19 years	.202 (.186-.219)	.090 (.070-.100)	.150 (.120-.170)	.210 (.200-.240)	.290 (.270-.330)	.410 (.370-.450)	.460 (.420-.510)	697
20 years and older	.170 (.161-.179)	.050 (.050-.060)	.100 (.090-.110)	.180 (.180-.200)	.290 (.260-.300)	.400 (.380-.420)	.450 (.420-.470)	1380
Gender								
Males	.197 (.184-.211)	.070 (.060-.080)	.140 (.130-.150)	.220 (.200-.230)	.310 (.290-.340)	.390 (.380-.420)	.440 (.420-.480)	1200
Females	.159 (.147-.173)	.060 (.050-.060)	.100 (.080-.110)	.180 (.150-.200)	.270 (.250-.290)	.380 (.350-.410)	.450 (.420-.480)	1213
Race/ethnicity								
Mexican Americans	.172 (.157-.188)	.060 (.050-.080)	.110 (.090-.130)	.190 (.170-.210)	.260 (.250-.290)	.370 (.330-.410)	.450 (.390-.480)	861
Non-Hispanic blacks	.217 (.200-.236)	.100 (.070-.110)	.140 (.130-.160)	.220 (.210-.240)	.340 (.310-.370)	.440 (.400-.480)	.550 (.460-.610)	561
Non-Hispanic whites	.170 (.158-.182)	.060 (.050-.060)	.110 (.090-.120)	.200 (.180-.210)	.280 (.260-.310)	.400 (.370-.420)	.440 (.420-.480)	801

is inadequate or unknown (IARC, NTP, U.S. EPA). Information about external exposure (environmental levels) and health effects is available from ATSDR at http://www.atsdr.cdc.gov/toxprofiles and from the EPA IRIS Web site at http://www.epa.gov/iris.

Interpreting Urine Thallium Levels Reported in the Tables

Urine thallium levels were measured in a subsample of NHANES participants aged 6 years and older. Subsamples were randomly selected within the specified age range to be a representative sample of the U.S. population. Finding low amounts of thallium in urine does not mean that the level of thallium causes adverse health effects. Urinary concentrations of 100 µg/L in asymptomatic workers (500 times higher than observed in this NHANES sample) are thought to correspond to workplace exposures at the threshold limit value of 0.1 mg/m^3 (Marcus, 1985). Brockhaus et al. (1981) studied 1,265 people living near a thallium-emitting cement plant in Germany. Nearby residents were exposed by eating garden plants on which thallium had been deposited. Seventy-eight percent of the urine specimens in that study contained > 1 µg/L, with concentrations ranging up to 76.5 µg/L. There was no increase in the prevalence of symptoms at levels < 20 µg/L and only a slight increase in neuroasthenic-type symptoms above 20 µg/L.

Previous studies have suggested that normal amounts of

Table 28. Thallium (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	.166 (.158-.174)	.090 (.085-.098)	.125 (.117-.130)	.168 (.162-.175)	.224 (.214-.236)	.297 (.273-.319)	.366 (.333-.389)	2413
Age group								
6-11 years	.221 (.200-.244)	.130 (.113-.145)	.169 (.147-.188)	.221 (.196-.233)	.292 (.246-.341)	.375 (.318-.444)	.424 (.356-.600)	336
12-19 years	.153 (.144-.161)	.088 (.081-.098)	.117 (.108-.127)	.154 (.146-.163)	.205 (.184-.223)	.257 (.229-.285)	.321 (.258-.375)	697
20 years and older	.162 (.153-.171)	.089 (.083-.097)	.121 (.114-.130)	.167 (.157-.173)	.217 (.205-.232)	.285 (.265-.313)	.364 (.313-.400)	1380
Gender								
Males	.154 (.147-.161)	.085 (.076-.090)	.118 (.112-.126)	.156 (.149-.164)	.202 (.192-.214)	.269 (.254-.297)	.338 (.300-.364)	1200
Females	.178 (.166-.191)	.099 (.089-.107)	.131 (.119-.147)	.182 (.169-.196)	.244 (.227-.258)	.313 (.286-.364)	.380 (.364-.421)	1213
Race/ethnicity								
Mexican Americans	.158 (.148-.169)	.087 (.077-.097)	.118 (.103-.129)	.159 (.148-.175)	.212 (.200-.234)	.282 (.265-.305)	.338 (.306-.389)	861
Non-Hispanic blacks	.142 (.134-.151)	.076 (.064-.085)	.102 (.096-.109)	.140 (.131-.150)	.200 (.179-.214)	.277 (.242-.312)	.383 (.303-.431)	561
Non-Hispanic whites	.169 (.158-.181)	.093 (.085-.104)	.129 (.117-.142)	.173 (.167-.183)	.226 (.213-.243)	.300 (.269-.329)	.364 (.331-.385)	801

thallium in the urine should be < 1 μg/L (Schaller et al., 1980; Brockhaus et al., 1981; Minoia et al., 1990), which are consistent with levels documented in this NHANES 1999-2000 subsample. Other population surveys have demonstrated urinary levels of roughly similar magnitude (White et al., 1998; Minoia et al., 1990; Paschal et al., 1998). The variation of urinary thallium levels across this NHANES 1999-2000 subsample was narrow, possibly indicating limited opportunities for exposure. Geometric mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, and urinary creatinine. Urinary thallium levels were slightly higher for people aged 6-11 years than for the other two age groups. Levels in Mexican Americans were slightly lower than in non-Hispanic whites. It is unknown whether differences between ages or races/ethnicities represent differences in exposure, body-size relationships, or metabolism.

Whether thallium at the levels reported here is a cause for health concern is not yet known; more research is needed. These urine thallium data provide physicians with a reference range so that they can determine whether people have been exposed to higher levels of thallium than those found in the general population. These data will also help scientists plan and conduct research about thallium exposure and health effects.

Tungsten

CAS No. 7440-33-7

General Information

Tungsten is a steel-gray to tin-white metal naturally occurring in the earth's crust, mainly as scheelite ($CaWO_4$). A major use of tungsten is in the production of hard metals, such as tungsten carbide, which is used in rock drills and metal-cutting tools, or ferrotungsten, which is used in the steel industry. Additionally, tungsten compounds are used as catalysts in the petroleum industry, lubricating agents, filaments for incandescent lamps, and bronzes in pigments.

Most background environmental exposures to tungsten are from the soluble forms, such as tungstate salts, whereas occupational exposure is from tungsten metal dusts released during the grinding or drilling of metals. Workplace air standards for external exposure are generally established (ACGIH) or recommended (NIOSH). Evidence for the carcinogenicity of tungsten is inadequate or unknown (IARC, NTP).

Interpreting Urine Tungsten Levels Reported in the Tables

Urine tungsten levels were measured in a subsample of NHANES participants aged 6 years and older. Subsamples were randomly selected within the specified age

Table 29. Tungsten

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	.085 (.077-.093)	< LOD	< LOD	.090 (.080-.090)	.180 (.150-.200)	.320 (.270-.370)	.500 (.410-.550)	2338
Age group								
6-11 years	.153 (.122-.192)	< LOD	.080 (.060-.120)	.160 (.120-.190)	.260 (.210-.330)	.490 (.360-.590)	.590 (.510-.950)	320
12-19 years	.106 (.090-.125)	< LOD	.050 (<LOD-.060)	.110 (.080-.120)	.200 (.170-.240)	.360 (.300-.440)	.530 (.410-.780)	679
20 years and older	.076 (.069-.083)	< LOD	< LOD	.070 (.070-.080)	.150 (.130-.190)	.270 (.250-.320)	.440 (.360-.520)	1339
Gender								
Males	.099 (.085-.114)	< LOD	.050 (<LOD-.060)	.100 (.080-.110)	.210 (.170-.240)	.380 (.310-.480)	.530 (.440-.780)	1160
Females	.073 (.067-.079)	< LOD	< LOD	.070 (.060-.070)	.140 (.120-.170)	.270 (.240-.290)	.390 (.320-.470)	1178
Race/ethnicity								
Mexican Americans	.105 (.090-.124)	< LOD	.060 (.040-.070)	.100 (.090-.120)	.190 (.160-.240)	.390 (.300-.500)	.550 (.430-.810)	790
Non-Hispanic blacks	.106 (.091-.123)	< LOD	.040 (<LOD-.050)	.090 (.080-.110)	.200 (.170-.240)	.360 (.280-.490)	.550 (.400-.810)	562
Non-Hispanic whites	.083 (.075-.093)	< LOD	< LOD	.070 (.060-.090)	.170 (.150-.200)	.310 (.270-.380)	.460 (.380-.550)	802

< LOD means less than the limit of detection, which is 0.03 µg/L.

range to be a representative sample of the U.S. population. Measuring tungsten at these levels in urine is possible because of advances in analytical chemistry. Finding a measurable amount of tungsten in urine does not mean that the level of tungsten causes an adverse health effect. A non-random subsample from NHANES III found higher values than those reported in Table 29 (Paschal et al., 1998), possibly due to methodologic differences. One small study of unexposed individuals (n = 14) yielded values similar to those reported here (Schramel et al., 1997). During grinding operations that release tungsten metal into the air, workers had elevated urinary tungsten levels that were more than 900 times higher than the overall geometric mean in the NHANES 1999-2000 subsample (Kraus et al., 2001). In addition, these urinary levels in workers did not correlate with air-exposure levels. Kraus et al. (2001) also indicated a reference value for unexposed populations of 1 µg/gram of creatinine (or 0.86 µg/L) as the 95th percentile. The application of the technique of neutron activation analysis to a control group of non-metal workers showed mean urine tungsten levels similar to levels at the 95th percentile of the NHANES 1999-2000 subsample, whereas the tungsten-worker group had mean urine levels 35 times higher (Nicolaou et al., 1987). The variation of urinary tungsten levels across this NHANES subsample was narrow, possibly indicating limited opportunities for exposure. Geometric mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, and urinary

Table 30. Tungsten (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	.079 (.072-.087)	< LOD	< LOD	.075 (.069-.082)	.136 (.119-.156)	.245 (.203-.301)	.381 (.314-.426)	2338
Age group								
6-11 years	.168 (.144-.196)	< LOD	.099 (.087-.116)	.169 (.141-.198)	.275 (.216-.326)	.438 (.326-.667)	.614 (.452-.880)	320
12-19 years	.079 (.070-.089)	< LOD	.045 (.038-.055)	.076 (.069-.084)	.137 (.117-.155)	.226 (.173-.262)	.339 (.234-.479)	679
20 years and older	.072 (.065-.080)	< LOD	< LOD	.069 (.062-.075)	.117 (.104-.136)	.203 (.174-.276)	.339 (.245-.421)	1339
Gender								
Males	.077 (.067-.087)	< LOD	.041 (.036-.045)	.071 (.060-.082)	.141 (.119-.165)	.271 (.200-.383)	.439 (.342-.573)	1160
Females	.082 (.075-.088)	< LOD	< LOD	.079 (.074-.084)	.133 (.116-.150)	.235 (.200-.274)	.339 (.278-.383)	1178
Race/ethnicity								
Mexican Americans	.099 (.084-.116)	< LOD	.055 (.043-.064)	.096 (.080-.109)	.178 (.146-.208)	.316 (.256-.412)	.493 (.354-.727)	790
Non-Hispanic blacks	.069 (.061-.077)	< LOD	.036 (.030-.047)	.069 (.061-.080)	.121 (.109-.144)	.201 (.185-.231)	.360 (.217-.465)	562
Non-Hispanic whites	.083 (.074-.093)	< LOD	< LOD	.077 (.069-.087)	.139 (.119-.169)	.271 (.206-.339)	.383 (.314-.438)	802

< LOD means less than the limit of detection (see previous table for LOD).

creatinine. Urinary tungsten levels were higher for people aged 6-11 years than for the other two age groups. Levels in Mexican Americans were higher than in non-Hispanic blacks. It is unknown whether differences between ages or races/ethnicities represent differences in exposure, body-size relationships, or metabolism.

Whether tungsten at the levels reported here is a cause for health concern is not yet known; more research is needed. These urine tungsten data provide physicians with a reference range so that they can determine whether people have been exposed to higher levels of tungsten than levels found in the general population. These data will also help scientists plan and conduct research about tungsten exposure and health effects.

Polycyclic Aromatic Hydrocarbons

General Information

Polycyclic aromatic hydrocarbons (PAHs) are a class of chemicals that result from the incomplete combustion of fossil fuels (e.g., coal). Exposure to these chemicals usually occurs as exposure to mixtures and not to individual chemicals. Tobacco smoking and air pollution are sources of exposure in the general population. PAHs enter the atmosphere from motor vehicle exhaust, residential and industrial furnaces, tobacco smoke, volcanoes, and forest fires. Seasonal variations in exposure to PAHs are known to occur. The soil and water near industrialized areas can contain elevated concentrations of PAHs. Another source of PAH exposure in the general population is food, including smoked, charcoal-broiled, and roasted foods and plant foods that become contaminated by atmospheric deposition. Cereal products (e.g., wheat, corn, oats, and barley) may contain PAHs because of methods used to dry them. Workers in certain occupational settings are exposed to PAHs from the burning or coking of petroleum products. Some of these occupations include working in coke production, coal gasification, and iron or steel production; working as roof tarrers, asphalt applicators, or chimney sweeps; and working with waste incineration, or in gas refineries or aluminum smelters. Coal tar is composed of PAHs and can be used as a medical therapy for psoriasis. The U.S. Food and Drug Administration (FDA) and OSHA have developed criteria on the allowable levels of these chemicals in foods and the workplace. The U.S. EPA has set similar criteria for water and for the storage and removal of waste.

The health effect of concern associated with PAH exposure is cancer. Lung, genitourinary, and skin cancers have been reported in occupational settings, where the amount of exposure is greater than it is in the general population (Lloyd, 1971; Redmond et al., 1976, Boffetta et al., 1997). Early studies have been limited by the lack of ability to evaluate the isolated effects of individual PAH analytes and other contributing carcinogens, such as those in tobacco smoke. According to IARC, benz[a]anthracene and benzo[a]pyrene are probable human carcinogens, and benzo[b]fluoranthene, benzo[j]fluoranthene, benzo[k]fluoranthene, and indeno[1,2,3,-cd]pyrene are possible human carcinogens. The NTP lists the following chemicals as reasonably anticipated to be human carcinogens: benz[a]anthracene, benzo[b]fluoranthene, benzo[j]fluoranthene, benzo[k]-fluoranthene, benzo[a]pyrene, dibenz[a,h]acridine, dibenz[a,j]acridine, dibenz[a,h]anthracene, 7H-dibenzo-[c,g]carbazole, dibenzo[a,e]pyrene, dibenzo[a,h]pyrene,

Table 31. Polycyclic aromatic hydrocarbons (PAHs) and their metabolites

PAH (CAS number)	**Urinary hydroxylated metabolite** (CAS number)
Benz[a]anthracene (56-55-3)	1-Hydroxybenz[a]anthracene (69847-26-3) 3-Hydroxybenz[a]anthracene (4834-35-9)
Benzo[c]phenanthrene (195-19-7)	1-Hydroxybenzo[c]phenanthrene 2-Hydroxybenzo[c]phenanthrene (22717-94-8) 3-Hydroxybenzo[c]phenanthrene
Chrysene (218-01-9)	3-Hydroxychrysene (63019-39-6) 6-Hydroxychrysene (37515-51-8)
Fluoranthene (206-44-0)	3-Hydroxyfluoranthrene
Fluorene (86-73-7)	2-Hydroxyfluorene (2443-58-5) 3-Hydroxyfluorene (6344-67-8)
Phenanthrene (85-01-8)	1-Hydroxyphenanthrene (2433-56-9) 2-Hydroxyphenanthrene 3-Hydroxyphenanthrene (605-87-8)
Pyrene (129-00-0)	1-Hydroxypyrene (5315-79-7)

dibenzo[a,i]pyrene, dibenzo[a,l]pyrene, indeno[1,2,3-cd]pyrene, and 5-methylchrysene (NTP 9th ROC). The U.S. EPA has classified as probable carcinogens the following: benz[a]anthracene, benzo[a]pyrene, benzo-[b]fluoranthene, benzo[k]fluoranthene, chrysene, dibenz-[a,h]anthracene, indeno[1,2,3-cd]pyrene,. Pyrene was reviewed by IARC and determined it to be not classifiable as to its human carcinogenicity. The IARC, NTP, and U.S. EPA also list chemical mixtures (e.g., soot, coke-oven emissions, coal tars), which contain PAH chemicals, as known carcinogens. Information about external exposure and health effects is available from ATSDR at http://www.atsdr.cdc.gov/toxprofiles.

Interpreting Urine PAH Metabolite Levels in the Tables

Urinary levels of hydroxylated metabolites of PAHs were measured in a subsample of NHANES 1999-2000 participants aged 6 years old and older. Subsamples were randomly selected within the specified age range to be a representative sample of the U.S. population. Measurement of these 14 metabolites reflects exposure to PAHs that has occurred within the previous few days. Some of the parent PAHs can produce more than one measureable urinary metabolite. Table 31 shows the relation between PAHs and their metabolites. The hydroxylated metabolites of the PAHs are excreted in human urine both as free hydroxylated metabolites and as hydroxylated metabolites conjugated to glucuronic acid and sulfate. Measurements provided in this *Report* include both free and conjugated forms of the hydroxylated metabolites (Tables 32-59).

Measuring these metabolites at these levels is possible because of advances in analytical chemistry. Finding a measurable amount of one or more metabolites in the urine does not mean that the levels of the PAHs cause an adverse health effect. Whether levels of PAH metabolites at the levels reported here are cause for health concern is not known; more research is needed. These data provide physicians with a reference range so that they can determine whether people have been exposed to higher levels of PAHs than those found in the general population. These data will help scientists plan and conduct research on exposure to PAHs and health effects.

1-Hydroxybenz[a]anthracene and 3-Hydroxybenz[a]anthracene

Metabolites of benz[a]anthracene
(CAS No. 56-55-3)

Urinary 1-hydroxybenz[a]anthracene levels were detected in less than 3.2% of the NHANES 1999-2000 subsample. Two previous investigations in general populations have measured these two metabolites (Chuang et al., 1999, Whiton et al., 1995) and found urinary levels exceeding the concentrations measured in this NHANES 1999-2000 subsample. In another study, adults had hydroxylated benz[a]anthracene levels two to six times higher than those of children (Chuang et al., 1999). The 90th and 95th percentiles reported here suggest that higher levels occur with decreasing age for the metabolite 3-hydroxybenz[a]anthracene. Workers manufacturing fireproof stone had 3-hydroxybenz[a] anthracene levels higher than the levels that were found in this NHANES 1999-2000 subsample (Gundel et al., 2000).

Table 32. 1-Hydroxybenz[a]anthracene

Geometric mean and selected percentiles of urine concentrations (in ng/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	2084
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	276
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	626
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1182
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1004
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1080
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	667
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	465
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	779

< LOD means less than the limit of detection, which is 4.7 ng/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 33. 1-Hydroxybenz[a]anthracene (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in ng/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	2084
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	276
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	626
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1182
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1004
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1080
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	667
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	465
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	779

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 34. 3-Hydroxybenz[a]anthracene

Geometric mean and selected percentiles of urine concentrations (in ng/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	7.50 (6.00-9.90)	11.6 (9.10-14.5)	2152
Age group								
6-11 years	*	< LOD	< LOD	< LOD	7.60 (<LOD-11.7)	14.4 (7.70-49.8)	32.0 (9.50-71.0)	285
12-19 years	*	< LOD	< LOD	< LOD	6.00 (<LOD-8.10)	10.7 (8.10-14.5)	14.9 (10.7-21.0)	652
20 years and older	*	< LOD	< LOD	< LOD	< LOD	5.70 (<LOD-7.20)	8.80 (6.30-12.6)	1215
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	7.80 (5.70-11.8)	13.5 (9.50-18.8)	1033
Females	*	< LOD	< LOD	< LOD	< LOD	7.20 (6.00-9.20)	10.2 (7.60-12.7)	1119
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	7.50 (6.30-9.40)	11.0 (7.90-15.7)	688
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	7.50 (5.70-11.3)	11.5 (7.50-19.0)	488
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	7.30 (5.60-10.0)	11.8 (8.80-15.6)	792

< LOD means less than the limit of detection, which is 5.4 ng/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 35. 3-Hydroxybenz[a]anthracene (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in ng/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	12.2 (10.0-14.6)	17.6 (15.2-21.1)	2152
Age group								
6-11 years	*	< LOD	< LOD	< LOD	9.61 (6.74-13.6)	18.1 (12.7-27.2)	23.6 (14.6-33.2)	285
12-19 years	*	< LOD	< LOD	< LOD	5.09 (4.37-6.11)	7.69 (6.44-8.84)	10.0 (8.64-11.9)	652
20 years and older	*	< LOD	< LOD	< LOD	< LOD	12.2 (10.0-14.6)	17.4 (15.2-21.1)	1215
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	9.77 (8.44-11.5)	14.7 (10.9-18.7)	1033
Females	*	< LOD	< LOD	< LOD	< LOD	14.1 (11.2-17.3)	21.1 (16.5-22.4)	1119
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	10.7 (9.27-14.1)	18.1 (12.7-21.1)	688
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	6.78 (5.85-8.62)	10.9 (7.31-14.1)	488
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	13.1 (10.3-16.5)	19.0 (16.5-22.4)	792

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

1-Hydroxybenzo[c]phenanthrene, 2-Hydroxybenzo[c]phenanthrene, and 3-Hydroxybenzo[c]phenanthrene

Metabolites of benzo[c]phenanthrene
(CAS No. 195-19-7)

Levels of 1-, 2- and 3-hydroxybenzo[c]phenanthrene are reported in Tables 36-41.

Table 36. 1-Hydroxybenzo[c]phenanthrene

Geometric mean and selected percentiles of urine concentrations (in ng/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	8.20 (6.10-11.5)	17.2 (12.9-25.0)	31.0 (21.4-42.7)	2200
Age group								
6-11 years	*	< LOD	< LOD	< LOD	9.10 (<LOD-16.4)	17.0 (10.8-32.4)	32.1 (14.9-48.4)	297
12-19 years	*	< LOD	< LOD	< LOD	9.40 (7.10-13.2)	18.0 (13.7-27.0)	31.2 (20.0-41.4)	665
20 years and older	*	< LOD	< LOD	< LOD	8.10 (<LOD-11.3)	16.9 (12.1-24.7)	30.3 (20.3-43.3)	1238
Gender								
Males	*	< LOD	< LOD	< LOD	8.40 (6.50-12.5)	18.0 (12.9-31.3)	35.4 (25.0-47.5)	1054
Females	*	< LOD	< LOD	< LOD	8.20 (<LOD-11.5)	16.5 (11.9-22.6)	24.7 (17.6-35.8)	1146
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	12.9 (8.00-17.5)	21.9 (16.2-30.3)	32.4 (23.1-47.5)	716
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	7.60 (<LOD-8.80)	12.8 (8.80-29.1)	30.3 (13.8-43.9)	497
Non-Hispanic whites	*	< LOD	< LOD	< LOD	8.40 (<LOD-12.9)	17.0 (11.9-25.8)	29.4 (18.0-47.2)	805

< LOD means less than the limit of detection, which is 5.7 ng/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 37. 1-Hydroxybenzo[c]phenanthrene (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in ng/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	10.1 (8.16-12.8)	22.3 (16.7-28.6)	36.1 (26.8-47.6)	2200
Age group								
6-11 years	*	< LOD	< LOD	< LOD	9.73 (7.69-15.9)	22.7 (13.0-32.8)	32.8 (21.6-63.5)	297
12-19 years	*	< LOD	< LOD	< LOD	7.69 (5.38-11.0)	16.3 (10.3-24.3)	24.3 (17.3-34.0)	665
20 years and older	*	< LOD	< LOD	< LOD	10.5 (8.51-13.3)	23.3 (16.7-30.7)	37.1 (26.8-61.4)	1238
Gender								
Males	*	< LOD	< LOD	< LOD	8.61 (6.67-10.8)	18.6 (12.7-26.8)	28.8 (23.0-37.1)	1054
Females	*	< LOD	< LOD	< LOD	11.8 (8.89-15.7)	24.3 (18.1-36.4)	40.4 (26.7-73.8)	1146
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	12.3 (9.50-17.0)	26.7 (19.0-36.3)	37.1 (28.7-48.8)	716
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	5.75 (4.65-7.41)	11.8 (8.77-18.8)	21.1 (12.5-39.6)	497
Non-Hispanic whites	*	< LOD	< LOD	< LOD	10.4 (8.17-13.5)	23.3 (15.7-30.3)	36.4 (25.8-55.0)	805

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 38. 2-Hydroxybenzo[c]phenanthrene

Geometric mean and selected percentiles of urine concentrations (in ng/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	14.3 (10.8-18.0)	21.2 (16.5-28.1)	2175
Age group								
6-11 years	*	< LOD	< LOD	< LOD	7.00 (<LOD-16.2)	19.9 (11.6-34.9)	30.2 (15.6-47.2)	285
12-19 years	*	< LOD	< LOD	< LOD	< LOD	14.0 (9.20-18.6)	20.0 (14.9-30.2)	657
20 years and older	*	< LOD	< LOD	< LOD	< LOD	13.5 (9.60-17.8)	20.1 (14.7-26.1)	1233
Gender								
Males	*	< LOD	< LOD	< LOD	7.00 (<LOD-10.3)	16.9 (12.4-23.6)	29.0 (20.7-34.9)	1046
Females	*	< LOD	< LOD	< LOD	< LOD	11.9 (8.90-16.2)	17.0 (13.6-21.3)	1129
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	12.2 (8.80-16.1)	17.0 (13.9-25.2)	686
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	10.0 (<LOD-16.0)	20.0 (14.9-30.2)	34.3 (20.3-51.6)	495
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	13.5 (9.10-19.1)	21.2 (15.2-29.4)	809

< LOD means less than the limit of detection, which is 6.8 ng/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 39. 2-Hydroxybenzo[c]phenanthrene (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in ng/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	2.18 (2.02-2.33)	2.98 (2.81-3.16)	4.95 (4.44-5.52)	9.80 (8.14-11.4)	20.0 (16.0-24.0)	28.2 (22.9-30.9)	2175
Age group								
6-11 years	*	< LOD	< LOD	< LOD	11.4 (9.06-16.2)	23.1 (12.0-41.7)	34.3 (20.8-47.3)	285
12-19 years	*	< LOD	< LOD	< LOD	< LOD	11.7 (8.88-14.3)	16.4 (12.0-26.1)	657
20 years and older	*	2.22 (2.01-2.38)	3.04 (2.86-3.29)	5.11 (4.53-5.75)	10.1 (8.14-12.6)	20.9 (16.0-26.3)	28.6 (23.3-34.3)	1233
Gender								
Males	*	1.97 (1.81-2.16)	2.69 (2.51-2.94)	4.32 (3.66-4.71)	8.42 (6.96-11.0)	17.3 (13.4-23.1)	25.3 (20.2-34.3)	1046
Females	*	< LOD	< LOD	< LOD	< LOD	20.9 (16.6-26.7)	30.0 (25.3-34.3)	1129
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	15.5 (11.7-20.8)	22.9 (17.3-25.0)	686
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	7.38 (6.08-10.7)	16.7 (12.1-21.5)	23.3 (19.6-28.7)	495
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	20.8 (15.4-25.3)	28.6 (23.3-34.3)	809

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 40. 3-Hydroxybenzo[c]phenanthrene

Geometric mean and selected percentiles of urine concentrations (in ng/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	2172
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	287
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	657
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1228
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1045
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1127
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	689
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	491
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	806

< LOD means less than the limit of detection, which is 4.9 ng/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 41. 3-Hydroxybenzo[c]phenanthrene (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in ng/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	2172
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	287
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	657
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1228
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1045
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1127
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	689
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	491
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	806

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

3-Hydroxychrysene and 6-Hydroxychrysene

Metabolites of chrysene (CAS No. 218-01-9)

The detection rates for 3-hydroxychrysene and 6-hydroxychrysene were low. In one study of families with incomes below the poverty line, Chuang et al., (1999) found that urinary 6-hydroxychrysene levels in adults and children were many times higher than those found in this NHANES 1999-2000 subsample.

Table 42. 3-Hydroxychrysene

Geometric mean and selected percentiles of urine concentrations (in ng/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	2233
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	11.0 (<LOD-44.8)	300
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	11.3 (<LOD-17.2)	674
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1259
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	10.1 (<LOD-16.5)	1067
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1166
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	10.8 (<LOD-13.1)	722
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	515
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	806

< LOD means less than the limit of detection, which is 9.9 ng/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 43. 3-Hydroxychrysene (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in ng/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	2233
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	26.9 (17.9-46.2)	300
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	17.3 (14.0-20.0)	674
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1259
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	20.6 (18.4-26.2)	1067
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1166
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	33.3 (21.9-37.1)	722
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	515
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	806

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 44. 6-Hydroxychrysene

Geometric mean and selected percentiles of urine concentrations (in ng/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 10th	25th	50th	75th	90th	95th	Sample size
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	4.50 (3.90-5.00)	6.00 (5.50-6.60)	2279
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	5.00 (<LOD-6.10)	6.10 (5.20-7.60)	298
12-19 years	*	< LOD	< LOD	< LOD	< LOD	5.70 (4.30-7.70)	7.70 (4.90-11.2)	689
20 years and older	*	< LOD	< LOD	< LOD	< LOD	4.40 (<LOD-4.90)	5.80 (4.90-6.60)	1292
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	4.80 (3.60-5.70)	6.40 (5.50-7.60)	1091
Females	*	< LOD	< LOD	< LOD	< LOD	4.20 (<LOD-4.80)	5.80 (4.80-6.60)	1188
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	4.70 (3.60-5.10)	6.00 (4.90-8.10)	749
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	4.90 (<LOD-6.50)	6.80 (4.90-7.90)	515
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	4.50 (3.90-5.20)	5.90 (5.50-6.80)	826

< LOD means less than the limit of detection, which is 3.4 ng/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 45. 6-Hydroxychrysene (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in ng/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	8.05 (7.07-9.14)	12.6 (10.4-14.1)	2279
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	7.74 (5.11-13.1)	11.0 (8.51-24.4)	298
12-19 years	*	< LOD	< LOD	< LOD	< LOD	6.32 (4.71-9.23)	9.23 (5.83-11.5)	689
20 years and older	*	< LOD	< LOD	< LOD	< LOD	8.18 (7.07-9.60)	13.3 (11.2-15.0)	1292
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	6.67 (5.45-8.13)	9.23 (8.05-12.0)	1091
Females	*	< LOD	< LOD	< LOD	< LOD	9.88 (8.00-11.4)	14.1 (12.6-17.1)	1188
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	8.05 (5.45-11.4)	13.3 (8.05-23.8)	749
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	4.62 (3.91-5.71)	7.50 (5.71-7.93)	515
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	8.57 (7.75-10.4)	13.1 (11.4-15.5)	826

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

3-Hydroxyfluoranthene

Metabolite of fluoranthene (CAS No. 206-44-0)

For this metabolite, geometric mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, urinary creatinine, and log serum cotinine. No differences were observed. Chuang et al. (1999) measured levels of 3-hydroxyfluoranthene in a selected population of families with incomes below the poverty line and found that the mean urinary levels in adults and children were approximately 10-fold higher than levels seen in the NHANES 1999-2000 subsample.

Table 46. 3-Hydroxyfluoranthene

Geometric mean and selected percentiles of urine concentrations (in ng/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	13.4 (10.3-17.3)	< LOD	< LOD	17.5 (11.0-23.1)	32.3 (28.8-38.4)	58.6 (49.2-74.0)	98.8 (77.2-147)	2236
Age group								
6-11 years	12.6 (9.33-16.9)	< LOD	< LOD	15.8 (5.70-22.5)	37.6 (25.1-45.1)	65.7 (45.1-146)	138 (57.1-216)	308
12-19 years	15.0 (10.7-21.1)	< LOD	< LOD	20.3 (9.30-28.4)	38.7 (29.9-47.6)	60.6 (47.6-98.5)	98.9 (62.2-260)	675
20 years and older	13.2 (10.2-17.3)	< LOD	< LOD	17.3 (11.4-22.6)	31.1 (27.6-37.2)	58.2 (45.5-78.9)	90.7 (71.7-150)	1253
Gender								
Males	13.5 (10.2-17.8)	< LOD	< LOD	17.4 (10.6-23.4)	32.6 (28.8-40.2)	58.2 (46.2-78.7)	98.8 (70.3-162)	1074
Females	13.3 (10.2-17.4)	< LOD	< LOD	17.5 (10.2-22.7)	31.8 (27.3-38.2)	58.7 (47.0-79.6)	88.4 (71.7-138)	1162
Race/ethnicity								
Mexican Americans	14.0 (10.1-19.4)	< LOD	< LOD	17.1 (10.1-23.9)	30.4 (25.6-40.8)	52.1 (44.4-67.6)	96.6 (65.6-312)	715
Non-Hispanic blacks	14.0 (9.51-20.6)	< LOD	< LOD	17.7 (6.40-26.8)	38.2 (27.2-55.8)	89.3 (57.6-163)	185 (96.9-283)	527
Non-Hispanic whites	13.2 (9.77-17.8)	< LOD	< LOD	17.3 (9.90-24.2)	32.0 (27.8-39.4)	54.3 (43.8-74.0)	87.3 (63.0-146)	802

< LOD means less than the limit of detection, which is 3.5 ng/L.

Table 47. 3-Hydroxyfluoranthene (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in ng/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	12.4 (9.38-16.3)	< LOD	< LOD	14.7 (9.96-20.4)	36.3 (28.6-43.8)	67.9 (56.0-83.2)	102 (83.2-129)	2236
Age group								
6-11 years	12.8 (9.31-17.7)	< LOD	< LOD	13.7 (5.95-25.3)	44.3 (25.3-56.3)	77.0 (53.2-115)	131 (67.3-254)	308
12-19 years	10.1 (6.83-14.9)	< LOD	< LOD	13.4 (7.08-20.3)	29.1 (21.5-42.7)	54.9 (37.4-86.0)	92.1 (60.6-134)	675
20 years and older	12.7 (9.68-16.7)	< LOD	< LOD	14.8 (10.2-20.8)	36.5 (28.9-43.0)	68.9 (56.0-83.2)	102 (80.5-129)	1253
Gender								
Males	10.7 (8.01-14.2)	< LOD	< LOD	12.1 (8.18-17.5)	32.9 (23.9-40.0)	62.5 (50.0-74.7)	91.3 (74.7-122)	1074
Females	14.2 (10.7-18.9)	< LOD	< LOD	17.5 (11.7-24.1)	39.6 (31.4-46.8)	75.5 (61.2-90.5)	107 (85.7-175)	1162
Race/ethnicity								
Mexican Americans	12.7 (8.95-18.1)	< LOD	< LOD	13.8 (9.10-20.5)	30.7 (23.0-43.4)	64.1 (51.1-94.8)	107 (83.4-153)	715
Non-Hispanic blacks	9.21 (6.07-14.0)	< LOD	< LOD	10.4 (4.31-17.8)	30.2 (20.2-40.0)	72.6 (51.0-107)	133 (84.3-216)	527
Non-Hispanic whites	13.1 (9.58-17.9)	< LOD	< LOD	16.0 (9.76-23.6)	36.9 (28.6-45.7)	68.8 (54.2-83.2)	90.6 (74.7-129)	802

< LOD means less than the limit of detection (see previous table).

2-Hydroxyfluorene and 3-Hydroxyfluorene

Metabolites of fluorene (CAS No. 86-73-7)

Geometric mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, urinary creatinine, and log serum cotinine. No differences were observed.

Table 48. 2-Hydroxyfluorene

Geometric mean and selected percentiles of urine concentrations (in ng/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	441 (330-590)	55.9 (36.8-81.6)	141 (107-192)	422 (279-706)	1350 (1030-2030)	3710 (2770-4650)	6450 (4720-8380)	2315
Age group								
6-11 years	294 (216-400)	62.1 (19.4-92.1)	124 (90.2-167)	262 (171-447)	780 (507-1240)	1800 (984-2220)	2010 (1410-5400)	306
12-19 years	469 (326-673)	79.7 (49.8-107)	187 (116-257)	421 (275-861)	1410 (932-2200)	2810 (2160-4390)	4980 (3100-6920)	694
20 years and older	461 (343-620)	50.8 (34.1-79.9)	136 (106-193)	456 (296-770)	1510 (1120-2300)	4280 (3010-5380)	7270 (4910-9520)	1315
Gender								
Males	474 (341-659)	75.4 (39.8-102)	156 (116-208)	468 (261-802)	1450 (957-2290)	3780 (2730-5050)	6920 (4600-10900)	1106
Females	412 (312-544)	45.7 (32.7-65.2)	131 (97.0-166)	385 (277-666)	1330 (988-1960)	3600 (2730-4650)	5790 (4410-9240)	1209
Race/ethnicity								
Mexican Americans	296 (225-390)	58.2 (42.1-70.4)	108 (81.8-143)	268 (174-423)	807 (481-1290)	1870 (1230-2530)	2930 (1910-4760)	750
Non-Hispanic blacks	646 (416-1000)	70.7 (45.8-125)	188 (119-332)	680 (341-1230)	2140 (1250-3320)	5790 (3310-10600)	10800 (5030-18500)	534
Non-Hispanic whites	419 (294-596)	45.7 (26.8-83.9)	131 (96.5-198)	402 (244-755)	1320 (903-2160)	3990 (2730-4660)	6450 (4640-8710)	841

Table 49. 2-Hydroxyfluorene (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in ng/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	408 (302-551)	68.9 (47.4-93.6)	146 (109-202)	382 (274-640)	1160 (841-1500)	2880 (2170-4040)	5270 (3820-6390)	2315
Age group								
6-11 years	307 (216-437)	79.0 (30.9-99.7)	121 (91.0-177)	336 (168-648)	787 (570-1200)	1380 (1010-2180)	1740 (1350-2950)	306
12-19 years	314 (219-450)	63.5 (37.8-82.7)	119 (83.7-186)	369 (206-543)	785 (600-1240)	1880 (1260-2570)	2570 (1920-4090)	694
20 years and older	443 (328-597)	69.4 (47.4-99.8)	155 (114-211)	400 (290-668)	1260 (880-1780)	3480 (2430-4880)	6040 (4290-7560)	1315
Gender								
Males	376 (267-528)	64.0 (33.6-92.1)	134 (99.8-177)	378 (250-630)	1070 (756-1460)	2440 (1830-4250)	4870 (2870-6750)	1106
Females	441 (332-584)	76.7 (54.3-103)	162 (119-213)	393 (282-686)	1260 (871-1630)	3300 (2440-4400)	5490 (3800-7420)	1209
Race/ethnicity								
Mexican Americans	275 (202-375)	68.7 (54.2-87.7)	120 (85.3-167)	252 (166-417)	597 (418-867)	1350 (884-1720)	2090 (1410-3110)	750
Non-Hispanic blacks	425 (266-677)	55.1 (20.5-97.0)	138 (79.5-252)	541 (222-882)	1190 (826-1960)	3090 (1760-6040)	6040 (3090-8500)	534
Non-Hispanic whites	414 (289-594)	68.8 (27.4-99.8)	142 (104-215)	391 (259-702)	1260 (828-1660)	3130 (2100-4800)	5620 (3820-6860)	841

Table 50. 3-Hydroxyfluorene

Geometric mean and selected percentiles of urine concentrations (in ng/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	171 (129-225)	16.7 (<LOD-25.1)	45.2 (35.5-64.0)	151 (104-235)	572 (401-813)	1840 (1460-2380)	3390 (2530-4540)	2312
Age group								
6-11 years	105 (76.5-144)	16.4 (<LOD-37.3)	39.4 (28.9-61.3)	92.8 (65.9-141)	247 (146-371)	615 (328-863)	851 (546-2390)	306
12-19 years	192 (137-270)	27.8 (<LOD-40.1)	70.0 (40.1-107)	198 (133-284)	621 (371-879)	1330 (948-1930)	2110 (1480-2400)	692
20 years and older	178 (133-240)	16.0 (<LOD-23.5)	43.5 (31.8-61.9)	156 (108-257)	639 (426-985)	2080 (1600-2700)	4060 (2700-4680)	1314
Gender								
Males	189 (137-259)	22.5 (<LOD-31.7)	50.0 (37.2-73.2)	167 (97.1-268)	689 (404-1010)	2060 (1480-2700)	3520 (2690-4680)	1105
Females	155 (118-204)	< LOD	41.8 (31.6-53.6)	141 (105-216)	478 (350-688)	1710 (987-2290)	3010 (1920-4430)	1207
Race/ethnicity								
Mexican Americans	105 (78.3-142)	15.8 (<LOD-18.9)	34.8 (24.2-47.0)	96.7 (57.7-154)	313 (196-472)	862 (472-1490)	1490 (941-1650)	748
Non-Hispanic blacks	266 (173-409)	26.4 (<LOD-46.1)	79.4 (43.6-118)	257 (136-445)	954 (525-1390)	2800 (1630-4920)	5290 (2550-8130)	534
Non-Hispanic whites	162 (115-226)	< LOD	42.2 (28.4-63.1)	137 (86.0-238)	557 (354-863)	1910 (1250-2670)	3590 (2490-4680)	841

< LOD means less than the limit of detection, which is 15.1 ng/L.

