Third National Report on Human Exposure to Environmental Chemicals

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Department of Health and Human Services
Centers for Disease Control and Prevention

Contents

Introduction

The *National Report on Human Exposure to Environmental Chemicals* provides an ongoing assessment of the exposure of the U.S. population to environmental chemicals using biomonitoring. The *Second National Report on Human Exposure to Environmental Chemicals (Second Report)* was released in 2003 and presented biomonitoring exposure data for 116 environmental chemicals for the civilian, noninstitutionalized U.S. population over the 2-year period 1999-2000. This *Third Report* presents similar exposure data for the U.S. population for 148 environmental chemicals over the period 2001-2002. The

Data from earlier *Reports* are included in the Third *Report*.

The *Third Report* includes data from the *First* and *Second Report*s in the tables and charts. One exception is that 10th and 25th percentiles are no longer included in the *Report* because of space limitations in the tables. Each chemical has 50th, 75th, 90th, and 95 th percentiles included in the tables along with the unadjusted geometric means and sample sizes for the survey periods (i.e., 1999-2000 and 2001-2002) for which that chemical was analyzed. Current plans are to release future *Reports* of the exposure of the U.S. population to cover 2-year periods (e.g., 2003-2004, 2005-2006, 2007-2008).

Statistical tests for significance of trends over time should await additional data from future *Reports*. More detailed research analyses of the data in the *Report* is encouraged.

We have not performed statistical tests for trends over time given that data are available only for the 1999-2000 and 2001-2002 survey periods. New data will be released for the U.S. population every 2 years, with the next release covering the survey period 2003-2004. With additional data points it will be possible to describe patterns over time and in some cases test for trends. We plan to investigate trends in future *Reports* for chemicals that have at least 3 survey periods

More in-depth statistical analysis, including additional covariates, interactions and predictive variables, are beyond the scope of this document. We hope that scientists will be stimulated to examine the data further through analysis of the raw data available at http://www.cdc.gov/nchs/nhanes.htm.

Research studies, separate from the *Report*, are required to determine which blood or urine levels are safe and which are associated with 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 *Third 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. The results shown in the *Third Report* should help prioritize and foster research on human health risks that result from exposure to environmental chemicals.

Not all the chemicals in the *Report* are measured in the same individuals. Therefore, it is not possible to determine how many of the 148 chemicals were found at detectable levels in a given person. As noted above, the presence of a chemical does not imply disease. The levels or concentrations of the chemical are more important determinants of the relation to disease, when established in appropriate research studies, than the detection or presence of a chemical.

For more 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 its chemical name or the Chemical Abstract Service (CAS) number, which is provided in the *Third Report*. The Agency for Toxic Substances and Disease Registry's (ATSDR) Toxicological Profiles and ToxFAQs provide good summaries of toxicology information 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 one or more sources, including air, water, food, soil, and dust.

Levels of a chemical in blood and urine are determined by how much of the chemical has entered the body through all routes of exposure, including ingestion, inhalation, or dermal absorption, and how the chemical is distributed in body tissues, transformed into metabolites, and eliminated from the body. Although the levels in the blood and urine are measures of the amount of a chemical that has entered the body by all routes of exposure, the blood or urine level alone does not determine which exposure source or which route of exposure has occurred. Except for metals, most measurements in urine quantify chemical metabolites.

Biomonitoring Exposure Measurements

The blood and urine exposure measurements presented in the *Third Report* were made at CDC's Environmental Health Laboratory (Division of Laboratory Sciences, National Center for Environmental Health). The analytical methods used for measuring the environmental chemicals or their metabolites in blood and urine were based on 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 B. Laboratory measurements undergo extensive quality control and quality assurance review, including tolerance limits for operational parameters, the measurement of quality control samples in each analytical run to detect unacceptable performance in accuracy or precision, and verification of traceable calibration materials.

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. The range and mean of creatinine levels were 2-650 mg/dL and 136.4 mg/dL in NHANES 1999-2000, and 5-774 mg/dL and 130.6 mg/dL in NHANES 2001-2002, respectively, results that are typical for the general U.S. population (see Barr et al., 2005). Creatinine corrects for urinary dilution in individual specimens, although this dilution variability has little effect on point estimates (e.g., means, percentiles). Interpretation of creatinine corrected results should also recognize that creatinine correction can also partially adjust for differences in lean body mass or renal function among persons.

For dioxins, furans, PCBs, and organochlorine pesticides, serum levels are presented per gram of total lipid and per whole weight of serum. These compounds are lipophilic and concentrate in the body's lipid stores, including the lipid in serum. Serum levels reported per gram of total lipid reflect the amount of these compounds that are stored in body fat. Serum levels per whole weight of serum are also included to facilitate comparison with studies investigating exposure to these chemicals that have published results in these units.

Units of measurement are important. Results are reported here using standard units, generally conforming to those most commonly used in biomonitoring measurements. Useful unit conversions are presented in Table 2.

Selection of Chemicals Included in the *Report*

Chemicals in the

Data Sources and Data Analysis

In the *Third Report*, all variance estimates (both 1999-2000 and 2001-2002 data) were calculated using the Taylor series (linearization) method within SUDAAN. In the *Second Report*, 1999-2000 variance estimates were calculated using the jackknife method (See Appendix C for details). The two methods produce very similar, but not identical, variance estimates. Consequently, some confidence intervals for 1999-2000 presented in the *Second Report* will differ slightly from confidence intervals for the same time period presented in the *Third Report*.

Selected percentiles and unadjusted geometric means of analyte concentrations are presented in tables and charts. Percentile estimates were calculated using SAS Proc Univariate using weighted data. Results are shown for the total population and also by age group, gender, and race/ethnicity as defined in NHANES. For these analyses, race/ethnicity is categorized as Mexican American, non-Hispanic black, and non-Hispanic white. Other racial/ethnic groups are sampled, but the proportion of the total population represented by other racial/ethnic groups is not large enough to produce valid estimates. Other racial/ethnic groups are included in estimates that are based on the entire population sample. Age groups are shown for each chemical in the results table. Gender is coded as male or female.

In the text (not in the tables), results are presented of comparisons of geometric mean levels for different demographic groups using analysis of covariance sample LODs, a conservative rule was used for reporting percentiles: if any individual sample LOD in the demographic group was above the percentile estimate, the percentile estimate was not reported.

For chemicals measured in urine, separate tables are presented for the chemical concentration expressed per volume of urine (uncorrected table) and the chemical concentration expressed per gram of creatinine (creatinine corrected table). Geometric mean and percentile calculations were performed separately for each of these concentrations. LOD calculations were performed using the chemical concentration expressed per volume of urine, because this concentration determines the analytical sensitivity. For this reason, LOD results for urine measurements in Appendix A are in weight per volume of urine. In the creatinine corrected tables, a result for a geometric mean or percentile was reported as < LOD if the corresponding geometric mean or percentile was < LOD in the uncorrected table. So for example, if the 50th percentile for males was < LOD in the uncorrected table, it would also be < LOD in the creatinine corrected table.

For chemicals measured in serum lipid, separate tables are presented for the chemical concentration expressed per volume of serum (lipid unadjusted table) and the chemical concentration expressed per amount of lipid (lipid adjusted table). Geometric mean and percentile calculations were performed separately for each of these concentrations. LOD calculations were performed using the chemical concentration expressed per amount of lipid, because this concentration determines the analytical sensitivity. For this reason, LOD results for chemicals measured in serum lipid in Appendix A are in weight per amount of lipid. In the lipid unadjusted tables, a result for a geometric mean or percentile was reported as < LOD if the corresponding geometric mean or percentile was < LOD in the lipid adjusted table.

Toxicology and Health-Risk Information

U.S. Food and Drug Administration (U.S. FDA)

Results by Chemical Group

Metals

Antimony

CAS No. 7440-36-0

General Information

In nature, antimony can be found in ores or other minerals, often combined with oxygen to form antimony trioxide. Elemental antimony can exist in one of four valences in its various chemical and physical forms: -3, 0, +3 and +5. Antimony is used in metal alloys, storage batteries, solder, sheet and pipe metal, ammunition, metal bearings, castings, and pewter. Antimony is used as a fire-retardant in textiles and plastics. It is also used in paints, ceramics, fireworks, enamels, and glass. Stibine is a metal hydride form of antimony used in the semiconductor industry. Two antimony compounds (sodium stibogluconate and antimony potassium tartrate) are used as antiparasitic medications.

Antimony enters the environment from natural sources and from its use in industry. People are exposed to antimony primarily from food and to a lesser extent from air and drinking water. 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. Dermal contact with soil, water, or other substances containing antimony is another means of exposure.

The absorption, distribution, and excretion of antimony vary depending on its oxidation state. Urinary excretion appears to be greater for pentavalent antimony than for trivalent compounds (Elinder and Friberg, 1986). An elimination half-life of about 95 hours has been estimated after occupational exposures (Kentner et al., 1995).

Inorganic antimony salts irritate the mucous membranes, skin, and eyes. Acute inhalational exposure to antimony has been associated with irritation of the respiratory tract

Table 3. 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, 1999-2002.

	Survey years						Sample size
Total, age 6 and older	99-00	**.132** (.120-.145)	**.130** (.120-.140)	**.210** (.200-.230)	[illegible] (.300-.350)	**.420** (.390-.460)	2276

and impaired pulmonary function (Renes, 1953). Pulmonary edema may occur in severe cases (Cordasco et al., 1973). Dysrhythmias and T-wave changes on electrocardiogram have also been noted in people after both therapeutic (Berman, 1988; Ming-Hsin et al., 1958) and occupational exposures (Briegner et al., 1954). Ingestion of antimony may cause people to experience a metallic taste, and gastrointestinal symptoms such as vomiting, diarrhea, abdominal pain, and ulcers (Werrin, 1962). The toxicity of stibine after acute inhalational exposure has been reported to be similar to that of arsine, resulting in hemolysis with abdominal and back pain (Dernehl et al., 1944).

Workplace standards for air exposure to antimony have been established by OSHA and ACGIH. Antimony trioxide is rated as being possibly carcinogenic to humans by IARC. Information about external exposure (i.e., environmental levels) and health effects is available from the U.S. EPA's IRIS Web site at http://www.epa.gov/iris and from ATSDR's Toxicological Profiles at http://www.atsdr.cdc.gov/toxprofiles.

Interpreting Levels of Urinary Antimony Reported in the Tables

Urinary antimony levels were measured in a subsample of NHANES participants aged 6 years and older. Participants were selected within the specified age range to be a representative sample of the U.S. population. Previous studies reporting measurements in general 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 here, which may be due to methodologic, population, or exposure differences. Several investigations of airborne exposures to antimony in workers show urinary levels that are many times higher than those seen in this *Report*, even when exposure levels were below workplace air standards (Iavicoli et al., 2002; Kentner et al., 1995; Ludersdorf et al., 1987; Bailly et al., 1991).

Table 4. Antimony (creatinine corrected)

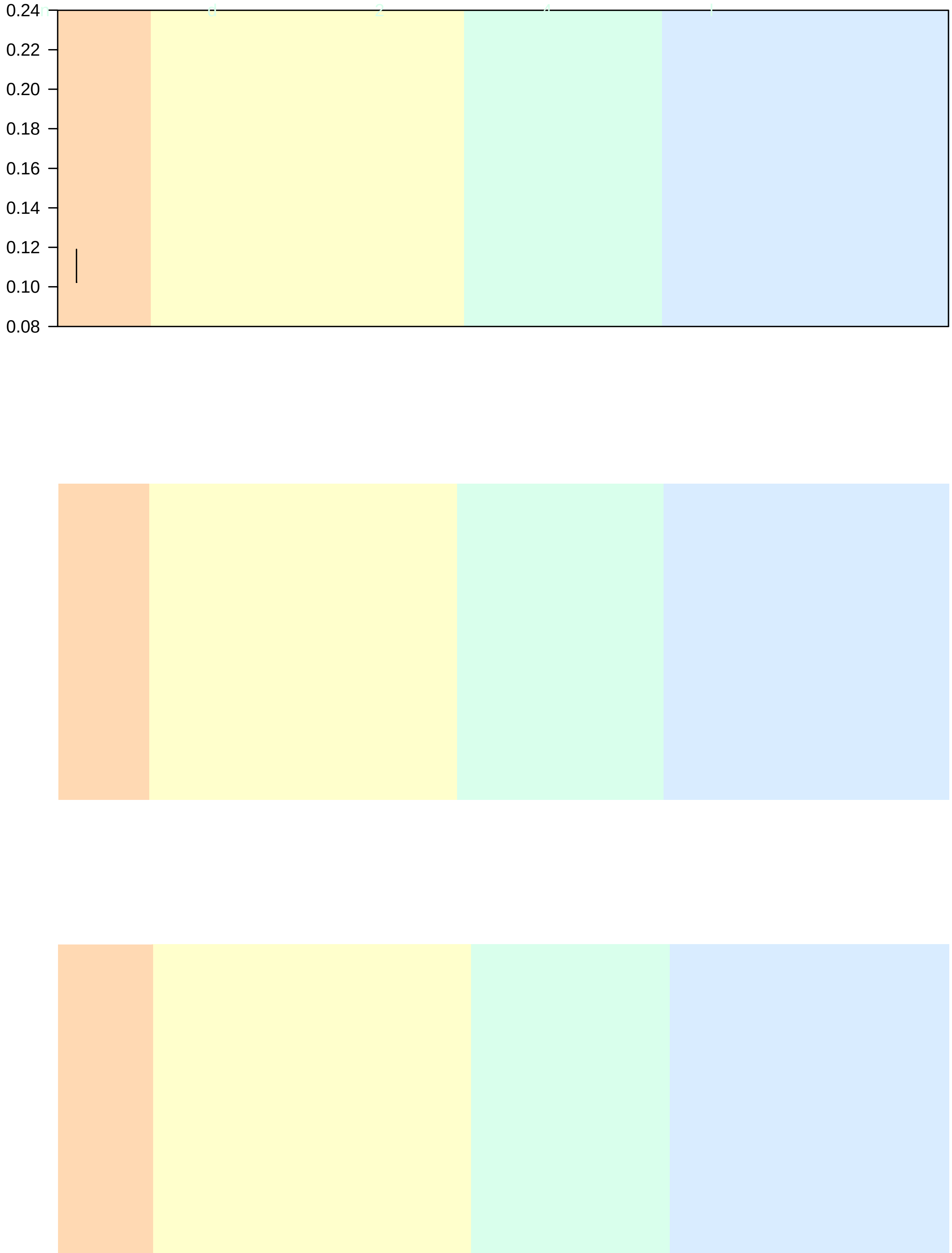
Geometric mean and selected percentiles of urine concentrations

Comparing Adjusted Geometric Means

Geometric mean levels of urinary antimony for the demographic groups were compared after adjusting for the covariates of race/ethnicity, age, gender, log serum cotinine, and urinary creatinine (data not shown). In NHANES 2001-2002, adjusted geometric mean levels of

Figure 1. Antimony (creatinine corrected)

Selected percentiles with 95% confidence intervals of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2002.