Table 51. 3-Hydroxyfluorene (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in ng/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	157 (118-210)	22.1 (15.1-30.5)	49.4 (35.6-67.4)	135 (93.5-202)	482 (321-714)	1510 (1020-2300)	2710 (1840-4010)	2312
Age group								
6-11 years	110 (78.2-154)	21.7 (8.17-37.9)	46.8 (29.0-66.9)	111 (66.9-187)	268 (175-401)	504 (324-832)	832 (472-1540)	306
12-19 years	129 (91.8-181)	22.8 (8.97-29.7)	49.0 (29.6-81.3)	140 (85.5-216)	374 (240-484)	799 (519-1120)	1130 (955-1390)	692
20 years and older	171 (126-231)	22.2 (16.0-31.5)	50.9 (37.6-67.4)	138 (97.9-213)	613 (362-913)	1820 (1270-2640)	3020 (2370-4100)	1314
Gender								
Males	150 (108-208)	20.1 (10.7-30.9)	43.5 (31.2-68.2)	128 (85.3-204)	496 (317-714)	1390 (913-2060)	2710 (1650-4100)	1105
Females	165 (124-219)	< LOD	54.1 (39.3-67.8)	138 (97.9-206)	477 (312-779)	1650 (1080-2330)	2860 (2000-3790)	1207
Race/ethnicity								
Mexican Americans	97.7 (70.2-136)	19.5 (15.3-25.2)	38.3 (24.9-56.0)	88.5 (60.0-132)	220 (149-331)	665 (345-977)	987 (721-1470)	748
Non-Hispanic blacks	175 (111-276)	23.1 (11.3-33.5)	54.0 (29.1-103)	176 (91.9-318)	550 (329-976)	1590 (978-2540)	2710 (1810-3390)	534
Non-Hispanic whites	160 (113-226)	< LOD	46.8 (33.8-69.6)	138 (85.9-215)	505 (317-807)	1650 (1050-2460)	2920 (2130-4100)	841

< LOD means less than the limit of detection (see previous table).

1-Hydroxyphenanthrene, 2-Hydroxyphenanthrene, and 3-Hydroxyphenanthrene

Metabolites of phenanthrene (CAS No. 85-01-8)

Geometric mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, urinary creatinine, and log serum cotinine. Children aged 6-11 years had a slightly higher urinary 3-hydroxyphenanthrene level than people in the other two age groups. Among residents of a housing unit in Germany, children younger than 6 years of age had slightly higher mean urinary (1-, 2-, 3- and 4-hydroxyphenanthrene) levels than people in the older age groups (Heudorf et al., 2001). Levels of urinary 1-hydroxyphenanthrene in the NHANES 1999-2000 subsample were higher in females than in males. No other differences were observed.

Table 52. 1-Hydroxyphenanthrene

Geometric mean and selected percentiles of urine concentrations (in ng/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	154 (128-186)	28.3 (21.3-37.9)	65.0 (52.8-83.2)	160 (123-211)	367 (301-462)	698 (610-833)	1070 (886-1360)	2246
Age group								
6-11 years	121 (95.7-153)	21.3 (<LOD-39.8)	57.6 (42.4-72.3)	102 (83.2-162)	257 (207-370)	513 (337-668)	666 (513-1540)	294
12-19 years	167 (133-210)	39.0 (26.6-47.3)	76.4 (56.2-99.8)	175 (137-229)	353 (260-473)	688 (477-1090)	1080 (721-1630)	680
20 years and older	157 (129-191)	27.7 (21.3-37.3)	64.7 (52.0-86.3)	163 (124-216)	400 (308-488)	739 (642-869)	1100 (903-1360)	1272
Gender								
Males	153 (124-188)	32.2 (23.5-43.0)	66.4 (52.9-89.9)	147 (106-207)	351 (277-473)	680 (585-845)	1020 (794-1330)	1072
Females	156 (128-188)	25.8 (17.6-34.1)	63.7 (51.8-80.7)	172 (131-222)	372 (301-462)	753 (609-946)	1100 (946-1450)	1174
Race/ethnicity								
Mexican Americans	112 (97.0-130)	30.2 (22.3-34.1)	55.3 (46.9-68.4)	113 (93.3-142)	230 (191-297)	447 (352-506)	618 (484-728)	727
Non-Hispanic blacks	162 (119-221)	24.7 (15.7-45.2)	67.3 (49.9-84.4)	170 (102-252)	441 (295-609)	821 (649-1130)	1210 (833-2250)	516
Non-Hispanic whites	154 (123-194)	27.0 (17.2-39.2)	64.7 (48.4-88.1)	157 (114-222)	378 (281-495)	704 (604-886)	1060 (886-1390)	814

< LOD means less than the limit of detection, which is 15.0 ng/L.

Table 53. 1-Hydroxyphenanthrene (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in ng/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	142 (116-173)	31.3 (22.4-44.2)	68.8 (54.8-88.2)	143 (114-184)	299 (248-363)	571 (478-652)	907 (693-1200)	2246
Age group								
6-11 years	127 (97.8-165)	23.7 (14.6-44.8)	67.5 (44.2-86.7)	135 (95.3-193)	265 (185-372)	457 (344-619)	622 (462-1200)	294
12-19 years	112 (88.2-141)	28.7 (13.3-43.5)	62.4 (43.8-86.9)	121 (102-144)	207 (165-278)	406 (293-596)	661 (431-972)	680
20 years and older	150 (123-183)	33.5 (23.0-47.5)	70.8 (56.2-92.8)	150 (117-194)	321 (265-385)	603 (494-701)	973 (774-1330)	1272
Gender								
Males	120 (97.2-149)	28.6 (17.6-39.3)	59.9 (44.1-76.2)	124 (99.9-157)	260 (214-307)	479 (383-618)	692 (606-887)	1072
Females	166 (135-203)	37.2 (23.0-56.2)	82.1 (63.7-99.3)	166 (127-205)	351 (272-421)	631 (509-847)	1120 (803-1530)	1174
Race/ethnicity								
Mexican Americans	104 (86.8-125)	33.3 (24.0-43.6)	59.8 (47.5-71.6)	104 (83.7-133)	192 (163-227)	327 (257-425)	474 (383-672)	727
Non-Hispanic blacks	107 (76.6-149)	17.0 (9.56-31.9)	43.3 (27.2-73.5)	109 (76.5-166)	269 (194-351)	548 (390-802)	887 (595-1240)	516
Non-Hispanic whites	151 (119-192)	33.6 (20.5-52.9)	74.7 (53.3-99.9)	153 (114-201)	323 (259-390)	580 (484-729)	1010 (711-1370)	814

Table 54. 2-Hydroxyphenanthrene

Geometric mean and selected percentiles of urine concentrations (in ng/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	98.4 (82.9-117)	13.5 (<LOD-17.8)	40.3 (29.3-49.9)	107 (86.5-127)	240 (202-316)	545 (452-689)	828 (738-928)	2179
Age group								
6-11 years	79.8 (61.1-104)	13.7 (<LOD-28.7)	37.2 (22.2-44.3)	74.1 (50.9-113)	189 (113-283)	401 (229-626)	698 (401-1140)	291
12-19 years	109 (84.5-141)	17.8 (11.3-33.5)	54.0 (35.8-73.8)	112 (87.3-149)	233 (174-313)	529 (368-721)	767 (529-1340)	650
20 years and older	99.5 (83.2-119)	13.2 (<LOD-17.2)	39.1 (25.1-50.9)	108 (86.5-134)	253 (212-332)	571 (472-702)	864 (759-928)	1238
Gender								
Males	107 (88.4-131)	14.9 (<LOD-23.9)	44.2 (31.4-53.5)	109 (89.1-136)	263 (214-355)	592 (450-767)	928 (698-1370)	1048
Females	90.6 (76.2-108)	12.1 (<LOD-16.5)	36.5 (24.2-46.6)	105 (82.8-127)	226 (183-307)	514 (413-612)	797 (612-876)	1131
Race/ethnicity								
Mexican Americans	87.5 (71.8-107)	11.2 (<LOD-18.0)	39.7 (30.1-47.6)	92.3 (67.9-125)	217 (174-276)	432 (329-482)	583 (439-913)	698
Non-Hispanic blacks	131 (99.1-172)	17.7 (<LOD-35.7)	47.5 (40.3-63.6)	141 (84.2-218)	370 (253-486)	698 (506-998)	1080 (809-2280)	509
Non-Hispanic whites	91.7 (73.7-114)	12.3 (<LOD-17.0)	33.9 (23.0-47.4)	103 (76.6-127)	231 (188-319)	514 (408-714)	810 (680-889)	791

< LOD means less than the limit of detection, which is 11.2 ng/L.

Table 55. 2-Hydroxyphenanthrene (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in ng/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	90.4 (76.3-107)	21.9 (15.5-30.1)	45.0 (38.0-53.3)	89.8 (74.3-108)	188 (154-237)	368 (319-429)	521 (442-695)	2179
Age group								
6-11 years	84.0 (65.8-107)	20.3 (6.22-32.8)	40.5 (27.2-60.2)	74.4 (62.3-88.1)	173 (104-282)	350 (260-413)	413 (342-790)	291
12-19 years	74.0 (59.7-91.6)	22.3 (11.9-30.2)	40.5 (34.5-51.0)	75.0 (59.4-88.0)	133 (107-186)	295 (209-400)	441 (299-781)	650
20 years and older	94.4 (79.3-112)	21.6 (15.5-30.4)	45.8 (38.8-55.2)	94.9 (75.9-117)	197 (169-243)	392 (331-443)	573 (501-762)	1238
Gender								
Males	85.4 (70.9-103)	19.0 (13.6-30.4)	44.3 (37.2-54.8)	80.6 (67.8-101)	175 (142-206)	375 (303-426)	544 (423-786)	1048
Females	95.5 (80.2-114)	23.9 (16.1-31.7)	45.3 (38.8-52.4)	97.1 (80.9-119)	207 (163-262)	367 (310-448)	536 (410-725)	1131
Race/ethnicity								
Mexican Americans	80.2 (66.2-97.2)	24.6 (15.5-30.4)	41.9 (34.3-52.6)	77.3 (62.8-99.4)	155 (124-189)	310 (236-368)	382 (304-618)	698
Non-Hispanic blacks	86.9 (64.6-117)	14.9 (10.1-24.8)	38.9 (23.4-54.8)	93.3 (59.3-134)	207 (152-279)	408 (293-602)	664 (470-961)	509
Non-Hispanic whites	89.4 (72.2-111)	21.6 (13.6-34.3)	45.7 (37.7-56.7)	87.8 (71.5-108)	188 (147-254)	366 (302-438)	536 (436-778)	791

< LOD means less than the limit of detection (see previous table).

Table 56. 3-Hydroxyphenanthrene

Geometric mean and selected percentiles of urine concentrations (in ng/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	127 (112-144)	27.8 (23.5-34.2)	67.3 (53.2-81.0)	138 (121-155)	256 (227-295)	464 (400-547)	657 (594-721)	2299
Age group								
6-11 years	136 (113-163)	36.4 (23.3-55.2)	81.2 (63.9-98.0)	140 (113-186)	247 (195-301)	383 (291-632)	622 (316-794)	302
12-19 years	147 (123-176)	41.6 (27.8-65.4)	84.8 (73.4-109)	163 (130-207)	281 (229-325)	417 (363-547)	611 (462-720)	700
20 years and older	122 (107-140)	25.8 (20.3-32.7)	62.2 (48.8-77.7)	133 (111-152)	254 (224-295)	477 (409-559)	671 (579-760)	1297
Gender								
Males	141 (122-164)	33.2 (25.9-44.6)	76.7 (59.8-93.4)	149 (128-173)	287 (236-341)	495 (428-608)	658 (576-788)	1100
Females	114 (100-130)	24.1 (15.7-30.2)	58.4 (48.6-75.0)	130 (105-147)	242 (210-274)	399 (341-515)	624 (506-760)	1199
Race/ethnicity								
Mexican Americans	113 (100-127)	29.9 (24.3-37.9)	61.5 (54.7-73.7)	120 (96.6-145)	231 (186-255)	353 (296-438)	495 (398-580)	763
Non-Hispanic blacks	174 (138-219)	32.5 (23.2-52.6)	84.4 (56.5-113)	182 (137-228)	390 (319-447)	671 (527-913)	1110 (690-2750)	522
Non-Hispanic whites	120 (102-140)	25.7 (15.7-34.2)	63.4 (46.2-81.0)	134 (111-157)	248 (218-291)	448 (363-547)	632 (513-721)	820

Table 57. 3-Hydroxyphenanthrene (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in ng/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	116 (102-133)	38.6 (26.5-48.9)	69.8 (58.5-80.4)	121 (106-136)	198 (176-227)	365 (316-398)	480 (418-566)	2299
Age group								
6-11 years	143 (116-175)	40.6 (23.3-80.5)	96.0 (74.3-120)	155 (128-179)	226 (187-327)	416 (264-440)	440 (389-525)	302
12-19 years	99.3 (85.0-116)	38.3 (17.4-49.6)	67.2 (54.7-80.9)	112 (93.0-124)	173 (144-191)	261 (215-311)	317 (278-402)	700
20 years and older	116 (101-134)	38.5 (26.7-48.2)	68.0 (57.9-77.3)	118 (104-134)	201 (175-232)	374 (334-410)	502 (436-675)	1297
Gender								
Males	111 (95.0-131)	35.4 (19.1-48.2)	66.9 (53.6-79.3)	122 (105-134)	189 (167-216)	355 (268-418)	470 (389-627)	1100
Females	121 (106-138)	40.8 (28.7-50.8)	71.7 (63.2-83.5)	120 (105-142)	214 (175-243)	369 (331-400)	487 (402-608)	1199
Race/ethnicity								
Mexican Americans	105 (93.4-118)	44.6 (35.1-51.5)	66.5 (59.1-78.5)	107 (93.1-124)	161 (146-177)	244 (205-303)	368 (302-415)	763
Non-Hispanic blacks	115 (89.5-147)	28.3 (11.5-45.5)	59.4 (38.5-93.0)	120 (98.7-158)	213 (174-270)	410 (330-535)	652 (461-959)	522
Non-Hispanic whites	117 (99.6-139)	39.2 (23.0-52.1)	70.4 (58.0-84.6)	124 (105-143)	203 (175-240)	373 (316-418)	480 (400-574)	820

1-Hydroxypyrene

Metabolite of pyrene (CAS No. 129-00-0)

Pyrene is commonly found in PAH mixtures, and its urinary metabolite is used as a surrogate marker for exposure to PAH chemicals in general. The 1-hydroxypyrene metabolite was detected in 99% of the NHANES 1999-2000 subsample. The geometric mean level for the overall population is similar to that of other general populations residing in an urban setting (Goen et al., 1995; Chuang et al., 1999). People living in one urban setting had severalfold higher urinary 1-hydroxypyrene levels than those who lived in a rural setting (Goen et al., 1995). The sources of PAH exposure in the urban setting include industrial and automobile exhaust (Jongeneelen et al., 1994; Kanoh et al., 1993). An additional source of PAH exposure is the use of coal for domestic heating. Women residing in an urban setting and using coal to heat their homes had higher urinary 1-hydroxypyrene levels than the women in this NHANES 1999-2000 subsample (Gundel et al., 1996). Tobacco smoking can be a more significant source of PAHs than urban exposures or road construction exposure (Goen et al., 1995; Szaniszlo et al., 2001). People who work in certain occupations (e.g., carbon electrode production) can have urinary 1-hydroxypyrene levels 100 times higher than the geometric mean level shown in this *Report* (Goen et al., 1995). An additional source of PAH exposure for children is the ingestion of PAH-contaminated soil.

Table 58. 1-Hydroxypyrene

Geometric mean and selected percentiles of urine concentrations (in ng/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	79.8 (69.0-92.2)	14.9 (11.7-18.6)	34.7 (27.4-41.6)	78.0 (67.8-92.8)	187 (161-229)	434 (371-506)	730 (551-940)	2312
Age group								
6-11 years	90.8 (72.2-114)	20.8 (14.8-39.8)	57.0 (39.8-70.7)	94.1 (77.9-124)	170 (124-229)	300 (206-405)	419 (293-757)	310
12-19 years	105 (85.0-129)	24.1 (18.9-33.5)	48.0 (38.7-61.0)	108 (78.1-141)	226 (171-290)	473 (317-618)	642 (425-1200)	693
20 years and older	74.8 (64.0-87.4)	13.6 (9.90-16.3)	30.7 (24.3-36.7)	70.1 (62.2-85.0)	187 (156-233)	446 (366-570)	795 (570-977)	1309
Gender								
Males	90.1 (76.0-107)	18.0 (12.7-23.5)	37.1 (28.4-48.5)	85.2 (72.9-101)	227 (178-284)	496 (404-596)	747 (570-1050)	1106
Females	71.2 (61.6-82.3)	13.5 (9.40-15.8)	32.1 (26.2-37.3)	70.9 (63.3-86.1)	163 (149-197)	361 (278-451)	669 (387-940)	1206
Race/ethnicity								
Mexican Americans	74.2 (64.5-85.4)	16.3 (14.3-19.7)	34.0 (29.9-39.6)	68.1 (58.9-82.8)	161 (120-225)	344 (270-468)	545 (413-650)	766
Non-Hispanic blacks	108 (87.0-135)	20.8 (17.6-24.0)	46.6 (34.5-59.0)	99.7 (74.8-148)	245 (199-358)	586 (420-778)	839 (569-1380)	528
Non-Hispanic whites	73.7 (61.1-88.9)	13.8 (8.50-17.6)	31.9 (23.9-40.1)	72.9 (62.8-87.7)	178 (153-229)	399 (324-506)	747 (451-977)	831

Geometric mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, urinary creatinine, and log serum cotinine. Children aged 6-11 years had about a two times higher urinary 1-hydroxypyrene adjusted geometric mean than did people in the two other age groups. This age-related difference also has been found by other investigators (Heudorf et al., 2001; Chuang et al., 1999). The urinary 1-hydroxypyrene levels for children documented in this *Report* are similar to levels measured in other studies (van Wijnen et al., 1996; Chuang et al., 1999; Heudorf et al., 2001; Kanoh et al., 1993). No differences were observed for race/ethnicity or gender. In previous investigations (Roggi et al., 1997; Kanoh et al., 1993; van Wijnen et al., 1996), gender did not influence urinary 1-hydroxypyrene levels. It is unknown whether differences in age groups represent differences in exposure, body-size relationships, or metabolism. Further research on the contribution of tobacco smoke to levels of 1-hydroxypyrene levels is needed.

Table 59. 1-Hydroxypyrene (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in ng/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	74.2 (64.1-85.9)	18.2 (14.6-22.4)	36.5 (30.0-41.9)	73.3 (63.4-83.8)	158 (139-178)	362 (282-416)	500 (438-607)	2312
Age group								
6-11 years	94.1 (76.9-115)	31.6 (13.1-46.5)	56.5 (45.7-65.6)	91.2 (82.1-107)	168 (124-237)	333 (231-486)	474 (332-849)	310
12-19 years	71.5 (60.4-84.5)	21.0 (14.9-29.1)	36.5 (30.9-46.8)	70.7 (56.0-89.8)	137 (119-170)	240 (184-380)	413 (236-663)	693
20 years and older	72.3 (61.6-84.8)	17.2 (12.5-21.5)	33.5 (27.5-40.0)	68.8 (59.5-81.5)	159 (135-182)	377 (288-441)	541 (447-633)	1309
Gender								
Males	72.1 (60.0-86.7)	16.1 (9.59-22.2)	32.6 (25.6-42.9)	69.9 (61.0-84.3)	167 (134-185)	349 (273-416)	525 (412-709)	1106
Females	76.1 (66.2-87.6)	19.9 (17.0-25.9)	37.8 (33.1-42.1)	77.2 (61.7-86.6)	148 (129-178)	370 (256-450)	500 (434-607)	1206
Race/ethnicity								
Mexican Americans	68.2 (59.3-78.4)	21.5 (19.7-25.6)	36.1 (31.2-39.5)	59.6 (52.4-71.5)	124 (97.9-152)	252 (203-333)	462 (325-557)	766
Non-Hispanic blacks	70.5 (56.6-87.9)	16.1 (12.6-19.3)	30.3 (25.0-41.2)	68.6 (54.4-92.7)	156 (113-184)	346 (232-441)	474 (338-847)	528
Non-Hispanic whites	73.2 (60.8-88.1)	17.4 (10.4-23.5)	34.4 (28.2-42.1)	72.3 (59.9-85.7)	163 (130-188)	377 (269-450)	547 (447-633)	831

Tobacco Smoke

Cotinine

CAS No. 486-56-6

General Information

Tobacco use is the most important, preventable cause of premature morbidity and mortality in the United States. The consequences of smoking and the use of smokeless tobacco products are well known and include an increased risk for cancer, emphysema, and cardiovascular disease. For example, lung cancer is the leading cancer-related killer of both men and women in the United States, and smoking is by far the leading cause of lung cancer.

Environmental tobacco smoke (ETS) is a known human carcinogen, and persistent exposure to ETS is associated with an increased risk for lung cancer and other diseases. Children are at particular risk from ETS, which may exacerbate asthma among susceptible children and greatly increase the risk for lower respiratory-tract illness, such as bronchitis and pneumonia, among young children.

Cotinine is a major metabolite of nicotine and is currently regarded as the best biomarker in active smokers and in nonsmokers exposed to ETS. Measuring cotinine is preferred over measuring nicotine because cotinine persists longer in the body. Cotinine can be measured in serum, urine, saliva, and hair. Nonsmokers exposed to typical levels of ETS have cotinine levels of less than 1

Table 60. Cotinine

Geometric mean and selected percentiles of serum concentrations (in ng/mL) for the non-smoking U.S. population aged 3 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 3 and older	*	< LOD	< LOD	.059 (<LOD-.070)	.236 (.180-.310)	1.02 (.740-1.27)	1.96 (1.64-2.56)	5999
Age group								
3-11 years	*	< LOD	< LOD	.109 (.064-.180)	.500 (.290-1.02)	1.88 (1.19-3.09)	3.37 (1.79-4.23)	1174
12-19 years	*	< LOD	< LOD	.107 (.080-.163)	.540 (.371-.762)	1.65 (1.25-2.11)	2.56 (2.35-3.23)	1773
20 years and older	*	< LOD	< LOD	< LOD	.167 (.137-.200)	.630 (.520-.863)	1.48 (1.23-1.77)	3052
Gender								
Males	*	< LOD	< LOD	.080 (.060-.100)	.302 (.220-.390)	1.20 (.890-1.56)	2.39 (1.78-3.06)	2789
Females	*	< LOD	< LOD	< LOD	.179 (.135-.250)	.850 (.590-1.14)	1.85 (1.41-2.37)	3210
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	.139 (.107-.182)	.506 (.340-.813)	1.21 (.813-1.84)	2242
Non-Hispanic blacks	*	< LOD	< LOD	.131 (.110-.150)	.505 (.400-.625)	1.43 (1.22-1.66)	2.34 (1.89-2.97)	1333
Non-Hispanic whites	*	< LOD	< LOD	.050 (<LOD-.070)	.210 (.150-.313)	.950 (.621-1.40)	1.92 (1.54-2.74)	1949

< LOD means less than the limit of detection, which is 0.05 ng/mL.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

ng/mL, with heavy exposure to ETS producing levels in the 1-10 ng/mL range. Active smokers almost always have levels higher than 10 ng/mL and sometimes higher than 500 ng/mL.

Interpreting Serum Cotinine Levels Reported in the Table

Table 60 presents data for the U.S. nonsmoking population aged 3 years and older. For these results, nonsmoking is defined as a serum cotinine level less than or equal to 10 ng/mL. Choosing a cutoff of 15 ng/mL makes little difference in the results. The LOD for these measurements was 0.050 ng/mL.

From 1988 through 1991, as part of NHANES III, CDC determined that the median level (50^{th} percentile) of cotinine among nonsmokers in the United States was 0.20 ng/mL (Pirkle et al., 1996). Table 60 shows that the median cotinine level in 1999-2000 has decreased to 0.059 ng/mL—more than a 70% decrease. This reduction in cotinine levels suggests a dramatic reduction in exposure of the general U.S. population to ETS since the period 1988-1991. Compared with results for the period 1988-1991 for population groups defined by age, gender, and race/ethnicity (Pirkle et al., 1996), cotinine levels declined in all categories.

Covariate-adjusted geometric means were not calculated because more than 40% of the population had cotinine levels less than the LOD. At comparable percentiles, men have higher cotinine levels than women, and non-Hispanic blacks have higher levels than non-Hispanic whites or Mexican Americans. Higher levels of cotinine have been reported for non-Hispanic blacks (Caraballo et al., 1998). As seen previously (Pirkle et al., 1996), males continue to have higher levels than females, and people aged 20 years and older have lower levels than those younger than 20 years of age.

Phthalates

General Information

Phthalates are industrial chemicals added to many consumer products, including vinyl flooring adhesives; detergents; lubricating oils; solvents; food packaging; automotive plastics; plastic clothing, such as raincoats; and personal-care products, such as soap, shampoo, hair spray, and nail polish. Phthalates are widely used in flexible polyvinyl chloride plastics, such as plastic bags, food packaging, garden hoses, inflatable recreational toys, blood-storage containers, intravenous tubing, children's toys, and some pharmaceutical and pesticide formulations. Soil and water contamination are greatest in areas of industrial use and waste disposal.

People are exposed through direct contact with products that use phthalates or through food in contact with packaging that contains phthalates. The different phthalates vary in their ability to produce the following effects in animal studies: testicular injury, liver injury, liver cancer, anti-androgenic activity, teratogenicity, and peroxisomal proliferation. For example, di-2-ethylhexyl phthalate (DEHP), benzylbutyl phthalate, dibutyl phthalates, and di-isononyl phthalate have reproductive effects in animal studies. Greater susceptibility to reproductive toxicity at lower doses occurs for *in utero* exposures or in younger animals. Peroxisomal proliferation may be a pathway to the development of liver cancers in animals. However, there is debate as to whether peroxisomal proliferation is relevant in people (Melnick, 2001) because of differing metabolic pathways in people. Effects of phthalates in people have not been well studied.

For several phthalates, it is suspected that the monoester metabolite may mediate toxic effects. Table 61 shows the relation between some phthalates and their monoester metabolites and also includes their commonly used abbreviations. The Center for the Evaluation of Risks to Human Reproduction of the NTP has recently reviewed the reproductive effects for many of the phthalates (see http://cerhr.niehs.nih.gov/news/). Not all the different phthalates have been reviewed by government agencies. Information about external exposure (environmental levels) and health effects is also available for some of the phthalates from the EPA IRIS Web site at http://www.epa.gov/iris and from ATSDR at http://www.atsdr.cdc.gov/toxprofiles.

Interpreting Urinary Phthalate Metabolite Levels Reported in the Tables

Urine levels of phthalate metabolites were measured in a subsample of NHANES participants aged 6 years and older. Subsamples were randomly selected within the specified age range to be a representative sample of the U.S. population. Results are presented in Tables 62-75. The amount of monoester metabolite in the urine for each phthalate is a fraction of the total excreted urinary metabolites (about one fourth in the case of DEHP), and the total amount of all metabolites in the urine is a fraction of the internal dose (Dirven et al., 1993). In the case of DEHP, the amount of its monoester metabolite in urine represents roughly one tenth of the ingested dose during the previous 24 hours. It is not clear whether the monoester metabolite of a phthalate is produced to the same extent by differing routes of exposure (Liss et al.,

Table 61. Phthalates and their metabolites

Phthalate name (CAS number)	**Abbreviation**	**Urinary metabolite** (CAS number)
Diethyl phthalate (84-66-2)	DEP	Mono-ethyl phthalate (2306-33-4)
Dibutyl phthalates (84-74-2)	DBP	Mono-butyl phthalates (131-70-4) (mono-iso-butyl and mono-n-butyl)
Benzylbutyl phthalate (85-68-7)	BzBP	Mono-benzyl phthalate (2528-16-7) (some mono-butyl phthalate)
Dicyclohexyl phthalate (84-61-7)	DCHP	Mono-cyclohexyl phthalate (7517-36-4)
Di-2-ethylhexyl phthalate (117-81-7)	DEHP	Mono-2-ethylhexyl phthalate (4376-20-9)
Di-n-octyl phthalate (117-84-0)	DOP	Mono-n-octyl phthalate (5393-19-1)
Di-isononyl phthalate (28553-12-0)	DINP	Mono-isononyl phthalate

1985; Peck and Albro, 1982). There is variation from person to person in the proportions or amounts of the metabolite excreted after receiving similar doses (Anderson et al., 2001). In addition, there is modest variation from day to day in the amounts excreted for any individual (Hoppin et al., 2002).

The rank order of concentrations for the monoester metabolites of the various phthalates in this NHANES 1999-2000 subsample is similar to those concentrations in a previous study using a non-random subsample from NHANES III specimens (Blount et al., 2000). DEHP is the most widely used and studied of the various phthalates. However, mono-ethyl phthalate, mono-butyl phthalates, and mono-benzyl phthalate have higher urinary concentrations than mono-2-ethylhexyl phthalate (MEHP). Such differences in the excretion of various phthalates may be due to differences in either exposure or toxicokinetics. For example, the higher levels of these particular phthalate metabolites may also be due to a greater fraction of the internal dose being converted to monoester phthalates; to a lesser conversion of these monoester phthalates to other products; or to greater accumulation from longer residence times, although the half-lives of phthalates are generally short. Several investigations have shown that two other metabolites of DEHP, mono-(2-ethyl-5-oxohexyl) phthalate and mono-(2-ethyl-5-hydroxyhexyl) phthalate, are produced at a threefold to tenfold greater extent than MEHP (Dirven et al., 1993; Peck and Albro, 1982).

The low detection rates for some of the long alkyl chain phthalates (di-isononyl- and dioctyl-) metabollites may be due to significantly less metabolism to the monoester metabolite as has been seen in animal studies. Diethyl-, dibutyl-, and benzylbutyl phthalates are contained to a greater extent in cosmetics, sundries, glues, and adhesives than is DEHP, and urine levels may reflect higher daily contact with those products or a greater extent of metabolism to these metabolites.

In this *Report*, there are several notable differences in concentrations for specific phthalate metabolites in regard to age, gender, and race/ethnicity. It is unknown whether such differences reflect differences in exposure, body-size relationships, or metabolism. Finding a measurable amount of one or more phthalate metabolites in urine does not mean that the level of one or more of these causes an adverse health effect. Measuring phthalate metabolites at these levels in urine is possible because of advances in analytical chemistry. Whether these levels of phthalate metabolites are a cause for health concern is not yet known; more research is needed. These levels of phthalate metabolites in urine provide physicians with a reference range so that they can determine whether people have been exposed to higher levels of phthalates than those levels found in the general population. These data will also help scientists plan and conduct research on phthalate exposure and health effects.

Mono-ethyl phthalate

CAS No. 2306-33-4

Metabolite of diethyl phthalate
CAS No. 84-66-2

Diethyl phthalate is an industrial solvent used in many consumer products, particularly those containing fragrances. Products that may contain diethyl phthalate include perfume, cologne, deodorant, soap, shampoo, and hand lotion. People exposed to diethyl phthalate will excrete mono-ethyl phthalate in their urine. The amount of mono-ethyl phthalate is an indicator of how much contact with diethyl phthalate has occurred. Workplace air standards for external exposure have been established (ACGIH) or recommended (NIOSH) for diethyl phthalate. Generally, diethyl phthalate has low acute toxicity. It has not been completely classified with respect to its carcinogenicity (U.S. EPA, IARC, NTP). Information about external exposure (environmental levels) and health effects is available from the EPA IRIS Web site at http://www.epa.gov/iris and from ATSDR at http://www.atsdr.cdc.gov/toxprofiles.

Concentrations reported in Table 62 are similar or slightly lower than those reported in a non-random subsample from NHANES III (Blount et al., 2000). In the current NHANES 1999-2000 subsample, geometric mean levels of the demographic groups were compared

Table 62. Mono-ethyl phthalate

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	179 (159-201)	28.9 (23.6-34.2)	61.4 (54.0-69.7)	164 (142-192)	450 (378-523)	1260 (988-1490)	2840 (2020-4070)	2536
Age group								
6-11 years	91.3 (73.0-114)	27.2 (20.4-35.7)	40.8 (35.9-46.8)	74.7 (50.6-107)	197 (129-259)	378 (290-644)	756 (379-1070)	328
12-19 years	211 (167-266)	32.7 (22.4-50.6)	72.4 (53.6-99.8)	193 (141-256)	558 (432-806)	1510 (1060-2100)	3260 (1670-4100)	752
20 years and older	190 (168-214)	27.7 (22.0-34.5)	63.3 (56.7-74.9)	180 (154-210)	482 (409-555)	1340 (1010-1660)	3480 (2210-5100)	1456
Gender								
Males	179 (157-204)	28.4 (23.8-35.4)	54.7 (48.3-64.1)	154 (121-191)	523 (400-621)	1430 (1150-2090)	3480 (2270-4330)	1214
Females	178 (154-206)	28.0 (21.8-32.1)	65.0 (57.6-80.2)	174 (145-205)	425 (356-482)	977 (825-1340)	2230 (1330-4100)	1322
Race/ethnicity								
Mexican Americans	181 (163-201)	30.2 (25.2-38.1)	66.8 (56.6-77.4)	174 (150-205)	441 (410-510)	1250 (893-1410)	1720 (1410-2450)	813
Non-Hispanic blacks	322 (278-373)	56.1 (48.3-73.2)	127 (111-143)	306 (256-350)	789 (588-996)	1880 (1340-2460)	3600 (2100-4900)	603
Non-Hispanic whites	152 (134-173)	27.2 (20.1-31.1)	52.3 (44.6-61.4)	133 (110-157)	366 (312-450)	977 (796-1340)	2470 (1430-4330)	907

after adjustment for the covariates of race/ethnicity, age, gender, and urinary creatinine. Urinary mono-ethyl phthalate levels were found to be lower for ages 6-11 years than for the other two age groups (trending in an opposite direction from mono-butyl, mono-benzyl, and mono-ethylhexyl phthalates, all of which decreased with increasing age). Levels in females were higher than levels in males. Non-Hispanic blacks had higher levels than non-Hispanic whites or Mexican Americans. It is unknown whether differences between ages, genders, or races/ethnicities represent differences in exposure, body-size relationships, or metabolism.

Table 63. Mono-ethyl phthalate (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	163 (148-179)	33.0 (29.1-35.8)	64.7 (57.5-73.5)	141 (132-155)	360 (313-411)	898 (762-1150)	1950 (1460-2730)	2536
Age group								
6-11 years	92.6 (74.2-116)	29.7 (24.9-34.9)	45.6 (33.6-57.7)	79.4 (61.2-121)	165 (124-208)	341 (219-559)	625 (365-784)	328
12-19 years	142 (120-168)	29.8 (27.0-33.5)	50.7 (41.4-57.9)	122 (86.2-168)	361 (279-495)	879 (676-1260)	1550 (907-2030)	752
20 years and older	179 (161-199)	34.5 (29.1-39.1)	75.6 (66.3-83.6)	154 (139-170)	390 (338-452)	1010 (810-1440)	2170 (1670-3490)	1456
Gender								
Males	141 (124-159)	27.6 (22.6-33.1)	48.9 (40.3-60.8)	120 (106-138)	324 (268-391)	996 (761-1420)	1940 (1460-2900)	1214
Females	187 (167-209)	42.7 (34.7-51.7)	81.4 (73.4-94.8)	157 (142-182)	377 (333-453)	821 (719-1150)	1920 (1100-3410)	1322
Race/ethnicity								
Mexican Americans	164 (145-186)	36.3 (29.2-41.5)	63.4 (53.6-77.9)	154 (136-175)	382 (323-469)	814 (692-886)	1330 (1010-1860)	813
Non-Hispanic blacks	208 (183-237)	46.7 (38.4-54.7)	86.4 (69.8-108)	196 (164-232)	443 (363-528)	1030 (762-1700)	1880 (1290-2450)	603
Non-Hispanic whites	149 (133-167)	31.8 (26.5-34.7)	58.6 (50.7-68.6)	128 (113-139)	313 (249-376)	834 (663-1200)	1950 (1420-3350)	907

Mono-butyl phthalates

CAS No. 131-70-4

Metabolites of dibutyl phthalates (CAS No. 84-74-2) and benzylbutyl phthalate (CAS No. 85-68-7)

Dibutyl phthalates (di-n-butyl, di-iso-butyl) are industrial solvents or additives used in many consumer products such as nail polish, cosmetics, some printing inks, pharmaceutical coatings, and insecticides. People exposed to dibutyl phthalates will excrete mono-butyl phthalates (n-butyl, iso-butyl) in their urine. Exposure to benzylbutyl phthalate will also result in small amounts of mono-butyl phthalates appearing in the urine (Anderson et al. 2001). The amount of mono-butyl phthalates is an indicator of how much contact with dibutyl phthalates has occurred.

Workplace air standards for external exposure to dibutyl phthalate have been established (NIOSH, ACGIH). Generally, dibutyl phthalates have low acute toxicity. Dibutyl phthalates have not been completely classified with respect to their carcinogenicity (U.S. EPA, IARC, NTP). Information about external exposure (environmental levels) and health effects is available from the EPA IRIS Web site at http://www.epa.gov/iris and from ATSDR at http://www.atsdr.cdc.gov/toxprofiles.

Concentrations reported here are similar to or slightly lower than those reported for a non-random subsample

Table 64. Mono-butyl phthalates

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	24.6 (22.7-26.6)	5.70 (4.80-6.40)	12.6 (11.0-14.3)	26.0 (24.2-28.5)	51.6 (46.9-56.1)	98.6 (90.7-114)	149 (126-167)	2541
Age group								
6-11 years	41.4 (35.8-47.8)	15.1 (11.0-16.9)	23.0 (19.1-27.2)	40.0 (33.7-50.3)	75.5 (59.0-94.5)	124 (92.8-166)	163 (114-306)	328
12-19 years	36.0 (31.9-40.5)	11.9 (8.10-14.8)	20.0 (17.3-25.4)	36.1 (31.7-42.3)	67.7 (56.7-76.1)	119 (94.3-146)	165 (133-209)	752
20 years and older	21.6 (19.7-23.6)	4.70 (4.20-5.90)	10.3 (9.40-11.6)	23.0 (20.7-25.0)	46.1 (39.7-51.3)	95.0 (81.1-107)	142 (118-161)	1461
Gender								
Males	22.0 (20.2-24.0)	5.70 (4.70-6.60)	11.3 (9.90-13.0)	23.1 (21.0-25.2)	43.1 (36.9-49.3)	83.9 (71.3-96.2)	115 (96.2-142)	1215
Females	27.3 (24.4-30.4)	5.80 (4.10-7.60)	13.8 (11.6-16.4)	30.0 (26.1-33.1)	59.5 (52.0-65.6)	119 (100-143)	167 (145-218)	1326
Race/ethnicity								
Mexican Americans	23.4 (20.8-26.4)	5.10 (4.40-6.10)	11.8 (10.1-13.9)	26.3 (23.6-29.2)	48.1 (41.8-54.6)	92.2 (71.9-107)	116 (101-136)	814
Non-Hispanic blacks	37.0 (32.5-42.1)	10.3 (8.00-14.4)	22.2 (18.2-24.6)	38.7 (34.5-42.6)	78.2 (63.1-86.7)	117 (104-149)	167 (143-192)	603
Non-Hispanic whites	21.8 (19.8-24.0)	5.00 (4.20-6.30)	10.6 (9.60-12.5)	23.1 (20.4-26.1)	45.9 (39.1-51.6)	90.2 (75.4-102)	138 (112-161)	911

from NHANES III (Blount et al., 2000). In the current NHANES 1999-2000 subsample, geometric mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, and urinary creatinine. Urinary mono-butyl phthalate levels were higher in people aged 6-11 years than for people in the other two age groups and higher in people aged 12-19 years than in those aged 20 years and older. Levels in females were higher than in males. It is unknown whether differences between ages or sexes represent differences in exposure, body-size relationships, or metabolism.

A statistical examination of phthalate levels in a non-random subsample from NHANES III (Koo et al., 2002) suggested that higher levels of mono-butyl phthalates in urine were associated with a lower level of education.

Table 65. Mono-butyl phthalates (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	22.4 (21.1-23.8)	7.74 (6.79-8.63)	12.8 (11.7-14.2)	21.9 (20.3-23.4)	38.9 (36.1-41.1)	68.3 (61.7-74.9)	97.5 (84.4-113)	2541
Age group								
6-11 years	41.9 (37.2-47.4)	16.7 (10.6-22.0)	27.8 (23.3-32.1)	38.9 (32.5-49.6)	65.7 (54.9-80.0)	107 (80.0-162)	159 (106-196)	328
12-19 years	24.3 (22.0-26.8)	9.80 (7.68-11.5)	15.4 (13.2-17.0)	23.6 (21.6-26.3)	37.6 (32.6-42.2)	62.3 (53.7-72.1)	88.1 (69.6-139)	752
20 years and older	20.4 (19.0-21.9)	7.08 (5.95-8.18)	11.7 (10.9-13.0)	19.5 (18.4-21.0)	34.9 (31.2-38.2)	62.4 (56.0-68.6)	91.0 (78.3-112)	1461
Gender								
Males	17.3 (16.0-18.7)	6.54 (5.70-7.46)	10.2 (9.57-11.3)	17.0 (15.5-18.7)	28.6 (25.8-32.0)	49.1 (42.4-53.9)	63.6 (57.3-76.7)	1215
Females	28.6 (26.5-30.9)	10.6 (8.54-11.7)	17.3 (15.9-18.6)	28.6 (26.2-30.4)	50.6 (44.9-54.2)	84.3 (73.5-97.6)	131 (98.5-153)	1326
Race/ethnicity								
Mexican Americans	21.2 (18.9-23.9)	6.98 (5.23-8.50)	12.9 (10.2-14.5)	20.0 (18.2-22.8)	40.1 (33.7-44.0)	63.6 (57.6-70.1)	81.6 (73.9-100)	814
Non-Hispanic blacks	23.9 (21.6-26.4)	8.51 (6.90-9.92)	13.9 (12.4-16.0)	25.0 (20.7-27.9)	42.2 (36.8-49.3)	69.6 (62.6-83.9)	94.4 (76.7-108)	603
Non-Hispanic whites	21.3 (19.6-23.2)	7.16 (6.03-8.54)	12.1 (11.1-13.9)	20.5 (18.9-22.9)	36.4 (32.3-39.6)	67.1 (58.1-74.9)	97.6 (81.4-135)	911

Mono-benzyl phthalate

CAS No. 2528-16-7

Metabolite of benzylbutyl phthalate (CAS No. 85-68-7)

Benzylbutyl phthalate is an industrial solvent and additive used in products such as adhesives, vinyl-flooring products, sealants, car-care products, and to a lesser extent, some personal-care products. People exposed to benzylbutyl phthalate will excrete mono-benzyl phthalate in their urine. The amount of mono-benzyl phthalate is an indicator of how much contact with benzylbutyl phthalate has occurred.

Workplace air standards for external exposure have not been established (OSHA, ACGIH) for benzylbutyl phthalate. Generally, benzylbutyl phthalate has low acute toxicity. It is classified as a possible human carcinogen (U.S. EPA) but considered not classifiable by IARC and incompletely classified by NTP. Information about external exposure (environmental levels) and health effects is available from the EPA IRIS Web site at http://www.epa.gov/iris.

Concentrations reported here are similar to or slightly lower than those reported in a non-random subsample from NHANES III participants (Blount et al., 2000). In the current NHANES 1999-2000 subsample, geometric

Table 66. Mono-benzyl phthalate

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	15.3 (14.0-16.8)	2.80 (2.30-3.50)	6.90 (6.00-8.20)	17.0 (15.3-18.6)	35.3 (32.8-38.9)	67.1 (56.8-80.7)	103 (90.3-123)	2541
Age group								
6-11 years	39.4 (34.7-44.8)	9.40 (7.20-13.9)	22.1 (17.2-28.1)	40.3 (34.2-48.6)	82.0 (59.9-90.0)	128 (98.1-214)	214 (107-464)	328
12-19 years	25.6 (22.7-29.0)	6.30 (5.10-8.10)	13.4 (10.8-15.9)	28.3 (23.0-33.6)	51.1 (43.7-58.5)	87.9 (71.2-106)	125 (100-160)	752
20 years and older	12.4 (11.3-13.8)	2.20 (1.80-2.80)	5.80 (5.10-6.40)	13.8 (12.3-15.3)	28.9 (26.5-31.9)	52.0 (45.3-56.8)	86.3 (61.3-103)	1461
Gender								
Males	16.2 (14.5-18.0)	3.40 (2.40-4.40)	8.00 (6.00-9.20)	17.7 (15.5-19.4)	35.4 (32.8-38.6)	69.4 (59.9-85.8)	108 (94.0-139)	1215
Females	14.6 (13.0-16.3)	2.40 (1.90-3.10)	6.10 (5.20-7.60)	16.0 (14.2-19.2)	35.8 (31.0-41.0)	63.7 (54.7-74.1)	103 (86.3-116)	1326
Race/ethnicity								
Mexican Americans	13.9 (11.9-16.4)	2.40 (1.70-3.50)	6.30 (5.20-7.80)	15.7 (12.1-18.0)	33.0 (26.7-37.2)	67.5 (55.9-80.6)	98.3 (80.6-150)	814
Non-Hispanic blacks	23.0 (20.0-26.5)	5.10 (3.70-6.40)	12.3 (10.0-13.7)	23.0 (20.0-27.0)	49.3 (40.1-56.1)	94.0 (79.1-130)	138 (115-233)	603
Non-Hispanic whites	14.3 (12.7-16.0)	2.50 (1.90-3.20)	6.50 (5.30-8.10)	16.1 (14.3-18.5)	33.9 (30.7-37.5)	58.7 (52.0-71.5)	103 (73.4-116)	911

mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, and urinary creatinine. Urinary mono-benzyl phthalate levels were found to be higher for children aged 6-11 years than for the other two age groups, and levels in people aged 12-19 years were higher than levels in those aged 20 years and older. Females had higher levels than males.

It is unknown whether differences between ages or genders represent differences in exposure, body-size relationships, or metabolism. A statistical examination of phthalate levels in a non-random subsample from NHANES III (Koo et al., 2002) suggested that a lower income and a lower level of education were associated with higher urinary concentrations of mono-benzyl phthalate.

Table 67. Mono-benzyl phthalate (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	14.0 (13.0-15.0)	4.41 (3.64-4.75)	7.57 (6.89-8.45)	13.3 (12.7-14.6)	25.1 (23.5-27.0)	50.1 (41.4-59.6)	77.4 (69.2-88.7)	2541
Age group								
6-11 years	40.0 (34.1-46.9)	12.5 (9.32-18.3)	21.7 (19.4-27.2)	38.4 (30.3-50.6)	73.2 (58.2-89.4)	104 (89.4-142)	142 (99.8-173)	328
12-19 years	17.3 (15.5-19.3)	6.01 (5.39-7.09)	10.6 (8.68-12.3)	17.0 (14.9-19.7)	28.3 (24.9-32.3)	49.7 (41.4-61.7)	69.3 (50.1-81.9)	752
20 years and older	11.8 (10.9-12.7)	3.59 (3.16-4.42)	6.67 (6.09-7.46)	12.1 (11.3-12.8)	20.1 (18.5-23.1)	34.3 (30.5-40.8)	57.2 (42.5-73.9)	1461
Gender								
Males	12.7 (11.6-13.9)	3.81 (3.26-4.67)	6.58 (5.94-7.61)	12.3 (11.5-13.1)	23.7 (21.5-26.1)	44.5 (36.6-53.3)	73.5 (57.0-89.4)	1215
Females	15.3 (14.1-16.5)	4.84 (4.38-5.72)	8.73 (7.52-9.63)	14.7 (13.3-16.1)	25.9 (24.1-29.2)	56.4 (41.4-64.3)	80.0 (64.8-99.1)	1326
Race/ethnicity								
Mexican Americans	12.6 (11.2-14.3)	3.49 (3.00-4.21)	6.55 (5.49-7.77)	11.9 (10.7-13.5)	24.1 (20.8-28.7)	46.5 (40.9-54.2)	68.1 (55.2-98.8)	814
Non-Hispanic blacks	14.8 (13.0-16.9)	4.93 (3.96-5.88)	7.81 (7.12-8.75)	13.6 (11.7-15.6)	26.9 (21.9-32.4)	55.5 (38.7-77.2)	86.8 (64.4-99.8)	603
Non-Hispanic whites	14.0 (12.7-15.3)	4.42 (3.52-4.77)	7.66 (6.47-8.75)	13.4 (12.6-15.2)	25.2 (23.2-27.3)	53.3 (38.6-65.6)	77.9 (69.1-90.3)	911

Mono-cyclohexyl phthalate

CAS No. 7517-36-4

Metabolite of dicyclohexyl phthalate (CAS No. 84-61-7)

Dicyclohexyl phthalate is used primarily in research laboratories. Human exposure to this phthalate would not be expected to be widespread. People exposed to dicyclohexyl phthalate will excrete mono-cyclohexyl phthalate in their urine. The amount of mono-cyclohexyl phthalate is an indicator of how much contact with dicyclohexyl phthalate has occurred.

Workplace air standards for external exposure have not been established for dicyclohexyl phthalate. Generally, dicyclohexyl phthalate has low acute toxicity. It has not been completely classified as to its carcinogenicity (U.S. EPA, IARC, NTP).

Only 7.0% of the NHANES 1999-2000 subsample had detectable levels. In a previous study of a non-random subsample from NHANES III, Blount et al. (2000) also demonstrated a low detection rate (0.7 µg/L detection limit).

Table 68. Mono-cyclohexyl phthalate

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 10th	25th	50th	75th	90th	95th	Sample size
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.00 (<LOD-1.50)	2541
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.70 (1.00-3.80)	328
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.70 (1.00-2.40)	752
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1461
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.00 (<LOD-1.70)	1215
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.00 (<LOD-1.70)	1326
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	814
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.00 (.900-1.20)	603
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	.900 (<LOD-1.40)	911

< LOD means less than the limit of detection, which is 0.9 µg/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 69. Mono-cyclohexyl phthalate (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	3.00 (2.60-3.33)	2541
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	2.82 (1.54-6.00)	328
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.67 (1.33-1.82)	752
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1461
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	2.14 (1.67-3.00)	1215
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	3.28 (2.86-3.53)	1326
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	814
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.43 (1.03-1.88)	603
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	3.00 (2.61-3.53)	911

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Mono-2-ethylhexyl phthalate

CAS No. 4376-20-9

Metabolite of di-2-ethylhexyl phthalate (CAS No. 117-81-7)

Di-2-ethylhexyl phthalate is primarily used to produce flexible plastics, mainly polyvinyl chloride, which is used for many home and garden products, food containers, toys, and blood-product storage and delivery systems. Concentrations in plastic materials may reach 40% by weight. Di-2-ethylhexyl phthalate has been removed from or replaced in most children's toys and food packaging in the United States. Other sources of exposure include food, such as milk, cheese, and fish, with fatty foods containing higher levels. People exposed to di-2-ethylhexyl phthalate will excrete mono-2-ethylhexyl phthalate in their urine.

Generally, di-2-ethylhexyl phthalate has low acute toxicity. The metabolite, mono-ethylhexyl phthalate, is considered to be a more toxic compound than the parent phthalate. Liver toxicity and testicular toxicity have been observed in animal studies at high doses and chronic doses. Recently, the U.S. Food and Drug Administration (FDA) considered the amounts of di-2-ethylhexyl phthalate or mono-2-ethylhexyl phthalate (the latter is formed *in situ* in blood from di-2-ethylhexyl phthalate) received from medicinal delivery systems to be below

Table 70. Mono-2-ethylhexyl phthalate

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	3.43 (3.19-3.69)	< LOD	1.20 (<LOD-1.40)	3.20 (2.90-3.50)	7.60 (6.80-8.20)	14.8 (13.6-17.3)	23.8 (19.2-28.6)	2541
Age group								
6-11 years	5.12 (4.25-6.16)	< LOD	2.40 (1.80-3.10)	4.90 (3.80-5.50)	11.1 (7.70-13.7)	19.0 (13.7-36.1)	34.5 (14.7-130)	328
12-19 years	3.75 (3.30-4.27)	< LOD	1.60 (1.30-1.80)	3.70 (2.90-4.50)	8.10 (6.30-9.60)	15.0 (11.5-20.2)	22.8 (19.5-26.3)	752
20 years and older	3.21 (2.95-3.49)	< LOD	< LOD	3.00 (2.60-3.30)	7.20 (6.30-8.10)	14.2 (12.2-16.5)	22.4 (16.8-27.8)	1461
Gender								
Males	3.68 (3.26-4.15)	< LOD	1.40 (1.20-1.80)	3.40 (2.80-4.10)	8.00 (6.80-9.10)	16.0 (13.8-20.2)	25.3 (18.3-38.3)	1215
Females	3.21 (2.93-3.51)	< LOD	1.20 (<LOD-1.40)	3.00 (2.70-3.50)	7.00 (5.90-8.10)	13.5 (11.4-15.2)	21.6 (17.2-26.0)	1326
Race/ethnicity								
Mexican Americans	3.49 (3.13-3.88)	< LOD	1.50 (<LOD-1.70)	3.50 (3.00-3.70)	7.00 (5.90-8.60)	13.3 (10.7-19.1)	23.9 (16.4-29.3)	814
Non-Hispanic blacks	4.82 (4.07-5.71)	< LOD	2.50 (1.70-3.00)	5.10 (4.10-5.90)	9.40 (7.80-11.2)	19.5 (14.6-24.5)	29.2 (19.5-39.3)	603
Non-Hispanic whites	3.16 (2.89-3.46)	< LOD	< LOD	2.70 (2.50-3.10)	7.30 (6.30-8.20)	14.4 (12.2-16.6)	22.4 (16.5-29.3)	911

< LOD means less than the limit of detection, which is 1.2 µg/L.

thresholds likely to cause injury in adults. However, in lifesaving instances, in which neonates would receive exchange blood transfusions, relatively higher exposures might occur (http://www.fda.gov/cdrh/ost/dehp-pvc.pdf).

Workplace air standards for external exposure to di-2-ethylhexyl phthalate are generally established (OSHA, ACGIH). It is classified as a probable human carcinogen by the U.S. EPA, reasonably anticipated to be a human carcinogen by NTP, but considered not classifiable by IARC. Information about external exposure (environmental levels) and health effects is available from the EPA IRIS Web site at http://www.epa.gov/iris and from ATSDR at http://www.atsdr.cdc.gov/toxprofiles.

Concentrations reported here are similar to those reported in a non-random subsample from NHANES III (Blount et al., 2000). In the current NHANES 1999-2000 subsample, geometric mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, and urinary creatinine. Urinary mono-ethylhexyl phthalate levels were higher for ages 6-11 years than for the other two age groups. It is unknown whether differences between ages represent differences in exposure, body-size relationships, or metabolism. A statistical examination of phthalate levels in a non-random subsample from NHANES III (Koo et al., 2002) suggested slightly higher levels in urban populations, low-income groups, and males.

Table 71. Mono-2-ethylhexyl phthalate (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	3.12 (2.92-3.35)	< LOD	1.52 (1.37-1.69)	3.08 (2.81-3.31)	5.88 (5.38-6.27)	10.8 (9.47-12.9)	18.5 (14.0-23.9)	2541
Age group								
6-11 years	5.19 (4.17-6.45)	< LOD	2.56 (2.05-3.33)	5.37 (4.00-6.29)	9.11 (7.51-12.1)	21.6 (11.6-41.9)	41.9 (13.5-86.2)	328
12-19 years	2.53 (2.21-2.89)	< LOD	1.22 (1.03-1.46)	2.31 (2.11-2.60)	5.83 (4.42-6.27)	9.63 (7.78-11.3)	12.1 (11.0-17.3)	752
20 years and older	3.03 (2.80-3.29)	< LOD	< LOD	2.98 (2.72-3.26)	5.55 (4.90-6.04)	10.0 (8.60-12.9)	17.5 (13.4-22.1)	1461
Gender								
Males	2.89 (2.58-3.24)	< LOD	1.33 (1.19-1.52)	2.76 (2.37-3.18)	5.58 (4.67-6.11)	10.3 (8.90-13.5)	21.6 (13.3-28.4)	1215
Females	3.36 (3.12-3.63)	< LOD	1.82 (1.63-1.99)	3.33 (3.00-3.66)	6.15 (5.55-6.76)	11.1 (9.33-13.5)	16.3 (12.9-23.7)	1326
Race/ethnicity								
Mexican Americans	3.16 (2.77-3.60)	< LOD	1.54 (1.36-1.79)	3.15 (2.62-3.74)	5.88 (4.92-7.20)	11.6 (10.0-12.6)	15.7 (12.6-23.1)	814
Non-Hispanic blacks	3.11 (2.68-3.61)	< LOD	1.68 (1.31-1.98)	3.13 (2.62-3.37)	5.84 (4.66-7.06)	10.2 (8.77-13.6)	18.4 (11.8-35.2)	603
Non-Hispanic whites	3.09 (2.80-3.41)	< LOD	< LOD	3.08 (2.67-3.48)	5.87 (5.14-6.67)	10.6 (8.74-13.7)	20.0 (13.1-27.7)	911

< LOD means less than the limit of detection (see previous table).

Mono-n-octyl phthalate

CAS No. 5393-19-1

Metabolite of dioctyl phthalate (CAS No. 117-84-0)

Dioctyl phthalate is used primarily to produce flexible plastics. People exposed to dioctyl phthalate will excrete mono-n-octyl phthalate in their urine. The amount of mono-n-octyl phthalate is an indicator of how much contact with dioctyl phthalate has occurred.

Workplace air standards for external exposure are established (OSHA) for dioctyl phthalate. Generally, dioctyl phthalate has low acute toxicity. It has not been completely classified with respect to its carcinogenicity (U.S. EPA, IARC, NTP). Information on external exposure and health effects is available from ATSDR at http://www.atsdr.cdc.gov/toxprofiles.

Concentrations documented in this *Report* are close to the detection limit. In a previous study of a non-random subsample from NHANES III, Blount et al. (2000) also demonstrated a low detection rate (0.9 µg/L detection limit) and 95th percentile levels similar to this *Report*.

Table 72. Mono-n-octyl phthalate

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 10th	25th	50th	75th	90th	95th	Sample size
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	1.60 (1.20-2.10)	2.90 (2.20-3.40)	2541
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	2.00 (1.10-2.90)	3.20 (2.00-4.10)	328
12-19 years	*	< LOD	< LOD	< LOD	< LOD	1.60 (.900-2.40)	2.80 (2.20-3.70)	752
20 years and older	*	< LOD	< LOD	< LOD	< LOD	1.50 (1.10-2.00)	2.90 (1.90-3.50)	1461
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	1.60 (1.10-2.00)	2.80 (2.10-3.40)	1215
Females	*	< LOD	< LOD	< LOD	< LOD	1.40 (.900-2.20)	3.10 (2.10-3.70)	1326
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	1.00 (<LOD-1.40)	1.50 (1.20-3.30)	814
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	1.80 (1.00-2.80)	3.00 (2.20-3.70)	603
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	1.50 (1.00-2.40)	3.00 (2.20-3.60)	911

< LOD means less than the limit of detection, which is 0.9 µg/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 73. Mono-n-octyl phthalate (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	2.40 (2.00-2.73)	3.51 (3.00-4.00)	2541
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	2.22 (1.54-3.75)	3.75 (1.90-10.3)	328
12-19 years	*	< LOD	< LOD	< LOD	< LOD	1.49 (1.30-1.69)	1.82 (1.58-3.00)	752
20 years and older	*	< LOD	< LOD	< LOD	< LOD	2.56 (2.07-2.86)	3.47 (3.08-4.00)	1461
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	1.82 (1.54-2.05)	2.52 (2.00-3.16)	1215
Females	*	< LOD	< LOD	< LOD	< LOD	2.95 (2.50-3.60)	4.00 (3.42-5.37)	1326
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	1.82 (1.46-2.61)	3.16 (2.86-3.94)	814
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	1.36 (1.05-1.88)	2.18 (1.43-3.42)	603
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	2.60 (2.07-3.08)	3.60 (3.16-4.49)	911

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Mono-isononyl phthalate

Metabolite of di-isononyl phthalate (CAS No. 28553-12-0)

Di-isononyl phthalate is actually a mixture of phthalates with alkyl side chains of varying length (C8, C9, and C10). Di-isononyl phthalate is primarily used to produce flexible plastics and has been used to replace di-2-ethylhexyl phthalate in some plastics. Di-isononyl phthalate is now widely used in such products as children's toys, flooring, gloves, food-packaging material, drinking straws, and garden hoses. People exposed to di-isononyl phthalate will excrete mono-isononyl phthalate in their urine. The amount of mono-isononyl phthalate is an indicator of how much contact with di-isononyl phthalate has occurred.

Workplace air standards for external exposure have not been established for di-isononyl phthalate. Generally, di-isononyl phthalate has low acute toxicity in animals. Although considered an animal carcinogen, di-isononyl phthalate has not been completely classified as to human carcinogenicity (U.S. EPA, IARC, NTP).

Concentrations documented in this *Report* are close to the detection limit. In a previous study of a non-random subsample from NHANES III, Blount et al. (2000) also demonstrated a low detection rate (0.8 µg/L detection limit) and 95th percentile levels similar to this *Report*.

Table 74. Mono-isononyl phthalate

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	3.50 (<LOD-11.9)	2541
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	5.70 (<LOD-22.5)	328
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	2.30 (<LOD-9.60)	752
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	3.10 (<LOD-11.9)	1461
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	4.90 (1.20-15.6)	1215
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	2.50 (<LOD-6.80)	1326
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.40 (<LOD-2.70)	814
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	6.80 (<LOD-15.6)	603
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	3.50 (<LOD-15.7)	911

< LOD means less than the limit of detection, which is 0.8 µg/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 75. Mono-isononyl phthalate (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	4.29 (3.16-6.76)	2541
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	6.00 (2.84-14.2)	328
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.94 (1.36-6.32)	752
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	4.62 (3.33-7.79)	1461
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	4.24 (2.22-8.91)	1215
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	4.29 (3.33-5.47)	1326
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	3.51 (2.86-4.94)	814
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	4.26 (1.88-8.57)	603
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	5.00 (3.23-9.07)	911

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Polychlorinated Dibenzo-*p*-dioxins, Polychlorinated Dibenzofurans, and Coplanar Polychlorinated Biphenyls

General Information

Polychlorinated dibenzo-*p*-dioxins and dibenzofurans are two similar classes of chlorinated aromatic chemicals that usually are produced as contaminants or byproducts. They have no known commercial or natural use. Processes that contribute to their production include the incineration or burning of waste; pulp and bleaching processes used in pulp and paper mills; and the chemical syntheses of trichlorophenoxyacetic acid, hexachlorophene, polychlorinated biphenyls, vinyl chloride, and pentachlorophenol. As a result of man-made environmental release and contamination, most soil and water samples reveal trace amounts of polychlorinated dibenzo-*p*-dioxins and dibenzofurans when advanced analytical techniques are applied. Releases from industrial sources have decreased approximately 80% since the 1980s. The largest release of these chemicals today is the open burning of household trash and municipal trash, landfill fires, and agricultural and forest fires. In the environment, these chemicals usually occur as a mixture of congeners (i.e., compounds that differ by numbers and positions of chlorine atoms attached to the dibenzo-*p*-dioxin or dibenzofuran structures).

People are exposed primarily through foods that are contaminated with polychlorinated dibenzo-*p*-dioxins and dibenzofurans as a result of the accumulation of these substances in the food chain and in high-fat foods, such as dairy products, eggs, animal fats, and some fish. People have also been exposed through industrial accidents (e.g., an explosion in a factory in Seveso, Italy), use of accidentally contaminated cooking oils (e.g., as occurred in Yusho in Japan and Yu-cheng in Taiwan), spraying of herbicides contaminated with 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD, as Agent Orange in Vietnam), and burning of or exposure to polychlorinated biphenyls contaminated with polychlorinated dibenzofurans, such as in old electrical tranformers. Workplace exposures are rare, and generally recognized standards for external exposure have not been established**.** Information about environmental levels and health effects is available online from ATSDR http://www.atsdr.cdc.gov/toxprofiles. The U.S. EPA provides updated exposure and health assessments online at http://www.epa.gov/ncea/pdfs/dioxin/.

Effects in people have been observed as a result of industrial or accidental exposures involving large quantities of these chemicals. Chloracne, biochemical liver-test abnormalities, elevated blood lipids, fetal injury, and porphyria cutanea tarda have been reported in many of the studies. In some of these exposures, hormonal, neurologic, and immunologic effects have also been reported although with varying consistency (Michalek et al., 1999; Halperin et al., 1998; Jung et al., 1998, Matsuura et al., 2001). Congenital anomalies and intrauterine growth retardation were observed in offspring of mothers exposed to cooking oil contaminated with electrical oil containing polychlorinated biphenyls and dibenzofurans. Dioxins and polychlorinated biphenyls may possibly be associated with abnormal neurological status in newborns (Koopman-Esseboom et al., 1997).

Further, carcinogenic, genetic, reproductive, and developmental effects have been observed in many animal studies although species differ dramatically in sensitivity to these chemicals. The Institute of Medicine has determined that human epidemologic evidence is sufficient for causally linking exposure to herbicides contaminated with TCDD to increased risk for non-Hodgkin's lymphoma, Hodgkin's lymphoma, and soft-tissue sarcoma (Institute of Medicine, 2000). Generally, the increased risk for these cancers occurs in association with large exposures encountered in contaminated occupational settings or massive unintentional releases.

Because general population exposure to these chemicals occurs as exposure to a mixture of different congeners, effects due to specific individual congeners are difficult to determine (Masuda et al., 1997; Masuda 2001). Clearly, however, many of the effects are mediated through an interaction with the aryl hydrocarbon receptor (AHR), particularly the induction of gene expression for cytochromes P450, CYP1A1, and CYP1A2. Dioxins and furans require three or four lateral chlorine atoms on the dibenzo-*p*-dioxin or dibenzofuran backbone to bind this receptor. The rank order of interaction with the AHR receptor by degree and position of chlorination is similar for both the dioxin and furan series. In addition, natural and endogenous substances may antagonize or add to the effects at this receptor. The variation in toxicity among the dioxins and furans and the effect at the AHR is 10,000-fold, with TCDD being the most potent. Because of its exceptional potency and because it is the most studied dioxin or furan, TCDD is separately classified by the IARC as a known human carcinogen (Group 1) and by NTP as a known human carcinogen. Other polychlorinated dibenzo-*p*-dioxins and dibenzofurans have not been studied sufficiently to determine their carcinogenicity (IARC).

Many of the other polychlorinated dibenzo-*p*-dioxins and dibenzofurans and certain polychlorinated biphenyls are less potent than TCDD but vary considerably in their respective concentrations. Each congener can be assigned a potency value relative to TCDD (toxic equivalency factor [TEF]). When a TEF is multiplied by the congener concentration level, a toxic equivalency (TEQ) value is obtained. Thus, the toxic contribution of the polychlorinated dibenzo-*p*-dioxins, dibenzofurans, and certain polychlorinated biphenyls can then be compared. The sum of all TEQs in a specimen (total TEQ) can be used to compare specimens. The coplanar polychlorinated biphenyls (unsubstituted at any ortho position, allowing a planar three-dimentional structure) and the mono-ortho-substituted polychlorinated biphenyls (a chlorine atom at one of the ortho positions) can also act through mechanisms thought to be similar to those described for the dioxins and furans. The coplanar-polychlorinated biphenyls have less potency, but their concentrations are often much higher than concentrations of TCDD (Kang et al., 1997; Patterson et al., 1994), so their relative contribution to the total TEQ is potentially sizable. For a discussion of the other polychlorinated biphenyls, see the section titled "Polychlorinated Biphenyls."

*Interpreting Levels of Lipid-Adjusted Serum Polychlorinated Dibenzo-*p*-dioxins, Polychlorinated Dibenzofurans, and Coplanar Polychlorinated Biphenyls Reported in the Tables*

Serum lipid-based measurements of polychlorinated dibenzo-*p*-dioxins, dibenzofurans, and coplanar polychlorinated biphenyls were measured in a subsample of NHANES 1999-2000 participants aged 12 years and older. Subsamples were randomly selected within the specified age range to be a representative sample of the U.S. population. It is estimated that human serum lipid-based levels of polychlorinated dibenzo-*p*-dioxins and dibenzofurans have decreased by more than 80% since the 1980s (Aylward and Hays, 2002). The generally low values reported here support that observation. Only the following polychlorinated dibenzo-*p*-dioxins, dibenzofurans and coplanar polychlorinated biphenyls (IUPAC nomenclature) had detection rates greater than 5% in the NHANES 1999-2000 subsample:

1,2,3,4,6,7,8,9-octachlorodibenzo-*p*-dioxin
1,2,3,4,6,7,8-heptachlorodibenzo-*p*-dioxin
1,2,3,6,7,8-hexachlorodibenzo-*p*-dioxin
1,2,3,7,8,9-hexachlorodibenzo-*p*-dioxin
1,2,3,7,8-pentachlorodibenzo-*p*-dioxin
1,2,3,4,6,7,8-heptachlorodibenzofuran
1,2,3,4,7,8-hexachlorodibenzofuran
1,2,3,6,7,8-hexachlorodibenzofuran
2,3,4,7,8-pentachlorodibenzofuran
coplanar polychlorinated biphenyls 169 and 126.

In addition, mono-ortho substituted PCBs 118 and 156 also had detection rates above 5% (discussed in the section titled "Polychlorinated Biphenyls").

In keeping with results from other reports (Papke et al., 1998), this NHANES 1999-2000 subsample shows that the more highly chlorinated dioxin and furan congeners, several coplanar polychlorinated biphenyls (listed above), and some of the mono-ortho substituted polychlorinated biphenyls (see the section titled "Polychlorinated Biphenyls") are the main contributors to the human body burden and total TEQ. Higher concentrations of these congeners are due to their greater presence in the food chain, resistance to metabolic degradation, and greater solubility in body fat. For example, people consuming fish from the Great Lakes have had modestly increased mean concentrations of dioxins and furans that are several times the population background values (Falk et al., 1999; Anderson et al., 1998; Hanrahan et al., 1999). The patterns of individual congeners in a specimen when present at high concentrations can represent the exposure source in some cases, but are less predictive at low levels due to mixing of many low-level sources before ingestion and the differential effect of elimination on different congeners from the body.

Differences in levels of polychlorinated dibenzo-*p*-dioxins, dibenzofurans, and coplanar polychlorinated biphenyls that are present in serum are due in part to exposure but also result from differences in absorption, tissue distribution, metabolism, and elimination. Half-lives for all the dioxins and furans vary from 3-19 years, with TCDD estimated at around 7 years (Geyer et al., 2002). The more highly chlorinated congeners are retained longer and accumulate more in the body. Because these chemicals are stored in adipose tissue, they will have longer residence times in people with higher amounts of body fat (Tepper et al., 1997). Current levels may be influenced by both past (fat-stored chemicals) and recent exposures. Several studies have shown that serum levels of dioxins and furans increase with the age of the individual (Falk et al., 1999). In this *Report*, 1,2,3,4,6,7,8,9-octachlorodibenzo-*p*-dioxin, 1,2,3,4,6,7,8-heptachlorodibenzo-*p*-dioxin and 1,2,3,6,7,8-hexachlorodibenzo-*p*-dioxin levels were higher in adults aged 20 years and older than in people aged 12-19 years when compared at the higher percentiles.

The most potent of the polychlorinated dibenzo-*p*-dioxins, dibenzofurans, and coplanar polychlorinated biphenyls is TCDD. In the current NHANES 1999-2000 subsample, the rate of detection was 0.7%. The LOD varied because of available specimen volumes. The average LOD was 4.8 picograms/gram (pg/gram) of lipid (standard deviation 1.8 pg/gram of lipid). Background levels in the United States and other developed countries have fallen to levels near or below these LODs (Papke et al., 1998; Calvert et al., 1996). These levels are much lower than those for chemical-production workers when they were examined 15 years after workplace exposure had ceased (median serum TCDD concentration = 68 pg/gram of lipid) (Calvert et al., 1996). The level of TCDD in fat and serum is also known to increase with age of the individual (Luotamo et al., 1991).

Levels in this *Report* are far below those associated with the occupational and unintentional exposures that produce health effects. There are no firmly established relationships between serum lipid-based concentrations and effects in people. Studies of industrial and accidental exposures suggest that concentrations of at least 800 pg/gram of lipid might be necessary to induce chloracne, a specific effect, although levels in the thousands of pg/gram of lipid do not always produce this effect

Table 76. Polychlorinated dibenzo-*p*-dioxins, polychlorinated dibenzofurans, and coplanar polychlorinated biphenyls

Polychlorinated dibenzo-*p*-dioxins	CAS number	
1,2,3,4,6,7,8,9-Octachlorodibenzo-*p*-dioxin (OCDD)	3268-87-9	
1,2,3,4,6,7,8-Heptachlorodibenzo-*p*-dioxin (HpCDD)	35822-46-9	
1,2,3,6,7,8-Hexachlorodibenzo-*p*-dioxin (HxCDD)	57653-85-7	
1,2,3,7,8,9-Hexachlorodibenzo-*p*-dioxin (HxCDD)	19408-74-3	
1,2,3,7,8-Pentachlorodibenzo-*p*-dioxin (PeCDD)	40321-76-4	
2,3,7,8-Tetrachlorodibenzo-*p*-dioxin (TCDD)	1746-01-6	
Polychlorinated dibenzofurans	**CAS number**	
1,2,3,4,6,7,8,9-Octachlorodibenzofuran (OCDF)	39001-02-0	
1,2,3,4,6,7,8-Heptachlorodibenzofuran (HpCDF)	67562-39-4	
1,2,3,4,7,8-Hexachlorodibenzofuran (HxCDF)	70648-26-9	
1,2,3,6,7,8-Hexachlorodibenzofuran (HxCDF)	57117-44-9	
1,2,3,7,8,9-Hexachlorodibenzofuran (HxCDF)	72918-21-9	
1,2,3,7,8-Pentachlorodibenzofuran (PeCDF)	57117-41-6	
2,3,4,6,7,8-Hexchlorodibenzofuran (HxCDF)	60851-34-5	
2,3,4,7,8-Pentachlorodibenzofuran (PeCDF)	57117-31-4	
2,3,7,8-Tetrachlorodibenzofuran (TCDF)	51207-31-9	
Polychlorinated biphenyls (coplanar)	**CAS number**	**IUPAC number**
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB 169)	32774-16-6	PCB 169
3,3',4,4',5-Pentachlorobiphenyl (PCB 126)	57465-28-8	PCB 126
3,4,4',5-Tetrachlorobiphenyl (PCB 81)	70362-50-4	PCB 81

(Mocarelli et al., 1991). The few studies showing effects in people after large unintentional exposures have demonstrated concentrations ranging from several hundred to the tens of thousands of pg/gram of lipid (Masuda 2001; Masuda et al., 1998; Mocarelli et al., 1991).