Barium

CAS No. 7440-39-3

General Information

Elemental barium is a silver-white metal. Barium’s abundance in the earth’s crust is approximately 0.05%. In nature, it combines with other chemicals such as sulfur or carbon and oxygen to form numerous barium salts. Of

Chronic accumulation of inhaled barium dust in the lung tissue may cause baritosis, a benign condition that may occur among barite ore miners. Chronic exposures to natural levels of barium in drinking water have not

Beryllium

CAS No. 7440-41-7

General Information

Pure beryllium is a hard gray metal. The lightest of all metals, beryllium can be found in mineral rocks, coal, soil, and volcanic dust. Beryllium compounds are commercially mined, and the beryllium is refined for use in mirrors and in special metal alloys used in the automobile, computer, nuclear, electrical, aircraft, and machine-parts industries. Beryllium is also used in the production of sports equipment such as golf clubs and bike frames. In medicine, beryllium is used in instruments, x-ray machines, and dental bridges.

Exposure to beryllium occurs mostly in the workplace, near some hazardous waste sites, and from breathing tobacco smoke. Two types of minerals, bertrandite and beryl, are mined for commercial recovery of beryllium. 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. Low-level beryllium exposure occurs through breathing air, eating food, or drinking water containing the metal. Small amounts of beryllium dust can enter air from burning coal and oil.

Beryllium may be harmful if inhaled. The effects depend on the concentration of beryllium in the inhaled air and the duration of air exposure. Air levels greater than 100 µg/m^3 can result in erythema and edema of the lung mucosa, producing pneumonitis. Chronic beryllium disease, or berylliosis, is a granulomatous interstitial lung disease that results from chronic beryllium inhalation and immunologic response. Skin contact with beryllium may also produce dermatitis, and some people demonstrate a hypersensitivity reaction to beryllium. Contact dermatitis and subcutaneous nodules have been reported with skin

Table 7. 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, 1999-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 6 and older	99-00	*	< LOD	< LOD	< LOD	< LOD	2465
	01-02	*	< LOD	< LOD	< LOD	< LOD	2690
Age group							
6-11 years	99-00	*	< LOD	< LOD	< LOD	< LOD	340
	01-02	*	< LOD	< LOD	< LOD	< LOD	368
12-19 years	99-00	*	< LOD	< LOD	< LOD	< LOD	719
	01-02	*	< LOD	< LOD	< LOD	.140 (<LOD-.160)	762
20 years and older	99-00	*	< LOD	< LOD	< LOD	< LOD	1406
	01-02	*	< LOD	< LOD	< LOD	< LOD	1560
Gender							
Males	99-00	*	< LOD	< LOD	< LOD	< LOD	1227
	01-02	*	< LOD	< LOD	< LOD	.130 (<LOD-.150)	1335
Females	99-00	*	< LOD	< LOD	< LOD	< LOD	1238
	01-02	*	< LOD	< LOD	< LOD	< LOD	1355
Race/ethnicity							
Mexican Americans	99-00	*	< LOD	< LOD	< LOD	< LOD	884
	01-02	*	< LOD	< LOD	< LOD	< LOD	683
Non-Hispanic blacks	99-00	*	< LOD	< LOD	< LOD	< LOD	568
	01-02	*	< LOD	< LOD	< LOD	< LOD	667
Non-Hispanic whites	99-00	*	< LOD	< LOD	< LOD	< LOD	822
	01-02	*	< LOD	< LOD	< LOD	< LOD	1132

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.
* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

exposure to beryllium.

Workplace air standards for external exposure have been established by OSHA and ACGIH. NTP considers beryllium to be a known carcinogen. IARC states that beryllium is an animal carcinogen, and sufficient evidence exists to consider beryllium and beryllium compounds as carcinogenic in people, causing lung and central nervous system cancers. More information about external exposure (i.e., environmental levels) and health effects is available from the U.S. EPA's IRIS Web site at http://www.epa.gov/iris and from ATSDR's Toxicological Profiles at http://www.atsdr.cdc.gov/toxprofiles.

Interpreting Levels of Urinary Beryllium Reported in the Tables

Urinary beryllium levels were measured in a subsample of NHANES participants aged 6 years old and older. Participants were selected within the specified age range to be a representative sample of the U.S. population. Comparable to the 1999-2000 subsample analysis, levels of beryllium were mostly undetectable. Previous studies have reported urinary levels for general populations as either undetectable concentrations or have not had comparable detection limits (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 the detection limits in past applications (less than 1 g/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, and when air levels were below the recommended threshold limit value, urinary beryllium concentrations ranged from 0.12 to 0.15 g/L. The 95th percentiles in this *Report* for people aged 12-19 years and for males (0.14 g/L and 0.13 g/L, respectively) are similar to those values reported by Apostoli and Schaller (2001). Because the

Table 8. Beryllium (creatinine corrected)

Geometric mean and selected percentiles of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2002.

	Survey years						Sample size
Total, age 6 and older	99-00	*	< LOD	< LOD	< LOD	< LOD	2465
	01-02	*	< LOD	< LOD	< LOD	< LOD	2689

detection limit documented in this *Report* was 0.13 g/L and because most of the samples were undetectable, these NHANES 1999-2002 levels are likely to be lower than levels considered safe for workers.

Finding a measurable amount of beryllium in urine does not mean that the level of beryllium causes an adverse health effect. Whether beryllium at the levels reported here is a cause for health concern is not yet known; more research is needed. These urinary beryllium data provide physicians with a reference range so that they can determine whether or not people have been exposed to

Cadmium

CAS No. 7440-43-9

General Information

Cadmium is a soft, malleable, bluish-white metal that is obtained chiefly as a by-product during the processing of zinc-containing ores (principally sphalerite, as zinc sulfide) and to a lesser extent during the refining of lead and copper from sulfide ore. The predominant commercial use of cadmium is in the manufacture of batteries (78% of uses). The use of cadmium in pigments accounts for 12% of consumption; in coatings and plating another 8% is used, and the remainder is used in stabilizers for plastic (1.5%), and nonferrous alloys and other uses (0.5%). From 2001 through 2004, the commercial use of cadmium declined approximately 70% in response to environmental concerns (U.S. Geological Survey, 2004). Emissions of cadmium into the environment occur mainly via anthropogenic activities, (Choudhury et al., 2001). Although several studies have found that the average gastrointestinal absorption of dietary cadmium is on the order of 5% (Diamond et al., 2003), two balance studies have suggested that this value may be five- to ten-fold greater in young women than in the general population (Kikuchi et al., 2003; Horiguchi et al., 2004*a*). With chronic exposure, cadmium accumulates in the liver and the kidney, with one-third to one half of the total amount accumulating in the kidney (Nordberg and Nordberg, 2001). In both organs, cadmium tightly binds to metallothionein, an inducible metal-binding protein that provides protection against many of cadmium's toxic effects (Klaasen et al., 1999). The estimated half-life of cadmium in the kidney is one to four decades (ATSDR, 1999; Diamond et al., 2003).

The kidney is a critical target for cadmium. Renal tubular damage and glomerular damage can be caused by high-dose chronic exposure, which may occur in people who are occupationally exposed, and g(s)2(to4)l(a)Tj/ihsTJ0.0014 T070.0005 Tw70 -1.153 TD[(tu(irral ss)]TJein t)6uria g(s)ei

Cesium

CAS No. 7440-46-2

General Information

Cesium is a silver-white metal that is found naturally in rock, soil, and clay. Inorganic cesium 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. Radio.00r1iv twice the median values reported in a nonrandom subsample from NHANES III (1988-1994) (Paschal et al., 1998), which may be due to methodologic, population, or exposure differences.

Comparing Adjusted Geometric Means

Geometric mean levels of urinary cesium for the demographic groups were compared after adjusting for the covariates of race/ethnicity, age, gender, log serum cotinine, and urinary creatinine (data not shown). In NHANES 2001-2002, adjusted geometric mean levels of urinary cesium were slightly higher for children aged 6-11 years than for either of the groups aged 12-19 years or 20 years and older. The group aged 12-19 years had lower levels than the 20 year and older group. Mexican Americans had higher levels than non-Hispanic blacks. Non-Hispanic whites had higher levels than non-Hispanic blacks. It is unknown whether these differences associated with age or race/ethnicity represent differences in exposure, pharmacokinetics, or the relationship of dose per body weight.

Finding a measurable amount of cesium in urine does not mean that the level of cesium causes an adverse health effect. Whether cesium at the levels reported here is a cause for health concern is not yet known; more research is needed. These urinary cesium data provide physicians with a reference range so that they can determine whether or not people have been exposed to higher levels of cesium than levels found in the general population.

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 the manufacture of superalloys used in gas turbines in aircraft engines, hard-metal alloys (in combination with tungsten carbide), blue-colored pigments, and fertilizers. Cobalt is used as a drying agent in paints, varnishes, and inks. It is also a component of porcelain enamel applied to steel bathroom fixtures, large appliances, and kitchenware. Cobalt compounds are used as catalysts in the production of oil and gas and in the synthesis of polyester and other materials. Cobalt compounds are also used in the manufacture of battery electrodes, steel-belted radial tires, automobile airbags, diamond-polishing wheels, and magnetic recording media.

Cobalt occurs naturally in airborne dust, seawater, and many types of soil. It is also emitted into the environment from burning coal and oil and from car and truck

Cobalt constitutes 4% by weight of vitamin B-12 (cobalamin), an essential human nutrient. A nutritional requirement for cobalt not contained in dietary cobalamin has not been established. Cobalt is absorbed by oral and pulmonary routes. Human studies with ^{60}Co administered as soluble cobalt chloride have measured oral absorption ranging from approximately 1% to 25% (Smith et al., 1972). Once absorbed and distributed in the body, cobalt is excreted predominantly in the urine and to a lesser extent in the feces. Elimination reflects a multi-compartmental model dominated by compartments with half-lives on the order of several hours to a week, but with a minor fraction (10% to 15%) exhibiting a half-life of several years (Smith et al., 1972; Mosconi et al., 1994). A portion of cobalt retained for long periods is concentrated in the liver. Lung retention of cobalt compounds of low solubility, such as cobalt oxide, may be prolonged, with some fractions exhibiting pulmonary clearance half-lives of 1-2 years (Hedge et al., 1979). Recent inhalation exposure to soluble cobalt compounds may be monitored effectively by measuring cobalt in urine or blood (Lison et al., 1994).
Most toxic effects of cobalt have been encountered in workplace situations. Cobalt compounds are a recognized cause of allergic contact dermatitis (Dickel et al., 2001; Lisi et al., 2003; Thomssen et al., 2001). Occupational exposure to cobalt-containing dusts has caused occupational asthma (Shirakawa et al., 1989; Pisati and Zedda, 1994). “Hard metal disease,” an interstitial lung disorder with findings that range from alveolitis to pulmonary fibrosis, has been associated with exposure to dusts that contain cobalt, usually in combination with tungsten carbide (Cugell et al., 1990). The extent to which cobalt exposure alone causes interstitial lung disease is unresolved (Swennen et al., 1993; Linna et al., 2003)

Cobalt was once added as a foaming agent to beer and caused outbreaks of cardiomyopathy among heavy drinkers in the mid-1960s (Alexander et al., 1972). Other case reports have suggested a link between occupational cobalt exposure and cardiomyopathy (Jarvis et al., 1992).

Table 15. Cobalt (creatinine corrected)

Geometric mean and selected percentiles of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 6 and older	99-00	**.353** (.319-.391)	**.328** (.302-.365)	**.515** (.457-.581)	**.810** (.679-.963)	**1.16** (.938-1.50)	2465
	01-02	**.358** (.333-.384)	**.335** (.313-.360)	**.523** (.487-.562)	**.844** (.750-.955)	**1.15** (1.00-1.28)	2689
Age group							
6-11 years	99-00	**.547** (.467-.640)	**.554** (.449-.647)	**.774** (.626-.938)	**1.00** (.830-1.48)	**1.23** (.895-1.50)	340
	01-02	**.552** (.508-.599)	**.548** (.503-.609)	**.756** (.660-.829)	**1.00** (.900-1.25)	**1.30** (1.03-1.73)	368
12-19 years	99-00	**.391** (.353-.433)	**.378** (.329-.407)	**.535** (.469-.595)	**.824** (.632-1.16)	**1.44** (.821-3.54)	719
	01-02	**.368** (.343-.396)	**.352** (.327-.372)	**.534** (.471-.611)	**.851** (.673-.949)	**1.06** (.932-1.24)	762
20 years and older	99-00	**.328** (.297-.362)	**.306** (.280-.328)	**.471** (.428-.522)	**.727** (.632-.905)	**1.12** (.861-1.36)	1406
	01-02	**.337** (.313-.363)	**.312** (.293-.336)	**.474** (.435-.513)	**.792** (.704-.955)	**1.15** (.963-1.33)	1559
Gender							
Males	99-00	**.290** (.259-.324)	**.279** (.248-.301)	**.400** (.365-.449)	**.608** (.534-.728)	**.833** (.667-1.10)	1227
	01-02	**.290** (.272-.310)	**.277** (.256-.297)	**.392** (.361-.425)	**.642** (.574-.707)	**.848** (.786-.929)	1334
Females	99-00	**.426** (.378-.479)	**.407** (.362-.457)	**.605** (.550-.694)	**.955** (.781-1.29)	**1.50** (1.11-1.83)	1238
	01-02	**.435** (.404-.468)	**.408** (.382-.438)	**.635** (.560-.708)	**.993** (.867-1.16)	**1.29** (1.12-1.60)	1355
Race/ethnicity							
Mexican Americans	99-00	**.386** (.339-.439)	**.376** (.333-.419)	**.598** (.500-.669)	**.895** (.826-1.00)	**1.23** (1.11-1.35)	884
	01-02	**.388** (.361-.417)	**.361** (.333-.394)	**.591** (.500-.662)	**.872** (.777-.990)	**1.10** (.990-1.27)	682
Non-Hispanic blacks	99-00	**.282** (.275-.289)	**.257** (.243-.278)	**.417** (.378-.462)	**.707** (.600-.785)	**.975** (.757-1.60)	568
	01-02	**.298** (.275-.323)	**.268** (.251-.294)	**.444** (.392-.511)	**.728** (.582-.917)	**1.03** (.740-1.55)	667
Non-Hispanic whites	99-00	**.369** (.324-.421)	**.351** (.313-.387)	**.533** (.452-.611)	**.861** (.667-1.16)	**1.25** (.895-1.57)	822
	01-02	**.362** (.331-.396)	**.343** (.313-.368)	**.523** (.479-.562)	**.830** (.736-.983)	**1.16** (.983-1.33)	1132

Cobalt compounds were formerly used in the treatment of anemia, a probable consequence of their capacity to stimulate erythropoetin production (Goldberg et al., 1988). A recent study observed elevated serum cobalt levels in association with excessive erythrocytosis among residents of a high-altitude mining community (Jefferson et al., 2002). Pharmaceutical preparations of cobalt used in the past as hematinics have been associated with the development of overt hypothyroidism (Kriss et al., 1955), and a subclinical decrement in thyroid production was observed in a study of cobalt-production workers (Swennen et al., 1993).

Cobalt compounds have elicited numerous genotoxic effects in both *in vitro* and *in vivo* assays (De Boeck et al., 2003) and have produced lung cancer in rats and mice following chronic inhalation (Bucher et al., 1999). An industry-wide study of hard-metal workers in France observed an increased mortality from lung cancer (Moulin et al., 1998). IARC considers cobalt and its compounds as possibly carcinogenic to humans. Information about external exposure (i.e., environmental levels) and health effects is available from ATSDR's Toxicological Profiles at http://www.atsdr.cdc.gov/toxprofiles.

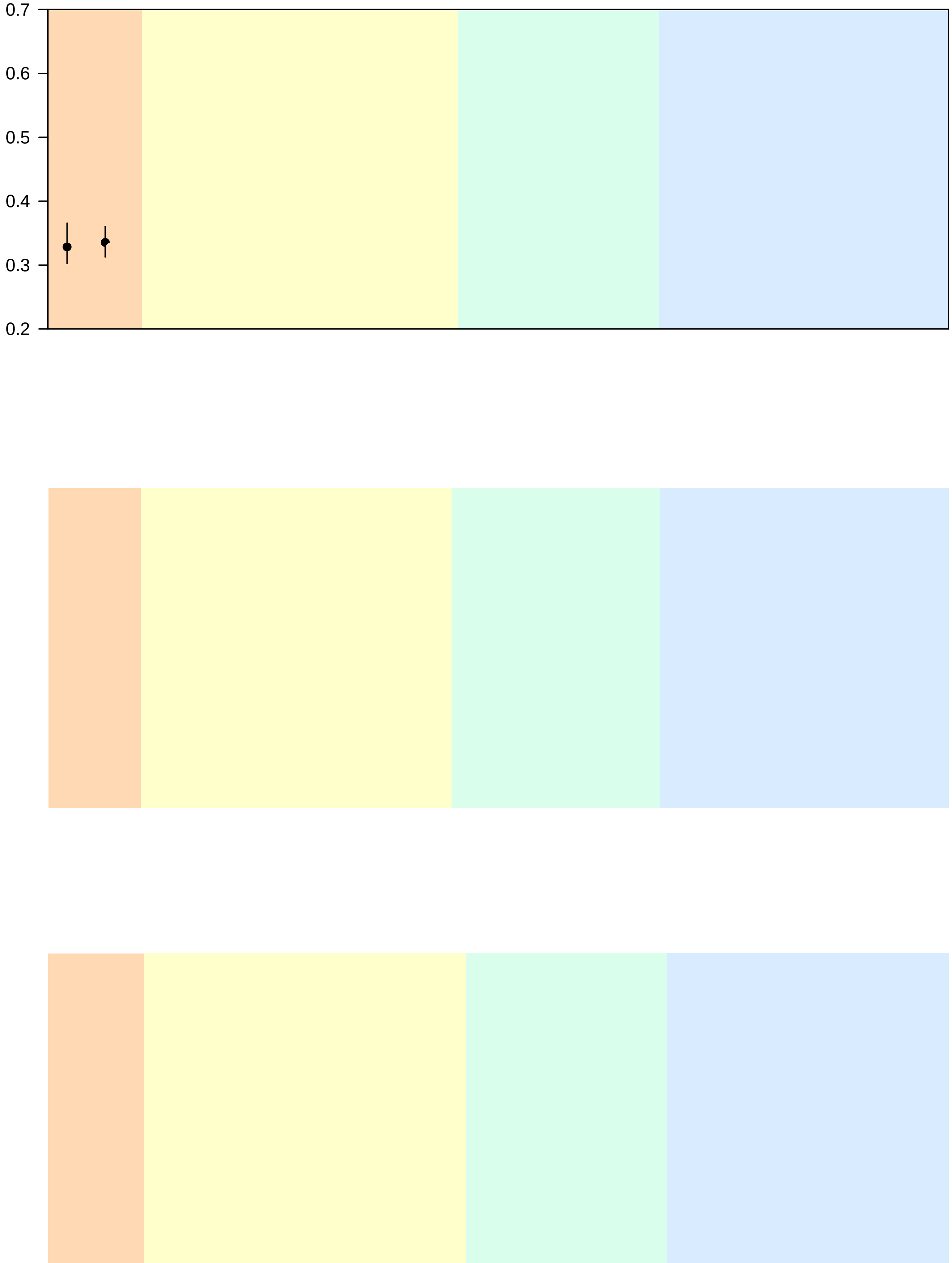
Interpreting Levels of Urinary Cobalt Reported in the Tables

Urinary cobalt levels were measured in a subsample of NHANES participants aged 6 years and older. Participants were selected within the specified age range to be a representative sample of the U.S. population. The levels of cobalt measured in the adults in the NHANES 2001-2002 also are similar to those found in recent smaller general population surveys of European adults (Kristiansen et al., 1997; White and Sabbioni, 1998). Because concentrations of cobalt in the urine decline rapidly within 24 hours after an exposure ceases (Alexandersson et al., 1988), urinary measurements mainly reflect recent exposure, although substantial occupational exposure can produce elevated urinary levels for many weeks.

Individuals with occupational exposure to cobalt often have urinary cobalt levels that are many times higher than those of the general population (ATSDR, 2004). The ACGIH biological exposure index (BEI) for inorganic forms of cobalt (except insoluble cobalt oxides) is 15 µg/L (ACGIH, 2001). Information about the BEI is provided here for comparison, not to imply that the BEI is a safety level for general population exposure. For workers exposed to cobalt in the air, a

Figure 5. Cobalt (creatinine corrected)

Selected percentiles with 95% confidence intervals of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2002.



Lead

CAS No. 7439-92-1

General Information

Elemental lead, a malleable, dense, blue-gray metal, is a naturally occurring element found in soils and rocks. It can be combined to form inorganic and organic molecules, such as lead phosphate and tetraethyl lead. Lead has a variety of uses in the manufacture of storage batteries; solders (particularly for electrical components and automobile radiators); metal alloys (including brass, bronze, and certain types of steel); plastics; leaded glass; ceramic glazes; ammunition; antique-molded or cast ornaments; and shielding used as protection from radiation sources. In the past, lead was added to residential paints and gasoline, and it has been used in plumbing for centuries. Small amounts of lead also may be emitted from the burning of fossil fuels.

Since the elimination of leaded gasoline in the United States and the removal of lead from solder in canned food containers, adult lead exposures tend to be limited to certain occupational and recreational sources. For children, the major sources of exposure are from deteriorated lead-based paint and the resulting dust and soil contamination. However, less common sources of

Lead Lead

dust in indoor firing ranges; and contact with soil, dust, or water contaminated by active or inactive mining or smelting operations. Children may also be exposed to lead brought into the home on the work clothes of adults whose work involves lead.

Following inhalation of fine lead particulate or fume or ingestion of soluble lead compounds, absorbed lead is bound to erythrocytes and is distributed initially to multiple soft tissues, including the brain, kidneys, bone marrow, and gonads, and to a slower extent to the small decrements in renal function (Payton et al., 1994; Kim et al., 1996; Muntner et al., 2003).

Low-level environmental lead exposure has been associated with subclinical decrements in neurocognitive function in young children and elevated blood pressure in adults. Although in 1991 the Centers for Disease Control and Prevention (CDC) established 10 µg/dL as a blood lead concentration of concern in children, no threshold for lead's effects has yet been identified (National Research Council, 1993). Recent studies have suggested possible neurodevelopmental effects at blood lead concentrations of less than 10 µg/dL (Lanphear et al., 2000; Canfield et al., 2003); further assessment is ongoing. In adults, subtle, nonspecific neurocognitive effects may occur at BLLs as low as 20-60 µg/dL (Mantere et al., 1984; Schwartz et al., 2001), with overt encephalopathy, seizures, and peripheral neuropathy at higher levels (e.g., levels greater than 100 µg/dL). Results of studies of adults with occupational or environmental lead exposure have shown consistent associations between increased BLLs and increased blood pressure (Schwartz, 1995; Staessen et al., 1995; Nash et al., 2003) and associations between increased bone lead concentrations and blood pressure (Hu et al., 1996; Korrick et al., 1999).

The potential adverse effects of lead on reproduction are an area of ongoing research and may include increased spontaneous abortion in women (Borja-Aburto et al., 1999) and problems with sperm formation in men (Alexander et al., 1996; Telisman et al., 2000). The International Agency for Research on Cancer (IARC) considers lead as a possible human carcinogen, and the National Toxicology Program (NTP) considers lead and its compounds as reasonably anticipated to be human carcinogens (NTP, 2005), but further study is needed on the relation between lead exposure and cancer in people (Jemal et al., 2002).

Table 18. Lead in urine (creatinine corrected)

Geometric mean and selected percentiles of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2002.

	Survey years						Sample size
Total, age 6 and older	99-00	**.721** (.700-.742)	**.700** (.677-.725)	**1.11** (1.06-1.15)	**1.70** (1.62-1.85)	**2.37** (2.21-2.76)	2465
	01-02	**.639** (.603-.677)	**.634** (.586-.676)	**1.03** (.962-1.08)	**1.52** (1.42-1.60)	**2.03** (1.89-2.22)	2689
Age group							
6-11 years	99-00	**1.17** (.975-1.41)	**1.06** (.918-1.22)	**1.55** (1.22-1.97)	**2.71** (1.67-4.66)	**4.66** (1.97-18.0)	340
	01-02	**.918** (.841-1.00)	**.870** (.798-.933)	**1.26** (1.12-1.43)	**2.33** (1.59-3.64)	**3.64** (1.83-5.56)	368
12-19 years	99-00	**.496** (.460-.535)	**.469** (.408-.508)	**.702** (.655-.828)	**1.10** (.981-1.28)	**1.65** (1.15-2.78)	719
	01-02	**.404** (.380-.428)	**.373** (.342-.400)	**.602** (.541-.702)	**.990** (.882-1.18)	**1.41** (1.07-1.63)	762
20 years and older	99-00	**.720** (.683-.758)	**.712** (.667-.739)	**1.10** (1.02-1.18)	**1.69** (1.53-1.87)	**2.31** (2.11-2.62)	1406
	01-02	**.658** (.617-.703)	**.649** (.608-.702)	**1.04** (.992-1.11)	**1.51**		

Interpreting Levels of Lead in Blood and Urine Reported in the Tables

Levels of lead in blood 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. Participants were selected to be a representative sample of the U.S. population. 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, particularly in the skeleton. Urinary lead measurements are more variable than blood lead levels for a given individual.