Finding a measurable amount of one or more of the polychlorinated dibenzo-*p*-dioxins, dibenzofurans, or coplanar biphenyls in serum does not mean that the level of one or more of these causes an adverse health effect. Whether the concentrations reported here are a cause for health concern is not yet known; more research is needed. These levels provide physicians with a reference range so that they can determine whether people have been exposed to higher levels of polychlorinated dibenzo-*p*-dioxins, dibenzofurans, or coplanar biphenyls than those found in the general population. These data will also help scientists plan and conduct research on exposure and health effects.

Measuring polychlorinated dibenzo-*p*-dioxins, dibenzofurans, or coplanar biphenyls at these levels in serum is possible because of advances in analytical chemistry. As seen in other recent population studies, pooling of approximately 50 or more specimens is required to have adequate amounts of sample to detect the general population levels of dioxin-like compounds that are needed to properly estimate a TEQ. Because of limited availability of serum volumes and the low levels detected in the NHANES 1999-2000 population, TEQ values are not estimated from this analysis of individual samples. Future plans for the *Report* include the analysis of pooled samples to significantly lower the LOD for these compounds and allow calculation of TEQ values.

Table 77. 1,2,3,4,6,7,8,9-Octachlorodibenzo-*p*-dioxin (OCDD) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval) 10th	25th	50th	75th	90th	95th	Sample size
Total, age 12 and older	*	< LOD	< LOD	< LOD	405 (369-446)	674 (598-741)	913 (806-986)	1921
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	421 (<LOD-597)	667
20 years and older	*	< LOD	< LOD	< LOD	445 (403-484)	704 (625-800)	948 (846-1030)	1254
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	515 (449-580)	704 (579-806)	919
Females	*	< LOD	< LOD	< LOD	503 (446-538)	802 (689-927)	1010 (948-1130)	1002
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	416 (367-496)	702 (582-916)	940 (737-1280)	632
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	444 (380-497)	741 (594-904)	1120 (799-1560)	411
Non-Hispanic whites	*	< LOD	< LOD	< LOD	390 (345-443)	625 (569-727)	848 (731-982)	721

< LOD means less than the limit of detection, which averaged 145 pg/g of lipid (SD 46.0, maximum value 329).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 78. 1,2,3,4,6,7,8-Heptachlorodibenzo-*p*-dioxin (HpCDD) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	58.2 (<LOD-63.3)	85.6 (75.1-97.0)	112 (102-128)	1894
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	63.6 (<LOD-72.3)	657
20 years and older	*	< LOD	< LOD	< LOD	61.9 (56.7-66.9)	92.0 (80.8-102)	119 (103-132)	1237
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	73.6 (68.7-83.1)	94.7 (81.7-103)	910
Females	*	< LOD	< LOD	< LOD	62.6 (<LOD-68.5)	102 (86.0-118)	129 (118-155)	984
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	61.2 (<LOD-69.0)	97.7 (81.2-112)	132 (105-164)	621
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	58.1 (<LOD-67.7)	95.0 (72.8-110)	125 (101-183)	408
Non-Hispanic whites	*	< LOD	< LOD	< LOD	58.9 (<LOD-64.5)	84.9 (72.0-97.0)	106 (96.7-121)	709

< LOD means less than the limit of detection, which averaged 24.7 pg/g of lipid (SD 7.8, maximum value 55.9).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 79. 1,2,3,6,7,8-Hexachlorodibenzo-*p*-dioxin (HxCDD) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	32.6 (29.2-36.6)	56.7 (51.0-64.4)	74.0 (69.1-79.4)	1885
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	26.7 (20.3-29.3)	648
20 years and older	*	< LOD	< LOD	< LOD	36.1 (32.5-39.8)	62.8 (55.0-68.3)	75.6 (71.1-82.8)	1237
Gender								
Males	*	< LOD	< LOD	< LOD	31.5 (25.7-35.6)	54.8 (47.0-62.8)	71.1 (63.8-77.7)	908
Females	*	< LOD	< LOD	< LOD	34.9 (29.3-39.4)	61.2 (51.9-68.3)	74.9 (69.2-90.4)	977
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	20.9 (<LOD-25.0)	43.3 (33.9-52.6)	58.0 (49.5-64.8)	624
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	31.8 (26.6-40.9)	56.7 (45.2-72.4)	81.6 (66.2-94.1)	402
Non-Hispanic whites	*	< LOD	< LOD	< LOD	35.5 (30.7-39.4)	60.9 (53.6-67.7)	74.3 (68.4-82.4)	703

< LOD means less than the limit of detection, which averaged 7.5 pg/g of lipid (SD 3.1, maximum value 20.1).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 80. 1,2,3,7,8,9-Hexachlorodibenzo-*p*-dioxin (HxCDD) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1870
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	642
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1228
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	895
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	975
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	618
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	396
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	701

< LOD means less than the limit of detection, which averaged 7.6 pg/g of lipid (SD 3.2, maximum value 20.3).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 81. 1,2,3,7,8-Pentachlorodibenzo-*p*-dioxin (PeCDD) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1915
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	659
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1256
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	920
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	995
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	632
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	408
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	717

< LOD means less than the limit of detection, which averaged 5.3 pg/g of lipid (SD 2.2, maximum value 14.2).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 82. 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin (TCDD) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1898
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	658
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1240
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	912
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	986
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	630
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	404
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	709

< LOD means less than the limit of detection, which averaged 4.8 pg/g of lipid (SD 1.8, maximum value 12.1).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 83. 1,2,3,4,6,7,8,9-Octachlorodibenzofuran (OCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1884
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	652
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1232
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	904
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	980
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	623
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	404
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	705

< LOD means less than the limit of detection, which averaged 12.6 pg/g of lipid (SD 5.7, maximum value 35.6).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 84. 1,2,3,4,6,7,8-Heptachlorodibenzofuran (HpCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	14.7 (<LOD-17.0)	19.5 (17.4-22.3)	1709
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	17.7 (<LOD-22.9)	24.0 (18.6-29.6)	600
20 years and older	*	< LOD	< LOD	< LOD	< LOD	14.2 (<LOD-16.4)	18.4 (16.0-22.4)	1109
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	16.3 (13.9-18.5)	21.0 (18.5-24.7)	815
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	17.5 (14.8-19.7)	894
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	19.7 (<LOD-26.0)	570
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	22.4 (15.3-28.2)	28.2 (23.8-29.8)	359
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	17.4 (15.5-18.5)	636

< LOD means less than the limit of detection, which averaged 5.2 pg/g of lipid (SD 2.1, maximum value 13.5).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 85. 1,2,3,4,7,8-Hexachlorodibenzofuran (HxCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1890
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	657
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1233
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	908
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	12.9 (<LOD-14.7)	982
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	631
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	14.3 (<LOD-15.1)	399
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	703

< LOD means less than the limit of detection, which averaged 4.7 pg/g of lipid (SD 2.0, maximum value 12.7).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 86. 1,2,3,6,7,8-Hexachlorodibenzofuran (HxCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1898
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	656
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1242
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	913
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	985
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	625
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	408
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	708

< LOD means less than the limit of detection, which averaged 4.8 pg/g of lipid (SD 2.0, maximum value 12.6).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 87. 1,2,3,7,8,9-Hexachlorodibenzofuran (HxCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1875
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	645
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1230
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	894
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	981
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	620
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	400
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	699

< LOD means less than the limit of detection, which averaged 4.6 pg/g of lipid (SD 2.0, maximum value 12.7).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 88. 1,2,3,7,8-Pentachlorodibenzofuran (PeCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1922
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	663
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1259
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	920
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1002
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	637
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	409
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	717

< LOD means less than the limit of detection, which averaged 5.0 pg/g of lipid (SD 2.1, maximum value 13.2).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 89. 2,3,4,6,7,8,-Hexachlorodibenzofuran (HxCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1884
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	652
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1232
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	900
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	984
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	614
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	408
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	704

< LOD means less than the limit of detection, which averaged 4.8 pg/g of lipid (SD 2.0, maximum value 12.9).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 90. 2,3,4,7,8-Pentachlorodibenzofuran (PeCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval) 10th	25th	50th	75th	90th	95th	Sample size
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	15.9 (13.8-17.0)	1895
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	656
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	16.1 (13.9-17.2)	1239
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	13.8 (<LOD-15.4)	906
Females	*	< LOD	< LOD	< LOD	< LOD	13.1 (<LOD-15.5)	16.7 (15.5-18.4)	989
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	632
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	16.3 (13.2-19.2)	400
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	15.5 (13.7-17.1)	706

< LOD means less than the limit of detection, which averaged 4.8 pg/g of lipid (SD 2.0, maximum value 12.7).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 91. 2,3,7,8-Tetrachlorodibenzofuran (TCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1903
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	660
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1243
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	912
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	991
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	628
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	409
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	707

< LOD means less than the limit of detection, which averaged 4.6 pg/g of lipid (SD 1.8, maximum value 11.9).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 92. 3,3',4,4',5,5'-Hexachlorobiphenyl (PCB 169) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	34.3 (31.9-37.5)	44.5 (40.3-49.1)	1888
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	648
20 years and older	*	< LOD	< LOD	< LOD	< LOD	36.4 (34.0-40.0)	47.8 (42.5-51.2)	1240
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	36.2 (32.8-40.0)	44.3 (40.0-49.6)	908
Females	*	< LOD	< LOD	< LOD	< LOD	34.0 (29.8-38.0)	46.5 (38.6-51.1)	980
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	31.0 (28.1-35.6)	622
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	40.3 (30.8-47.3)	51.1 (42.6-63.9)	403
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	34.6 (32.4-38.7)	45.3 (40.3-50.9)	709

< LOD means less than the limit of detection, which averaged 9.9 pg/g of lipid (SD 4.3, maximum value 27.0).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 93. 3,3',4,4',5-Pentachlorobiphenyl (PCB 126) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval) 10th	25th	50th	75th	90th	95th	Sample size
Total, age 12 and older	*	< LOD	< LOD	< LOD	28.5 (25.9-31.5)	53.2 (46.8-59.1)	80.5 (65.0-98.6)	1896
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	23.8 (<LOD-27.5)	30.6 (23.8-38.6)	658
20 years and older	*	< LOD	< LOD	< LOD	30.8 (27.8-34.9)	57.1 (50.6-65.5)	89.5 (68.3-104)	1238
Gender								
Males	*	< LOD	< LOD	< LOD	25.4 (<LOD-28.6)	41.6 (34.8-47.9)	61.9 (47.9-79.2)	911
Females	*	< LOD	< LOD	< LOD	33.3 (28.3-38.9)	59.4 (53.6-75.1)	96.7 (75.9-110)	985
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	23.8 (<LOD-29.0)	42.7 (37.6-51.8)	66.1 (54.8-74.0)	631
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	30.3 (25.8-41.4)	67.4 (48.9-104)	120 (75.1-203)	404
Non-Hispanic whites	*	< LOD	< LOD	< LOD	28.3 (23.5-31.9)	50.4 (41.6-56.6)	67.8 (57.1-94.1)	704

< LOD means less than the limit of detection, which averaged 9.0 pg/g of lipid (SD 3.6, maximum value 23.2).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 94. 3,4,4',5-Tetrachlorobiphenyl (PCB 81) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (picograms/gram [pg/g] of lipid or parts-per-trillion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1883
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	651
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1232
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	900
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	983
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	621
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	405
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	699

< LOD means less than the limit of detection, which averaged 25.8 pg/g of lipid (SD 10.7, maximum value 68.4).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Polychlorinated Biphenyls

(Non-coplanar PCBs are in this section; coplanar PCBs are in the section titled “Polychlorinated Dibenzo-*p*-dioxins, Polychlorinated Dibenzofurans, and Coplanar Polychlorinated Biphenyls.”)

General Information

Polychlorinated biphenyls (PCBs) are a class of chlorinated aromatic hydrocarbon chemicals that once were used as electrical insulating and heat-exchange fluids. Peak production occurred in the early 1970s, and production was banned in the United States after 1979. The continued concern about these chemicals is because of their release into and persistence in the environment.

Food is the main source of exposure for the general population. PCBs enter the food chain by a variety of routes, including migration into food from packaging materials, contamination of animal feeds, and accumulation in the fatty tissues of animals. PCBs are found at higher concentrations in fatty foods. Diets that contain PCB-contaminated fats (e.g., contaminated milk and dairy products, fish, whales) will increase exposure to PCBs. Other sources for the general population include the release of these chemicals from PCB-containing waste sites and fires involving transformers and capacitors. Additionally, the heat from fires can result in the production of dioxins and furans from PCBs (see the section titled “Polychlorinated Dibenzo-*p*-dioxins, Dibenzofurans, and Coplanar Biphenyls”). In certain occupational settings workers can be exposed to PCBs, including the repair or manufacture of transformers, capacitors, and hydraulic systems, and remediation at hazardous waste sites. Both FDA and OSHA have developed criteria on the allowable levels of these chemicals in foods and the workplace. The U.S. EPA has set similar criteria for water and for the storage and removal of waste that contains PCBs.

Exposures to these chemicals usually occur from mixtures rather than from individual PCBs. The different types of PCB chemicals are known as congeners, compounds that are distinguished by the number of chlorine atoms and their location on the biphenyl structure. PCB congeners can be divided into the coplanar, the mono-ortho substituted PCBs, and other PCBs. The significance of this designation is that the coplanar and the mono-ortho-substituted PCBs have similar toxicologic effects as the dioxins. The coplanar PCBs are discussed in the section titled “Polychlorinated Dibenzo-*p*-dioxins, Dibenzofurans, and Coplanar Biphenyls.” Table 95 shows the relation between the various PCBs and the arrangements of chlorine atoms and also includes their commonly used abbreviations.

The human health effects of concern include liver disorders (elevated hepatic enzymes), elevated lipids, and gastrointestinal cancers. Reproductive and developmental effects demonstrated in animals may also be of concern. PCBs are classified as probable human carcinogens by IARC and U.S. EPA and are reasonably anticipated to be carcinogens by NTP. Information about external exposure (environmental levels) and health effects is available from the EPA IRIS Web site at http://www.epa.gov/iris and from ATSDR at http://www.atsdr.cdc.gov/toxprofiles.

Interpreting Lipid-Adjusted Serum PCB Levels Reported in the Tables

Lipid-adjusted serum levels of PCBs were measured in a subsample of NHANES participants 12 years and older. Subsamples were randomly selected within the specified age range to be a representative sample of the U.S. population. Measuring these PCBs at these levels is possible because of advances in analytical chemistry. Finding a measurable amount of one or more PCBs in the blood does not indicate that the levels of the PCBs cause an adverse health effect. These data provide physicians with a reference range so that they can determine whether people have been exposed to higher levels of PCBs than those found in the general population. Whether PCBs at the levels reported here are cause for health concern is not known; more research is needed.

Measurement of serum PCBs can reflect either recent or past exposure to PCBs. PCBs with a higher degree of chlorination persist in the body from several months to years after exposure. The contribution of individual PCB congeners to the sum of PCB measurements in the body may vary by exposure source and differences in kinetics. Some of the PCBs measured may represent exposure to the breakdown of other PCBs in a person’s environment. Tables 96-117 summarize the results of these measurements. These data will help scientists plan and conduct research about exposure to PCBs and health effects.

Table 95. Polychlorinated biphenyl chemicals (PCBs) and their classification

PCB	CAS number	IUPAC number
Polychlorinated biphenyls (general class)	1336-36-3	
2,4,4'-Trichlorobiphenyl	7012-37-5	PCB 28
2,2',5,5'-Tetrachlorobiphenyl	35693-99-3	PCB 52
2,3',4,4'-Tetrachlorobiphenyl	32598-10-0	PCB 66
2,4,4',5-Tetrachlorobiphenyl	32690-93-0	PCB 74
3,4,4',5-Tetrachlorobiphenyl	70362-50-4	PCB 81
2,2',4,4',5-Pentachlorobiphenyl	38380-01-7	PCB 99
2,2',4,5,5'-Pentachlorobiphenyl	37680-73-2	PCB 101
2,3,3',4,4'-Pentachlorobiphenyl	32598-14-4	PCB 105
2,3',4,4',5-Pentachlorobiphenyl	31508-00-6	PCB 118
3,3',4,4',5-Pentachlorobiphenyl	57465-28-8	PCB 126
2,2',3,3',4,4'-Hexachlorobiphenyl	38380-07-3	PCB 128
2,2',3,4,4',5'-Hexachlorobiphenyl	35065-28-2	PCB 138
2,2',3,4',5,5'-Hexachlorobiphenyl	51908-16-8	PCB 146
2,2',4,4',5,5'-Hexachlorobiphenyl	35065-27-1	PCB 153
2,3,3',4,4',5-Hexachlorobiphenyl	38380-08-4	PCB 156
2,3,3',4,4',5'-Hexachlorobiphenyl	69782-90-7	PCB 157
2,3',4,4',5,5'-Hexachlorobiphenyl	52663-72-6	PCB 167
3,3',4,4',5,5'-Hexachlorobiphenyl	32774-16-6	PCB 169
2,2',3,3',4,4',5-Heptachlorobiphenyl	35065-30-6	PCB 170
2,2',3,3',4,5,5'-Heptachlorobiphenyl	52663-74-8	PCB 172
2,2',3,3',4,5',6'-Heptachlorobiphenyl	52663-70-4	PCB 177
2,2',3,3',5,5',6-Heptachlorobiphenyl	52663-67-9	PCB 178
2,2',3,4,4',5,5'-Heptachlorobiphenyl	35065-29-3	PCB 180
2,2',3,4,4',5',6-Heptachlorobiphenyl	52663-69-1	PCB 183
2,2',3,4',5,5',6-Heptachlorobiphenyl	52663-68-0	PCB 187

Mono-ortho-chlorine-substituted PCBs

Serum levels (expressed per gram of serum lipids) of eight mono-ortho-chlorine-substituted PCBs (PCBs 28, 66, 74, 105, 118, 156, 157, and 167) are reported. Mono-ortho-chlorine-substituted PCBs have been demonstrated to elevate liver enzymes in experimental animals (Parkinson et al., 1983). Like the coplanar PCBs, they have dioxin-like effects and possibly estrogen-receptor interactions. The mono-ortho-chlorine-substituted PCB congeners most frequently detected in general population studies are PCBs 105, 118, and 156. Of these, PCB 118 was the most commonly detected (47%) in the NHANES 1999-2000 subsample. The frequency of detection for the eight mono-ortho-chlorine-substituted PCBs ranged from 2% to 47%. In pooled (100 g) samples of serum collected from a convenience sample (240 donors) from the U.S. general population in 1988, the mean level of PCB 118 was 79 ng/gram of lipid (Patterson et al., 1994). In this NHANES 1999-2000 subsample, the 75th percentile level for PCB 118 was 13.1 ng/gram of lipid, a finding consistent with decreasing levels of the mono-ortho-chlorine-substituted PCBs over these years. In a convenience sample obtained from the general Canadian population in 1994, the PCB 118 level at the 50th percentile was 17.2 ng/gram of lipid (Longnecker et al., 2000). In a convenience sample of the Swedish general population, the median level for PCB 118 was 37.5 ng/gram of lipid (Glynn et al., 2000). The higher PCB 118 level (and other PCBs) in that study may be from heavy fish consumption, which can contribute to about a twofold increase in the level of PCB 118 (Patterson et al., 1994).

The PCB 156 levels in the NHANES 1999-2000 sub-sample are similar to those measured in the Canadian study (Longnecker et al., 2000), but lower than levels in the Swedish study (Glynn et al., 2000).

Di-ortho-chlorine-substituted PCBs

Serum (lipid-adjusted) levels are reported for 14 di-ortho-chlorine-substituted PCBs. The most frequently detected di-ortho-chlorine-substituted PCBs in general populations are 138, 153, and 180 (Patterson et al., 1994). These congeners also were found to contribute about 80% of the total PCB concentration in the Swedish general population (Glynn et al., 2000). Because of its predominance, PCB 153 has been used as a marker of exposure for the other PCBs. In 1994, levels of PCBs 138, 153, and 180 in pooled, banked serum were generally three to four times lower than levels reported in 1988 (Longnecker et al., 2000; Patterson et al., 1994). The concentrations of the di-ortho-substituted PCBs are generally higher than the mono-ortho-substituted PCBs, which are higher than the coplanar PCBs (Glynn et al., 2000; Longnecker et al., 2000; Patterson et al., 1994). Heavy fish consumption can also contribute to about a twofold increase in the concentration of these PCB congeners (Patterson et al., 1994).

Tri-ortho-chlorine-substituted PCBs

The tri-ortho-chlorine-substituted PCBs are 177, 178, 183, and 187. The levels for PCB 187 shown in this *Report* are similar to the levels meaured in a convenience sample of the general Canadian population in 1994 (Longnecker et al., 2000).

Table 96. PCB 28 (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval) 10th	25th	50th	75th	90th	95th	Sample size
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1849
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	647
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1202
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	886
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	963
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	618
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	392
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	687

< LOD means less than the limit of detection, which averaged 16.7 ng/g of lipid (SD 5.3, maximum value 32.5).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 97. PCB 52 (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1912
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	664
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1248
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	908
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1004
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	631
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	408
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	716

< LOD means less than the limit of detection, which averaged 6.4 ng/g of lipid (SD 2.0, maximum value 12.5).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 98. PCB 66 (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1931
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	671
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1260
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	919
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1012
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	636
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	414
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	723

< LOD means less than the limit of detection, which averaged 6.4 ng/g of lipid (SD 2.0, maximum value 12.5).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 99. PCB 74 (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	20.7 (17.5-23.6)	29.0 (24.5-32.3)	1924
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	671
20 years and older	*	< LOD	< LOD	< LOD	12.6 (<LOD-14.4)	22.3 (19.5-25.6)	30.0 (25.6-35.9)	1253
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	15.3 (12.8-17.8)	21.5 (18.1-24.7)	915
Females	*	< LOD	< LOD	< LOD	13.9 (<LOD-16.1)	24.5 (21.7-28.7)	31.6 (28.8-40.3)	1009
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	15.8 (12.9-18.0)	636
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	29.0 (19.8-37.1)	43.5 (34.5-65.7)	411
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	21.6 (19.1-24.0)	29.0 (24.3-31.9)	719

< LOD means less than the limit of detection, which averaged 6.4 ng/g of lipid (SD 2.0, maximum value 12.5).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 100. PCB 99 (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	13.1 (<LOD-14.7)	19.1 (15.6-21.4)	1897
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	654
20 years and older	*	< LOD	< LOD	< LOD	< LOD	13.9 (<LOD-16.2)	19.9 (16.1-23.5)	1243
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	16.7 (13.8-20.5)	905
Females	*	< LOD	< LOD	< LOD	< LOD	13.9 (<LOD-16.0)	20.0 (16.0-25.0)	992
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	624
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	20.3 (17.0-31.1)	31.5 (21.4-66.0)	400
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	12.5 (<LOD-14.7)	18.1 (14.3-20.8)	715

< LOD means less than the limit of detection, which averaged 6.4 ng/g of lipid (SD 2.0, maximum value 12.5).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 101. PCB 101 (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1929
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	669
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1260
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	918
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1011
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	634
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	413
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	724

< LOD means less than the limit of detection, which averaged 13.2 ng/g of lipid (SD 4.2, maximum value 25.7).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 102. PCB 105 (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1915
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	665
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1250
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	913
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1002
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	635
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	12.8 (<LOD-18.0)	409
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	714

< LOD means less than the limit of detection, which averaged 6.4 ng/g of lipid (SD 2.0, maximum value 12.5).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 103. PCB 118 (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	13.1 (<LOD-15.1)	27.0 (22.1-30.9)	40.3 (32.0-48.6)	1926
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	667
20 years and older	*	< LOD	< LOD	< LOD	14.7 (12.9-17.2)	28.0 (24.4-33.5)	43.6 (34.5-53.3)	1259
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	19.6 (16.5-24.4)	28.0 (23.4-38.3)	919
Females	*	< LOD	< LOD	< LOD	16.7 (14.1-18.8)	32.0 (27.5-40.3)	46.8 (40.3-57.8)	1007
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	17.0 (14.1-18.3)	23.7 (20.9-27.1)	636
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	18.9 (12.8-24.2)	38.6 (28.4-53.2)	59.7 (44.1-84.4)	413
Non-Hispanic whites	*	< LOD	< LOD	< LOD	13.1 (<LOD-16.3)	25.6 (20.7-32.0)	40.3 (29.1-47.9)	720

< LOD means less than the limit of detection, which averaged 6.4 ng/g of lipid (SD 2.0, maximum value 12.5).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 104. PCB 128 (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1927
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	668
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1259
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	917
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1010
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	636
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	409
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	725

< LOD means less than the limit of detection, which averaged 6.4 ng/g of lipid (SD 2.0, maximum value 12.5).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 105. PCB 138 (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval) 10th	25th	50th	75th	90th	95th	Sample size
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	49.2 (42.3-57.3)	70.8 (59.3-83.7)	1930
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	669
20 years and older	*	< LOD	< LOD	< LOD	< LOD	54.7 (46.0-62.3)	72.8 (65.3-90.5)	1261
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	47.2 (<LOD-59.0)	68.2 (54.5-88.3)	918
Females	*	< LOD	< LOD	< LOD	< LOD	52.8 (45.0-61.1)	72.0 (61.2-85.6)	1012
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	636
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	72.1 (61.7-97.8)	122 (83.6-200)	412
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	49.3 (<LOD-56.0)	70.1 (55.7-85.2)	727

< LOD means less than the limit of detection, which averaged 21.1 ng/g of lipid (SD 6.7, maximum value 41.1).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 106. PCB 146 (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	13.3 (<LOD-15.7)	1923
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	667
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	14.2 (<LOD-17.1)	1256
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	915
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	13.4 (<LOD-16.2)	1008
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	633
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	16.9 (13.5-22.4)	28.1 (17.6-44.3)	412
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	723

< LOD means less than the limit of detection, which averaged 6.4 ng/g of lipid (SD 2.0, maximum value 12.4).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 107. PCB 153 (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval) 10th	25th	50th	75th	90th	95th	Sample size
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	77.8 (67.9-88.8)	112 (93.0-128)	1926
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	668
20 years and older	*	< LOD	< LOD	< LOD	< LOD	83.2 (72.8-97.0)	122 (98.9-139)	1258
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	75.0 (64.2-89.0)	111 (83.9-137)	917
Females	*	< LOD	< LOD	< LOD	< LOD	79.0 (69.2-93.0)	118 (93.0-139)	1009
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	67.5 (56.8-76.0)	634
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	59.1 (<LOD-82.6)	121 (101-146)	176 (125-299)	412
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	76.4 (67.2-87.3)	102 (86.2-128)	725

< LOD means less than the limit of detection, which averaged 28.6 ng/g of lipid (SD 9.0, maximum value 55.6).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 108. PCB 156 (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	12.5 (<LOD-14.6)	16.5 (14.9-18.7)	1907
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	665
20 years and older	*	< LOD	< LOD	< LOD	< LOD	13.5 (<LOD-15.8)	17.5 (15.8-20.1)	1242
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	12.6 (<LOD-14.6)	16.0 (13.8-18.7)	912
Females	*	< LOD	< LOD	< LOD	< LOD	12.8 (<LOD-15.8)	16.3 (14.2-21.3)	995
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	631
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	14.6 (<LOD-18.6)	21.6 (16.0-33.0)	412
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	13.6 (<LOD-15.8)	17.4 (15.8-19.8)	711

< LOD means less than the limit of detection, which averaged 6.4 ng/g of lipid (SD 2.0, maximum value 12.5).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 109. PCB 157 (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1897
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	654
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1243
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	901
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	996
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	622
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	405
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	716

< LOD means less than the limit of detection, which averaged 6.4 ng/g of lipid (SD 2.0, maximum value 12.5).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 110. PCB 167 (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1908
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	666
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1242
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	908
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1000
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	627
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	411
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	715

< LOD means less than the limit of detection, which averaged 6.4 ng/g of lipid (SD 2.0, maximum value 12.5).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 111. PCB 170 (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	23.6 (21.6-25.8)	30.9 (26.5-36.6)	1798
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	645
20 years and older	*	< LOD	< LOD	< LOD	< LOD	24.9 (22.4-27.2)	33.9 (28.2-38.3)	1153
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	23.8 (22.0-26.3)	32.6 (27.2-41.9)	863
Females	*	< LOD	< LOD	< LOD	< LOD	22.4 (19.1-25.8)	29.7 (25.6-37.3)	935
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	23.2 (20.2-26.6)	606
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	30.9 (21.0-36.9)	39.6 (33.4-60.6)	382
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	24.0 (21.9-26.1)	31.0 (26.5-37.5)	658

< LOD means less than the limit of detection, which averaged 8.9 ng/g of lipid (SD 2.8, maximum value 17.2).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 112. PCB 172 (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1901
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	660
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1241
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	911
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	990
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	630
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	409
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	706

< LOD means less than the limit of detection, which averaged 6.4 ng/g of lipid (SD 2.0, maximum value 12.5).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 113. PCB 177 (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1873
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	653
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1220
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	887
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	986
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	622
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	399
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	698

< LOD means less than the limit of detection, which averaged 6.4 ng/g of lipid (SD 2.0, maximum value 12.5).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 114. PCB 178 (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1932
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	669
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1263
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	919
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1013
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	635
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	415
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	724

< LOD means less than the limit of detection, which averaged 6.4 ng/g of lipid (SD 2.0, maximum value 12.4).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 115. PCB 180 (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	37.4 (33.6-41.0)	62.0 (55.8-68.2)	79.0 (70.8-91.7)	1924
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	667
20 years and older	*	< LOD	< LOD	< LOD	41.0 (37.6-45.2)	65.5 (58.6-71.2)	83.8 (75.6-96.3)	1257
Gender								
Males	*	< LOD	< LOD	< LOD	40.5 (34.8-44.7)	65.1 (58.6-71.4)	83.8 (72.6-97.0)	919
Females	*	< LOD	< LOD	< LOD	34.4 (30.9-38.6)	56.7 (50.9-66.6)	74.6 (66.7-85.9)	1005
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	41.7 (33.2-50.5)	56.6 (48.0-65.0)	633
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	39.1 (32.4-48.2)	78.4 (63.1-102)	117 (89.4-160)	414
Non-Hispanic whites	*	< LOD	< LOD	< LOD	39.9 (35.9-45.0)	62.0 (56.2-68.8)	79.0 (69.5-91.9)	719

< LOD means less than the limit of detection, which averaged 14.5 ng/g of lipid (SD 4.6, maximum value 28.2).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 116. PCB 183 (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1928
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	668
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1260
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	919
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1009
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	635
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	413
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	722

< LOD means less than the limit of detection, which averaged 6.4 ng/g of lipid (SD 2.0, maximum value 12.5).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 117. PCB 187

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	17.7 (16.3-19.3)	24.6 (22.0-27.6)	1930
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	667
20 years and older	*	< LOD	< LOD	< LOD	< LOD	19.2 (17.0-21.5)	25.9 (24.1-29.4)	1263
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	17.7 (15.8-19.5)	25.9 (19.7-30.2)	917
Females	*	< LOD	< LOD	< LOD	< LOD	17.7 (15.7-20.4)	24.2 (21.8-26.4)	1013
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	17.3 (15.1-19.1)	636
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	15.3 (<LOD-21.1)	31.1 (26.0-39.0)	47.1 (35.6-76.4)	412
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	16.8 (14.9-18.6)	22.0 (19.3-24.3)	727

< LOD means less than the limit of detection, which averaged 6.4 ng/g of lipid (SD 2.0, maximum value 12.4).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Phytoestrogens

General Information

Phytoestrogens are naturally occurring chemical constituents of certain plants that have estrogenic, and in some cases, antiestrogenic or antiandrogenic activity in animals and humans. Isoflavones and lignans are two major groups of phytoestrogens found in the human diet.

Isoflavones include daidzein, genistein, O-desmethylangolensin, equol, and others. Plant sources of isoflavones include legumes, such as soybeans and soy-based products. Formononectin and biochanin A are methylated isoflavones found in clovers and are metabolized to daidzein and genistein. Daidzein is further metabolized to O-desmethylangolensin by the body and to equol by intestinal bacteria.

Lignans include matairesinol, secoisolariciresinol, enterolactone, enterodiol, and others. Sources for lignans include whole grains, flax, and some fruits and vegetables. Matairesinol is metabolized to enterolactone. Enterodiol may be metabolized from secoisolariciresinol or interconverted with enterolactone.

Naringenin (precursor to genistein) and hesperetin are flavinoids found in higher amounts in citrus fruits. Resveratrol and *trans*-resveratrol are phytoestrogens present in grape skins and wine.

Diet is the primary source of phytoestrogens. They are ingested in their natural beta-glycosidic forms, which are hydrolyzed to their aglycones in the intestine, absorbed, and then glucuronidated in the intestinal wall. The major circulating forms of the isoflavones are actually the glucuronidated metabolites (Setchell et al., 2001), and glucuronidated forms also predominate in the urine (Adlercreutz et al., 1995*b*).

Generally, phytoestrogens are much less potent than the endogenously produced estrogens, but phtyoestrogens can be present in much greater quantities. Phytoestrogens have not been found to be acutely toxic in large-dose animal testing but have caused reduced reproductive capability in animals at chronic dietary doses. A few animal studies have suggested that phytoestrogens alter the fetal hormonal environment when present during gestation. Some actions of phytoestrogens are thought to occur through pathways other than interaction with estrogen receptors (Adlercreutz et al., 1995*a*; Dixon and Ferreira, 2002). In vitro, the various phytoestrogens can either inhibit or promote cancer-cell growth. Isoflavones are also considered antioxidants and have been studied for their effects on atherogenic blood lipids. Many of the different phytoestrogens have been tested for mutagenic activity in vitro and do not appear to be mutagenic, but studies assessing the carcinogenicity of phytoestrogens have not been performed.

Comparisons of Western diets with Japanese diets, which include higher intakes in Japanese women of soy-based foods, suggest that the higher isoflavone intake may account for the lower incidence of menopausal symptoms, such as hot flashes and osteoporosis. Hormone-dependent cancers of the breast and prostate also are lower in Japan than in other developed countries. In some observational studies, it was found that cancer incidence varied inversely with dietary phytoestrogen intake. However, genetic differences may account for some population differences. In addition, many other non-phytoestrogen flavinoid chemicals and vitamins present in plant foods that were not measured in these studies may also contribute to health outcomes. The effects of diets containing phytoestrogens on the incidence of breast and prostate cancer have primarily been studied in case-control designs and vary in outcome but with some suggestion of a protective benefit (Knowles et al., 2000; den Tonkelaar et al., 2001; Stattin et al., 2002; Ingram et al., 1997; Murkies et al., 2000). Potential anti-cancer benefits of phytoestrogens have previously been summarized by Adlercreutz et al. (1995*a*). Ingestion of isoflavones by people has shown varying effects on menstrual cycle, sex-hormone protein binding, pituitary responses, and bone density, depending on dose, type of phytoestrogen used, hormonal state of the subjects, and design of the studies (see, for example, Teede et al., 2001; Murkies et al., 2000; Xu et al., 2000; Hodgert et al., 2000; Safe et al., 2001; Nicholls et al., 2002; Kotsopoulos et al., 2000; Cassidy et al., 1994; Adlercreutz et al., 1995*a*; Kim et al., 2002).

Interpreting Urine Phytoestrogen Levels Reported in the Tables

Urine levels of phytoestrogens were measured in a subsample of NHANES participants aged 6 years and older. Subsamples were randomly selected within the specified age range to be a representative sample of the U.S. population. These phytoestrogen measurements represent the first general examination of the U.S. population. Smaller studies have shown much higher levels of isoflavones in Japanese men and women than levels found in this NHANES 1999-2000 subsample, primarily because of a diet higher in soy products and lower in whole grains and cereals. Japanese women consuming approximately 16 and 30 mg/day of daidzein, equol, and genistein excreted approximately 3,000-5,000 µg/L of each isoflavone in their urine (Arai et al., 2000). Intake of 60 grams/day of soy powder by female subjects (n = 29) over a three-month period increased urinary levels of genistein, daidzein, and equol more than 13-fold over the baseline (unsupplemented) concentrations of 322, 42, 224, and 114 µg/L for enterolactone, equol, daidzein, and genistein, respectively (Albertazzi et al., 1999). The relation between the dose and urinary excretion is linear for many of the phytoestrogens studied, except for equol (Karr et al., 1997; Slavin et al., 1998; Lampe et al., 1999). Because excretory half-lives are reported to be in the range of 3-10 hours (Lu et al., 1995; Setchell et al., 2001), urinary concentrations reflect recent consumption. Urinary phytoestrogens have been measured to verify intake for several case-control studies. Levels in those control groups (varying with the base diet and population studied) were also much lower than levels in people consuming Japanese or high phytoestrogen diets although they were similar to or slightly higher than levels reported here.

In this NHANES 1999-2000 subsample, enterolactone showed the highest concentrations of any of the phytoestrogens measured, a finding which is consistent with a general U.S. diet that is higher in whole grains or cereals than in soybean sources of phytoestrogens. Geometric mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, and urinary creatinine. Urinary enterodiol and enterolactone levels were slightly higher for non-Hispanic whites than for Mexican Americans. Non-Hispanic blacks had lower enterodiol levels than non-Hispanic whites. Levels of the lignans have been previously reported to differ by race, with white females having higher concentrations than either Latina or African-American women (Horn-Ross et al., 1997). It is unknown whether these differences in race/ethnicity represent differences in exposure or metabolism.