The U.S. adult population has similar or slightly lower BLLs than adults in other developed nations. A general population survey of 4,646 adults in Germany in 1998 reported a geometric mean blood lead concentration of 3.07 µg/dL (Becker et al., 2002), a value nearly twice that found for U.S. adults in the 2001-2002 NHANES sample. A general population survey of 1,164 adults in Italy in 2000 found blood lead values slightly more than double those reported for U.S. adults in the 2001-2002 NHANES sample (Apostoli et al., 2002*a*).

In 1991, CDC designated 10 µg/dL as the blood lead level of concern in children, a level associated with the risk for subtle neurodevelopmental impairments. For children 1- 5 years old sampled over the four year period 1999-2002, the geometric mean BLL was 1.9 µg/dL (1.8-2.1), with 1.6% (1.1-2.3) of the children having BLLs greater than or equal to 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 aged 1-5 years was 2.7 µg/dL (Pirkle et al., 1998). State childhood blood lead surveillance systems reported blood lead results for 2.4 million children to CDC in 2001. Of these children, 3.09% had a confirmed BLL of greater than or equal to 10 µg/dL (CDC, 2003*a*). Among a predominantly non-white population of U.S. children aged 0 to 17 years who were screened at an urban medical center in Washington, D.C. in 2001 and 2002, the geometric mean BLL in males was 3.2 µg/dL (n = 5,584) and 3.0 µg/dL in females (n = 5,562) (Soldin et al., 2003). These levels are higher than levels in similar age groups in the 2001-2002 NHANES sample and may reflect a higher prevalence of elevated BLLs that occur among children who 1) are non-Hispanic black and Mexican American; 2) live in urban settings; 3) are from lower socioeconomic groups; 4) are immigrants, refugees, or 5) reside in housing built before 1950 (CDC, 2003*a*; CDC, 2002; Geltman et al., 2001). In places where leaded gasoline is still used, such as in Bangladesh, BLLs among school children are similar to BLLs measured in the United States before lead was removed from gasoline (i.e., a mean BLL of 15.0 µg/dL and 87.4% of children with levels in excess of 10 µg/dL [Kaiser et al., 2001]).

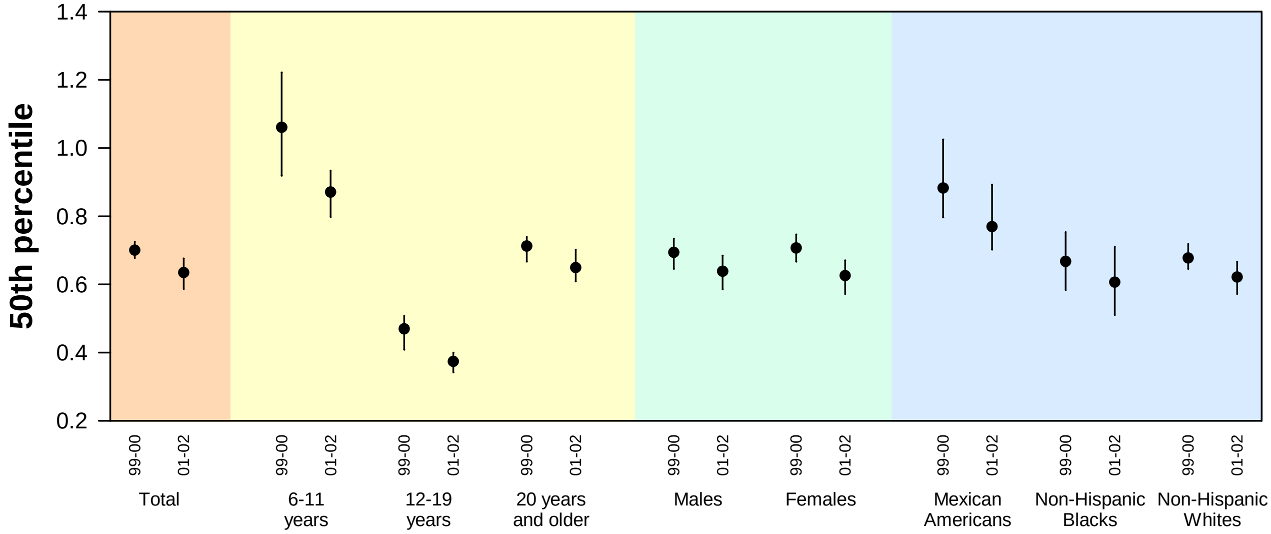
The U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) requires monitoring of blood lead levels when occupational exposure to airborne levels of lead exceeds the established action level of greater than 30 micrograms per cubic meter of air (OSHA, 29 CFR 1910.1025). First established in the late 1970s, OSHA regulations have required medical removal of workers from workplace lead exposure when blood lead concentrations exceed 50 µg/dL or at lower levels per a physician's discretion. The American Conference of Governmental Industrial Hygienists (ACGIH, 2001) established a Biological Exposure Index (BEI) for inorganic lead in 1995 which recommended that BLL in workers remain less than 30 µg/dL. Levels for adults in the NHANES 1999-2000 and 2001-2002 samples are generally below these worker thresholds (four adult NHANES participants were above 30 µg/dL).

decreasing exposure, dilution of lead by growth of body mass, or changing equilibria with bone turnover.

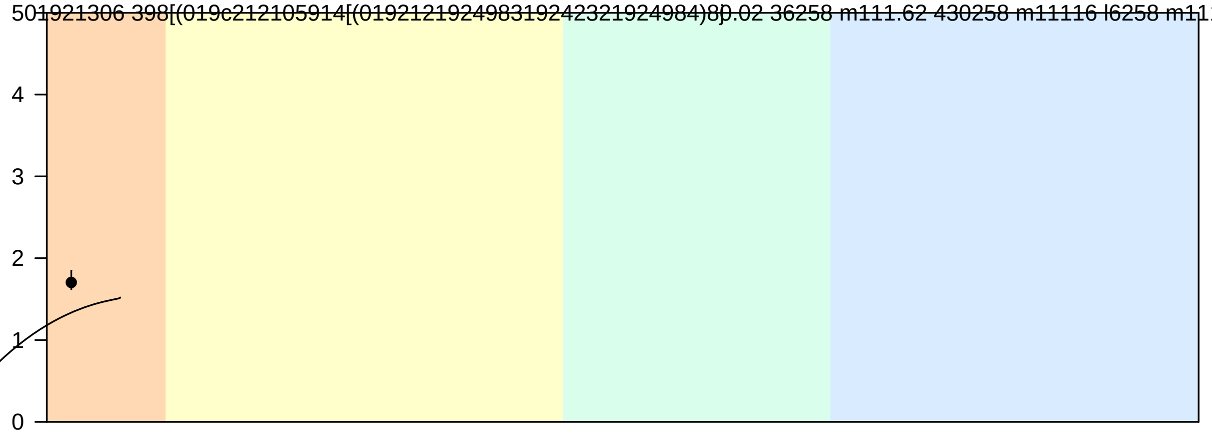
These blood and urine levels of lead provide physicians with a reference range so that they can determine whether or not people have been exposed to higher levels of lead than are found in the general population. These data will also help scientists plan and conduct research about exposure to lead and health effects.

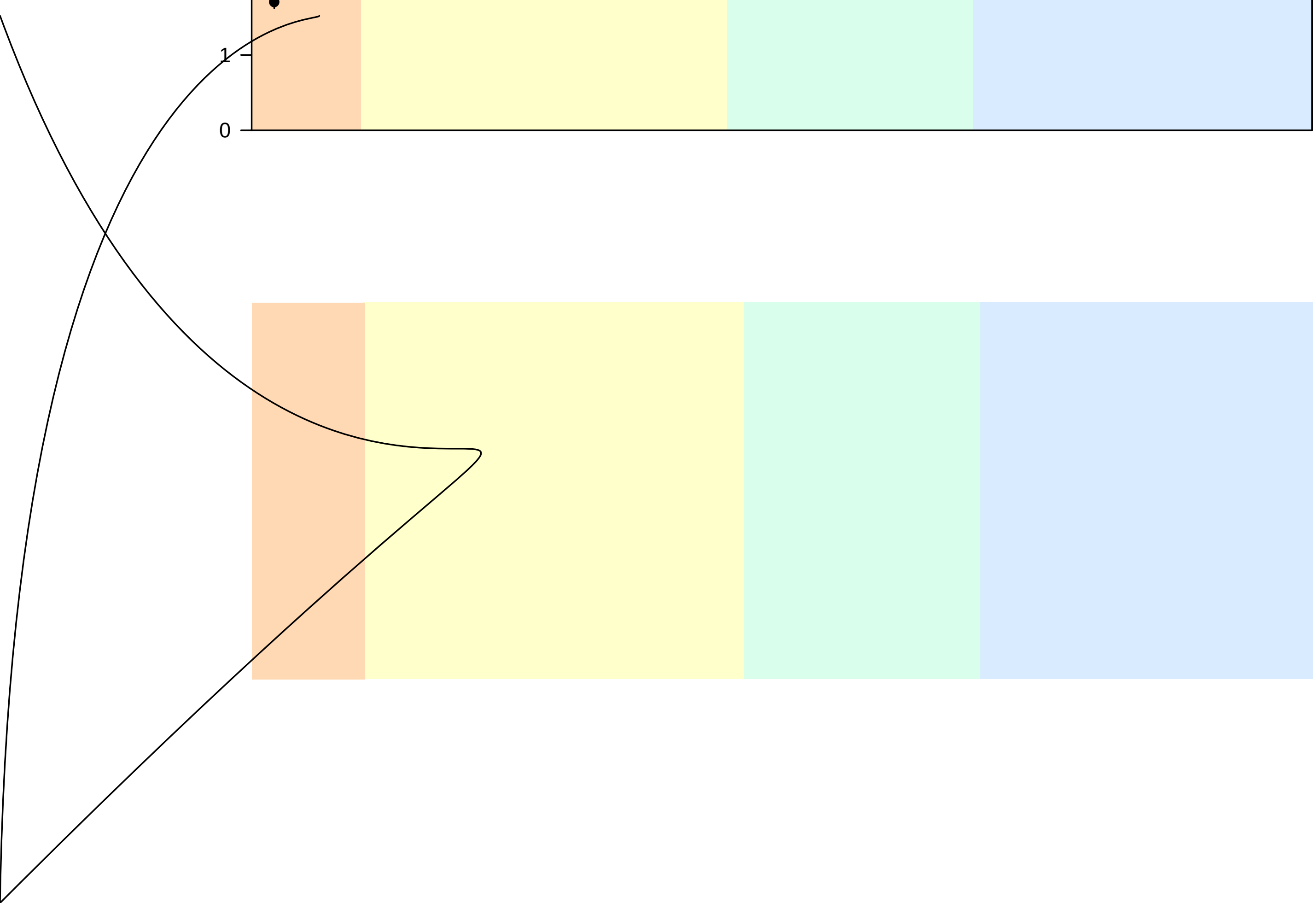
Figure 7. Lead in urine (creatinine corrected)

Selected percentiles with 95% confidence intervals of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2002.



501921306 398[(019c212105914[(019212192498319242321924984)80.02 36258 m111.62 430258 m11116 l6258 m11116 30258 7211116





Mercury

CAS No. 7439-97-6

General Information

Mercury is a naturally occurring metal that has elemental (metallic), inorganic, and organic forms.

Table 21. Mercury in urine (creatinine corrected)

Geometric mean and selected percentiles of urine concentrations (in µg/g of creatinine) for females aged 16 to 49 years in the U.S. population, National Health and Nutrition Examination Survey, 1999-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Age group (females)							
16-49 years	99-00	**.710** (.624-.806)	**.723** (.636-.833)	**1.41** (1.24-1.65)	**2.48** (2.10-2.97)	**3.27** (2.85-3.92)	1748
	01-02	**.620** (.579-.664)	**.650** (.582-.709)	**1.27** (1.15-1.42)	**2.30** (2.07-2.45)	**3.00** (2.68-3.39)	1960
Race/ethnicity (females, 16-49 years)							
Mexican Americans	99-00	**.685** (.580-.809)	**.639** (.508-.790)	**1.45** (1.27-1.61)	**2.89** (2.21-3.42)	**4.51** (3.07-5.68)	595
	01-02	**.600** (.526-.686)	**.596** (.426-.709)	**1.32** (1.04-1.47)	**2.41** (2.14-2.77)	**3.21** (2.65-4.46)	531
Non-Hispanic blacks	99-00	**.658** (.520-.831)	**.615** (.475-.892)	**1.22** (.909-1.79)	**2.56** (1.69-3.99)	**3.99** (2.76-5.14)	381
	01-02	**.522** (.410-.665)	**.516** (.387-.664)	**1.03** (.742-1.47)	**1.97** (1.42-3.25)	**3.21** (1.87-4.44)	442
Non-Hispanic whites	99-00	**.706** (.605-.824)	**.721** (.631-.846)	**1.41** (1.23-1.72)	**2.46** (1.99-2.97)	**3.05** (2.46-4.00)	594
	01-02	**.632** (.578-.691)	**.655** (.569-.744)	**1.28** (1.14-1.45)	**2.30** (2.03-2.56)	**2.95** (2.45-3.53)	826

palsy (National Research Council, 2000). In recent epidemiologic studies, lower levels of prenatal exposure due to maternal seafood consumption have been associated with an increased risk for abnormal neurocognitive test results in children (National Research Council, 2000; Rice et al., 2003). Although recent investigations have suggested a possible link between chronic ingestion of methyl mercury and an increased risk for myocardial infarction (Guallar et al., 2002; National Research Council, 2000), the existence of a causal relation is unresolved. Information about external exposure (i.e., environmental levels) and health effects is available from the U.S. EPA's IRIS Web site at http://www.epa.gov/iris, the U.S. EPA's mercury homepage at http://www.epa.gov/mercury, and from ATSDR's Toxicological Profiles at http://www.atsdr.cdc.gov/toxprofiles.

Interpreting Levels of Mercury in Blood and Urine 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. Participants were selected within the specified age range 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, the total blood mercury concentration is due mostly to the dietary intake of organic forms, particularly of methyl mercury. Little organic mercury is excreted in the urine. Urinary mercury consists mostly of inorganic mercury (Cianciola et al., 1997; Kingman et al., 1998). These distinctions can assist in interpreting mercury blood levels in people. Total blood mercury levels are known to increase with greater fish consumption (Grandjean et al., 1995; Mahaffey and Mergler, 1998; Sanzo et al., 2001; Dewailly et al., 2001), and urine levels will increase with the number of teeth filled with mercury-containing amalgams (Becker et al., 2003).

The data in this *Report* are similar or slightly lower than levels found in other population studies. In Germany, for example, the geometric mean for blood mercury was 0.58 µg/L for 4,645 adults aged 18 to 69 years participating in a 1998 representative population survey (Becker et al., 2002). During the years 1996 through 1998, Benes et al. (2000) studied 1,216 blood donors in the Czech Republic (896 men and 320 women; average age 33 years) and 758 children (average age 9.9 years). The median concentration of blood mercury for adults was 0.78 µg/L and 0.46 µg/L for the juvenile population. A cohort of 1,127 U.S. men (mean age 52.8 years, range 40 years to 78 years) with no occupational exposure to mercury, but who received dental care at military facilities during the mid to late

Metals

Figure 9. Mercury in urine (creatinine corrected)

Selected percentiles with 95% confidence intervals of urine concentrations (in µg/g of creatinine) for females aged 16 to 49 years in the U.S. population,

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, inks and paints.

Molybdenum is a nutritionally essential trace element and enters the body primarily from dietary sources. Molybdenum is a cofactor for a limited number of human enzymes, principally sulfite oxidase and xanthine oxidase (Kisker et al., 1997). The recommended dietary allowance for adult men and women is 45 µg/day (Institute of Medicine, 2001), and the average dietary daily intake of molybdenum is approximately 100 µg/day (WHO, 1996; Institute of Medicine, 2001). Molybdenum occurs in natural waters and may be present in concentrations of several hundred micrograms per liter or higher in ground and surface water in the vicinity of mining operations or ore deposits. In industry, dust and other fine particles produced during the refining or shaping of molybdenum or molybdenum-containing alloys are sources of exposure.

Gastrointestinal absorption of molybdenum averages 88-93% for dietary intakes of 22 to 1490 µg/day. Excretion occurs predominantly via the kidney, which exerts homestatic regulation over molybdenum balance. At a daily oral molybdenum dose of 24 µg, urinary excretion over a six day period was 18% of the ingested dose, but at daily oral doses of 95 µg and 428 µg, urinary excretion over a six day period rose to 50% and 67% of the ingested dose, respectively (Turnlund et al., 1995).

Table 22. 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, 1999-2002.

	Survey years						Sample size
Total, age 6 and older	99-00	**45.9** (40.1-52.6)	**50.7** (44.6-58.4)	**84.9** (78.7-92.3)	**134** (125-146)	**178** (154-216)	2257
	01-02	**45.0** (42.1-48.0)	**52.4** (48.9-55.5)	**83.3** (79.1-88.5)	**124** (117-130)	**165** (145-176)	2690
Age group							
6-11 years	99-00	**78.2** (61.0-100)	**83.4** (67.7-105)	**126** (106-147)	**174** (147-242)	**267** (159-840)	310
	01-02	**63.3** (53.4-75.0)	**69.2** (63.0-77.6)	**109** (94.5-124)	**169** (138-197)	**197** (161-291)	368
12-19 years	99-00	**54.3** (47.6-62.0)	**60.6** (52.2-70.3)	**93.3** (79.9-109)	**146** (112-171)	**183** (146-216)	648
	01-02	**60.6** (55.5-66.2)	**65.7** (58.7-73.1)	**96.9** (91.8-108)	**145** (129-159)	**179** (155-227)	762
20 years and older	99-00	**41.7** (36.7-47.4)	**46.5** (40.5-52.3)	**76.7** (73.4-82.2)	**125** (114-134)	**167** (143-206)	1299
	01-02	**41.1** (38.3-44.1)	**47.4** (43.7-51.2)	**79.0** (71.9-83.6)	**11[illegible]** (103-124)	**150** (130-166)	1560
Gender							
Males	99-00	**52.7** (45.7-60.7)	**57.4** (48.5-68.4)	**93.2** (83.8-106)	**150** (128-187)	**213** (161-278)	1121
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Females	99-00						

Molybdenum is generally considered to be of low toxicity to people, and clinical or epidemiological evidence of adverse effects is limited. Chronic exposure to high levels may possibly result in higher serum uric acid levels and gout-like illness (Koval'skiy et al., 1961; U.S. EPA, 1993). Based on studies finding adverse reproductive effects in rats and mice, the Panel on Micronutrients of the Institute of Medicine identified a no observed adverse effect level (NOAEL) of 0.9 mg/kg/day and established a tolerable upper intake level of 0.03 mg/kg/day in humans (Institute of Medicine, 2001). A long term inhalation bioassay of molybdenum trioxide in mice yielded "some evidence" of carcinogenicity (NTP, 1997). A recent case-control study suggested a possible link between occupational exposure to molybdenum and lung cancer (Droste et al., 1999) but the available epidemiological data are scant and molybdenum has not been systematically evaluated for carcinogenicity by U.S. EPA or IARC.

Interpreting Levels of Urinary Molybdenum Reported in the Tables

Urinary 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. Because molybdenum is an essential element for good health, intake and loss in the urine is expected. The levels documented for adults in the

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 topical exposure may occur in occupational exposure settings (e.g., platinum refining plants).

Workplace air standards for external exposure are generally established for soluble salts of platinum by OSHA and ACGIH, or recommended for the metal form by NIOSH (Czerczak & Gromiec, 2000). The pharmaceutical cisplatin is an animal carcinogen as determined by NTP and a possible human carcinogen. The carcinogenicity of other platinum compounds remains uncertain. Information about external exposure (i.e., environmental levels) and health effects is available on line (W.H.O. International Programme on Chemical Safety at

Thallium

CAS No. 7440-28-0

General Information

Workplace air standards for external exposure are generally established by OSHA and ACGIH. Chronic high-level exposures have been associated with weight

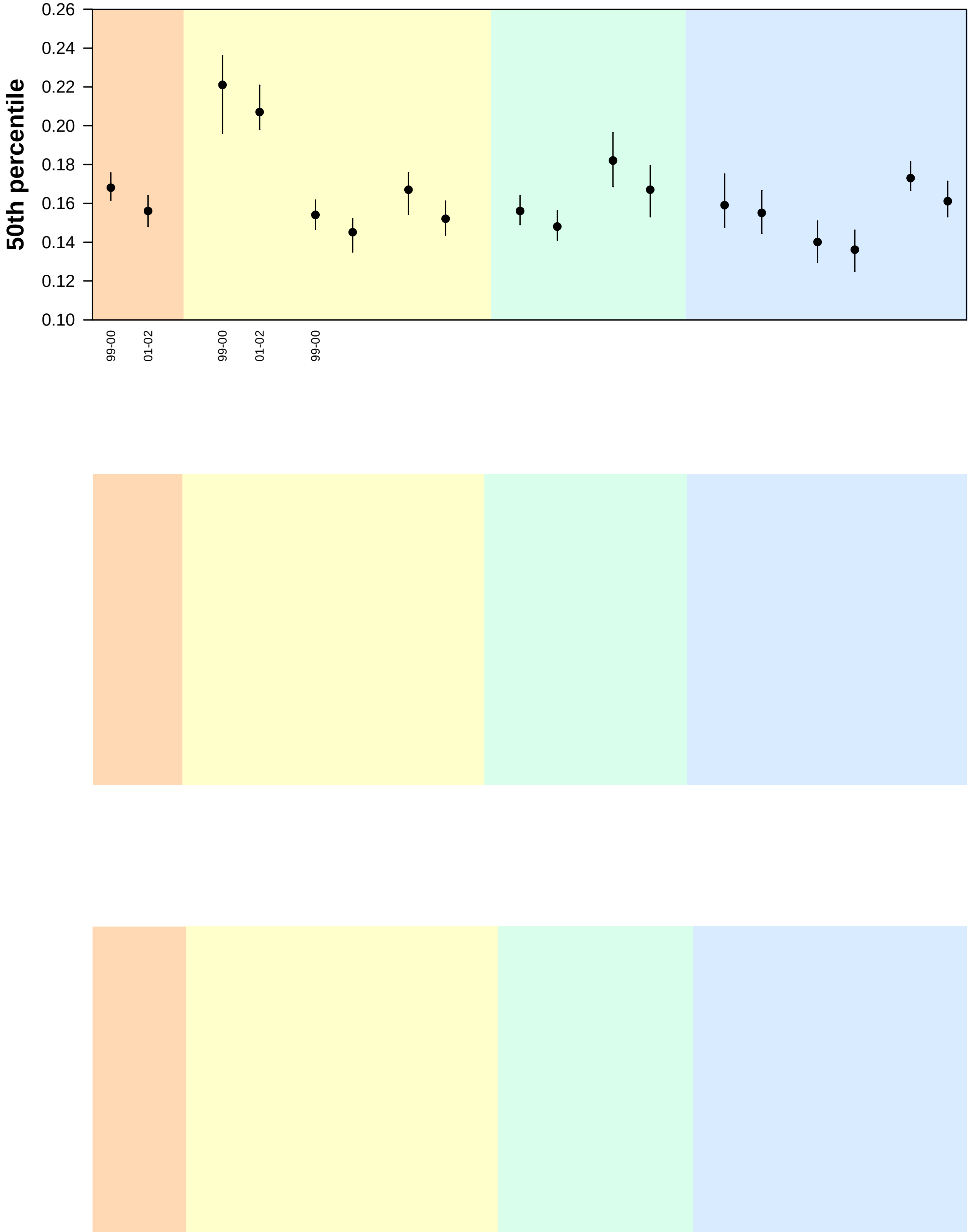
Comparing Adjusted Geometric Means

Geometric mean levels of urinary thallium for the demographic groups were compared after adjusting for the covariates of race/ethnicity, age, gender, log serum cotinine, and urinary creatinine (data not shown). In NHANES 2001-2002, adjusted geometric mean levels of urinary thallium were slightly higher for people aged 6-11 years than for the other two age groups. It is unknown whether these differences associated with age represent differences in exposure, pharmacokinetics, or the relationship of dose per body weight.

Finding low amounts of thallium in urine does not mean that the level of thallium causes adverse health effects. Whether thallium at the levels reported here is a cause for health concern is not yet known; more research is needed. These urinary thallium data provide physicians with a reference range so that they can determine whether individuals or groups have been exposed to higher levels of thallium than are found in the general population. These data will also help scientists plan and conduct research about thallium exposure and health effects.

Figure 11. Thallium (creatinine corrected)

Selected percentiles with 95% confidence intervals of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2002.



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, and ferrotungsten, which is used in the steel industry. Additionally, tungsten compounds are used as lubricating agents, filaments for incandescent lamps, bronzes in pigments, and as catalysts in the petroleum industry.

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. Drinking water also can be a source of exposure. Workplace air standards for external exposure have been

Interpreting Levels of U[redacted] the Tables

Urinary tungsten levels [redacted] NHANES participants a[redacted] Participants were selected [redacted] specified age range to be a representative sample of the U.S. population. A nonrandom subsample from NHANES III demonstrated higher values than those in this *Report* (Paschal et al., 1998), possibly due to methodologic, population, or exposure differences. One small study of unexposed individuals (n = 14) yielded values similar to those reported here (Schramel et al., 1997). Median urinary tungsten levels may be increased as much as 15-fold over median levels in this *Report* due to natural increases in drinking water sources (CDC, 2003*b*). 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 [redacted] al., 2001). The application of the technique of ne[redacted] a control group of non-metal [redacted]d mean urinary tungsten levels similar to [redacted] 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). Patients with medically-inserted tungsten embolization coils showed elevated tungsten levels in blood, urine, and hair (Bachthaler et al., 2004). Urinary tungsten levels [redacted] these patients were often hundreds-fold higher th[redacted] demonstrated in this *Report*.