Adjusted geometric mean genistein concentrations were higher in Mexican Americans than in non-Hispanic blacks. Mexican Americans had lower excretions of O-desmethylangolensin than either non-Hispanic whites or non-Hispanic blacks. There were no differences by race/ethnicity, gender, or age grouping for the excretion of the isoflavone, daidzein. Equol has more potent estrogen activity than its parent, daidzein. Higher urinary concentrations of equol were seen in non-Hispanic whites than in non-Hispanic blacks or Mexican Americans. Some studies have described excreters and nonexcreters of equol. Equol excretion may possibly depend on diet and the type of intestinal flora present (Hutchins et al., 1995; Karr et al., 1997; Setchell et al., 2001). No bimodality was apparent in the distribution of either equol concentrations or the equol/daidzein ratio in this NHANES subsample.

Finding a measurable amount of one or more of the phytoestrogens in urine does not mean that the level of one or more of these causes an adverse health effect. Whether the concentrations of the phytoestrogens reported here is a cause for health concern is not yet known; more research is needed. Measuring phytoestrogens at these levels in urine is possible because of advances in analytical chemistry. These levels provide physicians with reference levels so that they can determine whether people have been exposed to higher levels of phytoestrogens than to levels found in the general population. These data will also help scientists plan and conduct research on exposure and health effects.

Table 118. Phytoestrogens

Phytoestrogen	CAS number
Daidzein	486-66-8
Enterodiol	80226-00-2
Enterolactone	78473-71-9
Equol	531-95-3
Genistein	446-72-0
O-Desmethylangolensin	21255-69-6

Table 119. Daidzein

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	75.1 (64.7-87.1)	11.1 (9.30-12.8)	24.4 (22.1-29.2)	69.7 (59.8-78.7)	229 (183-299)	538 (462-710)	1310 (980-1580)	2554
Age group								
6-11 years	90.5 (70.8-116)	13.9 (9.41-21.9)	30.1 (22.9-39.7)	98.4 (71.3-139)	261 (194-375)	505 (437-765)	1130 (558-1770)	330
12-19 years	123 (98.8-154)	19.5 (16.8-26.2)	44.1 (35.8-55.1)	123 (92.9-160)	325 (264-407)	776 (483-1260)	1440 (964-2050)	753
20 years and older	67.6 (56.4-80.9)	9.89 (7.82-11.7)	22.4 (19.5-26.9)	60.9 (51.8-71.7)	215 (154-262)	518 (432-702)	1320 (838-1580)	1471
Gender								
Males	88.9 (76.1-104)	13.7 (11.5-17.6)	30.1 (24.6-37.9)	80.6 (70.8-101)	262 (217-328)	573 (510-935)	1540 (980-2080)	1220
Females	64.1 (51.9-79.2)	9.42 (7.69-11.6)	20.5 (17.9-26.9)	57.8 (46.8-72.1)	199 (142-259)	476 (389-722)	1220 (557-1530)	1334
Race/ethnicity								
Mexican Americans	79.0 (66.8-93.3)	11.2 (8.96-13.4)	23.4 (20.4-26.7)	66.7 (52.4-82.1)	249 (201-341)	800 (585-968)	1270 (978-2260)	817
Non-Hispanic blacks	91.9 (72.0-117)	13.6 (10.6-17.2)	29.6 (23.3-39.5)	101 (81.6-139)	286 (233-368)	545 (462-640)	1190 (756-1700)	607
Non-Hispanic whites	74.3 (63.7-86.6)	11.2 (9.30-13.9)	24.8 (22.2-29.8)	65.9 (57.5-75.0)	216 (157-287)	510 (432-772)	1360 (945-1740)	916

Table 120. Daidzein (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	68.5 (58.9-79.6)	10.5 (8.90-12.2)	23.2 (19.9-27.6)	65.1 (54.9-78.3)	204 (163-240)	555 (478-624)	944 (807-1260)	2554
Age group								
6-11 years	92.6 (73.6-116)	16.2 (11.1-22.7)	30.1 (25.3-49.2)	92.9 (67.9-118)	251 (158-319)	529 (359-838)	1030 (677-2150)	330
12-19 years	83.1 (63.7-108)	12.2 (8.18-18.6)	28.5 (22.6-36.4)	83.9 (56.0-113)	207 (162-304)	628 (386-944)	1000 (726-1530)	753
20 years and older	63.8 (53.7-75.8)	9.71 (7.86-11.8)	21.2 (18.0-26.3)	59.3 (50.2-72.4)	194 (150-235)	554 (468-624)	908 (714-1290)	1471
Gender								
Males	69.7 (58.6-82.8)	11.2 (8.91-13.2)	25.0 (19.7-28.0)	70.2 (54.8-82.5)	197 (158-247)	620 (497-807)	1050 (836-1400)	1220
Females	67.4 (55.4-82.1)	9.92 (8.06-13.0)	22.4 (18.4-29.9)	61.4 (51.9-79.9)	207 (155-249)	495 (372-624)	838 (610-1410)	1334
Race/ethnicity								
Mexican Americans	72.5 (62.6-83.9)	9.73 (8.47-11.7)	20.4 (17.3-25.3)	64.2 (47.1-91.1)	243 (195-303)	674 (492-944)	1360 (885-2370)	817
Non-Hispanic blacks	59.1 (47.3-73.8)	7.38 (5.36-10.7)	21.3 (15.4-29.6)	66.9 (52.1-86.1)	171 (129-216)	377 (291-562)	797 (552-1020)	607
Non-Hispanic whites	72.8 (62.5-84.7)	12.1 (10.4-15.1)	26.0 (21.6-30.3)	67.5 (58.0-79.6)	207 (162-249)	555 (464-628)	908 (701-1410)	916

Table 121. Enterodiol

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	26.6 (22.8-31.1)	2.94 (<LOD-4.52)	11.8 (9.50-14.5)	34.0 (29.9-37.9)	78.7 (67.0-90.9)	165 (138-196)	266 (229-288)	2527
Age group								
6-11 years	26.5 (19.8-35.4)	3.92 (<LOD-6.85)	13.8 (7.55-18.6)	29.4 (21.5-42.2)	77.6 (51.7-91.8)	193 (103-276)	276 (142-375)	327
12-19 years	29.8 (24.1-36.7)	4.18 (2.46-6.94)	14.0 (9.86-21.1)	33.9 (29.0-40.7)	83.9 (61.6-101)	166 (119-219)	247 (170-337)	744
20 years and older	26.1 (22.1-30.8)	2.60 (<LOD-4.47)	11.1 (8.59-14.0)	34.3 (30.0-38.5)	78.2 (67.0-89.9)	160 (135-195)	261 (219-288)	1456
Gender								
Males	25.3 (21.0-30.4)	2.92 (<LOD-4.51)	11.4 (7.70-15.2)	33.0 (28.4-37.3)	72.6 (58.2-87.7)	149 (110-215)	258 (175-278)	1206
Females	27.9 (23.3-33.5)	3.13 (<LOD-5.52)	12.0 (9.99-15.3)	36.0 (29.4-40.5)	84.4 (69.9-98.8)	174 (142-219)	279 (229-335)	1321
Race/ethnicity								
Mexican Americans	21.7 (18.4-25.6)	< LOD	9.36 (7.43-11.5)	28.0 (23.7-34.9)	70.4 (60.8-78.8)	143 (120-169)	213 (168-282)	791
Non-Hispanic blacks	25.8 (21.7-30.8)	4.33 (2.46-5.97)	11.5 (9.97-14.5)	31.2 (24.4-36.5)	66.0 (50.6-84.4)	157 (116-219)	260 (172-348)	608
Non-Hispanic whites	29.2 (24.5-34.8)	3.53 (1.80-5.38)	13.2 (9.64-17.1)	37.5 (31.7-43.5)	85.8 (71.1-97.5)	171 (138-228)	270 (226-307)	914

< LOD means less than the limit of detection, which is 0.8 µg/L.

Table 122. Enterodiol (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	24.2 (21.0-28.0)	2.68 (2.05-3.78)	10.9 (9.06-13.1)	29.9 (26.3-33.6)	70.5 (60.2-81.6)	146 (124-177)	240 (197-321)	2527
Age group								
6-11 years	27.0 (21.1-34.6)	3.15 (1.46-7.29)	13.6 (9.13-15.3)	33.7 (23.1-42.2)	62.7 (47.9-91.1)	150 (83.2-260)	290 (150-411)	327
12-19 years	20.1 (17.0-23.7)	2.36 (1.58-3.94)	9.69 (7.70-12.3)	24.1 (20.8-28.6)	55.0 (43.0-71.4)	99.5 (91.3-121)	158 (106-184)	744
20 years and older	24.7 (20.9-29.0)	2.65 (1.92-3.90)	10.9 (8.47-13.4)	30.6 (26.3-34.5)	72.7 (62.5-84.5)	155 (129-184)	240 (199-344)	1456
Gender								
Males	19.8 (16.5-23.8)	2.34 (1.24-3.01)	8.65 (6.66-11.2)	25.4 (21.4-30.0)	55.1 (47.6-63.7)	121 (96.4-167)	197 (151-260)	1206
Females	29.3 (24.8-34.7)	3.56 (2.05-5.68)	13.5 (10.5-15.3)	34.9 (29.5-41.8)	85.2 (72.7-98.3)	164 (132-216)	321 (220-371)	1321
Race/ethnicity								
Mexican Americans	19.6 (16.5-23.3)	< LOD	8.69 (6.35-11.1)	23.5 (20.4-27.7)	59.6 (50.0-76.3)	134 (114-154)	193 (154-230)	791
Non-Hispanic blacks	16.6 (14.0-19.6)	2.40 (.994-3.46)	6.91 (5.35-9.31)	18.8 (14.3-23.0)	47.3 (37.7-55.8)	113 (88.0-143)	165 (134-237)	608
Non-Hispanic whites	28.6 (24.4-33.5)	3.33 (2.48-5.91)	13.5 (10.9-15.6)	33.8 (29.5-38.6)	75.8 (64.1-91.3)	162 (128-203)	252 (199-370)	914

< LOD means less than the limit of detection (see previous table).

Table 123. Enterolactone

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	239 (204-281)	25.4 (18.8-38.9)	107 (83.8-126)	315 (248-377)	726 (616-850)	1970 (1490-2330)	2790 (2480-3070)	2548
Age group								
6-11 years	308 (232-408)	46.5 (19.1-117)	161 (114-211)	353 (283-434)	721 (596-1250)	1730 (1250-2440)	2840 (1730-3350)	331
12-19 years	250 (201-311)	29.6 (13.7-55.3)	122 (84.3-162)	317 (254-380)	670 (486-840)	1760 (984-2480)	2900 (1900-4420)	746
20 years and older	230 (194-273)	23.3 (16.7-37.5)	98.4 (76.5-118)	310 (239-381)	728 (608-879)	1980 (1530-2330)	2790 (2530-3540)	1471
Gender								
Males	254 (212-305)	24.0 (17.5-35.7)	110 (79.0-137)	351 (266-417)	778 (636-959)	1980 (1610-2340)	2730 (2430-3440)	1219
Females	226 (181-283)	31.5 (13.7-51.0)	105 (77.1-129)	287 (236-338)	684 (539-824)	1880 (1240-2420)	2830 (2280-3880)	1329
Race/ethnicity								
Mexican Americans	212 (164-274)	30.7 (10.4-43.9)	99.6 (73.3-123)	281 (231-332)	631 (531-740)	1650 (896-2260)	2690 (2120-3720)	813
Non-Hispanic blacks	262 (208-328)	31.8 (12.3-57.8)	132 (104-163)	360 (312-417)	759 (657-861)	1710 (1150-2290)	2500 (1980-3280)	605
Non-Hispanic whites	247 (200-304)	24.1 (16.9-43.8)	105 (78.0-132)	317 (242-400)	751 (599-956)	2040 (1400-2530)	2950 (2530-3640)	916

Table 124. Enterolactone (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	218 (186-257)	21.4 (14.0-31.2)	91.2 (76.2-107)	284 (250-329)	733 (617-867)	1570 (1280-1850)	2240 (1880-2770)	2548
Age group								
6-11 years	315 (246-403)	69.3 (41.3-91.9)	146 (103-208)	384 (278-431)	703 (564-1020)	1570 (1020-2010)	2100 (1580-3410)	331
12-19 years	169 (138-206)	17.9 (11.9-29.3)	80.5 (64.0-101)	208 (172-254)	484 (394-596)	1150 (815-1540)	1850 (1310-2320)	746
20 years and older	217 (181-261)	18.6 (11.1-28.1)	85.8 (72.1-105)	288 (249-350)	785 (653-923)	1610 (1350-1890)	2300 (1930-2950)	1471
Gender								
Males	199 (168-236)	18.7 (13.3-27.4)	82.2 (69.2-104)	263 (234-308)	664 (531-810)	1380 (1180-1780)	2010 (1790-2320)	1219
Females	238 (191-297)	27.9 (13.1-44.2)	101 (75.4-131)	302 (254-381)	819 (653-973)	1690 (1420-1990)	2550 (1930-3410)	1329
Race/ethnicity								
Mexican Americans	194 (154-245)	21.2 (10.7-33.2)	92.4 (64.5-125)	254 (211-305)	605 (478-738)	1340 (913-1860)	2100 (1550-2800)	813
Non-Hispanic blacks	168 (132-214)	25.4 (7.33-40.8)	87.4 (63.5-112)	212 (183-253)	539 (424-664)	1130 (937-1440)	1590 (1290-1970)	605
Non-Hispanic whites	241 (195-300)	20.3 (13.1-36.4)	96.0 (74.6-132)	323 (270-393)	828 (653-1040)	1780 (1410-2020)	2480 (1980-3330)	916

Table 125. Equol

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	8.37 (7.03-9.97)	< LOD	< LOD	8.02 (5.98-10.1)	17.2 (14.5-20.5)	35.0 (29.6-39.7)	53.5 (41.6-71.7)	2182
Age group								
6-11 years	10.5 (7.77-14.1)	< LOD	4.52 (<LOD-6.61)	11.2 (6.11-17.5)	24.9 (17.3-29.5)	34.4 (28.6-56.1)	54.8 (31.0-76.3)	272
12-19 years	10.9 (8.54-13.9)	< LOD	4.53 (<LOD-6.96)	10.7 (8.28-13.8)	22.0 (16.2-34.8)	42.9 (35.4-68.7)	71.6 (48.2-147)	657
20 years and older	7.79 (6.59-9.22)	< LOD	< LOD	7.43 (5.52-9.17)	16.0 (12.9-18.7)	33.1 (26.4-37.7)	52.2 (37.5-75.3)	1253
Gender								
Males	9.15 (7.33-11.4)	< LOD	3.08 (<LOD-4.64)	8.44 (6.11-11.9)	19.0 (15.9-24.0)	35.6 (30.2-48.7)	71.3 (45.2-112)	1042
Females	7.70 (6.54-9.07)	< LOD	< LOD	7.57 (5.64-9.28)	15.6 (12.6-19.0)	33.5 (26.4-37.7)	48.2 (37.5-58.7)	1140
Race/ethnicity								
Mexican Americans	5.24 (4.81-5.71)	< LOD	< LOD	4.49 (3.77-5.11)	9.44 (7.90-10.5)	18.5 (13.7-23.1)	30.9 (22.3-47.6)	726
Non-Hispanic blacks	6.73 (5.46-8.30)	< LOD	< LOD	6.24 (4.09-9.95)	15.1 (12.7-17.6)	27.6 (21.1-32.7)	36.4 (30.2-47.6)	514
Non-Hispanic whites	9.26 (7.47-11.5)	< LOD	3.63 (<LOD-5.04)	8.95 (6.43-12.3)	19.0 (15.7-23.7)	36.1 (30.1-45.4)	56.1 (45.2-75.3)	757

< LOD means less than the limit of detection, which is 3.0 µg/L.

Table 126. Equol (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	7.70 (6.51-9.12)	< LOD	< LOD	7.96 (6.42-9.73)	16.2 (12.5-19.5)	30.6 (26.1-37.1)	50.3 (41.2-69.9)	2182
Age group								
6-11 years	10.3 (7.71-13.7)	< LOD	4.38 (2.87-7.94)	11.4 (7.64-16.3)	22.6 (12.7-30.6)	31.5 (25.5-48.1)	47.8 (32.7-150)	272
12-19 years	7.61 (6.11-9.47)	< LOD	3.55 (2.86-4.82)	8.02 (6.24-9.87)	13.9 (11.4-20.4)	27.3 (21.0-37.3)	47.4 (28.2-79.0)	657
20 years and older	7.45 (6.29-8.82)	< LOD	< LOD	7.63 (5.99-9.54)	15.3 (12.3-18.3)	30.8 (25.0-37.2)	51.6 (41.1-71.8)	1253
Gender								
Males	7.01 (5.75-8.54)	< LOD	2.87 (2.02-3.78)	7.31 (5.45-9.18)	13.8 (11.6-17.6)	29.3 (21.4-41.8)	54.1 (35.8-81.0)	1042
Females	8.41 (7.13-9.93)	< LOD	< LOD	8.65 (7.08-10.3)	17.4 (14.0-21.5)	31.6 (26.3-37.5)	46.0 (38.8-57.0)	1140
Race/ethnicity								
Mexican Americans	4.89 (4.34-5.50)	< LOD	< LOD	4.73 (3.85-5.46)	8.83 (7.99-10.1)	22.3 (16.3-27.7)	36.8 (25.3-58.1)	726
Non-Hispanic blacks	4.36 (3.57-5.32)	< LOD	< LOD	4.57 (3.10-6.17)	10.2 (7.95-12.0)	17.1 (14.8-19.8)	25.6 (19.6-32.0)	514
Non-Hispanic whites	9.13 (7.41-11.3)	< LOD	4.24 (2.99-5.73)	9.38 (7.31-11.7)	18.0 (14.0-22.6)	35.1 (28.8-41.8)	56.5 (43.8-78.5)	757

< LOD means less than the limit of detection (see previous table).

Table 127. Genistein

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	24.4 (20.5-29.1)	1.91 (.670-3.05)	8.67 (7.24-10.3)	27.0 (22.9-31.6)	93.6 (74.4-119)	284 (229-353)	562 (413-734)	2557
Age group								
6-11 years	27.6 (21.4-35.7)	3.30 (1.26-6.81)	8.15 (6.81-10.6)	31.9 (18.5-39.5)	104 (67.6-151)	218 (151-318)	376 (234-725)	331
12-19 years	43.7 (35.0-54.4)	6.04 (3.65-9.60)	17.2 (12.8-21.7)	45.4 (34.7-59.5)	137 (93.7-184)	319 (257-446)	547 (363-753)	754
20 years and older	21.9 (17.6-27.1)	1.26 (<LOD-2.80)	8.09 (5.94-9.50)	24.0 (21.1-28.7)	86.2 (61.6-119)	284 (217-362)	566 (393-797)	1472
Gender								
Males	29.8 (24.2-36.6)	2.85 (1.56-4.28)	10.1 (8.12-12.1)	31.8 (27.1-36.9)	108 (80.1-151)	335 (256-440)	709 (443-981)	1222
Females	20.3 (16.4-25.1)	1.10 (<LOD-2.64)	7.39 (5.11-9.46)	23.1 (18.7-28.4)	84.7 (55.6-113)	235 (193-303)	427 (339-674)	1335
Race/ethnicity								
Mexican Americans	31.1 (26.3-36.8)	3.35 (2.01-4.32)	9.97 (8.51-12.3)	30.0 (25.1-37.5)	117 (95.8-153)	328 (247-494)	570 (479-893)	819
Non-Hispanic blacks	26.7 (20.1-35.3)	1.70 (<LOD-4.80)	10.4 (6.30-14.9)	32.8 (26.3-39.4)	103 (77.3-143)	252 (209-367)	495 (346-898)	608
Non-Hispanic whites	23.6 (19.2-29.0)	1.69 (.500-3.10)	8.55 (6.89-10.3)	25.3 (22.0-31.6)	90.4 (66.8-124)	288 (217-371)	525 (355-797)	916

< LOD means less than the limit of detection, which is 0.3 µg/L.

Table 128. Genistein (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	22.3 (18.7-26.5)	1.99 (1.13-3.16)	7.64 (6.39-9.01)	23.8 (19.3-28.4)	84.7 (69.1-103)	222 (190-274)	380 (323-524)	2557
Age group								
6-11 years	28.3 (21.8-36.6)	3.66 (1.86-6.91)	10.4 (7.44-12.8)	27.8 (16.8-40.7)	94.3 (65.6-145)	206 (154-286)	490 (255-895)	331
12-19 years	29.4 (23.1-37.4)	4.07 (2.45-6.26)	11.2 (7.51-15.3)	32.0 (23.8-41.6)	83.2 (65.7-101)	181 (134-264)	336 (199-737)	754
20 years and older	20.6 (16.8-25.3)	1.62 (.724-2.98)	6.85 (5.48-8.58)	21.6 (17.3-26.9)	83.1 (65.4-105)	234 (190-287)	381 (325-562)	1472
Gender								
Males	23.3 (18.6-29.3)	2.28 (1.34-4.02)	7.75 (6.19-9.50)	23.8 (18.3-31.2)	86.1 (67.6-114)	234 (190-323)	523 (317-889)	1222
Females	21.3 (17.6-25.9)	1.90 (1.00-3.00)	7.56 (5.66-9.68)	22.9 (17.4-29.5)	83.1 (62.7-104)	209 (161-282)	357 (273-435)	1335
Race/ethnicity								
Mexican Americans	28.4 (24.0-33.7)	3.14 (1.93-4.26)	8.12 (5.99-10.1)	27.9 (21.8-36.3)	109 (91.5-137)	257 (215-344)	562 (323-844)	819
Non-Hispanic blacks	17.1 (13.2-22.2)	1.32 (.329-3.68)	6.81 (5.01-8.69)	19.5 (15.7-25.0)	59.0 (43.1-93.0)	178 (130-245)	299 (222-427)	608
Non-Hispanic whites	23.1 (18.9-28.4)	2.00 (1.00-3.77)	8.11 (6.26-10.2)	24.8 (19.0-30.5)	86.1 (67.6-105)	232 (178-295)	381 (318-593)	916

Table 129. O-Desmethylangolensin

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	4.34 (3.55-5.32)	< LOD	.750 (.310-1.15)	4.88 (3.92-5.93)	22.7 (18.7-29.9)	100 (74.8-146)	217 (154-275)	2295
Age group								
6-11 years	5.33 (3.82-7.45)	< LOD	.920 (.400-2.42)	6.93 (3.93-11.6)	36.2 (20.3-45.0)	78.7 (45.8-176)	176 (74.8-264)	290
12-19 years	5.96 (4.09-8.68)	< LOD	1.23 (<LOD-2.58)	7.58 (5.37-12.2)	36.4 (24.3-51.8)	106 (74.1-140)	194 (123-228)	677
20 years and older	4.02 (3.25-4.97)	< LOD	.700 (<LOD-1.08)	4.40 (3.40-5.42)	19.4 (16.2-25.5)	101 (70.5-155)	228 (150-322)	1328
Gender								
Males	4.94 (3.92-6.21)	< LOD	.780 (<LOD-1.26)	5.62 (4.50-8.03)	28.4 (20.7-40.3)	121 (94.4-157)	234 (179-309)	1098
Females	3.85 (2.95-5.03)	< LOD	.690 (<LOD-1.18)	4.21 (3.02-5.51)	19.1 (14.1-25.5)	83.8 (56.6-149)	191 (93.1-272)	1197
Race/ethnicity								
Mexican Americans	2.24 (1.66-3.03)	< LOD	< LOD	1.99 (1.33-2.88)	19.7 (9.90-27.4)	96.6 (57.4-137)	190 (125-317)	742
Non-Hispanic blacks	5.63 (4.20-7.53)	< LOD	.870 (<LOD-2.05)	8.43 (5.47-11.3)	33.2 (22.5-51.8)	108 (88.8-149)	177 (133-242)	540
Non-Hispanic whites	4.48 (3.57-5.62)	< LOD	.790 (.480-1.23)	4.96 (3.56-6.55)	22.5 (17.7-31.9)	103 (70.5-155)	228 (150-281)	827

< LOD means less than the limit of detection, which is 0.2 µg/L.

Table 130. O-Desmethylangolensin (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	3.97 (3.19-4.95)	< LOD	.776 (.560-1.05)	4.42 (3.40-5.73)	21.5 (17.3-28.0)	90.3 (60.6-125)	165 (125-235)	2295
Age group								
6-11 years	5.67 (4.00-8.02)	< LOD	1.30 (.556-2.50)	6.73 (4.23-12.8)	28.8 (18.8-39.0)	79.8 (47.7-130)	179 (83.3-262)	290
12-19 years	4.08 (2.62-6.36)	< LOD	.734 (.230-1.85)	5.63 (3.20-9.74)	26.0 (16.9-38.1)	71.4 (47.6-100)	115 (77.7-223)	677
20 years and older	3.79 (3.05-4.71)	< LOD	.724 (.551-.971)	3.89 (2.91-5.34)	20.2 (13.9-25.8)	96.5 (57.6-140)	165 (125-270)	1328
Gender								
Males	3.92 (3.07-5.00)	< LOD	.720 (.359-1.16)	4.46 (3.29-6.02)	24.5 (16.9-33.4)	96.5 (62.4-123)	209 (131-262)	1098
Females	4.03 (3.06-5.29)	< LOD	.782 (.605-1.13)	4.17 (3.10-6.20)	19.8 (14.3-26.7)	83.3 (49.7-140)	155 (90.3-220)	1197
Race/ethnicity								
Mexican Americans	2.03 (1.52-2.72)	< LOD	< LOD	1.76 (1.13-2.67)	13.9 (11.1-25.2)	67.3 (54.0-95.5)	136 (97.9-218)	742
Non-Hispanic blacks	3.58 (2.67-4.81)	< LOD	.612 (.165-1.24)	5.20 (3.37-7.33)	23.4 (17.3-32.1)	67.1 (51.7-79.7)	115 (79.2-308)	540
Non-Hispanic whites	4.40 (3.45-5.60)	< LOD	.884 (.645-1.18)	4.65 (3.40-6.35)	22.2 (17.3-31.5)	102 (57.5-148)	170 (126-235)	827

< LOD means less than the limit of detection (see previous table).

Organophosphate Pesticides: Dialkyl Phosphate Metabolites

General Information

Organophosphate pesticides account for about half of the insecticides used in the United States. Approximately 60 million pounds of organophosphate pesticides are applied to about 60 million acres of U.S. agricultural crops annually; nonagricultural uses account for about 17 million pounds per year (U.S. EPA*a*). Organophosphate pesticides are active against a broad spectrum of insects and are used on food crops, in residential and commercial buildings, on ornamental plants and lawns, and for mosquito-vector control. Some chemicals in this class are also used in plastics manufacturing and do not have insecticidal properties.

Exposures may occur by ingestion, inhalation, or dermal contact. Ingestion of food contaminated with organophosphorus pesticides and contact during residential application are the main sources of exposure for the general population. However, farm workers, applicators, and manufacturers of these pesticides may have higher or acute exposures. The acute effects of the organophosphates from intentional and unintentional overdoses or from high-dose agricultural exposure are well known and include neurologic dysfunction that results from inhibition of acetylcholine breakdown in neural tissue. The dialkyl phosphates are metabolites of various organophosphate pesticides. The organophosphates, not the dialkyl phosphates, prevent acetylcholine breakdown by inhibiting the enzyme acetylcholinesterase. Dialkyl phosphates themselves are not considered toxic but rather are markers of exposure to organophosphates. Dialkyl phosphates may also be present in the environment from the degradation of organophosphates. Generally recognized guidelines for urinary levels of these metabolites have not been established.

About 75% of registered organophosphate pesticides will metabolize to measurable dialkyl phosphate metabolites (U.S. EPA*b*). This *Report* provides measurements in urine for the following six metabolites of organophosphate pesticides:

- Dimethylphosphate (DMP)
- Dimethylthiophosphate (DMTP)
- Dimethyldithiophosphate (DMDTP)
- Diethylphosphate (DEP)
- Diethylthiophosphate (DETP)
- Diethyldithiophosphate (DEDTP)

Table 131 shows the six urinary metabolites and their parent organophosphate pesticides. For example, chlorpyrifos metabolizes to both diethylphosphate and diethythiophosphate. Measurement of these metabolites reflects exposure to organophosphate pesticides that has occurred predominantly in the last few days. Each of the six urinary dialkyl phosphate metabolites can be produced from the metabolism of more than one organophosphate pesticide. In addition to reflecting exposure to the parent pesticides, the level of the metabolite in a person's urine may reflect exposure to the metabolite itself, if it was present in the person's environment.

Interpreting Urine Organophosphate Metabolite Levels Reported in the Tables

Urine levels of the dialkyl phosphate metabolites were measured in a subsample of NHANES participants aged 6-59 years. Subsamples were randomly selected within the specified age range to be a representative sample of the U.S. population. Levels of the six dialkyl phosphates reported here may result from exposure to a variety of organophosphate pesticides (see Table 131). Measurements of the urinary dialkyl phosphates (Tables 132-143) provide an estimate of exposure to various classes of these organophosphate pesticides; however, without additional information, linking these metabolites to specific pesticides is not possible. These data provide physicians with a reference range so that they can determine whether people have been exposed to higher levels of organophosphate pesticides than those found in the general population. These data will help scientists plan and conduct research about exposure to organophosphate pesticides and health effects. Finding a measurable amount of one or more metabolites in urine does not mean that the level of the organophosphate an adverse health effect. Whether organophosphate pesticides at the levels of the metabolites reported here are a cause for health concern is not known; more research is needed.

The measurement of dialkyl phosphates in urine has been used to document exposure of farmers, agricultural workers, pest-control workers, and others exposed to organophosphorus pesticides (Jauhiainen et al., 1992; Das et al., 1983; Davies and Peterson, 1997; Davies et al., 1982; Franklin et al., 1981; Takamiya, 1994; Brokopp, 1981; Morgan et al., 1977; Richter et al., 1992). In such occupational studies, levels of dialkyl phosphates often exceed levels seen in the general population by up to 50-fold. Generally, in workers, doses of the parent organophosphate pesticide have been shown to correlate with the urinary excretion of the dialkyl phosphate metabolites (Lauwerys and Hoet, 2001). Dialkyl phosphate metabolites can be present in urine following low-level organophosphate exposures that do not cause clinical symptoms (Davies and Peterson, 1997; Franklin et al., 1981).

Aprea et al. (1996) studied 124 people near Tuscany, Italy, and found that DMTP and DMP were the most frequently detected alkyl phosphates (99% and 87%, respectively). The geometric mean concentration for DMTP was sevenfold higher in the Italian study than the geometric mean of the NHANES 1999-2000 subsample.

Geometric mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, and urinary creatinine. Urinary DEP and DMPT levels in the group aged 6-11 years were higher than in the group aged 20-59 years. There were no other differences noted for race/ethnicity

Table 131. Organophosphate pesticides and their metabolites

Pesticide (CAS number)	**Dimethyl-phosphate** (813-79-5)	**Dimethylthio-phosphate** (1112-38-5)	**Dimethyldithio-phosphate** (756-80-9)	**Diethyl-phosphate** (598-02-7)	**Diethylthio-phosphate** (2465-65-8)	**Diethyldithio-phosphate** (298-06-6)
Azinphos methyl	•	•	•			
Chlorethoxyphos				•	•	
Chlorpyrifos				•	•	
Chlorpyrifos methyl	•	•				
Coumaphos				•	•	
Dichlorvos (DDVP)	•					
Diazinon				•	•	
Dicrotophos	•					
Dimethoate	•	•	•			
Disulfoton				•	•	•
Ethion				•	•	•
Fenitrothion	•	•				
Fenthion	•	•				
Isazaphos-methyl	•	•				
Malathion	•	•	•			
Methidathion	•	•	•			
Methyl parathion	•	•				
Naled	•					
Oxydemeton-methyl	•	•				
Parathion				•	•	
Phorate				•	•	•
Phosmet	•	•	•			
Pirimiphos-methyl	•	•				
Sulfotepp				•	•	
Temephos	•	•				
Terbufos				•	•	•
Tetrachlorviphos	•					
Trichlorfon	•					

or gender. In a study of 195 Italian children aged 6-7 years, Aprea et al. (2000) detected levels of DMTP in 94% of the children, and the geometric mean was about five times higher than for the NHANES 1999-2000 subsample in children aged 6-11 years. In addition, these investigators noted that levels in children were higher than levels in adults living in the same region of Italy.

Table 132. Dimethylphosphate

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	.740 (<LOD-1.30)	2.80 (2.10-3.90)	7.90 (5.90-9.50)	13.0 (9.50-21.0)	1949
Age group								
6-11 years	*	< LOD	< LOD	1.00 (.590-2.00)	4.40 (2.90-6.80)	10.0 (6.60-18.0)	21.0 (10.0-41.0)	471
12-19 years	*	< LOD	< LOD	.650 (<LOD-1.50)	3.80 (2.40-5.50)	9.90 (6.10-18.0)	22.0 (12.0-29.0)	664
20-59 years	*	< LOD	< LOD	.680 (<LOD-1.20)	2.60 (1.80-3.60)	6.50 (5.20-8.80)	9.70 (8.50-16.0)	814
Gender								
Males	*	< LOD	< LOD	.650 (<LOD-1.20)	2.80 (2.10-4.10)	7.90 (5.90-10.0)	18.0 (9.00-25.0)	952
Females	*	< LOD	< LOD	.780 (<LOD-1.40)	2.80 (2.00-4.00)	7.60 (5.40-9.50)	10.0 (8.50-15.0)	997
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	1.00 (<LOD-1.60)	3.80 (2.70-4.70)	9.50 (6.80-13.0)	15.0 (10.0-23.0)	672
Non-Hispanic blacks	*	< LOD	< LOD	.980 (.650-1.30)	3.60 (2.40-5.50)	8.90 (6.50-15.0)	21.0 (12.0-24.0)	509
Non-Hispanic whites	*	< LOD	< LOD	< LOD	2.90 (1.80-4.20)	7.90 (5.50-9.60)	10.0 (8.90-21.0)	594

< LOD means less than the limit of detection, which is 0.58 µg/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 133. Dimethylphosphate (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	.806 (.586-1.11)	2.93 (2.12-3.86)	8.46 (6.74-11.2)	16.1 (12.1-19.5)	1949
Age group								
6-11 years	*	< LOD	< LOD	1.38 (.889-2.38)	4.48 (2.63-8.20)	15.9 (7.65-21.7)	21.7 (16.7-45.1)	471
12-19 years	*	< LOD	< LOD	.586 (.451-.949)	2.27 (1.67-2.91)	7.70 (4.16-13.8)	14.5 (7.78-35.3)	664
20-59 years	*	< LOD	< LOD	.759 (.562-1.11)	2.87 (1.91-3.92)	8.11 (5.45-10.6)	14.6 (10.1-17.6)	814
Gender								
Males	*	< LOD	< LOD	.623 (.453-.886)	2.38 (1.78-3.23)	7.58 (4.64-11.6)	15.2 (9.74-19.5)	952
Females	*	< LOD	< LOD	1.00 (.677-1.50)	3.53 (2.35-5.00)	9.12 (7.59-12.2)	16.4 (10.4-21.4)	997
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	1.06 (.722-1.47)	3.68 (2.77-4.67)	9.41 (7.24-12.2)	15.9 (12.7-23.2)	672
Non-Hispanic blacks	*	< LOD	< LOD	.686 (.527-1.06)	2.67 (1.78-3.87)	7.07 (4.77-11.5)	13.9 (9.61-19.5)	509
Non-Hispanic whites	*	< LOD	< LOD	< LOD	3.15 (2.03-4.26)	8.73 (6.12-12.8)	15.8 (10.2-19.7)	594

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 134. Dimethylthiophosphate

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	1.82 (1.43-2.32)	< LOD	< LOD	2.70 (1.50-3.80)	10.0 (8.00-16.0)	38.0 (21.0-38.0)	46.0 (38.0-60.0)	1948
Age group								
6-11 years	2.72 (1.85-4.01)	< LOD	< LOD	4.10 (2.30-7.60)	20.0 (13.0-30.0)	40.0 (38.0-54.0)	62.0 (38.0-110)	471
12-19 years	2.53 (1.72-3.73)	< LOD	< LOD	3.60 (1.70-6.00)	16.0 (8.80-24.0)	37.0 (21.0-38.0)	69.0 (39.0-190)	664
20-59 years	1.59 (1.25-2.03)	< LOD	< LOD	2.20 (1.10-3.40)	9.10 (7.10-13.0)	38.0 (18.0-38.0)	38.0 (38.0-48.0)	813
Gender								
Males	2.10 (1.58-2.78)	< LOD	< LOD	3.40 (2.40-4.50)	13.0 (8.50-20.0)	38.0 (17.0-38.0)	41.0 (38.0-62.0)	952
Females	1.59 (1.20-2.11)	< LOD	< LOD	2.00 (.720-3.30)	9.70 (6.70-16.0)	38.0 (19.0-38.0)	52.0 (38.0-120)	996
Race/ethnicity								
Mexican Americans	1.79 (1.11-2.90)	< LOD	< LOD	2.00 (.600-4.30)	10.0 (6.60-16.0)	38.0 (26.0-79.0)	130 (41.0-230)	671
Non-Hispanic blacks	2.13 (1.38-3.28)	< LOD	< LOD	3.60 (1.60-5.60)	11.0 (8.30-18.0)	37.0 (25.0-38.0)	39.0 (38.0-88.0)	509
Non-Hispanic whites	1.77 (1.30-2.39)	< LOD	< LOD	2.60 (1.10-4.00)	10.0 (7.00-17.0)	37.0 (15.0-38.0)	45.0 (38.0-62.0)	594

< LOD means less than the limit of detection, which is 0.18 µg/L.