Comparing Adjusted Geometri[redacted]

Geometric mean levels [redacted] demographic grou[redacted] the covariates [redacted] cotinine [redacted] NH[redacted] had [redacted]inary [redacted] 12-19 years or 20 [redacted] 12-19 years had higher

Geometric mean and selected percen[redacted]atinine) for the U.S. population aged 6 years and older, National Health and [redacted]002.

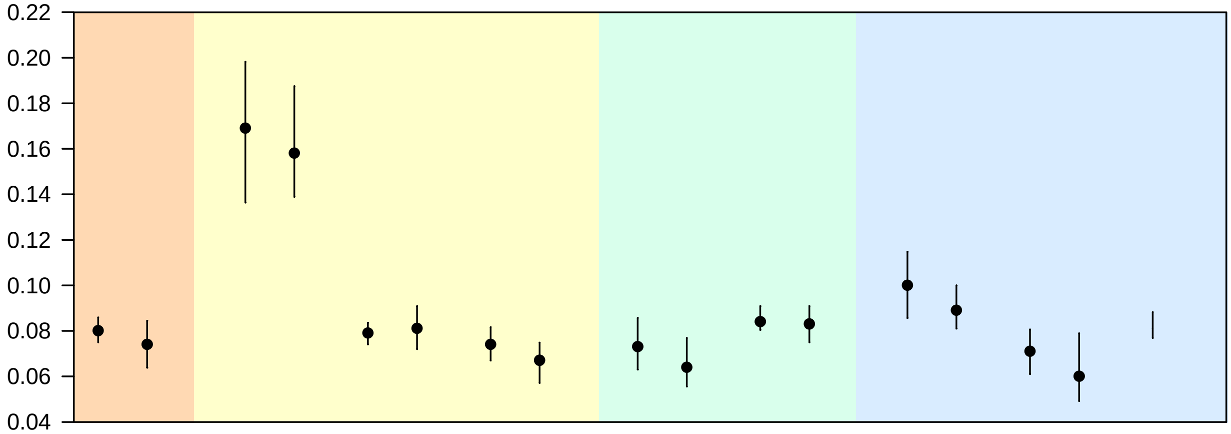
	Survey years	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	Sample size
Total, age 6 and older	99-00	[redacted]	**.080** (.075-.086)	**.146** (.136-.158)	**.270** (.206-.333)	**.381** (.302-.459)	2338
	01-02	[redacted] (.069-.087)	**.074** (.064-.084)	**.138** (.122-.154)	**.255** (.216-.300)	**.359** (.315-.436)	2651
Age group							
6-11 years	99-00	**.174** (.150-.201)	**.169** (.136-.198)	**.293** (.216-.333)	**.438** (.331-.667)	**.614** (.452-.880)	320
	01-02	**.168** (.144-.197)	**.158** (.139-.188)	**.275** (.231-.326)	**.412** (.333-.554)	**.634** (.436-1.28)	363
12-19 years	99-00	**.084** (.078-.091)	**.079** (.074-.084)	**.138** (.124-.158)	**.231** (.180-.287)	**.339** (.237-.465)	679
	01-02	**.081** (.071-.092)	**.081** (.072-.091)	**.147** (.122-.167)	**.250** (.208-.301)	**.359** (.272-.431)	744

levels than the group aged 20 years and older. Levels in Mexican Americans were higher than in non-Hispanic blacks and non-Hispanic whites. It is unknown whether these differences associated with age or race/ethnicity represent differences in exposure, pharmacokinetics, or the relationship of dose per body weight.

Finding a measurable amount of tungsten in urine does not mean that the level of tungsten causes an adverse health effect. Whether tungsten at the levels reported here is a cause for health concern is not yet known; more

Figure 12. Tungsten (creatinine corrected)

Selected percentiles with 95% confidence intervals of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2002.



Uranium

CAS No. 7440-61-1

General Information

Uranium is a silver-white, extremely dense, and weakly radioactive metal. It is typically extracted from ores containing less than 1% natural uranium. Natural uranium is a mixture of three isotopes: ^{238}U (99.2739%), ^{235}U (0.7204%), and ^{234}U (0.0057%). It usually occurs as an inorganic compound with oxygen, chlorine, or other elements. Uranium has many commercial uses, including its use in nuclear weapons, nuclear fuel, in some ceramics, and as an aid in electron microscopy and photography. Depleted uranium (DU) refers to uranium in which the proportion of ^{235}U and ^{234}U isotopes have been reduced, compared with the proportion in natural uranium. DU is used in the production of armor-piercing projectiles.

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 excretion 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. Soluble uranium compounds may exhibit some dermal absorption. Exposure to DU can occur after internal contact with DU-containing shrapnel or dust.

After absorption, soluble uranium is predominantly distributed to the kidneys and the bones. Approximately 50% of uranium is eliminated in the urine within the first

Table 30. 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, 1999-2002.

	Survey years						Sample size
Total, age 6 and older	99-00	**.008** (.007-.009)	**.007** (.006-.007)	**.013** (.010-.016)	**.026** (.021-.038)	**.046** (.036-.054)	2464
	01-02	**.009** (.007-.010)	**.008** (.006-.009)	**.014** (.011-.016)	**.029** (.022-.037)	**.046** (.034-.062)	2690
Age group							
6-11 years	99-00	**.009** (.007-.011)	**.007** (.005-.007)	**.013** (.009-.019)	**.032** (.018-.048)	**.046** (.033-.066)	340
	01-02	**.008** (.007-.010)	**.008** (.006-.010)	**.014** (.010-.020)	**.025** (.020-.036)	**.037**	

al. (1992), Karpas et al. (1996), and Galletti (2003) reported urinary levels for small groups of normal individuals in a range similar to those values seen in both the 1999-2000 and 2001-2002 subsamples. In addition,

Figure 13. Uranium (creatinine corrected)

Selected percentiles with 95% confidence intervals of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2002.

0.018.0232
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002

Results by Chemical Group

Tobacco Smoke

Cotinine

CAS No. 486-56-6

nicotine because cotinine persists longer in the body (plasma half-life is about 16 hours) (Benowitz and Jacob, 1994). Cotinine can be measured in serum, urine, saliva, and hair. Nonsmokers exposed to typical levels of ETS have serum cotinine levels of less than 1 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.

Nicotine stimulates preganglionic cholinergic receptors within peripheral sympathetic autonomic ganglia and at cholinergic sites within the central nervous system. Nicotine indirectly causes a release of dopamine in the brain regions that control pleasure and motivation, a process leading to addiction. Acute tobacco or nicotine intoxication can produce dizziness, nausea, vomiting, diaphoresis, salivation, diarrhea, variable changes in blood pressure and heart rate, seizures, and death. Symptoms of nicotine withdrawal include irritability, craving, cognitive and sleep disturbances, and increased appetite.

Tobacco smoke is considered a human carcinogen by IARC and NTP. 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. Persistent exposure to ETS is associated with an increased risk for lung cancer. More recently, coronary heart disease (Whincup et al., 2004) and prothrombotic risk factors (Bazzano et al., 2003) have been associated with ETS exposure. ETS may exacerbate asthma among susceptible children and increase the risk for lower respiratory-tract illnesses, such as bronchitis and pneumonia, among young children. Exposure to ETS has also been associated recently with decrements in pulmonary function in adults with asthma (Eisner, 2002). More information about the effects of smoking and nicotine can be found at: http://www.nida.nih.gov/researchreports/nicotine/nicotine.html.

Interpreting Levels of Serum Cotinine Reported in the Table

Serum cotinine levels were measured in a subsample of nonsmoking NHANES participants aged 3 years and older. Participants were selected within the specified age range to be a representative sample of the U.S. population. Nonsmoking is defined as a serum cotinine level of less than or equal to 10 ng/mL. Choosing a cutoff of 15 ng/mL makes little difference in the results. Serum cotinine has been measured in many studies of non-smoking populations, and such levels are similar or slightly higher than those reported here, depending on the degree of ETS exposure.

From 1988 through 1991, as part of NHANES III, CDC determined that the median level (50th percentile) of cotinine among nonsmokers in the United States was 0.20 ng/mL (Pirkle et al., 1996). Since that 1988-1991 survey period, median levels of cotinine (as measured in NHANES 1999-2002) have decreased 68% in children, 69% in adolescents, and about 75% in adults. This reduction in cotinine levels suggests a major reduction in exposure of the general U.S. population to ETS since the period 1988-1991.

Note: Results are reported as less than the limit of detection (LOD) if they are less than the LOD of the individual sample, which could be either 0.015 ng/mL or 0.050 ng/mL for the 2001-2002 subsample (more sensitive instrumentation was introduced during 2001-2002 analyses). The reporting requirement for a geometric mean is that 60% of the serum cotinine levels must be greater than or equal to the respective specimen-specific LOD. To calculate geometric means and percentiles, measurements below their LOD are assigned values of LOD/square root of 2.

The reporting requirement for percentiles is that they must be greater than the maximum LOD (i.e., greater than 0.050 ng/mL). This requirement avoids confusion in interpretation that could result if a percentile estimate was lower than one of the two LODs. These two reporting requirements (one for geometric means and one for percentiles) occasionally result in a geometric mean being reported with no estimate being reported for the 50th percentile (as is the case for cotinine). For completeness, we list here, for 2001-2002, the computed 50th percentiles (with 95% confidence limits), recognizing that these estimates are in between the two LODs; that is, between 0.015 ng/mL-0.050 ng/mL.

Age 3 years and older	0.035	(0.032-0.052)
Age 20 years and older	0.034	(0.024-0.038)
Males	0.045	(0.035-0.063)
Females	0.034	(0.023-0.038)
Mexican Americans	0.036	(0.025-0.060)
Non-Hispanic whites	0.034	(0.022-0.043)

Comparing Adjusted Geometric Means

Geometric mean levels of serum cotinine for the demographic groups in the NHANES 2001-2002 subsample were compared after adjusting for the covariates of age, race/ethnicity, and gender (data not

Results by Chemical Group

Polycyclic Aromatic Hydrocarbons

Polycyclic Aromatic Hydrocarbons

General Information

Polycyclic aromatic hydrocarbons (PAHs) are a class of chemicals that result from the incomplete burning of benzo[b]fluoranthene, benzo[j]fluoranthene, benzo[k]fluoranthene, and indeno[1,2,3,cd]pyrene as possible human carcinogens. The NTP lists the following chemicals as reasonably anticipated to be human carcinogens: benz[a]anthracene, benzo[b]fluor-anthene, 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, dibenzo[a,i]-pyrene, dibenzo[a,l]pyrene, indeno[1,2,3-cd]pyrene, and 5-methylchrysene (NTP, 2002). The U.S. EPA has classified as probable carcinogens the following: benz[a]anthracene, benzo[a]pyrene, benzo[b]fluor-anthene, benzo[k]fluoranthene, chrysene, dibenz[a,h]-anthracene, and indeno[1,2,3-cd]pyrene. Pyrene was reviewed by IARC and determined it not to be classifiable as to its human carcinogenicity. In 2005, NTP listed naphthalene as reasonably anticipated to be a human carcinogen (NTP, 2005). 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.

1-Hydroxybenz[a]anthracene and 3- and 9-Hydroxybenz[a]anthracene

Metabolites of Benz[a]anthracene, CAS No. 56-55-3

Interpreting Levels of Urinary Benz[a]anthracene Metabolites Reported in the Tables

Urinary levels of 1-hydroxybenz[a]anthracene and combined levels of 3-hydroxybenz[a]-anthracene and 9-hydroxybenz[a]anthracene were measured in a subsample of NHANES 2001-2002 participants aged 6 years and older. Similar levels of 1- and 3-hydroxy-benz[a]anthracene have been reported in a small sample of pre-school children (Wilson et al., 2003). A sampling of 24 adults and 24 children from low income households in North Carolina found higher urinary levels of urinary 1-hydroxybenz[a]anthracene and 3-hydroxybenz[a]-

Table 36. 3- and 9-Hydroxybenz[a]anthracene

	Survey years						Sample size
Total, age 6 and older	99-00	*	**< LOD**	**< LOD**	**7.50** (6.00-9.90)	**11.6** (8.40-15.6)	2152
	01-02	*	**< LOD**	**< LOD**	**11.0** (<LOD-15.0)	**24.0** (19.0-31.0)	2748
Age group							
6-11 years	99-00	*	**< LOD**	**7.70** (<LOD-11.9)	**14.4** (7.70-49.8)	**32.0** (9.50-71.0)	285
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**14.0** (11.0-21.0)	387
12-19 years	99-00	*	**< LOD**	**6.20** (<LOD-7.50)	**10.5** (8.80-13.8)	**14.9** (11.4-16.8)	652
	01-02	*	**< LOD**	**< LOD**	**14.0** (<LOD-18.0)	**28.0** (18.0-42.0)	735
20 years and older	99-00	*	**< LOD**	**< LOD**	**5.80** (<LOD-7.20)	**8.80** (6.50-11.8)	1215
	01-02	*	**< LOD**	**< LOD**	**11.0** (<LOD-16.0)	**23.0** (18.0-31.0)	1626
Gender							
Males	99-00	*	**< LOD**	**< LOD**	**7.90** (5.70-12.6)	**13.5** (9.20-18.8)	1033
	01-02	*	**< LOD**	**< LOD**	**15.0** (12.0-18.0)	**25.0** (20.0-31.0)	1349
Females	99-00	*	**< LOD**	**< LOD**	**7.10** (6.00-9.10)	**10.3** (8.90-11.9)	1119
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**21.0** (14.0-35.0)	1399
Race/ethnicity							
Mexican Americans	99-00	*	**< LOD**	**< LOD**	**7.70** (6.80-8.90)	**11.1** (8.10-14.2)	688
6 *	01-02	*	**< LOD**	**< LOD**	**11.0** (<LOD-16.0)	**23.0** (16.0-31.0)	665
Non-Hispanic blacks	99-00	*	**< LOD**	**< LOD**	**7.60** (5.80-11.5)		

Table 37. 3- and 9-Hydroxybenz[a]anthracene (creatinine corrected)

	Survey years						Sample size
Total, age 6 and older	99-00	*	**< LOD**	**< LOD**	**12.2** (10.1-14.6)	**17.6** (15.7-21.1)	2152
	01-02	*	**< LOD**	**< LOD**	**21.4** (19.2-23.7)	**31.8** (28.4-35.5)	2748
Age group							
6-11 years	99-00	*	**< LOD**	**9.61** (6.63-14.6)	**18.1** (10.3-29.6)	**23.6** (12.8-40.5)	285
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**29.6** (23.7-39.8)	387
12-19 years	99-00	*	**< LOD**	**5.09** (4.42-5.94)	**7.69** (6.44-8.64)	**10.0** (8.50-11.9)	652
	01-02	*	**< LOD**	**< LOD**	**18.2** (15.2-24.8)	**29.1** (21.5-50.7)	735
20 years and older	99-00	*	**< LOD**	**< LOD**	**12.2** (10.2-14.3)	**17.4** (15.2-21.1)	1215
	01-02	*	**< LOD**	**< LOD**	**21.5** (20.3-24.5)	**32.3** (28.1-35.5)	1626
Gender							
Mal-23Gender							

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

Metabolites of Benzo[c]phenanthrene, CAS No. 195-19-7

Urinary levels of 1-hydroxybenzo[c]phenanthrene, 2-hydroxybenzo-[c]phenanthrene, and 3-hydroxybenzo[c]phenanthrene were measured in a subsample of NHANES participants aged 6 years and older.

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, 1999-2002.

	Survey years	Geometric	Selected percentiles				Sample size
Total, age 6 and older	99-00	*	**< LOD**	**8.20** (<LOD-13.1)	**17.2** (10.8-31.3)	**31.0** (19.0-47.2)	2200
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**34.0** (16.0-54.0)	2732
Age group							
6-11 years	99-00	*	**< LOD**	**9.10** (<LOD-17.5)	**17.0** (9.20-40.1)	**32.1** (13.8-254)	297
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**15.0** (<LOD-35.0)	385
12-19 years	99-00	*	**< LOD**	**9.50** (7.10-13.2)	**18.0** (12.4-31.2)	**31.2** (16.9-48.1)	665
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**29.0** (11.0-64.0)	728
20 years and older	99-00	*	**< LOD**	**8.10** (<LOD-12.8)	**16.9** (10.5-31.0)	**30.3** (19.4-47.2)	1238
	01-02	*	**< LOD**	**< LOD**	**4.00** (<LOD-19.0)	**37.0** (16.0-79.0)	1619
Gender							
Males	99-00	*	**< LOD**	**8.40** (<LOD-13.8)	**18.0** (11.5-33.6)	**35.4** (25.2-47.2)	1054
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**19.0** (5.00-33.0)	1340
Females	99-00	*	**< LOD**	**8.20** (<LOD-13.3)	**16.5** (9.80-25.8)	**24.7** (15.2-47.2)	1146
	01-02	*	**< LOD**	**< LOD**	**13.0** (<LOD-37.0)	**51.0** (26.0-94.0)	1392
Race/ethnicity							
Mexican Americans	99-00	*	**< LOD**	**12.9** (7.40-20.2)	**21.9** (15.2-32.4)	**32.4** (23.3-47.5)	716
	01-02	*	**< LOD**	**< LOD**	**11.0** (<LOD-84.0)	**52.0** (9.00-105)	659
Non-Hispanic blacks	99-00	*	**< LOD**	**7.60** (<LOD-9.90)	**12.8** (8.20-32.4)	**30.3** (11.0-49.2)	497
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**21.0** (<LOD-72.0)	687
Non-Hispanic whites	99-00	*	**< LOD**	**8.40** (<LOD-14.4)	**17.0** (10.0-32.9)	**29.4** (16.7-58.7)	806
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**35.0** (15.0-83.0)	1205

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.

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

Table 40. 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, 1999-2002.

	Survey years	Geometric	Selected percentiles				Sample size
Total, age 6 and older	99-00	*	**< LOD**	**< LOD**	**14.3** (9.60-19.6)	**21.2** (16.5-28.1)	2175
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**13.0** (6.00-20.0)	2748
Age group							
6-11 years	99-00	*	**< LOD**	**7.00** (<LOD-16.2)	**19.9** (11.6-34.9)	**30.2** (14.2-47.2)	285
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	387
12-19 years	99-00	*	**< LOD**	**< LOD**	**14.0** (8.90-20.0)	**20.0** (14.6-32.3)	657
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	735
20 years and older	99-00	*	**< LOD**	**< LOD**	**13.5** (8.50-21.2)	**20.1** (14.0-29.4)	1233
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**16.0** (9.00-24.0)	1626
Gender							
Males	99-00	*	**< LOD**	**7.00** (<LOD-10.9)	**16.9** (12.2-23.8)	**29.0** (22.2-34.9)	1046
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**13.0** (6.00-20.0)	1349
Females	99-00	*	**< LOD**	**< LOD**	**11.9** (8.20-17.5)	**17.0** (12.8-22.0)	1129
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**13.0** (<LOD-27.0)	1399
Race/ethnicity							
Mexican Americans	99-00	*	**< LOD**	**< LOD**	**12.2** (8.10-17.1)	**17.0** (12.2-28.9)	686
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**15.0** (<LOD-42.0)	665
Non-Hispanic blacks	99-00	*	**< LOD**	**10.0** (<LOD-16.6)	**20.0** (14.4-34.3)	**34.3** (19.0-51.6)	495
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**18.0** (<LOD-23.0)	692
Non-Hispanic whites	99-00	*	**< LOD**	**< LOD**	**13.5** (8.40-20.5)	**21.2** (15.0-29.4)	810
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**15.0** (<LOD-22.0)	1208

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix

Table 41. 2-Hydroxybenzo[c]phenanthrene (creatinine corrected)

	Survey years						Sample size
Total, age 6 and older	99-00	*	**< LOD**	**< LOD**	**20.0** (16.0-23.7)	**28.2** (23.1-30.9)	2175
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**20.3** (15.9-23.3)	2748
Age group							
6-11 years	99-00	*	**< LOD**	**11.4** (9.53-13.0)	**23.1** (12.3-32.0)	**34.3** (20.0-67.3)	285
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	387
12-19 years	99-00	*	**< LOD**	**< LOD**	**11.7** (8.77-15.0)	**16.4** (11.7-26.1)	657
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	735
20 years and older	99-00	*	**< LOD**	**< LOD**	**20.9** (16.0-26.7)	**28.6** (25.3-32.8)	1233
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**21.4** (16.7-29.1)	1626
Gender							
Males	99-00	*	**< LOD**	**8.42** (6.96-10.9)	**17.3** (13.3-23.1)	**25.3** (19.3-34.3)	1046
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**17.5** (13.5-23.3)	1349
Females	99-00	*	**< LOD**	**< LOD**	**20.9** (16.6-26.7)	**30.0** (26.7-30.9)	1129
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**21.9** (16.7-35.0)	1399
Race/ethnicity							
Mexican Americans	99-00	*					

Table 42. 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, 1999-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 6 and older	99-00	*	< LOD	< LOD	< LOD	< LOD	2172
	01-02	*	< LOD	< LOD	< LOD	**11.0** (8.00-16.0)	2748
Age group							
6-11 years	99-00	*	< LOD	< LOD	< LOD	< LOD	287
	01-02	*	< LOD	< LOD	**8.00** (<LOD-13.0)	**13.0** (8.00-24.0)	387
12-19 years	99-00	*	< LOD	< LOD	< LOD	< LOD	657
	01-02	*	< LOD	< LOD	< LOD	**12.0** (<LOD-21.0)	735
20 years and older	99-00	*	< LOD	< LOD	< LOD	< LOD	1228
	01-02	*	< LOD	< LOD	< LOD	**11.0** (8.00-16.0)	1626
Gender							
Males	99-00	*	< LOD	< LOD	< LOD	< LOD	1045
	01-02	*	< LOD	< LOD	**7.00** (<LOD-11.0)	**11.0** (9.00-15.0)	1349
Females	99-00	*	< LOD	< LOD	< LOD	< LOD	1127
	01-02	*	< LOD	< LOD	< LOD	**12.0** (6.00-18.0)	1399
Race/ethnicity							
Mexican Americans	99-00	*	< LOD	< LOD	< LOD	< LOD	689
	01-02	*	< LOD	< LOD	< LOD	**14.0** (8.00-21.0)	665
Non-Hispanic blacks	99-00	*	< LOD	< LOD	< LOD	< LOD	491
	01-02	*	< LOD	< LOD	< LOD	**14.0** (<LOD-26.0)	692
Non-Hispanic whites	99-00	*	< LOD	< LOD	< LOD	< LOD	807
	01-02	*	< LOD	< LOD	< LOD	**11.0** (8.00-15.0)	1208

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.

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

Table 43. 3-Hydroxybenzo[c]phenanthrene (creatinine corrected)

	Survey years						Sample size
Total, age 6 and older	99-00	*	< LOD	< LOD	< LOD	< LOD	2172
	01-02	*	< LOD	< LOD	< LOD	**15.9** (14.6-16.7)	2748
Age group							
6-11 years	99-00	*	< LOD	< LOD	< LOD	< LOD	287
	01-02	*	< LOD	< LOD	**10.9** (8.75-14.0)	**14.6** (12.5-15.9)	387
12-19 years	99-00	*	< LOD	< LOD	< LOD	< LOD	657
	01-02	*	< LOD	< LOD	< LOD	**13.1** (10.0-17.5)	735
20 years and older	99-00	*	< LOD	< LOD	< LOD	< LOD	1228
	01-02	*	< LOD	< LOD	< LOD	**15.9** (14.3-17.1)	1626
Gender							
Males	99-00	*	< LOD	< LOD	< LOD	< LOD	1045
	01-02	*	< LOD	< LOD	**9.46** (8.54-10.5)	**12.5** (11.3-15.9)	1349
Females	99-00	*	< LOD	< LOD	< LOD	< LOD	1127
	01-02	*	< LOD	< LOD	< LOD	**16.7** (15.9-19.6)	1399
Race/ethnicity							
Mexican Americans	99-00	*	< LOD	< LOD	< LOD	< LOD	689
	01-02	*	< LOD	< LOD	< LOD	**17.5** (14.0-23.3)	665
Non-Hispanic blacks	99-00	*	< LOD	< LOD	< LOD	< LOD	491
	01-02	*	< LOD	< LOD	< LOD	**13.4**	

Table 45. 1-Hydroxychrysene (creatinine corrected)

Geometric mean and selected percentiles of urine concentrations (in ng/g of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 2001-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 6 and older	01-02	*	**< LOD**	**17.1** (11.3-25.0)	**50.0** (41.2-59.7)	**89.2** (71.4-104)	2748
Age group							
6-11 years	01-02	*	**< LOD**	**< LOD**	**42.6** (22.2-54.7)	**58.1** (47.0-74.2)	387
12-19 years	01-02	*	**< LOD**	**13.3** (7.61-18.6)	**35.0** (28.3-41.0)	**49.3** (37.4-65.7)	735
20 years and older	01-02	*	**< LOD**	**18.1** (11.7-28.5)	**55.9** (42.8-70.2)	**103** (78.9-120)	1626
Gender							
Males	01-02	*	**< LOD**	**19.4** (11.7-28.8)	**50.0** (41.1-57.7)	**86.4** (59.7-109)	1349
Females	01-02	*	**< LOD**	**15.9** (10.6-23.3)	**50.0** (38.9-66.0)	**91.5** (69.2-126)	1399
Race/ethnicity							
Mexican Americans	01-02	*	**< LOD**	**< LOD**	**58.2** (36.3-92.5)	**108** (61.8-147)	665
Non-Hispanic blacks	01-02	*	**< LOD**	**18.3** (6.48-33.9)	**56.6** (37.9-83.0)	**106** (62.4-154)	692
Non-Hispanic whites	01-02	*	**< LOD**	**16.5** (10.9-24.7)	**47.3** (38.4-59.4)	**91.5** (68.6-107)	1208

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.