Table 135. Dimethylthiophosphate (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	1.64 (1.27-2.10)	< LOD	< LOD	2.12 (1.38-3.11)	9.57 (6.67-15.1)	32.0 (23.9-40.4)	51.0 (39.0-71.1)	1948
Age group								
6-11 years	2.95 (2.00-4.34)	< LOD	< LOD	5.25 (2.50-7.03)	18.7 (11.6-31.5)	45.2 (32.1-60.3)	65.9 (50.7-100)	471
12-19 years	1.71 (1.13-2.59)	< LOD	< LOD	2.14 (1.22-4.13)	13.4 (7.01-21.0)	36.0 (25.1-51.4)	61.5 (37.1-179)	664
20-59 years	1.47 (1.14-1.90)	< LOD	< LOD	1.90 (1.00-2.83)	8.09 (5.58-12.4)	27.0 (20.6-37.1)	47.4 (34.2-70.1)	813
Gender								
Males	1.61 (1.19-2.18)	< LOD	< LOD	2.28 (1.42-3.35)	9.27 (6.43-15.4)	28.9 (20.5-37.6)	41.1 (32.0-57.1)	952
Females	1.66 (1.24-2.21)	< LOD	< LOD	2.01 (.920-3.11)	10.0 (6.20-17.5)	34.5 (25.4-47.4)	69.5 (41.7-118)	996
Race/ethnicity								
Mexican Americans	1.60 (.962-2.67)	< LOD	< LOD	1.83 (.737-3.75)	10.4 (5.93-17.1)	37.0 (22.8-63.1)	112 (38.5-207)	671
Non-Hispanic blacks	1.45 (.948-2.23)	< LOD	< LOD	1.75 (1.01-3.38)	8.21 (4.65-12.4)	25.5 (17.9-38.8)	52.1 (25.5-97.6)	509
Non-Hispanic whites	1.68 (1.21-2.32)	< LOD	< LOD	2.20 (1.17-3.42)	9.27 (5.96-16.9)	32.5 (21.3-49.4)	54.4 (39.2-74.7)	594

< LOD means less than the limit of detection (see previous table).

Table 136. Dimethyldithiophosphate

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	< LOD	2.30 (1.40-3.60)	12.0 (5.40-17.0)	19.0 (17.0-37.0)	1949
Age group								
6-11 years	*	< LOD	< LOD	< LOD	4.30 (2.50-6.90)	16.0 (5.90-18.0)	32.0 (18.0-38.0)	471
12-19 years	*	< LOD	< LOD	< LOD	2.20 (1.30-4.50)	12.0 (6.20-17.0)	19.0 (12.0-52.0)	664
20-59 years	*	< LOD	< LOD	< LOD	2.10 (1.10-3.10)	10.0 (4.20-17.0)	16.0 (6.30-19.0)	814
Gender								
Males	*	< LOD	< LOD	< LOD	2.30 (1.30-4.30)	16.0 (5.80-17.0)	18.0 (17.0-32.0)	952
Females	*	< LOD	< LOD	< LOD	2.10 (1.30-3.20)	10.0 (4.50-17.0)	20.0 (13.0-40.0)	997
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	1.80 (1.20-2.30)	5.70 (4.00-9.70)	12.0 (6.80-17.0)	672
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	3.20 (1.70-6.50)	14.0 (7.00-18.0)	18.0 (17.0-39.0)	509
Non-Hispanic whites	*	< LOD	< LOD	< LOD	2.00 (.850-3.70)	13.0 (4.20-17.0)	18.0 (16.0-40.0)	594

< LOD means less than the limit of detection, which is 0.08 µg/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 137. Dimethyldithiophosphate (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	< LOD	1.86 (1.04-3.25)	10.1 (5.63-16.6)	21.7 (13.8-30.8)	1949
Age group								
6-11 years	*	< LOD	< LOD	< LOD	4.07 (2.34-7.00)	16.2 (9.25-27.0)	30.8 (20.2-38.9)	471
12-19 years	*	< LOD	< LOD	< LOD	1.52 (.636-3.37)	9.42 (4.02-16.8)	18.5 (8.76-44.8)	664
20-59 years	*	< LOD	< LOD	< LOD	1.71 (.920-2.82)	8.46 (4.96-16.6)	19.2 (9.82-35.2)	814
Gender								
Males	*	< LOD	< LOD	< LOD	1.64 (.870-3.45)	11.0 (5.32-16.6)	17.8 (10.1-34.2)	952
Females	*	< LOD	< LOD	< LOD	1.99 (1.00-3.67)	9.30 (5.41-21.5)	27.0 (9.82-47.5)	997
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	1.35 (.968-1.99)	6.55 (4.10-11.6)	16.7 (6.94-34.2)	672
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	2.39 (1.18-4.53)	9.41 (5.11-16.6)	17.8 (11.6-36.0)	509
Non-Hispanic whites	*	< LOD	< LOD	< LOD	1.75 (.847-4.00)	11.3 (4.79-20.2)	21.5 (12.8-30.8)	594

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 138. Diethylphosphate

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	1.03 (.757-1.40)	< LOD	< LOD	1.20 (.800-1.50)	3.10 (2.40-4.60)	7.50 (5.20-11.0)	13.0 (8.00-21.0)	1949
Age group								
6-11 years	1.32 (.846-2.05)	< LOD	< LOD	1.40 (.990-2.10)	4.50 (2.30-6.50)	10.0 (4.80-16.0)	15.0 (11.0-27.0)	471
12-19 years	1.21 (.852-1.72)	< LOD	< LOD	1.30 (1.00-1.90)	3.70 (2.40-5.40)	7.90 (4.20-23.0)	20.0 (8.00-27.0)	664
20-59 years	.955 (.701-1.30)	< LOD	< LOD	1.00 (.730-1.40)	3.00 (2.10-4.40)	7.20 (4.90-10.0)	10.0 (6.90-19.0)	814
Gender								
Males	1.11 (.807-1.54)	< LOD	< LOD	1.10 (.850-1.40)	3.80 (2.50-4.90)	8.00 (5.00-19.0)	18.0 (7.40-27.0)	952
Females	.954 (.692-1.32)	< LOD	< LOD	1.10 (.730-1.50)	2.90 (2.10-4.40)	7.50 (4.90-10.0)	11.0 (7.70-14.0)	997
Race/ethnicity								
Mexican Americans	1.22 (.869-1.71)	< LOD	< LOD	1.10 (.840-1.50)	4.10 (2.60-6.40)	11.0 (6.90-13.0)	17.0 (12.0-23.0)	672
Non-Hispanic blacks	1.56 (1.23-1.98)	< LOD	< LOD	1.60 (1.30-1.80)	4.20 (2.90-5.80)	10.0 (6.20-16.0)	18.0 (10.0-26.0)	509
Non-Hispanic whites	.980 (.666-1.44)	< LOD	< LOD	1.10 (.580-1.50)	3.30 (2.30-4.90)	7.60 (4.80-14.0)	14.0 (7.90-23.0)	594

< LOD means less than the limit of detection, which is 0.2 µg/L.

Table 139. Diethylphosphate (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	.924 (.687-1.24)	< LOD	< LOD	.924 (.632-1.28)	2.73 (1.89-4.29)	7.94 (4.90-11.7)	12.1 (8.75-17.5)	1949
Age group								
6-11 years	1.43 (.940-2.16)	< LOD	< LOD	1.47 (1.02-2.41)	3.94 (2.39-8.15)	10.3 (4.55-20.6)	16.2 (10.5-32.7)	471
12-19 years	.818 (.588-1.14)	< LOD	< LOD	.786 (.622-1.13)	2.29 (1.40-3.42)	5.38 (2.89-12.3)	12.3 (4.87-23.8)	664
20-59 years	.883 (.649-1.20)	< LOD	< LOD	.857 (.583-1.18)	2.63 (1.71-4.38)	7.37 (4.60-11.3)	12.1 (8.57-15.7)	814
Gender								
Males	.855 (.626-1.17)	< LOD	< LOD	.811 (.593-1.19)	2.61 (1.76-4.13)	7.69 (4.55-11.7)	12.2 (8.00-21.6)	952
Females	.996 (.729-1.36)	< LOD	< LOD	.956 (.636-1.45)	2.80 (1.89-4.72)	8.00 (4.90-11.7)	12.1 (8.10-17.5)	997
Race/ethnicity								
Mexican Americans	1.09 (.753-1.58)	< LOD	< LOD	1.05 (.737-1.57)	3.78 (2.29-5.79)	9.84 (6.57-14.4)	15.6 (10.3-19.3)	672
Non-Hispanic blacks	1.07 (.836-1.36)	< LOD	< LOD	1.17 (.833-1.53)	2.55 (2.13-3.24)	5.98 (4.22-8.93)	11.7 (6.62-19.4)	509
Non-Hispanic whites	.931 (.639-1.36)	< LOD	< LOD	.900 (.505-1.48)	2.82 (1.75-5.33)	8.46 (4.95-13.3)	12.6 (8.89-19.6)	594

< LOD means less than the limit of detection (see previous table).

Table 140. Diethylthiophosphate

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	.490 (<LOD-.620)	.760 (.660-.910)	1.30 (1.20-1.60)	2.20 (1.70-2.80)	1949
Age group								
6-11 years	*	< LOD	< LOD	.590 (<LOD-.720)	.900 (.730-1.20)	1.70 (1.30-2.40)	3.13 (1.70-5.00)	471
12-19 years	*	< LOD	< LOD	.210 (<LOD-.640)	.780 (.630-1.20)	1.40 (1.20-1.90)	2.20 (1.60-3.10)	664
20-59 years	*	< LOD	< LOD	.480 (<LOD-.590)	.740 (.630-.910)	1.30 (.990-1.50)	2.00 (1.50-2.80)	814
Gender								
Males	*	< LOD	< LOD	.500 (<LOD-.630)	.790 (.700-1.00)	1.40 (1.20-1.90)	2.70 (1.90-4.10)	952
Females	*	< LOD	< LOD	< LOD	.720 (.600-.910)	1.24 (.950-1.50)	1.70 (1.30-2.70)	997
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	.560 (<LOD-.700)	.840 (.740-.980)	1.40 (1.10-1.90)	2.20 (1.90-2.90)	672
Non-Hispanic blacks	*	< LOD	< LOD	.560 (<LOD-.670)	.810 (.690-1.20)	1.80 (1.24-3.30)	3.50 (1.80-4.80)	509
Non-Hispanic whites	*	< LOD	< LOD	.160 (<LOD-.630)	.730 (.600-1.00)	1.30 (.980-1.50)	1.80 (1.50-2.80)	594

< LOD means less than the limit of detection, which is 0.09 µg/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 141. Diethylthiophosphate (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	.254 (.102-.417)	.706 (.511-.957)	1.70 (1.21-2.17)	2.64 (2.12-2.96)	1949
Age group								
6-11 years	*	< LOD	< LOD	.470 (.146-.827)	1.08 (.827-1.30)	1.73 (1.44-2.36)	2.45 (1.88-5.42)	471
12-19 years	*	< LOD	< LOD	.176 (.061-.330)	.509 (.335-.761)	1.07 (.777-1.53)	1.97 (1.07-3.92)	664
20-59 years	*	< LOD	< LOD	.250 (.102-.409)	.685 (.467-.958)	1.79 (1.18-2.32)	2.75 (2.12-3.06)	814
Gender								
Males	*	< LOD	< LOD	.267 (.100-.415)	.672 (.521-.809)	1.34 (1.08-2.18)	2.66 (1.56-3.23)	952
Females	*	< LOD	< LOD	< LOD	.790 (.452-1.20)	1.89 (1.22-2.33)	2.52 (2.08-2.96)	997
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	.335 (.097-.567)	.829 (.567-1.13)	1.69 (1.30-2.16)	2.71 (1.86-3.55)	672
Non-Hispanic blacks	*	< LOD	< LOD	.300 (.153-.463)	.717 (.539-.838)	1.35 (.902-2.89)	2.89 (1.35-5.13)	509
Non-Hispanic whites	*	< LOD	< LOD	.230 (.081-.456)	.705 (.462-1.05)	1.88 (1.20-2.36)	2.58 (2.12-2.96)	594

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 142. Diethyldithiophosphate

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	.080 (<LOD-.110)	.200 (.150-.290)	.470 (.390-.630)	.870 (.650-1.00)	1949
Age group								
6-11 years	*	< LOD	< LOD	.080 (<LOD-.110)	.190 (.150-.240)	.430 (.300-.550)	.850 (.490-1.00)	471
12-19 years	*	< LOD	< LOD	.080 (<LOD-.110)	.260 (.120-.350)	.640 (.360-.860)	.900 (.680-1.30)	664
20-59 years	*	< LOD	< LOD	.080 (<LOD-.110)	.210 (.130-.290)	.450 (.360-.620)	.900 (.610-1.10)	814
Gender								
Males	*	< LOD	< LOD	.090 (<LOD-.110)	.220 (.160-.290)	.470 (.360-.660)	.870 (.650-1.10)	952
Females	*	< LOD	< LOD	.080 (<LOD-.100)	.190 (.110-.300)	.450 (.350-.690)	.850 (.460-1.40)	997
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	.100 (.070-.150)	.310 (.230-.390)	.650 (.490-1.00)	1.10 (.630-1.70)	672
Non-Hispanic blacks	*	< LOD	< LOD	.090 (<LOD-.100)	.270 (.180-.330)	.560 (.420-.820)	.850 (.650-1.20)	509
Non-Hispanic whites	*	< LOD	< LOD	.080 (<LOD-.120)	.190 (.120-.280)	.420 (.320-.680)	.870 (.510-1.10)	594

< LOD means less than the limit of detection, which is 0.05 µg/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 143. Diethyldithiophosphate (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	.074 (.057-.105)	.196 (.152-.264)	.549 (.407-.692)	.859 (.692-1.13)	1949
Age group								
6-11 years	*	< LOD	< LOD	.102 (.069-.133)	.193 (.154-.250)	.571 (.385-.797)	1.03 (.596-1.57)	471
12-19 years	*	< LOD	< LOD	.051 (.039-.074)	.167 (.098-.222)	.435 (.229-.731)	.731 (.385-.948)	664
20-59 years	*	< LOD	< LOD	.075 (.057-.108)	.205 (.148-.293)	.549 (.380-.714)	.859 (.667-1.16)	814
Gender								
Males	*	< LOD	< LOD	.066 (.046-.100)	.186 (.139-.222)	.415 (.317-.524)	.719 (.486-.938)	952
Females	*	< LOD	< LOD	.087 (.059-.117)	.219 (.156-.321)	.667 (.411-.861)	.886 (.707-1.38)	997
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	.094 (.068-.150)	.302 (.192-.407)	.812 (.517-1.00)	1.16 (.859-2.66)	672
Non-Hispanic blacks	*	< LOD	< LOD	.067 (.048-.103)	.175 (.131-.223)	.450 (.283-.675)	.692 (.481-1.07)	509
Non-Hispanic whites	*	< LOD	< LOD	.074 (.053-.108)	.204 (.143-.286)	.554 (.386-.731)	.875 (.654-1.16)	594

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Organophosphate Pesticides: Specific Metabolites

General Information

These metabolites differ from the dialkyl phosphates because they are more specific in their reference to the parent compound. The mechanism of action and pathways of exposure to the general population are similar to those of the other organophosphate pesticides (see the section titled “Organophosphate Pesticides: Dialkyl Phosphate Metabolites”). Malathion, chlorpyrifos, and diazinon are commonly used organophosphate insecticides in the United States. Malathion and several other pesticides are used to control adult mosquitoes. Chlorpyrifos accounted for 20% of total insecticide use in the United States in 1997, but its use is likely to decrease over time as a result of provisions in the Food Quality and Protection Act of 1996. Parathion use will be banned after 2003.

This *Report* provides measurements for the metabolites of six organophosphate pesticides. Table 144 shows the parent organophosphate pesticides and their metabolites. For example, malathion metabolizes to malathion dicarboxylic acid. *Para*-Nitrophenol can result from the metabolism of several organophosphate pesticides: parathion, ethyl *p*-nitrophenyl thionobenzenephosphonate (EPN), 4-nitroanisole, nitrofen, and nitrobenzene. Chlorpyrifos and chlorpyrifos methyl are metabolized to 3,5,6-trichloro-2-pyridinol. In addition to reflecting exposure to the parent insecticide, the level of the metabolite in a person’s urine may also reflect exposure to the metabolite if it was present in the person’s environment. The FDA, U.S. EPA, and OSHA have developed criteria on the allowable levels of these chemicals in foods, the environment, and the workplace.

Information about external exposure (environmental levels) and health effects of specific organophosphate pesticides is available from the EPA IRIS Web site at http://www.epa.gov/iris and from ATSDR at http://www.atsdr.cdc.gov/toxprofiles.

Interpreting Selected Urine Organophosphate Metabolite Levels Reported in the Tables

Urine levels of the metabolites of six organophosphate pesticides were measured in a subsample of NHANES participants aged 6-59 years. Subsamples were randomly selected within the specified age range to be a representative sample of the U.S. population. Measuring these chemicals at these levels is possible because of advances in analytical chemistry. Finding a measurable amount of one or more metabolites in the urine does not mean that the levels of the organophosphate pesticide cause an adverse health effect. Whether organophosphate pesticides at the levels reported here are cause for health concern is not known; more research is needed.

Generally recognized guidelines for urine levels of these metabolites are not available. However, urinary measurements of the specific metabolites of the organophosphate pesticides can be used to monitor worker exposure. As with the dialkyl phosphate metabolites, the specific metabolites can be measured at low levels of exposure that do not cause depression of cholinesterase activity. These data provide physicians with a reference range so that they can determine whether people have been exposed to higher levels of these select organophosphate pesticides than those found in the general population. Tables 145-152 summarize the results of these measurements. These data will help scientists plan and conduct research about exposure to these chemicals and their health effects.

Table 144. Organophosphate pesticides: specific metabolites

Organophosphate pesticide (CAS number)	**Primary urinary metabolite** (CAS number)
Malathion (121-75-5)	Malathion dicarboxylic acid (1190-28-9)
Parathion (56-38-2)	*para* -Nitrophenol (100-02-7)
Methyl parathion (298-00-0)	*para* -Nitrophenol (100-02-7)
Chlorpyrifos (2921-88-2)	3,5,6-Trichloro-2-pyridinol (6515-38-4)
Chlorpyrifos methyl (5598-13-0)	3,5,6-Trichloro-2-pyridinol (6515-38-4)
Diazinon (333-41-5)	2-Isopropyl-4-methyl-6-hydroxypyrimidine (2814-20-2)

Malathion dicarboxylic acid

CAS No. 1190-28-9

Metabolite of malathion (CAS No. 121-75-5)

Urinary levels of malathion dicarboxylic acid at the 95th percentile for children aged 6-11 years are severalfold lower than levels that were measured in Minnesota children (aged 3-13 years, adjusted for sociodemographic variables) in 1997 (Adgate, 2001). In this Minnesota study, children from an urban setting had urinary levels of malathion dicarboxylic acid that were similar to levels in children from a nonurban setting.

Table 145. Malathion dicarboxylic acid

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1920
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	2.80 (<LOD-5.50)	453
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	660
20-59 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	807
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	937
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	983
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	680
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	498
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	579

< LOD means less than the limit of detection, which averaged 0.29 µg/L (SD 0.78, maximum value 2.64).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 146. Malathion dicarboxylic acid (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1920
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	3.74 (2.27-4.65)	453
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	660
20-59 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	807
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	937
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	983
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	680
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	498
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	579

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

para-Nitrophenol

CAS No. 100-02-7

Metabolite of parathion and other pesticides (CAS No. 56-38-2)

The *para*-nitrophenol (PNP) levels in this *Report* are similar to levels measured in a non-random subsample of NHANES III (1988-1994) participants (Hill et al., 1995). The urinary *para*-nitrophenol levels in this *Report* for the group aged 6-11 years are lower than levels measured in children residing in households close to pesticide-treated farmlands but similar to levels in children residing farther away (Fenske et al., 2002). Inappropriate residential application of methylparathion led to a 25-fold increase in the median urinary PNP level of the people living in those residences (Esteban et al., 1996).

In a study of workers who handle parathion, end-of-shift urine PNP levels ranged from 190-410 µg/gram of creatinine (Len and Lewalter, 1999), or about 100 times higher than levels documented in this *Report.* ACGIH recommends a BEI of 0.5 mg/gram of creatinine for workers at the end of the shift. In 1975, the World Health Organization indicated that no depression of chloinesterase activity occurred from parathion exposure when urinary PNP levels were below 2 mg/L (2000 µg/L) (Lauwerys and Hoet, 2001). All PNP values in this *Report* are much lower than these levels of concern for workers.

Table 147. *para*-Nitrophenol

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	< LOD	< LOD	2.40 (1.70-3.80)	5.00 (3.30-9.00)	1989
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	2.63 (1.90-3.80)	4.20 (2.70-6.40)	479
12-19 years	*	< LOD	< LOD	< LOD	< LOD	3.40 (1.70-5.70)	5.70 (2.60-19.0)	680
20-59 years	*	< LOD	< LOD	< LOD	< LOD	2.30 (1.60-4.00)	4.50 (2.50-9.20)	830
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	2.40 (1.60-4.00)	4.40 (2.60-11.0)	971
Females	*	< LOD	< LOD	< LOD	< LOD	2.50 (1.70-4.20)	5.20 (3.00-9.50)	1018
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	5.80 (3.00-20.0)	21.0 (4.99-31.0)	695
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	2.90 (1.90-4.70)	4.80 (2.70-9.00)	518
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	2.10 (<LOD-3.80)	4.20 (2.20-9.50)	602

< LOD means less than the limit of detection, which is 0.8 µg/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 148. *para*-Nitrophenol (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	< LOD	< LOD	2.08 (1.43-3.37)	4.20 (2.55-7.64)	1989
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	2.80 (1.98-3.54)	4.20 (3.33-6.67)	479
12-19 years	*	< LOD	< LOD	< LOD	< LOD	1.79 (1.07-3.44)	4.00 (1.57-7.29)	680
20-59 years	*	< LOD	< LOD	< LOD	< LOD	2.00 (1.33-3.37)	4.29 (2.43-10.2)	830
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	1.90 (1.12-3.00)	3.39 (1.90-7.55)	971
Females	*	< LOD	< LOD	< LOD	< LOD	2.22 (1.67-4.28)	6.90 (3.54-12.3)	1018
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	4.80 (2.75-14.9)	17.4 (4.80-34.9)	695
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	2.07 (1.40-3.26)	3.71 (2.17-5.16)	518
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	1.94 (1.17-3.54)	3.75 (2.08-7.64)	602

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

3,5,6-Trichloro-2-pyridinol

CAS No. 6515-38-4

Metabolite of chlorpyrifos (CAS No. 2921-88-2)

The 3,5,6-trichloro-2-pyridinol (TCPy) levels shown in this *Report* are similar to levels measured in a non-random subsample from NHANES III (1988-1994) participants (Hill et al., 1995). The urinary TCPy levels for the group aged 20-59 years are lower than or similar to levels found in other studies (Byrne et al., 1998; Bartels and Kastl, 1992). In one study from 1996, urinary TCPy levels measured in Maryland adults were about three times higher than the levels for adults documented in this *Report* (MacIntosh et al., 1999). These higher levels may represent variations in the local use of pesticides, participant selection, or sampling methods. The seasonal use of pesticides can contribute to differences in TCPy levels as well since urine TCPy levels were found to be higher during the spring and summer than during the fall and winter (MacIntosh et al., 1999). Levels in applicators of chlorpyrifos methyl and chlorpyrifos can be greather than 40-fold higher than levels in control subjects (Lauwerys and Hoet, 2001).

The urinary TCPy levels for children aged 6-11 years in this *Report* are similar to levels measured in 1997 in a group of non-urban Minnesota children (aged 3-13 years, adjusted by their sociodemographic variables) (Adgate et al., 2001). In this latter study, children from an urban setting had levels that were 1.5 times higher than levels

Table 149. 3,5,6-Trichloro-2-pyridinol

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	1.77 (1.56-2.01)	< LOD	.870 (.770-.990)	1.70 (1.50-2.00)	3.50 (2.70-4.50)	7.30 (5.40-9.40)	9.90 (7.60-14.0)	1994
Age group								
6-11 years	2.88 (2.13-3.88)	.780 (.630-.970)	1.20 (1.10-1.70)	2.70 (1.80-4.20)	6.90 (3.70-9.40)	11.0 (7.70-17.0)	16.0 (10.0-24.0)	481
12-19 years	2.37 (2.00-2.81)	.790 (.700-.890)	1.20 (1.00-1.50)	2.10 (1.60-2.60)	4.50 (3.10-5.70)	8.00 (5.70-12.0)	12.5 (8.40-23.0)	681
20-59 years	1.53 (1.36-1.73)	< LOD	.750 (.620-.880)	1.50 (1.20-1.60)	2.80 (2.40-3.70)	5.90 (4.30-7.94)	8.60 (6.30-12.0)	832
Gender								
Males	1.92 (1.67-2.21)	.450 (<LOD-.630)	1.00 (.810-1.10)	1.90 (1.60-2.20)	3.50 (2.90-4.60)	7.30 (5.60-9.40)	9.90 (7.90-14.0)	972
Females	1.63 (1.41-1.88)	< LOD	.770 (.650-.870)	1.50 (1.20-1.70)	3.30 (2.50-4.70)	7.20 (4.86-9.70)	10.0 (6.90-16.0)	1022
Race/ethnicity								
Mexican Americans	1.61 (1.37-1.90)	< LOD	.870 (.610-1.10)	1.67 (1.30-2.10)	3.20 (2.60-3.80)	5.00 (4.00-6.40)	7.40 (5.50-12.0)	697
Non-Hispanic blacks	2.17 (1.71-2.76)	.560 (<LOD-.800)	1.00 (.840-1.20)	1.90 (1.50-2.50)	4.20 (2.80-7.30)	9.40 (6.70-12.0)	13.0 (9.60-25.0)	521
Non-Hispanic whites	1.76 (1.52-2.03)	.420 (<LOD-.600)	.880 (.760-1.10)	1.60 (1.50-2.00)	3.40 (2.60-4.57)	7.10 (4.70-9.60)	10.0 (6.90-16.0)	601

< LOD means less than the limit of detection, which is 0.4 µg/L.

of children from a non-urban setting. Fenske et al. (2002) found that children residing either near pesticide-treated farmland or in households where pesticide use occurred had higher urinary TCPy levels than those living in surroundings where less pesticide exposure occurred.

Geometric mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, and urinary creatinine. The group aged 6-11 years had slightly higher urine TCPy levels than the other two age groups. Further research is necessary to evaluate this difference in TCPy levels among age groups. There were no differences in TCPy levels among genders or racial/ethnic categories.

Table 150. 3,5,6-Trichloro-2-pyridinol (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	1.58 (1.41-1.77)	< LOD	.870 (.757-.966)	1.47 (1.31-1.65)	2.85 (2.22-3.38)	5.43 (4.26-6.62)	8.42 (6.27-11.6)	1994
Age group								
6-11 years	3.11 (2.39-4.05)	.864 (.535-1.36)	1.64 (1.18-2.05)	3.20 (2.05-4.35)	6.37 (4.21-8.19)	10.1 (6.75-16.0)	14.0 (8.74-21.7)	481
12-19 years	1.60 (1.40-1.83)	.608 (.549-.698)	.930 (.816-1.08)	1.45 (1.24-1.69)	2.58 (2.03-3.56)	4.82 (3.92-5.57)	6.16 (4.95-9.76)	681
20-59 years	1.41 (1.26-1.58)	< LOD	.786 (.694-.892)	1.33 (1.16-1.50)	2.37 (1.96-2.86)	4.25 (3.29-5.63)	6.42 (4.98-10.7)	832
Gender								
Males	1.48 (1.30-1.67)	.473 (.402-.557)	.796 (.698-.914)	1.44 (1.27-1.61)	2.52 (2.09-3.24)	4.95 (3.98-6.27)	7.63 (5.73-10.7)	972
Females	1.69 (1.49-1.91)	< LOD	.913 (.816-1.00)	1.51 (1.33-1.74)	2.96 (2.37-3.70)	5.63 (4.25-7.19)	8.44 (6.25-13.1)	1022
Race/ethnicity								
Mexican Americans	1.46 (1.27-1.67)	< LOD	.859 (.737-.994)	1.44 (1.16-1.73)	2.38 (2.11-2.86)	3.82 (3.33-5.07)	5.79 (4.35-9.04)	697
Non-Hispanic blacks	1.47 (1.18-1.84)	.435 (.405-.513)	.733 (.591-.917)	1.33 (1.02-1.76)	2.86 (1.84-4.38)	5.88 (4.26-8.93)	8.93 (5.91-13.7)	521
Non-Hispanic whites	1.66 (1.46-1.89)	.543 (.462-.675)	.909 (.802-1.03)	1.55 (1.33-1.74)	2.93 (2.14-3.68)	5.50 (4.21-6.95)	8.44 (6.14-12.5)	601

< LOD means less than the limit of detection (see previous table).

2-Isopropyl-4-methyl-6-hydroxypyrimidine

CAS No. 2814-20-2

Metabolite of diazinon (CAS No. 333-41-5)

Urinary concentrations of 2-isopropyl-4-methyl-6-hydroxypyrimidine from the NHANES 1999-2000 sub-sample are similar to those reported previously in a non-random sample from the U.S. population (Baker et al., 2000).

Table 151. 2-Isopropyl-4-methyl-6-hydroxypyrimidine

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1842
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	454
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	632
20-59 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	756
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	894
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	948
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	644
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	484
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	553

< LOD means less than the limit of detection, which averaged 2.0 µg/L (SD 1.7, maximum value 7.20).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 152. 2-Isopropyl-4-methyl-6-hydroxypyrimidine (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1842
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	454
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	632
20-59 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	756
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	894
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	948
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	644
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	484
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	553

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Organochlorine Pesticides

General Information

Organochlorine pesticides are effective against a variety of insects. Hexachlorobenzene and pentachlorophenol had been used primarily as fungicides. These chemicals were introduced in the 1940s and are used rarely in the United States today because of their environmental persistence. The U.S. EPA banned many of the uses of these chemicals during the 1970s and 1980s. Although many of these chemicals are no longer produced in the United States, they continue to be used by other countries.

Organochlorine pesticides enter the environment from disposal of contaminated wastes into landfills, emissions from waste incinerators, and releases from manufacturing plants that produce these chemicals. In aquatic systems, organochlorine pesticides are adsorbed onto sediments in water that can then bioconcentrate in marine mammals. Because these chemicals are soluble in fat, they are found at higher concentrations in fatty foods. Diets that contain fats that may be contaminated with organochlorine pesticides (e.g., contaminated milk and dairy products, fish, whales) lead to increased exposure to these chemicals. Children can be exposed to these chemicals through breast milk and *in utero* through the placenta. The health effects of exposure to organochlorine chemical exposure on the general population at current levels of exposure are unknown. Workers can be exposed to organochlorine chemicals in the manufacture, formulation, or application of these chemicals. The FDA, U.S. EPA, and OSHA have developed criteria on the allowable levels of these chemicals in foods, the environment, and the workplace.

The organochlorine pesticides are a unique class of pesticides because of their cyclic structure, number of chlorine atoms, and low volatility. They can be classified into four categories: dichlorodiphenylethanes (e.g., DDT), cyclodienes, chlorinated benzenes (e.g., hexachlorobenzene [HCB]), and cyclohexanes (e.g., hexachlorocyclohexane [HCH]). Table 153 shows the parent organochlorine pesticides and their metabolites measured in this *Report*. For example, DDT metabolizes to DDE.

Table 153. Organochlorine pesticides and their metabolites

Organochlorine pesticide (CAS number)	**Serum pesticide or metabolite(s)** (CAS number)	**Urinary pesticide or metabolite(s)** (CAS number)
Hexachlorobenzene (118-74-1)	Hexachlorobenzene (118-74-1)	Pentachlorophenol (87-86-5) 2,4,6-Trichlorophenol (88-06-2) 2,4,5-Trichlorophenol (95-95-4)
Hexachlorocyclohexanes including beta-HCH (319-85-7) and gamma-HCH (58-89-9) isomers	Hexachlorocyclohexane (608-73-1)	Pentachlorophenol (87-86-5) 2,4,6-Trichlorophenol (88-06-2) 2,4,5-Trichlorophenol (95-95-4)
DDT (50-29-3) *p,p'*-DDT (50-29-3) *o,p'*-DDT (789-02-6)	*p,p'*-DDE (72-55-9)	
Heptachlor (76-44-8)	Heptachlor epoxide (1024-57-3)	
Mirex (2385-85-5)	Mirex (2385-85-5)	
Chlordane (12789-03-6)	Oxychlordane (27304-13-8)	
Pentachlorophenol (87-86-5)		Pentachlorophenol (87-86-5) 2,4,6-Trichlorophenol (88-06-2) 2,4,5-Trichlorophenol (95-95-4)

Measurements of these chemicals can reflect either recent or accumulated chronic exposures or both. Some of the metabolites can be produced from the metabolism of more than one pesticide. In addition to reflecting exposure to the parent pesticide, the level of the metabolite in a person's blood or urine may also reflect exposure to the metabolite itself if it was present in the person's environment.

Interpreting Lipid-Adjusted Serum Organochlorine Levels Reported in the Tables

Lipid-adjusted serum levels of organochlorine pesticides or their metabolites were measured in a subsample of NHANES 1999-2000 participants aged 12 years and older. Subsamples were randomly selected within the specified age range to be a representative sample of the U.S. population. Urine levels of metabolites were measured in people aged 6 years and older. Measuring these chemicals at these levels is possible because of advances in analytical chemistry. Finding a measurable amount of one or more organochlorines in the serum or urine does not mean that the levels of the organochlorines cause an adverse health effect. Whether organochlorines at the levels reported here are cause for health concern is not known; more research is needed.

These data provide physicians with a reference range so that they can determine whether people have been exposed to higher levels of organochlorines than those found in the general population. These data will help scientists plan and conduct research about exposure to organochlorines and their health effects.

Hexachlorobenzene

CAS No. 118-74-1

General Information

Hexachlorobenzene (HCB) is an organochlorine pesticide that was once used in the United States as a fungicide to pretreat grain. The U.S. EPA canceled registered use in 1984. Use of HCB has been declining since the 1970s. However, HCB is still being produced and used by other countries. In addition, the allowable limits of HCB as a byproduct in the production of other chemicals have decreased. Exposure to HCB has caused serious health effects. For example, in the years 1955-1959, HCB-treated grain was processed into bread and consumed by people living in southeastern Turkey. Those with significant exposures developed porphyria and other manifestations, including weakness, paresthesia, hyperpigmentation, thyromegaly, and arthritis. Children born to mothers exposed during that time developed sores on their skin, and many died within the first 2 years of life (Peters et al., 1982). HCB causes reproductive disorders and developmental disorders in experimental animal studies.

Pentachlorophenol (PCP), 2,4,5-trichlorophenol (245TCP), and 2,4,6-trichlorophenol (246TCP) are urinary metabolites of HCB. Urinary PCP can also result from exposure to other chlorinated hydrocarbons such as pentachlorobenzene, hexachlorocyclohexane, or pentachloronitrobenzene. Similarly, urinary 245TCP and 246TCP can result from exposure to other chlorinated hydrocarbons such as hexachlorocyclohexane. Because urinary PCP, 245TCP, and 246TCP can occur from

Table 154. Hexachlorobenzene (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1702
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	591
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1111
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	807
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	895
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	583
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	350
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	636

< LOD means less than the limit of detection, which averaged 60.5 ng/g of lipid (SD 19.3, maximum value 118).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

exposures to chemicals other than HCB, measuring HCB in serum is a more specific indicator of exposure to this specific pesticide.

Interpreting Lipid-Adjusted Serum HCB levels Reported in the Tables

Generally recognized guidelines for serum levels of HCB are not available. HCB was detected in only 0.6% of people in this 1999-2000 NHANES subsample.

Age-dependent increases of HCB in body fat have been reported (Bertram et al., 1986). Grimalt et al. (1994) showed that residents living near an HCB chemical plant had serum HCB levels that were about fivefold greater than levels of residents from a reference community. In another study, serum HCB levels in workers at an HCB plant were about fivefold greater than levels in the local population (Herrero et al., 1999). In a convenience sample of 287 people living near a dumpsite during the period 1984-1986, the median serum HCB level was 0.189 µg/L (approximately 31 ng/gram of lipid) (Needham et al., 1990). About 25 years after the afore-mentioned incident in Turkey, the mean HCB level in the breast milk of women with porphyria who lived in the area of exposure was about sevenfold higher than that of women without porphyria who lived outside of the affected area (Peters et al., 1982). HCB has a residence time of about 15 years in body fat.

Hexachlorocylclohexane

CAS No. 608-73-1

General Information

Hexachlorocylclohexane (HCH) is an organochlorine pesticide with several isomeric forms: alpha, beta, gamma, and delta. The gamma isomer, commonly known as lindane, is the only isomer with insecticidal activity. The other isomers are used either as fungicides or to synthesize other chemicals and may be formed during the synthesis of lindane. Technical-grade HCH contains all four isomers but mostly the alpha isomer. Although lindane and technical-grade HCH were banned from production in the United States during the late 1970s and early 1980s, these chemicals are still produced by other countries. In the United States, lindane has restricted use in agriculture and in treating human scabies and lice.

HCH isomers are mainly metabolized to chlorophenols, such as 2,4,6-trichlorophenol, 2,4,5-trichlorophenol, and 2,3,5-trichlorophenol. Beta-HCH has a blood elimination half-life of 7 years, whereas gamma-HCH has a blood elimination half-life of only 20 hours.

Interpreting Lipid-Adjusted Serum Beta-HCH Levels Reported in the Table

The Deutsche Forschungsgemeinshaft (2000) established a biological tolerance level of 25 µg/L (approximately 4,200 ng/gram of serum lipid) in serum or plasma for

Table 155. Beta-hexachlorocyclohexane (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval) 10th	25th	50th	75th	90th	95th	Sample size
Total, age 12 and older	9.68 (<LOD-10.4)	< LOD	< LOD	< LOD	19.0 (17.0-20.7)	42.0 (35.9-47.1)	68.9 (52.7-80.5)	1893
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	11.4 (<LOD-16.2)	653
20 years and older	10.9 (10.1-11.7)	< LOD	< LOD	< LOD	21.0 (19.1-23.8)	46.0 (39.6-50.7)	73.4 (59.3-90.2)	1240
Gender								
Males	*	< LOD	< LOD	< LOD	14.5 (11.8-17.1)	29.8 (25.1-36.1)	44.6 (37.5-56.2)	901
Females	11.1 (10.2-12.0)	< LOD	< LOD	< LOD	22.0 (19.4-27.5)	51.3 (44.0-64.4)	81.1 (68.9-102)	992
Race/ethnicity								
Mexican Americans	16.7 (13.6-20.4)	< LOD	< LOD	15.5 (11.6-20.4)	37.5 (26.9-51.5)	97.9 (60.9-139)	139 (97.9-200)	632
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	14.7 (12.4-21.1)	36.6 (30.0-41.7)	48.9 (40.9-81.1)	403
Non-Hispanic whites	*	< LOD	< LOD	< LOD	17.5 (15.3-19.4)	34.4 (27.0-44.0)	51.3 (44.6-64.4)	702

< LOD means less than the limit of detection, which averaged 4.8 ng/g of lipid (SD 1.7, maximum value 9.36).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

workers at the end of their shifts. The values reported in this NHANES 1999-2000 subsample are well below this level of concern for workers.

Beta-HCH levels in the U.S. population have been declining since 1970 (Radomski et al., 1971; Stehr-Green et al., 1989; Kutz et al., 1991; Sturgeon et al., 1998). Kutz et al. (1991) estimated that nearly 100% of the U.S. population had detectable beta-HCH in adipose tissue in 1970 and 80% in 1980, with the mean adipose beta-HCH level decreasing from 0.37 µg/gram of lipid (370 ng/gram) in 1971 to 0.10 µg/gram of lipid (100 ng/gram) in 1983. Beta-HCH is usually the isomer with the highest concentration in the general population. In a control population from Canada (n = 70), the mean lipid-adjusted level of beta-HCH collected in 1994 (Lebel et al., 1998) was similar to the geometric mean level in the NHANES 1999-2000 subsample. In 1976, the median serum lipid-adjusted level of beta-HCH was 119 ng/gram for a control population of 7,712 Danish females (Hoyer et al., 1998). The difference between these 1976 levels and current U.S. levels may represent a global change in levels over time.

An increase of beta-HCH levels with age has previously been observed by the German Commisision on Biological Monitoring (Ewers et al., 1999). In addition, a positive age relationship was observed previously in both a non-random subsample from the NHANES II (1976-1980) and for beta-HCH levels in adipose tissue (Stehr-Green et al., 1989; Kutz et al., 1991). Also, higher levels in females had been observed for beta-HCH levels in serum (Stehr-Green et al., 1989) but not in adipose tissue (Burns, 1974). In this *Report*, comparisons of adjusted geometric means were not possible among the demographic groups. Differences similar to those in the aforementioned studies can be observed at the upper percentiles. It is unknown whether differences between

Table 156. Gamma-hexachlorocyclohexane (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey,

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 10th	25th	50th	75th	90th	95th	Sample size
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1799
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	660
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1139
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	863
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	936
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	631
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	380
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	646

< LOD means less than the limit of detection, which averaged 7.5 ng/g of lipid (SD 2.4, maximum value 14.5).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

ages, genders, or races/ethnicities represent differences in exposure, body-size relationships, or metabolism.

Lipid-Adjusted Gamma-HCH Levels Reported in the Tables

Lipid-adjusted serum gamma-HCH (lindane) levels were measured in a subsample of NHANES 1999-2000 participants aged 12 years and older. Subsamples were randomly selected within the specified age range to be a representative sample of the U.S. population. Lindane was detected in only 1.7% of the population surveyed for this *Report*, a finding that is similar to other measurements made from non-random samples of the general U.S. population (Radomski et al., 1971; Dorgan et al., 1999). Levels of lindane in the general population of other countries can be higher than levels in the U.S. population (Radomski et al., 1971), probably because of regional variations in the use of the pesticide. The upper reference limit of gamma-HCH in general populations described by the German Commission on Human Biological Monitoring is 0.3 µg/L of blood (Ewers et al., 1999).

Serum lindane levels in workers involved in the manufacture, processing, application, or formulation of HCH were found to be severalfold higher than levels in people with no known occupational exposure to the pesticide (Nigam et al., 1986; Radomski et al., 1971; Angerer et al., 1983). The recommended biological limit value in blood for lindane has been established by various agencies and organizations. The United Kingdom's benchmark guidance value for lindane is 35 nanomoles per liter (approximately 1,700 ng/gram of lipid) in whole blood or 70 nanomoles per liter in plasma (Wilson et al., 1999). The German Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area sets the biological tolerance value for lindane as 20 µg/L (approximately 3,300 ng/gram of lipid) (Deutsche Forschungsgemeinshaft, 2000). The levels shown in this *Report* are far below these levels of concern for workers.

Dichlorodiphenyltrichloroethane

CAS No. 50-29-3 for techinal grade

General Information

Dichlorodiphenyltrichloroethane (DDT) is an insecticide that was used initially in the 1940s by the military against mosquitoes that carried vector-borne diseases (e.g., malaria). The U.S. EPA banned use of DDT in the United States in 1973, and it is no longer being produced in this country. However, DDT still is being used and produced in limited quantities in other countries. Commercially available DDT (technical grade) contains two chemical forms of DDT: *p,p'*- DDT and *o,p'*-DDT.

Food is the primary pathway of DDT exposure for the general population. Diets that contain large amounts of fish from the Great Lakes will increase a person's exposure to DDT. The estimated food intake of DDT in the United States has decreased since the 1950s (Walker et al., 1954; Durham et al., 1965; Duggan and Corneliussen, 1972). However, food imported into the United States from other countries that still use DDT may have DDT contamination. Food from tropical regions may contain more DDT because of its greater use in these regions.

A major metabolite of DDT is 1,1'-(2,2-dichloroethenylidene)-bis[4-chlorobenzene] (DDE), which can be produced in people or in the environment. DDE is more persistent than DDT in the environment and in people. The presence of DDT in the body reflects either a

Table 157. *p,p'*-DDT (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	27.0 (<LOD-34.0)	1679
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	677
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	29.4 (22.2-37.3)	1002
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	24.3 (<LOD-34.1)	799
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	29.1 (22.5-34.0)	880
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	59.7 (28.9-150)	150 (63.4-493)	635
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	25.7 (<LOD-63.9)	356
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	564

< LOD means less than the limit of detection, which averaged 10.6 ng/g of lipid (SD 3.4, maximum value 20.7).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

relatively recent exposure or cumulative past exposure. A high DDT to DDE ratio may indicate recent exposure, and a low DDT to DDE ratio may indicate an exposure in the more distant past (Radomski et al., 1971).

The health effects associated with DDT after large accidental exposures or workplace exposures have been described (Hayes, 1976). Elevations of liver enzymes in serum have been observed in exposed workers. The toxic effects of DDT demonstrated in experimental animals include infertility (Jonsson et al., 1975), a decrease in the number of implanted ova (Lundberg, 1974), intrauterine growth retardation (Fabro et al., 1984), cancer (Cabral et al., 1982), neurologic developmental disorders (Eriksson et al., 1990) and fetal death (Clement and Okey, 1974). The association of DDT exposure and breast cancer has been studied but not clearly established (Lebel et al., 1998; Hoyer et al., 1998; Helzlsouer et al., 1999; Hunter et al., 1997). IARC classifies DDT (p,p'-DDT) as a possible human carcinogen; NTP considers that DDT is reasonably anticipated to be a human carcinogen; and the U.S. EPA has classified DDT as a probable human carcinogen.

Table 158. *p,p'*-DDE (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	260 (234-289)	74.2 (66.1-84.2)	114 (99.8-129)	226 (191-267)	538 (485-609)	1120 (991-1290)	1780 (1520-2230)	1964
Age group								
12-19 years	118 (101-137)	45.9 (34.9-56.6)	69.8 (59.2-80.4)	108 (90.6-132)	185 (141-233)	343 (255-479)	528 (364-644)	686
20 years and older	297 (267-330)	86.0 (75.2-96.7)	130 (115-150)	269 (229-303)	626 (538-697)	1250 (1100-1420)	1990 (1570-2510)	1278
Gender								
Males	249 (221-281)	77.6 (68.6-88.2)	119 (101-133)	222 (182-266)	489 (383-570)	985 (756-1130)	1350 (1190-1610)	937
Females	270 (241-302)	68.9 (55.1-82.5)	112 (96.0-129)	228 (191-286)	604 (516-697)	1320 (1100-1600)	2150 (1650-2750)	1027
Race/ethnicity								
Mexican Americans	674 (572-795)	154 (133-214)	300 (252-370)	623 (505-750)	1350 (1090-1660)	3090 (2100-4610)	4940 (3280-7810)	657
Non-Hispanic blacks	295 (253-344)	62.2 (56.9-80.5)	113 (98.3-128)	203 (164-253)	452 (392-571)	1340 (974-1910)	2160 (1470-4010)	416
Non-Hispanic whites	217 (193-244)	73.0 (63.2-82.2)	107 (94.5-127)	197 (175-238)	459 (372-513)	852 (693-1010)	1220 (1040-1410)	732

Interpreting Lipid-Adjusted Serum DDT and DDE Levels Reported in the Tables

The 95th percentile levels for *p,p'*-DDT and *p,p'*-DDE in this *Report* are about 15-fold and 5-fold lower than levels found in 1976-1980 for a non-random subsample from NHANES II participants (Stehr-Green et al., 1989). These decreases in U.S. levels are consistent with the decreased use and manufacture of these chemicals. In 1976, the median lipid-adjusted serum levels of *p,p'*-DDT and *p,p'*-DDE were 141 ng/gram and 1,183 ng/gram, respectively, in a population of 717 Danish females participating in a breast cancer study (Hoyer et al., 1998). For a control population from California during 1989-1990, *p,p'*-DDE was detected in 100% of the samples, and the median lipid-adjusted serum *p,p'*-DDE level was 1,358 ng/gram (Sturgeon et al., 1998), a level about fivefold greater than levels found in the 1999-2000 NHANES subsample. Local spraying with DDT can add greatly to body burdens. For example, a single application of DDT for malaria control increased serum DDT levels sevenfold in people tested 1 year after the application (Dua et al., 1996). For this 1999-2000 NHANES subsample, *o,p'*-DDT was detected in less than 1% of the population.

Geometric mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, and gender. The group aged 12-19 years had more than a twofold lower level of *p,p'*-DDE than the group aged 20 years and older. Similarly, in 1971, lower *p,p'*-DDE levels were found in children

Table 159. *o,p'*-DDT (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1669
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	667
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1002
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	796
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	873
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	632
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	354
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	560

< LOD means less than the limit of detection, which averaged 10.6 ng/g of lipid (SD 3.3, maximum value 20.7).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

than were found in adults in Argentina (Radomski et al., 1971). In NHANES II participants, levels of *p,p'*-DDE were also shown to increase with age (Stehr-Green et al., 1989). There was no difference in *p,p'*-DDE levels between males and females documented in this *Report*. However, others have reported differences in levels of DDT or its metabolites between females and males (Waliszewski et al., 1996; Stehr-Green et al., 1989; Finklea et al., 1972; Sala et al., 1999).

In the NHANES 1999-2000 subsample, the adjusted geometric mean level of *p,p'*-DDE in Mexican Americans was 653 ng/gram, or about three times higher than levels in non-Hispanic whites and two times higher than levels in non-Hispanic blacks. This higher level of *p,p'*-DDE in the Mexican-American population is similar to levels found in a 1997 study in which the majority of the control population was born in Mexico (Balluz et al., 2001). In 1998, Mexican-American migrant workers had a mean serum *p,p'*-DDE level that was threefold greater than the geometric mean level found in Mexican Americans in this *Report* (Hernandez-Valero et al., 2001). Previous measurements of total DDT congeners in adipose tissue have demonstrated that African Americans had levels that were about twofold higher than levels in non-Hispanic whites (Kutz et al., 1977). It is unknown whether differences between ages or races/ethnicities represent differences in exposure, body-size relationships, or metabolism.

Chlordane
CAS No.12789-03-6 for technical grade

and

Heptachlor
CAS No. 76-44-8

General information

Chlordane is an organochlorine pesticide that was once used on agricultural crops and lawns and in buildings to kill termites. In 1988, the U.S. EPA cancelled registration for the production and use of chlordane in the United States.

The technical grade of chlordane consists of several related chemicals, including *cis*- and *trans*-chlordane, *trans*-nonachlor, and heptachlor. Chlordane is primarily metabolized to oxychlordane. Heptachlor (a separate pesticide) is metabolized to heptachlor epoxide. Chlordane is an unlikely source of exposure if heptachlor epoxide is found in the absence of either oxychlordane or *trans*-nonachlor. Because pesticide applications were generally made with technical-grade chlordane, it is the main form of exposure for people. During the period 1981-1982 in Hawaii, heptachlor was applied to pineapples that were subsequently fed to milk-producing cows. As a result, heptachlor appeared in commercial milk products, human breast milk, and serum (Baker et al., 1991).

Interpreting Levels of Lipid-Adjusted Serum Levels of Oxychlordane, trans-*Nonachlor, and Heptachlor Epoxide Reported in the Tables*

Generally recognized guidelines for serum levels of these metabolites have not been established. The levels for these chemicals in this NHANES 1999-2000 subsample are similar to levels measured in a control population during 1987-1990 (Sturgeon et al., 1998). For a control population from Canada (n = 70) collected in 1994, the mean lipid-adjusted levels of oxychlordane and *trans*-nonachlor were similar to the geometric mean level in the NHANES 1999-2000 subsample (Lebel et al., 1998). The 95th percentile level estimated from a non-random subsample of NHANES II (1976-1980) participants (Stehr-Green, 1989) was about two times the 95th percentile that is reported here. In another study, Warishi et al. (1986) reported that Japanese adults had geometric mean levels of *trans*-nonachlor similar to levels documented in this *Report* and oxychlordane levels that were slightly higher.

Table 160. Oxychlordane (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval) 10th	25th	50th	75th	90th	95th	Sample size
Total, age 12 and older	*	< LOD	< LOD	< LOD	21.4 (18.6-23.5)	35.7 (30.5-41.3)	44.8 (41.4-49.6)	1661
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	663
20 years and older	*	< LOD	< LOD	< LOD	24.6 (21.4-27.7)	37.8 (33.5-44.0)	49.6 (44.0-51.2)	998
Gender								
Males	*	< LOD	< LOD	< LOD	17.8 (15.3-21.1)	30.9 (25.1-37.5)	41.5 (34.2-48.6)	793
Females	*	< LOD	< LOD	< LOD	23.7 (20.6-28.0)	37.4 (31.9-44.0)	49.6 (43.5-53.3)	868
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	16.7 (<LOD-19.3)	29.0 (21.2-39.8)	41.1 (29.8-56.1)	628
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	29.3 (21.8-41.1)	44.7 (36.9-55.7)	350
Non-Hispanic whites	*	< LOD	< LOD	< LOD	22.6 (20.0-25.5)	36.7 (30.1-42.3)	44.8 (38.6-49.8)	559

< LOD means less than the limit of detection, which averaged 7.4 ng/g of lipid (SD 2.4, maximum value 14.5).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 161. *trans*-Nonachlor (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval) 10th	25th	50th	75th	90th	95th	Sample size
Total, age 12 and older	18.3 (16.9-19.7)	< LOD	< LOD	18.0 (16.4-20.4)	32.7 (29.5-36.0)	54.6 (47.4-64.5)	77.1 (65.9-84.6)	1933
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	19.0 (<LOD-25.2)	25.2 (18.8-30.1)	664
20 years and older	20.8 (19.2-22.6)	< LOD	< LOD	21.5 (19.3-23.5)	36.0 (32.3-40.0)	59.9 (50.7-67.9)	80.7 (70.7-89.6)	1269
Gender								
Males	17.7 (16.4-19.2)	< LOD	< LOD	17.9 (15.5-20.3)	30.5 (27.5-35.8)	50.5 (45.5-59.2)	66.5 (57.1-82.7)	922
Females	18.8 (17.0-20.8)	< LOD	< LOD	18.4 (16.2-21.9)	33.7 (29.7-38.4)	59.3 (48.2-71.5)	80.8 (71.4-96.3)	1011
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	25.2 (22.9-29.0)	45.8 (36.4-51.8)	56.3 (49.4-74.0)	650
Non-Hispanic blacks	20.3 (17.7-23.2)	< LOD	< LOD	15.3 (<LOD-17.2)	28.0 (24.4-31.9)	55.3 (43.3-77.0)	90.0 (67.2-114)	404
Non-Hispanic whites	19.1 (17.4-20.9)	< LOD	< LOD	19.4 (17.6-22.2)	34.1 (29.7-38.5)	54.6 (45.6-65.9)	78.5 (64.4-88.1)	722

< LOD means less than the limit of detection, which averaged 7.5 ng/g of lipid (SD 2.4, maximum value 14.5).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 162. Heptachlor Epoxide (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval) 10th	25th	50th	75th	90th	95th	Sample size
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	16.0 (<LOD-20.9)	24.1 (16.9-35.5)	1589
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	638
20 years and older	*	< LOD	< LOD	< LOD	< LOD	18.3 (<LOD-24.7)	27.1 (18.6-38.8)	951
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	19.2 (<LOD-27.1)	760
Females	*	< LOD	< LOD	< LOD	< LOD	18.3 (<LOD-26.4)	28.3 (18.6-47.4)	829
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	15.3 (<LOD-21.4)	22.2 (15.3-46.5)	598
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	16.8 (<LOD-24.1)	336
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	16.8 (<LOD-23.3)	26.4 (15.4-46.1)	539

< LOD means less than the limit of detection, which averaged 7.5 ng/g of lipid (SD 2.4, maximum value 14.6).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Mirex

CAS No. 2385-85-5

General Information

Mirex has not been produced or used in the United States since 1977. This chemical was formerly used in southern regions of the United States to control fire ants.

Interpreting Lipid-Adjusted Serum Mirex Levels Reported in the Table

Generally recognized guidelines for serum levels of mirex are not available. Mirex serum levels were generally not detectable both in the subsample represented in this *Report* or in a non-random subsample from NHANES II (1976-1980). In a control population of Canadian women sampled in 1994, the geometric mean lipid-adjusted level of mirex was 3.1 ng/gram of lipid (Lebel et al., 1998).

Table 163. Mirex (lipid adjusted)

Geometric mean and selected percentiles of serum concentration (nanograms/gram [ng/g] of lipid or parts-per-billion on a lipid weight basis) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. Interval)	Selected percentiles (95% confidence interval) 10th	25th	50th	75th	90th	95th	Sample size
Total, age 12 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1853
Age group								
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	659
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1194
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	887
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	966
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	617
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	18.8 (<LOD-58.3)	398
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	688

< LOD means less than the limit of detection, which averaged 7.5 ng/g of lipid (SD 2.4, maximum value 14.6).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Pentachlorophenol

CAS No. 87-86-5

General Information

Pentachlorophenol (PCP) is used primarily as a fungicide to preserve wood in the United States. The use of PCP over the years has decreased as a result of regulations by the U.S. EPA issued in 1984. The general population is exposed through food and water sources, which can be contaminated from either PCP releases or waste-site runoffs or from breakdown products of other organochlorinated chemicals (e.g., HCH, HCB). Homes containing PCP-treated wood are another source of exposure. Workers who use PCP may absorb the chemical through their skin and lungs. Unintentional overdoses of PCP can lead to inhibition of oxidative phosphorylation and clinical hyperthermia. IARC has determined that pentachlorophenol is possibly carcinogenic to humans, and the U.S. EPA has classified pentachlorophenol as a probable human carcinogen.

Interpreting Urine Pentachlorophenol Levels Reported in the Tables

Most of the PCP excreted in human urine is either unchanged PCP or PCP conjugated to glucuronic acid and sulfate. Measurements provided in this *Report* include both free and conjugated forms of PCP. The 95th percentile level in a non-random subsample from NHANES III participants (Hill et al., 1995) was about

Table 164. Pentachlorophenol

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.30 (.660-2.00)	1994
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	.760 (<LOD-1.60)	1.65 (<LOD-2.30)	482
12-19 years	*	< LOD	< LOD	< LOD	< LOD	.650 (<LOD-1.90)	2.00 (.660-5.40)	681
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.10 (<LOD-1.60)	831
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	.630 (<LOD-1.20)	1.40 (.660-1.90)	973
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	.860 (<LOD-2.00)	1021
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	.650 (<LOD-1.90)	696
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	.970 (.500-1.64)	1.64 (1.00-2.70)	521
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.30 (.550-2.10)	602

< LOD means less than the limit of detection, which is 0.5 µg/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

eight times higher than the 95th percentile for adults reported here. In the German Environmental Survey of 1990-1992, urinary PCP levels for adults were 9.4 µg/L and 12.8 µg/L at the 90th and 95th percentiles, respectively. For children aged 6 to 14 years, urinary PCP levels at the 90th and 95th percentiles were 11.7 µg/L and 14.9 µg/L, respectively (Seifert et al., 2000).

The ACGIH lists a BEI for PCP as 2 mg/gram of creatinine (ACGIH, 2000). Concentrations in this NHANES 1999-2000 subsample are well below this level of concern for workers. Workers involved in timber treatment have urinary PCP levels many times higher (Jones et al., 1986) than levels found in the NHANES 1999-2000 subsample. In another study, Angerer et al. (1992) reported levels in municipal incineration workers and control subjects that are similar to levels reported here.

Table 165. Pentachlorophenol (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.12 (.870-1.29)	1994
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	.930 (.553-1.14)	1.39 (.949-2.53)	482
12-19 years	*	< LOD	< LOD	< LOD	< LOD	.525 (.323-1.00)	1.26 (.529-2.51)	681
20 years and older	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.06 (.857-1.26)	831
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	.750 (.462-.947)	1.13 (.874-1.53)	973
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.10 (.818-1.26)	1021
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	.947 (.692-1.57)	696
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	.713 (.391-1.17)	1.34 (.720-1.57)	521
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.13 (.845-1.26)	602

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Trichlorophenols

Metabolites of organochlorine pesticides

General Information

The chemicals 2,4,5-trichlorophenol (245TCP, CAS No. 95-95-4) and 2,4,6-trichlorophenol (246TCP, CAS No. 88-06-2) are metabolites of several organochlorine chemicals, including HCH, HCB, and pentachlorophenol. Trichlorophenols are no longer intentionally manufactured, but they may be produced as byproducts of the manufacture of other chlorinated aromatic compounds. Small amounts of trichlorophenols can be produced during combustion of natural materials and from the chlorination of wastewater that contains phenols.

Interpreting Urine Trichlorphenol Levels Reported in the Tables

Trichlorophenols are excreted in human urine as unchanged trichlorophenols and as trichlorophenols conjugated to glucuronic acid and sulfate. Measurements provided in this *Report* include both free and conjugated forms of trichlorophenols. Generally recognized guidelines for urine levels of 245TCP and 246TCP have not been established. The levels for these chemicals are higher than levels measured previously in a non-random subsample from NHANES III during 1988-1994 (Hill et

Table 166. 2,4,5-Trichlorophenol

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	1.40 (1.00-2.40)	5.40 (2.50-15.0)	16.0 (4.30-39.0)	1998
Age group								
6-11 years	*	< LOD	< LOD	< LOD	1.30 (1.20-2.00)	4.60 (2.30-11.0)	11.0 (5.30-23.0)	483
12-19 years	*	< LOD	< LOD	< LOD	1.60 (1.00-3.10)	5.40 (2.80-22.0)	24.0 (4.70-40.0)	682
20 years and older	*	< LOD	< LOD	< LOD	1.40 (.970-2.50)	5.30 (2.20-18.0)	18.0 (4.20-46.0)	833
Gender								
Males	*	< LOD	< LOD	< LOD	1.40 (1.00-2.60)	5.30 (2.50-8.60)	9.30 (5.20-28.0)	974
Females	*	< LOD	< LOD	< LOD	1.50 (1.00-3.00)	6.50 (2.20-27.0)	21.0 (3.20-48.0)	1024
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	1.70 (1.40-3.50)	8.50 (4.70-18.0)	21.0 (12.0-29.0)	697
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	1.20 (.940-1.90)	4.80 (2.20-7.70)	8.60 (4.20-63.0)	524
Non-Hispanic whites	*	< LOD	< LOD	< LOD	1.40 (.960-3.20)	4.50 (2.40-7.50)	9.20 (4.40-25.0)	602

< LOD means less than the limit of detection, which is 0.9 µg/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

al., 1995). The 245TCP levels at the 90th and 95th percentiles for adults in this *Report* are threefold to sixfold higher than their respective percentile levels in a non-random subsample from NHANES III. Similarly, the 246TCP level at the 95th percentile for adults is about sixfold higher than in NHANES III. Levels in this *Report* are also higher than levels reported in municipal incineration workers, control subjects, a general population in Germany (Angerer et al., 1992), and also in a control group of children (Hill et al., 1989).

Geometric mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, and urinary creatinine. Urinary 246TCP levels were higher in the group aged 6-11 years than the groups aged 12-19 years or 20 years and older. Levels in the group aged 12-19 years were higher than levels in the group aged 20 years and older. There were no differences in 246TCP levels for gender or race/ethnicity. It is unknown whether differences between ages or races/ethnicities represent differences in exposure, body-size relationships, or metabolism.

Table 167. 2,4,5-Trichlorophenol (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	*	< LOD	< LOD	< LOD	2.36 (1.60-3.05)	5.50 (3.16-11.9)	11.9 (4.78-20.0)	1998
Age group								
6-11 years	*	< LOD	< LOD	< LOD	2.27 (1.54-3.93)	5.79 (4.03-11.9)	12.8 (5.28-25.4)	483
12-19 years	*	< LOD	< LOD	< LOD	1.44 (1.03-2.19)	3.77 (2.19-10.8)	11.2 (2.71-17.6)	682
20 years and older	*	< LOD	< LOD	< LOD	2.46 (1.64-3.15)	5.71 (3.16-12.7)	11.7 (4.31-20.0)	833
Gender								
Males	*	< LOD	< LOD	< LOD	1.67 (1.08-2.92)	4.24 (3.01-9.55)	9.55 (3.91-16.0)	974
Females	*	< LOD	< LOD	< LOD	2.57 (1.80-4.00)	7.73 (3.01-17.8)	16.2 (4.85-30.2)	1024
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	2.49 (1.79-3.90)	6.89 (4.35-11.7)	11.8 (6.90-16.9)	697
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	1.16 (.831-1.92)	3.39 (2.31-6.08)	6.79 (2.95-18.2)	524
Non-Hispanic whites	*	< LOD	< LOD	< LOD	2.44 (1.60-3.15)	4.72 (3.20-9.55)	9.55 (4.08-19.6)	602

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 168. 2,4,6-Trichlorophenol

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	2.85 (2.58-3.15)	< LOD	1.20 (<LOD-1.20)	2.45 (2.30-2.70)	4.80 (4.00-6.62)	14.8 (8.80-21.0)	25.0 (17.0-37.0)	1989
Age group								
6-11 years	4.47 (3.53-5.66)	< LOD	2.00 (1.20-2.40)	3.72 (2.80-5.20)	11.0 (5.10-18.0)	24.0 (15.0-35.9)	32.0 (25.0-45.0)	481
12-19 years	3.56 (3.06-4.14)	< LOD	1.50 (1.20-2.20)	3.00 (2.70-3.40)	6.00 (4.70-9.10)	20.0 (11.0-32.0)	37.0 (24.0-47.0)	678
20 years and older	2.52 (2.25-2.83)	< LOD	1.20 (<LOD-1.20)	2.40 (2.00-2.50)	4.20 (3.50-5.00)	11.6 (7.59-18.0)	21.0 (13.0-32.0)	830
Gender								
Males	2.92 (2.56-3.33)	< LOD	1.10 (<LOD-1.20)	2.60 (2.30-2.90)	5.10 (3.90-7.79)	15.0 (8.90-21.0)	26.0 (15.0-37.0)	970
Females	2.78 (2.40-3.22)	< LOD	1.20 (<LOD-1.20)	2.40 (2.00-2.60)	4.80 (3.80-6.40)	16.0 (7.50-23.0)	25.0 (16.0-45.0)	1019
Race/ethnicity								
Mexican Americans	2.70 (2.20-3.33)	< LOD	< LOD	2.60 (2.10-3.10)	4.80 (4.10-6.80)	14.0 (8.00-23.0)	22.0 (15.0-32.0)	694
Non-Hispanic blacks	3.14 (2.47-3.99)	< LOD	1.20 (<LOD-1.70)	2.80 (2.20-3.40)	6.40 (3.80-11.0)	18.0 (11.0-31.0)	32.0 (19.0-49.0)	519
Non-Hispanic whites	2.74 (2.48-3.04)	< LOD	1.20 (<LOD-1.30)	2.45 (2.30-2.80)	4.60 (3.90-6.00)	13.0 (7.70-19.0)	20.0 (13.0-36.0)	601

< LOD means less than the limit of detection, which is 1.0 µg/L.

Table 169. 2,4,6-Trichlorophenol (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6 and older	2.54 (2.28-2.84)	< LOD	1.17 (.950-1.44)	2.38 (2.12-2.73)	4.91 (3.93-6.09)	12.1 (9.41-16.8)	21.2 (14.9-28.5)	1989
Age group								
6-11 years	4.82 (3.91-5.95)	< LOD	2.22 (1.64-2.93)	4.71 (3.40-6.67)	11.5 (7.59-15.3)	21.8 (15.3-31.1)	31.5 (24.7-33.8)	481
12-19 years	2.40 (2.04-2.83)	< LOD	1.22 (.800-1.57)	2.33 (1.98-2.64)	4.27 (3.38-5.54)	11.6 (7.67-13.5)	14.4 (12.1-20.6)	678
20 years and older	2.32 (2.04-2.63)	< LOD	1.04 (.852-1.31)	2.22 (1.89-2.57)	4.25 (3.51-5.44)	9.95 (7.07-14.5)	19.6 (12.4-28.6)	830
Gender								
Males	2.24 (1.92-2.61)	< LOD	.968 (.750-1.30)	2.15 (1.82-2.43)	4.41 (3.64-5.59)	10.8 (7.22-15.3)	17.5 (11.2-28.5)	970
Females	2.88 (2.50-3.32)	< LOD	1.33 (1.05-1.66)	2.63 (2.23-2.96)	5.53 (4.27-6.90)	13.3 (10.1-20.6)	24.7 (16.9-34.4)	1019
Race/ethnicity								
Mexican Americans	2.43 (2.03-2.90)	< LOD	< LOD	2.50 (2.22-2.83)	5.43 (4.04-7.04)	10.8 (8.63-14.7)	18.3 (12.5-21.3)	694
Non-Hispanic blacks	2.13 (1.72-2.65)	< LOD	.899 (.696-1.27)	1.90 (1.58-2.56)	3.97 (3.01-6.47)	11.6 (5.54-19.5)	19.4 (12.7-25.2)	519
Non-Hispanic whites	2.59 (2.27-2.95)	< LOD	1.24 (1.02-1.57)	2.41 (2.11-2.93)	4.87 (3.83-5.88)	11.2 (7.62-16.9)	19.6 (13.2-31.5)	601

< LOD means less than the limit of detection (see previous table).

Carbamate Pesticides

General Information

Carbamate pesticides are widely used against insects, fungi, and weeds. Their estimated annual use worldwide ranged from 20,000 to 35,000 tons (International Programme on Chemical Safety, 1986). The carbamates are used on agricultural crops and on residential lawns and gardens by homeowners and professionals. In the United States, the annual use of the carbamate insecticide, carbaryl, during the period 1995-1996 was between 1 and 3 million pounds. Carbamate insecticides do not persist long in the environment, so they tend not to bioaccumulate.

Exposure of the general population to these pesticides occurs primarily from ingestion of food products or from residential use. The FDA, U.S. EPA, and OSHA have developed criteria on the allowable levels of these chemicals in foods, the environment, and the workplace. Additional sources of exposure include aerial spraying of these chemicals and workplace exposure during the manufacture, formulation, or application of these chemicals. Both dermal and inhalational routes of entry can occur in workers. Carbamate insecticides inhibit acetylcholinesterase, leading to an increase of acetylcholine at certain nerve terminals, and causing symptoms such as weakness and sometimes paralysis. Generally, carbamate insecticides inhibit acetylcholinesterase activity for a shorter amount of time than do organophosphate pesticides.

This *Report* provides measurements for the urinary metabolites of six carbamate insecticides. Table 170 shows the various metabolites measured in this *Report* and their parent carbamate pesticides. For example, propoxur metabolizes to 2-isopropoxyphenol. The presence of these chemicals generally reflects recent exposure to carbamate insecticides. Some of the metabolites can be produced from the metabolism of more than one insecticide. Although the presence of 1-naphthol in the urine can occur from carbaryl exposure, it may also result from exposure to naphthalene (e.g., in older types of mothballs), fires, and smoking (see the section titled "Pest Repellents and Disinfectants"). In addition to reflecting exposure to the parent insecticide, the level of the metabolite in a person's urine may reflect exposure to the metabolite itself.

Interpreting Urine Carbamate Insecticide Metabolite Levels Reported in the Tables

Generally recognized guidelines for urine levels of these metabolites have not been established. Urine levels of the metabolites of carbamate insecticides were measured in a subsample of NHANES 1999-2000 participants aged 6-59 years. Subsamples were randomly selected within the specified age range to be a representative sample of the U.S. population. Measuring these chemicals at these levels is possible because of advances in analytical chemistry. Finding a measurable amount of one or more metabolites in the urine does not mean that the levels of the carbamate insecticide cause an adverse health effect. Whether carbamate pesticides at the levels reported here are cause for health concern is not known; more research is needed.

These data provide physicians with a reference range so that they can determine whether people have been exposed to higher levels of carbamates than those found in the general population. These data will help scientists plan and conduct research about exposure to carbamates and health effects.

Table 170. Carbamate insecticides and their metabolites

Carbamate insecticide (CAS number)	**Primary urinary metabolite** (CAS number)
Carbaryl (63-25-2)	1-Naphthol (90-15-3)
Propoxur (114-26-1)	2-Isopropoxyphenol (4812-20-8)
Carbofuran (1563-66-2)	Carbofuranphenol (1563-38-8)
Benfuracarb (82560-54-1)	Carbofuranphenol (1563-38-8)
Carbosulfan (55285-14-8)	Carbofuranphenol (1563-38-8)
Furathiocarb (65907-30-4)	Carbofuranphenol (1563-38-8)

1-Naphthol

CAS No. 90-15-3

Metabolite of carbaryl (CAS No. 63-25-2) and other chemicals

Carbaryl is metabolized to 1-naphthol. Both 1-naphthol and 2-naphthol may result from exposure to naphthalene in older types of mothballs, fires that produce PAHs, and tobacco smoke. Thus, these metabolites in the urine may reflect multiple sources of exposure.

The levels of 1-napthol reported here are lower than levels measured in a non-random subsample from NHANES III (1988-1994) participants (Hill et al., 1995). The median level in the NHANES III subsample was about two to three times higher than the median level for adults reported here. In addition, the urinary 1-naphthol levels for the group aged 6-11 years in this *Report* are similar to levels reported for Minnesota children aged 3-13 years (adjusted for sociodemographic factors) in 1997 (Adgate et al., 2001). In a population of Maryland adults, the median urinary 1-naphthol level was 4.2 µg/L (MacIntosh et al., 1999) compared with the median level of 1.4 µg/L reported here. There were no differences in 1-naphthol levels among the various age, gender, or race/ethnic groups.

Table 171. 1-Naphthol

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	1.70 (1.38-2.09)	< LOD	< LOD	1.22 (1.00-1.60)	2.72 (1.90-3.76)	6.20 (4.10-9.60)	12.0 (7.20-19.0)	1998
Age group								
6-11 years	*	< LOD	< LOD	1.11 (<LOD-1.60)	2.30 (1.50-3.10)	3.61 (3.00-5.10)	5.60 (4.20-11.0)	483
12-19 years	1.54 (1.22-1.94)	< LOD	< LOD	1.20 (<LOD-1.50)	2.16 (1.60-3.80)	6.00 (3.20-11.0)	8.70 (5.20-19.0)	682
20-59 years	1.79 (1.43-2.23)	< LOD	< LOD	1.40 (1.10-1.70)	2.90 (2.10-4.10)	6.60 (4.20-12.0)	14.0 (7.20-22.0)	833
Gender								
Males	1.73 (1.42-2.11)	< LOD	< LOD	1.40 (1.10-1.80)	2.90 (2.00-3.90)	6.60 (4.40-9.00)	11.0 (7.20-16.0)	974
Females	1.67 (1.33-2.10)	< LOD	< LOD	1.30 (<LOD-1.63)	2.60 (1.80-3.80)	6.20 (3.71-13.0)	14.0 (6.30-22.0)	1024
Race/ethnicity								
Mexican Americans	1.48 (1.19-1.85)	< LOD	< LOD	1.10 (<LOD-1.70)	2.20 (1.60-3.10)	4.50 (3.00-6.70)	7.70 (4.60-14.0)	697
Non-Hispanic blacks	1.80 (1.42-2.28)	< LOD	< LOD	1.38 (1.10-1.80)	3.10 (1.89-4.80)	7.10 (4.40-13.0)	13.0 (7.20-41.0)	524
Non-Hispanic whites	1.70 (1.32-2.18)	< LOD	< LOD	1.30 (<LOD-1.60)	2.70 (1.80-3.90)	5.90 (3.70-11.0)	11.0 (5.90-21.0)	602

< LOD means less than the limit of detection, which is 1.0 µg/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 172. 1-Naphthol (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	1.52 (1.24-1.85)	< LOD	< LOD	1.25 (1.00-1.61)	3.00 (2.26-4.18)	6.80 (5.09-9.70)	11.6 (8.33-16.8)	1998
Age group								
6-11 years	*	< LOD	< LOD	1.34 (1.13-1.73)	2.57 (1.93-3.18)	4.53 (3.78-6.83)	8.21 (4.67-13.9)	483
12-19 years	1.04 (.839-1.29)	< LOD	< LOD	.845 (.652-1.04)	2.00 (1.24-2.91)	4.42 (2.67-6.20)	6.20 (3.78-10.0)	682
20-59 years	1.64 (1.32-2.05)	< LOD	< LOD	1.33 (1.08-1.78)	3.43 (2.36-4.87)	8.46 (5.77-11.5)	13.5 (8.65-19.7)	833
Gender								
Males	1.33 (1.09-1.61)	< LOD	< LOD	1.13 (.866-1.37)	2.41 (1.79-3.43)	6.23 (4.09-8.76)	10.0 (7.14-12.8)	974
Females	1.73 (1.39-2.16)	< LOD	< LOD	1.51 (1.15-1.91)	3.80 (2.54-4.79)	7.92 (5.50-12.8)	13.5 (8.33-19.7)	1024
Race/ethnicity								
Mexican Americans	1.34 (1.05-1.70)	< LOD	< LOD	1.18 (.899-1.61)	2.42 (1.68-3.44)	4.80 (3.54-6.32)	7.08 (4.95-8.86)	697
Non-Hispanic blacks	1.22 (.956-1.57)	< LOD	< LOD	.983 (.765-1.26)	2.46 (1.55-4.15)	7.19 (4.29-10.4)	10.7 (6.80-14.8)	524
Non-Hispanic whites	1.60 (1.24-2.06)	< LOD	< LOD	1.32 (1.00-1.81)	3.16 (2.18-4.73)	7.69 (5.00-11.5)	13.5 (7.92-18.9)	602

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

2-Isopropoxyphenol

CAS No. 4812-20-8

Metabolite of propoxur (CAS No. 114-26-1)

2-Isopropoxyphenol was detected in only 1.2% of the NHANES 1999-2000 subsample. In a non-random subsample from NHANES III (1988-1994), the 95th percentile level of 2-isopropoxyphenol was 1.7 µg/L (Hill et al., 1995).

Table 173. 2 - Isopropoxyphenol

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1917
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	456
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	655
20-59 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	806
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	936
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	981
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	664
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	500
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	584

< LOD means less than the limit of detection, which is 1.1 µg/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 174. 2-Isopropoxyphenol (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1917
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	456
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	655
20-59 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	806
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	936
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	981
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	664
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	500
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	584

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Carbofuranphenol

CAS No. 1563-38-8

Metabolite of benfuracarb, carbofuran, and other chemicals

In a non-random subsample from NHANES III (1988-1994), the 99th percentile level of carbofuranphenol was 2.1 µg/L (Hill et al., 1995).

Table 175. Carbofuranphenol

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	< LOD	< LOD	< LOD	.740 (<LOD-1.30)	1994
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	.430 (<LOD-2.16)	482
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	.570 (<LOD-1.20)	681
20-59 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	.840 (<LOD-1.50)	831
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	.740 (<LOD-1.30)	973
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	.840 (<LOD-1.70)	1021
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	.570 (<LOD-1.90)	1.90 (<LOD-3.70)	696
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	.430 (<LOD-1.50)	521
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	.740 (<LOD-1.50)	602

< LOD means less than the limit of detection, which is 0.4 µg/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 176. Carbofuranphenol (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	< LOD	< LOD	< LOD	.777 (.638-1.00)	1994
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	.988 (.435-2.63)	482
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	.472 (.326-.778)	681
20-59 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	.824 (.638-1.06)	831
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	.655 (.500-1.08)	973
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	.875 (.667-1.06)	1021
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	.778 (.438-1.65)	1.83 (.778-3.33)	696
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	.645 (.318-1.08)	521
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	.717 (.609-.881)	602

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Herbicides

General Information

Herbicides are used to control broadleaf weeds and woody plants on agricultural and residential property. These chemicals can be classified as chlorophenoxy acids (e.g., 2,4,5-trichlorophenoxyacetic acid, 2,4-dichlorophenoxyacetic acid), triazines (e.g,. atrazine), and chloroacetamides (e.g., alachlor). The U.S. EPA has restricted use of all these chemicals. Concern about contamination of 2,4,5-trichlorophenoxyacetic acid with 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) has led to the discontinuation of this herbicide. The general population may be exposed to this and other herbicides from their residential use, by living near application sites, or by ingesting herbicide-contaminated food or water. Workers who manufacture, formulate, or apply these chemicals also may be exposed to them. The FDA, U.S. EPA, and OSHA have developed criteria for the allowable levels of these chemicals in foods, the environment, and the workplace.

Atrazine is a commonly used herbicide in this country. Atrazine is listed as a "not classifiable" human carcinogen by IARC and as "not a likely human carcinogen" by U.S. EPA. 2,4-dichlorophenoxyacetic acid (2,4-D) is also used in the United States and is listed as a possible human carcinogen by IARC.

Table 177 shows the various metabolites and their parent herbicides. For example, atrazine is metabolized to atrazine mercapturate. The presence of these chemicals in a person generally reflects recent exposure to herbicides. In addition to reflecting exposure to the parent herbicide, the level of the metabolite in a person's blood or urine may also reflect exposure to the metabolite itself if it was present in the person's environment.

Interpreting Urine Herbicide Levels Reported in the Tables

Generally recognized guidelines for urine levels of these metabolites have not been established. Urine levels of the herbicides were measured in a subsample of NHANES 1999-2000 participants aged 6-59 years. Subsamples were randomly selected within the specified age range to be a representative sample of the U.S. population. Measuring these chemicals at these levels is possible because of advances in analytical chemistry. Finding a measurable amount of one or more herbicide in the urine does not mean that the levels of the herbicides cause an adverse health effect. Whether herbicides at the levels reported here are cause for health concern is not known; more research is needed.

These data provide physicians with a reference range so that they can determine whether people have been exposed to higher levels of herbicides than those found in the general population. Tables 178-187 summarize the results of these measurements. These data will help scientists plan and conduct research on exposure to organochlorines and their health effects.

Table 177. Herbicides and their metabolites

Herbicide (CAS number)	**Urinary metabolite** (CAS number)
Salts and esters of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) (93-76-5)	2,4,5-Trichlorophenoxyacetic acid (93-76-5)
Salts and esters of 2,4-dichlorophenoxyacetic acid (2,4-D) (94-75-7)	2,4-Dichlorophenoxyacetic acid (94-75-7) 2,4-Dichlorophenol (minor) (120-83-2)
Alachlor (15972-60-8)	Alachlor mercapturate
Atrazine (1912-24-9)	Atrazine mercapturate

2,4,5-Trichlorophenoxyacetic acid

CAS No. 93-76-5

Ninety percent of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) is eliminated unchanged in human urine. The route of worker exposure to 2,4,5-T is dermal, although inhalation can occur, depending on the method of application. Applicators had urine 2,4,5-T levels ranging from 250 µg/L to 11,000 µg/L (Simpson et al., 1978; Kolmodin-Hedman et al., 1980). Only 1.2% of participants in the NHANES 1999-2000 subsample had detectable levels of this chemical.

Table 178. 2,4,5-Trichlorophenoxyacetic acid

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1814
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	430
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	618
20-59 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	766
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	891
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	923
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	652
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	483
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	530

< LOD means less than the limit of detection, which averaged 0.14 µg/L (SD 0.35, maximum value 1.20).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 179. 2,4,5-Trichlorophenoxyacetic acid (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1814
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	430
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	618
20-59 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	766
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	891
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	923
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	652
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	483
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	530

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

2,4-Dichlorophenoxyacetic acid

CAS No. 94-75-7

About 95% of absorbed 2,4-dichlorophenoxyacetic acid (2,4-D) is excreted in the urine, mostly as unchanged 2,4-D. The 90th percentile for adults in a non-random subsample from NHANES III (1988-1994) (Hill et al., 1995) was 1.2 µg/gram of creatinine. Levels in children reported here are similar to levels in children from a reference community in Arkansas (Hill et al., 1989) who were studied in 1988-1994. Levels of 2,4-D were found to increase threefold to tenfold over pre-application levels when measured in 2,4-D spray applicators (Draper et al., 1982). Levels reaching 30 mg/L (30,000 µg/L) have been reported in herbicide workers (Lauwerys and Hoet, 2001).

Table 180. 2,4-Dichlorophenoxyacetic acid

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1977
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.30 (<LOD-1.90)	477
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.00 (<LOD-1.60)	677
20-59 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	823
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.10 (<LOD-1.40)	962
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1015
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	695
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.20 (<LOD-1.60)	520
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	588

< LOD means less than the limit of detection, which averaged .09 µg/L (SD .29, maximum value 0.95).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 181. 2,4-Dichlorophenoxyacetic acid (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1977
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	1.32 (.784-2.38)	477
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	.570 (.340-1.05)	677
20-59 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	823
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	.667 (.476-.866)	962
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1015
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	695
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	.570 (.420-1.05)	520
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	588

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

2,4-Dichlorophenol

CAS No. 120-83-2

The chemical 2,4-dichlorophenol is a minor metabolite of 2,4-dichlorophenoxyacetic acid. It can also result from the metabolism of several other chemicals, or it may be a byproduct in the manufacture of chemicals. Median levels of 2,4-dichlorophenol were three times lower than levels measured in a non-random subsample from NHANES III (1988-1994) (Hill et al., 1995). 2,4-dichlorophenol levels in municipal waste-incinerator workers were three times higher than levels in the adults documented in this *Report* (Angerer, 1992).

Geometric mean blood levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, and urinary creatinine. Children aged 6-11 years had levels slightly higher than the levels in people in the other two age groups. Non-Hispanic whites had a lower adjusted geometric mean 2,4-dichlorophenol level in urine than either Non-Hispanic blacks or Mexican Americans.

Table 182. 2,4-Dichlorophenol

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	1.11 (.883-1.40)	< LOD	< LOD	.750 (.600-1.00)	2.90 (1.80-4.70)	11.0 (6.40-17.0)	22.0 (17.0-31.0)	1990
Age group								
6-11 years	1.27 (.878-1.83)	< LOD	< LOD	.820 (.560-1.40)	3.30 (1.50-7.70)	17.0 (6.50-27.0)	29.0 (17.0-83.0)	481
12-19 years	1.30 (.987-1.71)	< LOD	.400 (<LOD-.480)	.950 (.710-1.30)	3.50 (2.20-5.20)	11.0 (6.00-18.0)	21.6 (12.0-36.0)	679
20-59 years	1.05 (.838-1.32)	< LOD	< LOD	.700 (.560-.940)	2.50 (1.50-4.50)	9.40 (6.00-17.0)	21.0 (15.0-31.0)	830
Gender								
Males	1.35 (1.01-1.80)	< LOD	.360 (<LOD-.470)	1.00 (.680-1.50)	3.80 (2.12-6.30)	12.0 (6.40-18.0)	21.0 (14.0-31.0)	971
Females	.920 (.719-1.18)	< LOD	< LOD	.590 (.470-.800)	2.20 (1.20-3.60)	8.30 (4.70-18.0)	25.0 (11.0-32.0)	1019
Race/ethnicity								
Mexican Americans	1.80 (1.31-2.48)	< LOD	.430 (<LOD-.670)	1.00 (.770-1.60)	5.90 (3.90-8.80)	23.0 (14.0-34.0)	50.0 (28.0-78.0)	695
Non-Hispanic blacks	2.24 (1.48-3.39)	< LOD	.530 (.450-.690)	1.60 (.850-2.61)	8.80 (3.20-18.0)	22.0 (16.0-43.0)	39.0 (18.0-140)	518
Non-Hispanic whites	.892 (.701-1.14)	< LOD	< LOD	.600 (.450-.810)	2.00 (1.30-3.50)	7.20 (4.20-13.0)	17.0 (8.40-27.0)	602

< LOD means less than the limit of detection, which is 0.3 µg/L.

Table 183. 2,4-Dichlorophenol (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	.994 (.807-1.22)	< LOD	< LOD	.794 (.605-.971)	2.15 (1.43-3.33)	6.79 (5.09-9.67)	13.9 (10.3-23.0)	1990
Age group								
6-11 years	1.37 (.974-1.92)	< LOD	< LOD	.966 (.604-1.36)	3.15 (1.49-7.63)	12.8 (6.79-23.7)	25.3 (12.8-76.9)	481
12-19 years	.877 (.694-1.11)	< LOD	.306 (.267-.341)	.645 (.494-.971)	2.19 (1.33-3.55)	5.70 (4.22-9.89)	10.3 (6.34-15.3)	679
20-59 years	.967 (.787-1.19)	< LOD	< LOD	.795 (.621-.962)	1.95 (1.32-3.06)	6.36 (4.62-8.84)	11.6 (8.70-21.8)	830
Gender								
Males	1.04 (.796-1.35)	< LOD	.337 (.274-.462)	.819 (.590-1.09)	2.51 (1.48-4.26)	7.55 (5.14-11.0)	12.3 (9.77-27.4)	971
Females	.955 (.771-1.18)	< LOD	< LOD	.735 (.582-.893)	1.91 (1.27-2.88)	6.66 (4.12-10.2)	15.3 (8.84-24.1)	1019
Race/ethnicity								
Mexican Americans	1.62 (1.20-2.19)	< LOD	.471 (.328-.657)	1.15 (.843-1.70)	4.00 (2.63-6.34)	19.8 (10.8-44.9)	48.7 (26.7-65.9)	695
Non-Hispanic blacks	1.52 (1.03-2.26)	< LOD	.419 (.330-.543)	1.16 (.672-1.97)	5.12 (2.38-7.20)	12.7 (6.36-41.7)	28.9 (8.47-161)	518
Non-Hispanic whites	.843 (.675-1.05)	< LOD	< LOD	.663 (.542-.870)	1.58 (1.18-2.35)	5.00 (3.27-8.70)	10.7 (6.43-19.2)	602

< LOD means less than the limit of detection (see previous table).

Atrazine mercapturate

Metabolite of atrazine (CAS No. 1912-24-9)

Atrazine is an herbicide that inhibits photosynthesis in broadleaf and some grassy weeds. It can be used in agriculture on a wide variety of crops, but of the 75 million pounds produced annually, 96% is used on corn and sorghum. Atrazine is degraded in the environment to several products and metabolized in people along multiple pathways. In animal studies, the hydroxy-atrazine class of degradation products and metabolites may produce kidney injury. Atrazine has low acute toxicity. Chronic exposure in animal studies has demonstrated reproductive and developmental effects. Amphibians may be particularly sensitive to environmental contamination. Human exposure to atrazine or its degradation products can occur through agricultural runoff into drinking-water systems. Workers can be exposed during residential and agricultural application of the herbicide. Children may be exposed by playing on lawns were atrazine was applied.

In people, atrazine is metabolized predominantly to its mercapturate. Atrazine mercapturate was detected in 3.3% of the NHANES 1999-2000 subsample. The low frequency of detection for atrazine mercapturate in urine was previously reported in the U.S. population (MacIntosh et al., 1999).

In one 1997 study of Minnesota children aged 3-13 years, urinary atrazine mercapturate levels averaged 0.55 µg/L (Adgate et al., 2001).

Table 184. Atrazine mercapturate

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1878
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	449
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	639
20-59 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	790
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	919
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	959
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	667
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	498
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	549

< LOD means less than the limit of detection, which averaged 0.047 µg/L (SD 0.25, maximum value 0.79).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 185. Atrazine mercapturate (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1878
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	449
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	639
20-59 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	790
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	919
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	959
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	667
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	498
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	549

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Alachlor mercapturate

Metabolite of alachlor (CAS No. 15972-60-8)

Table 186. Alachlor mercapturate

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1942
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	463
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	662
20-59 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	817
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	950
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	992
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	679
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	507
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	585

< LOD means less than the limit of detection, which averaged 0.09 µg/L (SD 0.36, maximum value 1.18).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 187. Alachlor Mercapturate (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1942
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	463
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	662
20-59 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	817
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	950
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	992
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	679
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	507
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	585

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Pest Repellents and Disinfectants

General Information

The pest repellents and disinfectants measured for this *Report* include naphthalene, *p*-dichlorobenzene (DCB), N,N-diethyl-3-methylbenzamide (formerly, N,N-diethyl-meta-toluamide [DEET]), and *ortho*-phenylphenol (OPP). Naphthalene and DCB are used as moth repellents and fumigants. DCB is also used as a bathroom deodorizer. Additional sources of naphthalene are the incomplete combustion of fossil fuels (e.g., coal) and tobacco smoke. DEET is an insect repellent that is commonly used against mosquitoes. It is available in several concentrations, ranging from 4% to 100%, and can be applied to clothing and skin. OPP is a disinfectant that is used topically on surfaces and as a fungicide for stored food crops. Hexachlorobenzene has also been used as a fungicide (see the section titled "Organochlorine Pesticides"). Exposure to these pesticides may also result from the ingestion of contaminated food products or from residential use. Workers involved in the manufacture, formulation, or application of these chemicals can be exposed as well.

Table 188 shows the various metabolites and their parent chemicals. The naphthalene metabolites, 1-naphthol and 2-naphthol, may result from exposure to naphthalene in old forms of mothballs, but exposure is more likely from sources of polycyclic aromatic hydrocarbons, such as tobacco smoke. In addition, carbaryl is metabolized to 1-naphthol (see the section titled "Carbamate Pesticides"). Thus, the presence of these metabolites in urine may reflect multiple sources of exposure. In addition to reflecting exposure to the parent chemical, the level of the metabolite in a person's urine may also reflect exposure to the metabolite if it was present in the person's environment.

Interpreting Levels of Urine Pest Repellent and Disinfectants Reported in the Tables

Urinary levels of the metabolites and the parent compounds of pest repellents and disinfectants were measured in a subsample of NHANES 1999-2000 participants aged 6-59 years. Subsamples were randomly selected within the specified age range to be a representative sample of the U.S. population. These samples were collected throughout the year and were not intended to reflect any pattern of seasonal use. Thus, samples may have been obtained during a seasonal period when the pest repellent was used less frequently.

Measuring these chemicals at these levels is possible because of advances in analytical chemistry. Finding a measurable amount of one or more metabolites in the urine does not identify the source of exposure, nor does it mean that the levels of the pest repellent or disinfectant cause an adverse health effect. Whether the chemicals at the levels reported here are cause for health concern is not known; more research is needed.

Generally recognized guidelines for urine levels of these metabolites have not been established. The FDA and OSHA have developed criteria on the allowable levels of these chemicals in foods and the workplace. The U.S. EPA has set similar criteria for water and for the storage and removal of waste (U.S. EPA*c*).

These data provide physicians with a reference range so that they can determine whether people have been exposed to higher levels of these chemicals than those

Table 188. Repellents or disinfectants and their urinary metabolites

Repellent or disinfectant (CAS number)	**Urinary metabolite** (CAS number)
Naphthalene (91-20-3)	1-Naphthol (90-15-3) 2-Naphthol (135-19-3)
p-Dichlorobenzene (DCB) (106-46-7)	2,5-Dichlorophenol (583-78-8)
N,N-diethyl-3-methylbenzamide (DEET) (134-62-3)	
ortho-Phenylphenol (90-43-7)	

found in the general population. These data will help scientists plan and conduct research about exposure to pest repellents and disinfectants and health effects.

2-Naphthol

CAS No. 135-19-3

Metabolite of naphthalene (CAS No. 91-20-3)

The 50th and 90th percentile levels for urinary 2-naphthol levels are lower than those values in a non-random subsample from NHANES III (1988-1994) (Hill et al., 1995). Geometric mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, and urinary creatinine. The group aged 12-19 years had a slightly lower urine 2-naphthol level than the group aged 20-59 years. Urinary 2-naphthol levels among racial/ethnic or gender categories did not differ.

Table 189. 2-Naphthol

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	.471 (.327-.680)	< LOD	< LOD	.370 (<LOD-.740)	2.00 (1.10-3.30)	7.90 (4.00-12.0)	15.0 (9.90-19.3)	1993
Age group								
6-11 years	*	< LOD	< LOD	< LOD	1.50 (.470-2.70)	3.30 (2.00-5.30)	5.00 (3.50-11.0)	481
12-19 years	.423 (.279-.639)	< LOD	< LOD	.290 (<LOD-.630)	1.70 (.750-3.20)	5.80 (3.20-11.0)	9.80 (6.00-16.0)	681
20-59 years	.516 (.355-.751)	< LOD	< LOD	.450 (.200-.810)	2.20 (1.20-3.70)	9.90 (4.30-15.0)	15.0 (11.0-23.0)	831
Gender								
Males	.502 (.335-.752)	< LOD	< LOD	.420 (<LOD-.950)	2.00 (1.20-3.50)	9.40 (4.10-14.5)	15.0 (9.90-22.0)	973
Females	.444 (.304-.647)	< LOD	< LOD	.330 (<LOD-.660)	1.50 (.810-3.30)	6.60 (3.60-12.0)	13.0 (8.30-21.0)	1020
Race/ethnicity								
Mexican Americans	.557 (.379-.819)	< LOD	< LOD	.530 (.260-1.10)	1.90 (1.10-3.60)	5.00 (3.30-8.30)	9.60 (5.50-18.0)	696
Non-Hispanic blacks	.801 (.476-1.35)	< LOD	< LOD	.740 (.310-1.50)	3.70 (1.50-7.50)	14.0 (5.60-23.0)	24.0 (15.0-31.0)	520
Non-Hispanic whites	*	< LOD	< LOD	.300 (<LOD-.650)	1.50 (.810-2.90)	6.50 (3.00-15.0)	14.5 (6.50-24.0)	602

< LOD means less than the limit of detection, which is 0.2 µg/L.

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 190. 2-Naphthol (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	.421 (.297-.596)	< LOD	< LOD	.338 (.196-.625)	1.56 (.964-2.65)	5.98 (3.25-9.46)	10.8 (6.53-16.0)	1993
Age group								
6-11 years	*	< LOD	< LOD	< LOD	1.63 (.533-2.69)	2.94 (2.24-3.55)	3.57 (3.11-9.36)	481
12-19 years	.285 (.194-.420)	< LOD	< LOD	.206 (.115-.435)	.979 (.503-1.81)	3.47 (1.60-5.58)	5.37 (3.58-8.43)	681
20-59 years	.474 (.332-.677)	< LOD	< LOD	.412 (.247-.681)	1.68 (1.03-3.18)	6.79 (4.25-10.8)	14.7 (8.41-17.6)	831
Gender								
Males	.385 (.262-.565)	< LOD	< LOD	.332 (.163-.618)	1.36 (.894-2.72)	5.13 (3.02-10.0)	10.9 (5.58-17.2)	973
Females	.460 (.325-.652)	< LOD	< LOD	.339 (.206-.652)	1.65 (.988-2.80)	6.25 (3.18-9.63)	9.64 (6.03-16.5)	1020
Race/ethnicity								
Mexican Americans	.501 (.337-.744)	< LOD	< LOD	.445 (.250-.909)	1.61 (.833-2.91)	4.24 (2.66-6.67)	6.79 (4.34-10.3)	696
Non-Hispanic blacks	.543 (.329-.897)	< LOD	< LOD	.467 (.199-1.21)	2.11 (1.10-4.81)	8.16 (4.05-11.0)	11.0 (8.16-15.2)	520
Non-Hispanic whites	*	< LOD	< LOD	.308 (.171-.596)	1.38 (.833-2.64)	5.98 (2.68-11.0)	13.2 (5.37-17.6)	602

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

2,5-Dichlorophenol

CAS No. 583-78-8

Metabolite of p-*dichlorobenzene (CAS No. 106-46-7)*

In a non-random subsample from NHANES III, the median level of 2,5-dichlorophenol was 30 µg/L, (Hill et al., 1995), which is about five times higher than the median shown in this *Report*. Angerer et al. (1992) measured 2,5-dichlorophenol in the urine of municipal waste-incinerator workers and reported a median level similar to the median in the adults documented in this *Report*.

Geometric mean levels of the demographic groups were compared after adjustment for the covariates of race/ethnicity, age, gender, and urinary creatinine. Urinary 2,5-dichlorophenol levels in children aged 6-11 years were higher than in people aged 12-19 years. Non-Hispanic blacks and Mexican Americans had levels of 2,5-dichlorophenol that were two to three times higher than levels in non-Hispanic whites.

Table 191. 2,5-Dichlorophenol

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	6.01 (4.22-8.57)	< LOD	1.40 (.710-2.10)	6.50 (4.60-9.90)	37.8 (23.0-52.0)	144 (88.0-240)	440 (240-700)	1989
Age group								
6-11 years	7.57 (4.26-13.5)	< LOD	1.60 (.620-3.10)	9.00 (4.30-15.0)	46.0 (20.0-130)	240 (87.0-640)	630 (230-760)	480
12-19 years	5.85 (3.88-8.81)	< LOD	1.70 (.780-2.60)	4.80 (3.80-7.60)	32.0 (18.0-45.0)	130 (70.0-250)	382 (170-820)	680
20-59 years	5.82 (4.04-8.40)	< LOD	1.30 (.610-2.00)	6.60 (4.60-11.0)	36.7 (21.0-51.0)	130 (83.0-200)	420 (200-660)	829
Gender								
Males	6.84 (4.95-9.47)	< LOD	1.70 (1.30-2.70)	7.90 (5.68-11.0)	37.0 (24.0-52.0)	150 (98.0-240)	440 (195-590)	970
Females	5.30 (3.31-8.51)	< LOD	1.00 (.350-2.00)	5.40 (3.30-9.80)	37.8 (18.0-57.0)	150 (75.0-290)	490 (200-850)	1019
Race/ethnicity								
Mexican Americans	14.3 (7.13-28.5)	< LOD	3.30 (.970-7.20)	13.0 (8.00-24.0)	110 (45.0-270)	660 (280-1000)	1100 (650-2400)	695
Non-Hispanic blacks	15.8 (9.83-25.4)	< LOD	4.30 (1.60-8.30)	19.0 (11.0-32.0)	110 (54.0-180)	460 (241-704)	770 (470-1100)	517
Non-Hispanic whites	3.81 (2.66-5.44)	< LOD	1.10 (.230-1.80)	4.40 (3.00-5.90)	19.0 (12.0-33.0)	75.0 (47.0-130)	170 (98.0-550)	602

< LOD means less than the limit of detection, which is 0.1 µg/L.

Table 192. 2,5-Dichlorophenol (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	5.38 (3.86-7.49)	< LOD	1.29 (.857-2.06)	5.60 (4.11-8.16)	26.0 (16.9-41.1)	125 (68.8-216)	299 (226-458)	1989
Age group								
6-11 years	8.17 (4.64-14.4)	< LOD	1.88 (.943-3.07)	11.3 (4.79-21.0)	47.7 (22.4-100)	247 (80.8-473)	516 (267-762)	480
12-19 years	3.95 (2.59-6.02)	< LOD	1.19 (.500-2.20)	4.11 (2.60-6.08)	19.4 (12.1-31.7)	64.7 (47.1-196)	233 (151-398)	680
20-59 years	5.36 (3.87-7.41)	< LOD	1.23 (.749-1.95)	5.60 (4.11-8.41)	24.5 (15.1-40.6)	115 (64.5-209)	280 (216-509)	829
Gender								
Males	5.25 (3.84-7.18)	< LOD	1.49 (.974-2.09)	5.44 (4.11-7.48)	24.1 (15.4-32.1)	96.8 (64.5-213)	289 (213-432)	970
Females	5.50 (3.58-8.46)	< LOD	1.17 (.496-2.27)	6.15 (3.97-9.87)	28.9 (15.1-50.0)	136 (68.1-216)	352 (216-644)	1019
Race/ethnicity								
Mexican Americans	12.9 (6.53-25.4)	< LOD	2.97 (1.01-6.10)	12.7 (7.24-26.2)	72.7 (34.1-200)	515 (200-1170)	1170 (580-2790)	695
Non-Hispanic blacks	10.7 (6.93-16.7)	< LOD	3.29 (1.52-5.10)	13.5 (8.10-22.1)	57.8 (32.2-97.4)	241 (124-339)	433 (245-746)	517
Non-Hispanic whites	3.60 (2.56-5.06)	< LOD	.944 (.368-1.53)	3.81 (2.84-4.90)	14.4 (9.86-21.7)	57.4 (35.0-136)	202 (88.8-355)	602

< LOD means less than the limit of detection (see previous table).

N,N-diethyl-3-methylbenzamide

CAS No. 134-62-3

N,N-diethyl-3-methylbenzamide (DEET) is an insect repellent that was first marketed in 1957. It is commonly used against mosquitoes and can be applied to clothing and the skin. The annual use of DEET in the total U.S. population is estimated at 30% and among children at 34% (U.S. EPA*d*, 1980). Commercial DEET ranges in concentration from 4% to 100% (95% m-DEET, 5% o-DEET and p-DEET). The o- and p-DEET isomers are byproducts of manufacturing. The isomers differ in toxicity and their effectiveness as repellents; m-DEET is most effective as a repellent and o-DEET may be more toxic (Ambrose and Yost, 1965). When applied to the skin, DEET is absorbed and eliminated primarily in the urine.

The general population may be exposed to DEET from the ingestion of contaminated food or from personal use. Workers involved in the manufacture, formulation, or application of these chemicals can be exposed as well. People in occupations involving increased outdoor activity (e.g., field biologists, military personnel) may have additional exposure to DEET from increased use (Robbins and Cherniack, 1986). Urinary m-DEET levels as high as 5,690 µg/L have been measured in eight park employees who applied 71% m-DEET once a day (Smallwood et al., 1992).

Table 193. N,N-diethyl-3-methylbenzamide (DEET)

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1977
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	480
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	672
20-59 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	825
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	964
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1013
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	688
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	518
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	597

< LOD means less than the limit of detection, which averaged .06 µg/L (SD .13, maximum value 0.45).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 194. N,N-diethyl-3-methylbenzamide (DEET) (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1977
Age group								
6-11 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	480
12-19 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	672
20-59 years	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	825
Gender								
Males	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	964
Females	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	1013
Race/ethnicity								
Mexican Americans	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	688
Non-Hispanic blacks	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	518
Non-Hispanic whites	*	< LOD	< LOD	< LOD	< LOD	< LOD	< LOD	597

< LOD means less than the limit of detection (see previous table).

* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

ortho-Phenylphenol

CAS No. 90-43-7

General Information

Ortho-phenylphenol (OPP) and its water soluble salt, sodium *o*-phenylphenate (SOPP), are pesticides used agriculturally to control fungal and bacterial growth on stored crops (e.g,. fruits, vegetables). These agents came into use in the mid 1930s. SOPP is applied topically to the crop and then rinsed off, leaving the chemical residue, *o*-phenylphenol. OPP offers additional protection to the crop from infection at scarred or injured sites (Johnson et al., 2001). OPP is also used as a disinfectant fungicide for industrial and indoor home use.

The general population may be exposed to these chemicals from residential use and by ingesting treated food or contaminated ground water. Workers who manufacture, formulate, or apply these chemicals may be exposed to them as well. The major urinary metabolites from SOPP exposure are OPP glucuronide and sulfate conjugates. IARC has classified SOPP as a possible human carcinogen and OPP as not classifiable as a human carcinogen. The NTP conducted a 2-year experimental animal dermal study using OPP and found no evidence of carcinogenicity. The effects on the general population at the current level of exposure are not yet known. Further research is needed.

Table 195. *ortho*-Phenylphenol

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	.494 (.412-.593)	< LOD	< LOD	.490 (.300-.590)	.850 (.650-1.10)	1.46 (1.10-1.80)	2.00 (1.60-2.50)	1991
Age group								
6-11 years	.506 (.419-.613)	< LOD	< LOD	.490 (<LOD-.580)	.890 (.670-1.30)	1.80 (1.40-2.10)	2.20 (1.90-3.30)	480
12-19 years	.506 (.400-.640)	< LOD	< LOD	.490 (<LOD-.600)	.890 (.640-1.30)	1.60 (1.20-2.10)	2.00 (1.40-6.30)	681
20-59 years	.489 (.408-.587)	< LOD	< LOD	.490 (.300-.600)	.810 (.630-1.10)	1.41 (1.10-1.70)	1.90 (1.60-2.50)	830
Gender								
Males	.495 (.412-.595)	< LOD	< LOD	.460 (<LOD-.570)	.820 (.660-1.20)	1.60 (1.20-1.90)	1.90 (1.60-2.90)	973
Females	.493 (.405-.600)	< LOD	< LOD	.480 (<LOD-.580)	.860 (.620-1.10)	1.50 (1.10-1.80)	2.10 (1.60-2.40)	1018
Race/ethnicity								
Mexican Americans	.548 (.406-.739)	< LOD	< LOD	.410 (<LOD-.790)	1.10 (.660-1.60)	2.20 (1.50-4.10)	3.80 (2.40-6.70)	695
Non-Hispanic blacks	.562 (.443-.715)	< LOD	< LOD	.560 (.440-.740)	.970 (.730-1.40)	1.60 (1.30-1.80)	1.90 (1.50-2.30)	520
Non-Hispanic whites	.463 (.373-.575)	< LOD	< LOD	.440 (<LOD-.570)	.760 (.580-1.10)	1.40 (.980-1.70)	1.90 (1.50-2.50)	602

< LOD means less than the limit of detection, which is 0.3 µg/L.

Interpreting Urine ortho-Phenylphenol (OPP) Levels Reported in the Tables

Urine levels of OPP were measured in a subsample of NHANES 1999-2000 participants aged 6-59 year. Subsamples were randomly selected within the specified age range to be a representative sample of the U.S. population. Measuring these chemicals at these levels is possible because of advances in analytical chemistry. Finding a measurable amount of OPP in the urine does not identify the source of exposure, nor does it mean that the level of OPP causes an adverse health effect. Whether OPP at the levels reported here is cause for health concern is not known; more research is needed.

These data provide physicians with a reference range so that they can determine whether people have been exposed to higher levels of OPP than those found in the general population. These data will help scientists plan and conduct research on exposure to sodium *o*-phenyl phenol and their health effects.

Generally recognized guidelines for urine levels have not been established. There were no differences found among the demographic age, race/ethnicity, or gender groups.

Table 196. *ortho*-Phenylphenol (creatinine adjusted)

Geometric mean and selected percentiles of urine concentrations (in µg/gram of creatinine) for the U.S. population aged 6 to 59 years, National Health and Nutrition Examination Survey, 1999-2000.

	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)						Sample size
		10th	25th	50th	75th	90th	95th	
Total, age 6-59	.441 (.369-.528)	< LOD	< LOD	.413 (.328-.524)	.840 (.660-1.07)	1.84 (1.31-2.21)	2.93 (2.14-3.89)	1991
Age group								
6-11 years	.547 (.470-.636)	< LOD	< LOD	.504 (.413-.636)	1.02 (.800-1.27)	1.96 (1.51-2.57)	2.61 (2.09-3.58)	480
12-19 years	.342 (.270-.432)	< LOD	< LOD	.319 (.218-.430)	.691 (.505-.877)	1.14 (.889-1.70)	1.96 (1.19-3.95)	681
20-59 years	.450 (.373-.542)	< LOD	< LOD	.420 (.325-.538)	.861 (.656-1.09)	1.89 (1.35-2.24)	3.28 (2.21-4.29)	830
Gender								
Males	.379 (.315-.457)	< LOD	< LOD	.353 (.258-.444)	.752 (.589-.943)	1.43 (1.09-1.82)	2.07 (1.65-3.11)	973
Females	.511 (.423-.619)	< LOD	< LOD	.459 (.400-.577)	.909 (.732-1.24)	2.04 (1.51-2.59)	3.78 (2.29-4.95)	1018
Race/ethnicity								
Mexican Americans	.492 (.353-.686)	< LOD	< LOD	.420 (.250-.696)	1.11 (.659-1.62)	2.99 (1.37-4.60)	4.61 (3.00-10.0)	695
Non-Hispanic blacks	.382 (.302-.482)	< LOD	< LOD	.375 (.288-.494)	.672 (.534-.859)	1.21 (.860-1.65)	1.69 (1.23-3.17)	520
Non-Hispanic whites	.438 (.350-.547)	< LOD	< LOD	.410 (.301-.568)	.861 (.627-1.11)	1.86 (1.24-2.29)	2.93 (2.03-3.90)	602

< LOD means less than the limit of detection (see previous table).

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Appendix A

References for Biomonitoring Analytical Methods

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Appendix B

Confidence Interval Estimation for Percentiles

A common practice to calculate confidence intervals from survey data is to use large-sample normal approximations. 95% confidence intervals on point estimates of percentiles are often computed by adding and subtracting from the point estimate a quantity equal to twice its standard error. This normal approximation method may not be adequate, however, when estimating the proportion of subjects above or below a selected value (especially when the proportion is near 0.0 or 1.0 or when the effective sample size is small). In addition, confidence intervals on proportions deviating from 0.5 are not theoretically expected to be symmetric around the point estimate. Also, adding and subtracting a multiple of the standard error to an estimate near 0.0 or 1.0 can lead to impossible confidence limits (i.e., proportion estimates below 0.0 or above 1.0).

We used the method of Korn et al. (1998) to obtain 95% confidence intervals about percentile estimates. We describe the method below, using SAS Proc Univariate and SUDAAN.

Procedure to calculate confidence intervals about percentiles.

Step 1: Use SAS (SAS Institute Inc. 1999) Proc Univariate to obtain a point estimate of the percentile of a chemical's results for the demographic group of interest, for example, the 90th percentile of blood lead results for children aged 1-5 years. Use the Freq option to assign the correct sample weight for each chemical result.

Step 2: Use SUDAAN (SUDAAN Users Manual, 2001) Proc Descript with Jackknife design option to estimate the proportion of subjects with results below the percentile estimate obtained in Step 1 and to obtain the standard error associated with this proportion estimate.

Step 3: After obtaining an estimate of the proportion of subjects below the estimated percentile value (i.e., the proportion obtained in Step 2), compute the Clopper-Pearson 95% confidence interval using the degrees-of-freedom adjusted effective sample size (Korn and Graubard, 1998). (Note: If the degrees-of-freedom adjusted effective sample size is greater than the actual sample size, 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 Freq option to assign weights) to determine the chemical values that correspond to the proportion obtained in Step 2 and the lower and upper limits on this proportion obtained in Step 3.

Example:
To estimate the 75th percentile, use SAS Proc Univariate with the Freq option to get a point estimate of the chemical value that corresponds to the 75th percentile. Then use SUDAAN to estimate the proportion of subjects with results below the 75th percentile (which should be very near 0.75). Next, obtain a confidence interval on this proportion by computing the Clopper-Pearson 95% confidence limits using the degrees-of-freedom adjusted effective sample size. Suppose these confidence limits are 0.67 and 0.81, then use SAS Proc Univariate with the Freq option to determine the chemical values corresponding to the 67th and 81st percentiles. These point estimates are the lower and upper confidence limits on the 75th percentile.

Appendix C

Abbreviations and Acronyms

(*Excludes abbreviations of chemical categories or specific chemicals)*

ACGIH	American Conference of Governmental Industrial Hygienists
ANCOVA	Analysis of covariance
ATSDR	Agency for Toxic Substances and Disease Registry
BAT	Biologischen arbeitsstoff-toleranz [German] or biological tolerance level
BEI	Biological exposure index
BLL	Blood lead level
CAS	Chemical Abstract Service
CDC	Centers for Disease Control and Prevention
CPSC	U.S. Consumer Product Safety Commission
FDA	United States Food and Drug Administration
IARC	International Agency for Research on Cancer
IUPAC	International Union of Pure and Applied Chemistry
LOD	Limit of detection
MSDS	Material Safety Data Sheets
NCEH	National Center for Environmental Health
NCHS	National Center for Health Statistics
NHANES	National Health and Nutrition Examination Survey
NIEHS	National Institute of Environmental Health Sciences
NIH	National Institutes of Health
NIOSH	National Institute for Occupational Safety and Health
NRC	United States Nuclear Regulatory Commission
NTP	National Toxicology Program
OSHA	Occupational Safety and Health Administration
TEF	Toxic equivalency factor
TEQ	Toxic equivalency
TLV	Threshold limit value
USDA	United States Department of Agriculture
U.S. DOE	United States Department of Energy
U.S. DOT	United States Department of Transportation
U.S. EPA	United States Environmental Protection Agency
U.S. HHS	United States Department of Health and Human Services
U.S. HUD	United States Department of Housing and Urban Development
WHO	World Health Organization