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

Table 46. 2-Hydroxychrysene

		Survey years						Sample size
< LOD	**Total, age 6 and older**	01-02 *	*	**< LOD**	**< LOD**	**11.0** (<LOD-26.0)	**31.0** (14.0-45.0)	2748

< LOD

Table 47. 2-Hydroxychrysene (creatinine corrected)

	Survey years						Sample size
Total, age 6 and older	01-02	*	**< LOD**	**< LOD**	**17.5** (12.1-24.5)	**27.8** (20.9-35.0)	2748
Age group							
6-11 years	01-02	*	**< LOD**	**< LOD**	**21.9** (17.2-29.0)	**29.9** (22.0-34.2)	387
12-19 years	01-02	*	**< LOD**	**< LOD**	**14.3** (8.14-18.5)	**24.1** (15.2-35.0)	735
20 years and older	01-02	*	**< LOD**	**< LOD**	**17.6** (11.7-25.2)	**27.8** (20.6-38.9)	1626
Gender							
Males	01-02	*	**< LOD**	**< LOD**	**17.3** (9.72-24.9)	**26.3** (18.2-34.2)	1349
Females	01-02	*	**< LOD**	**< LOD**	**18.2** (14.0-24.5)	**30.2** (21.7-39.4)	1399
Race/ethnicity							
Mexican Americans	01-02	*	**< LOD**	**< LOD**	**< LOD**	**21.8** (15.9-31.3)	665
Non-Hispanic blacks	01-02	*	**< LOD**	**< LOD**			

Table 48. 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, 1999-2002.

	Survey years	Geometric (95% conf. interval)	Selected percentiles				Sample size
Total, age 6 and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	2233
	01-02	*	**< LOD**	**< LOD**	**27.0** (24.0-31.0)	**42.0** (36.0-46.0)	2748
Age group							
6-11 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**11.0** (<LOD-44.8)	300
	01-02	*	**< LOD**	**< LOD**	**21.0** (15.0-38.0)	**42.0** (22.0-62.0)	387
12-19 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**11.3** (<LOD-17.2)	674
	01-02	*	**< LOD**	**< LOD**	**23.0** (18.0-30.0)	**37.0** (27.0-39.0)	735
20 years and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1259
	01-02	*	**< LOD**	**< LOD**	**29.0** (25.0-31.0)	**43.0** (37.0-47.0)	1626
Gender							
Males	99-00	*	**< LOD**	**< LOD**	**< LOD**	**10.1** (<LOD-17.7)	1067
	01-02	*	**< LOD**	**< LOD**	**30.0** (25.0-37.0)	**45.0** (37.0-54.0)	1349
Females	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1166
	01-02	*	**< LOD**	**< LOD**	**25.0** (20.0-30.0)	**35.0** (30.0-44.0)	1399
Race/ethnicity							
Mexican Americans	99-00	*	**< LOD**	**< LOD**	**< LOD**	**10.8** (<LOD-14.5)	722
	01-02	*	**< LOD**	**< LOD**	**24.0** (18.0-28.0)	**30.0** (27.0-38.0)	665
Non-Hispanic blacks	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	515
	01-02	*	**< LOD**	**< LOD**	**25.0** (16.0-35.0)	**43.0** (28.0-63.0)	692
Non-Hispanic whites	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	807
	01-02	*	**< LOD**	**9.00** (<LOD-15.0)	**30.0** (25.0-34.0)	**44.0** (36.0-49.0)	1208

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.

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

Table 51. 4-Hydroxychrysene (creatinine corrected)

Geometric mean and selected percentiles of urine concentrations (in ng/g of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 2001-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 6 and older	01-02	*	< LOD	< LOD	< LOD	< LOD	2748
Age group							
6-11 years	01-02	*	< LOD	< LOD	< LOD	**9.55** (7.24-12.4)	387
12-19 years	01-02	*	< LOD	< LOD	< LOD	< LOD	735
20 years and older	01-02	*	< LOD	< LOD	< LOD	< LOD	1626
Gender							
Males	01-02	*	< LOD	< LOD	< LOD	< LOD	1349
Females	01-02	*	< LOD	< LOD	< LOD	< LOD	1399
Race/ethnicity							
Mexican Americans	01-02	*	< LOD	< LOD	< LOD	< LOD	665
Non-Hispanic blacks	01-02	*	< LOD	< LOD	< LOD	**9.00** (7.49-12.2)	692
Non-Hispanic whites	01-02	*	< LOD	< LOD	< LOD	< LOD	1208

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.
* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 53. 6-Hydroxychrysene (creatinine corrected)

Geometric mean and selected percentiles of urine concentrations (in ng/g of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 6 and older	99-00	*	< LOD	< LOD	**8.05** (7.06-9.15)	**12.6** (10.4-13.3)	2279
	01-02	*	< LOD	**9.26** (6.36-13.8)	**36.9** (28.0-46.0)	**61.5** (47.7-76.4)	2736
Age group							
6-11 years	99-00	*	< LOD	< LOD	**7.74** (5.11-13.1)	**11.0** (8.09-24.5)	298
	01-02	*	< LOD	**12.2** (5.00-18.9)	**39.4** (24.5-62.7)	**80.6** (40.0-115)	386
12-19 years	99-00	*	< LOD	< LOD	**6.32** (4.61-9.35)	**9.23** (5.83-11.7)	689
	01-02	*	< LOD	**9.05** (6.49-12.7)	**36.0** (21.1-46.9)	**62.7** (44.3-97.6)	728
20 years and older	99-00	*	< LOD	< LOD	**8.18** (7.07-9.60)	**13.3** (11.4-14.1)	1292
	01-02	*	< LOD	**8.65** (5.19-14.2)	**36.4** (26.7-46.2)	**60.7** (46.0-76.0)	1622
Gender							
Males	99-00	*	< LOD	< LOD	**6.67** (5.22-8.51)	**9.23** (8.28-11.7)	1091
	01-02	*	< LOD	**12.0** (8.24-15.5)	**41.5** (30.4-56.1)	**64.4** (52.2-97.2)	1341
Females	99-00	*	< LOD	< LOD	**9.88** (8.00-11.4)	**14.1** (12.6-17.1)	1188
	01-02	*	< LOD	< LOD	**32.5** (22.6-44.6)	**50.8** (42.6-68.8)	1395
Race/ethnicity							
Mexican Americans	99-00	*	< LOD	< LOD	**8.05** (5.45-11.4)	**13.3** (7.74-24.2)	749
	01-02	*	< LOD	**14.8** (8.29-20.8)	**48.5** (33.6-63.4)	**75.0** (50.3-123)	664
Non-Hispanic blacks	99-00	*	< LOD	< LOD	**4.62** (3.81-6.00)	**7.50** (5.71-7.93)	515
	01-02	*	< LOD	**7.04** (3.89-11.6)	**41.6** (29.9-55.5)	**68.8** (46.0-113)	683
Non-Hispanic whites	99-00	*	< LOD	< LOD	**8.57** (7.75-10.4)	**13.1** (11.4-15.5)	827
	01-02	*	< LOD	**9.42** (6.09-14.7)	**38.2** (26.5-47.7)	**62.4** (45.5-85.4)	1206

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.

* 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

Data for 3-hydroxyfluoranthene are not available for the current survey period 2001-2002. The table shown here reports data from 1999-2000 only.

Comparing Adjusted Geometric Means

For the 1999-2000 subsample, geometric mean levels of urinary fluorene metabolites in the demographic groups were compared after adjusting for the covariates of race/ethnicity, age, gender, creatinine, and log serum cotinine (data not shown). There were no differences between the demographic groups in adjusted geometric mean levels of urinary 3-hydroxyfluoranthene.

Table 54. 3-Hydroxyfluoranthene

	Survey years						Sample size
Total, age 6 and older	99-00	**13.4** (9.43-19.0)	**17.5** (7.90-25.9)	**32.3** (27.4-40.2)	**58.6** (49.4-73.0)	**98.8** (78.9-147)	2236
Age group							
6-11 years	99-00	**12.6** (8.82-17.9)	**15.8** (3.90-24.7)	**37.6** (24.7-45.1)	**65.7** (44.6-146)	**138** (66.3-216)	308
12-19 years	99-00	**15.0** (9.47-23.9)	**20.3** (5.10-31.8)	**38.7** (29.6-48.8)	**60.6** (47.6-91.4)	**98.9** (75.4-162)	

Table 55. 3-Hydroxyfluoranthene (creatinine corrected)

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

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 6 and older	99-00	**12.3** (8.39-18.2)	**14.7** (7.90-24.9)	**36.3** (25.0-47.8)	**67.9** (54.4-84.7)	**102** (86.0-127)	2236
Age group							
6-11 years	99-00	**12.8** (8.49-19.4)	**13.7** (5.32-27.2)	**44.3** (21.3-66.5)	**77.0** (54.7-115)	**131** (67.3-254)	308
12-19 years	99-00	**10.1** (5.86-17.4)	**13.4** (4.90-24.1)	**29.1** (19.0-44.3)	**54.9** (39.2-84.6)	**92.1** (66.6-134)	675
20 years and older	99-00	**12.7** (8.76-18.4)	**14.8** (8.03-25.7)	**36.5** (25.6-46.8)	**68.9** (54.4-85.0)	**102** (82.9-128)	1253
Gender							
Males	99-00	**10.7** (7.16-15.9)	**12.1** (6.41-20.7)	**32.9** (20.7-45.3)	**62.5** (44.3-82.4)	**91.3** (72.6-122)	1074
Females	99-00	**14.2** (9.70-20.7)	**17.5** (9.10-28.0)	**39.6** (28.9-49.9)	**75.5** (61.3-89.1)	**107** (90.5-172)	1162
Race/ethnicity							
Mexican Americans	99-00	**12.7** (7.69-21.1)	**13.8** (6.76-23.0)	**30.7** (20.8-48.2)	**64.1** (48.2-97.4)	**107** (67.7-312)	715
Non-Hispanic blacks	99-00	**9.14** (5.44-15.4)	**10.4** (2.98-21.3)	**30.2** (19.8-42.6)	**72.6** (47.6-116)	**133** (84.2-216)	527
Non-Hispanic whites	99-00	**13.1** (8.31-20.7)	**16.0** (6.45-29.7)	**36.9** (25.0-52.1)	**68.8** (51.2-86.0)	**90.6** (77.0-127)	803

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.

Table 57. 2-Hydroxyfluorene (creatinine corrected)

	Survey years						Sample size
Total, age 6 and older	99-00	**408** (259-642)	**382** (233-713)	**1160** (756-1660)	**2880** (1960-4350)	**5270** (3540-6860)	2315
	01-02	**298** (261-340)	**240** (209-266)	**530** (432-681)	**1310** (1100-1490)	**1890** (1590-2290)	2745
Age group							
6-11 years	99-00	**307** (180-525)	**336** (140-724)	**787** (520-1200)	**1380** (1030-2180)	**1740** (1410-2880)	306
	01-02	**275** (238-319)	**256** (224-289)	**387** (319-508)	**695** (527-989)	**1040** (724-1470)	387
12-19 years	99-00	**314** (190-519)	**369** (153-619)	**785** (543-1300)	**1880** (1260-2550)	**2570** (2220-3360)	694
	01-02	**228** (194-268)	**187** (164-220)	**358** (278-479)	**852** (537-1100)	**1170** (885-2150)	733
20 years and older	99-00	**443** (283-692)	**400** (259-739)	**1260** (806-2080)	**3480** (2290-5200)	**6040** (3990-7970)	1315
	01-02	**314** (275-358)	**245** (213-277)	**597** (491-766)	**1430** (1270-1590)	**2080** (1700-2530)	1625
Gender							
Males	99-00	**376** (225-628)	**378** (195-702)	**1070** (657-1750)	**2440** (1550-4870)	**4870** (2630-6870)	1106
	01-02	**305** (263-353)	**248** (209-290)	**563** (449-717)	**1330** (1030-1590)	**1900** (1460-2460)	1346
Females	99-00	**441** (291-667)	**393** (250-741)	**1260** (841-1680)	**3300** (2200-4410)	**5490** (3580-7720)	1209
	01-02	**291** (255-332)	**227** (207-260)	**497** (399-649)	**1220** (1060-1490)	**1890** (1590-2290)	1399
Race/ethnicity							
Mexican Americans	99-00	**275** (187-405)	**252** (155-443)	**597** (394-999)	**1350** (960-1720)	**2090** (1410-3110)	750
	01-02	**250** (206-303)	**221** 399-649)**E0-741)221**				

Figure 14.

Table 58. 3-Hydroxyfluorene

Survey

Table 60. 9-Hydroxyfluorene

Table 61. 9-Hydroxyfluorene (creatinine corrected)

	Survey years						Sample size
Total, age 6 and older	01-02	**205** (183-229)	**206** (181-232)	**353** (312-393)	**585** (507-697)	**852** (736-1120)	2745
Age group							
6-11 years	01-02	**189** (156-228)	**197** (162-238)	**330** (285-372)	**542** (426-660)	**740** (568-1010)	387
12-19 years	01-02	**152** (130-179)	**145** (120-183)	**256** (212-313)	**432** (348-584)	**642** (497-970)	733
20 years and older	01-02	**217** (194-243)	**219** (189-245)	**373** (331-412)	**608** (525-736)	**933** (747-1250)	1625
Gender							
Males	01-02	**203** (180-230)	**198** (173-227)	**348** (300-408)	**607** (526-722)	**843** (745-1070)	1346

For adjusted geometric mean levels of urinary 2-hydroxyphenanthrene in the NHANES 2001-2002, there were no demographic differences observed.

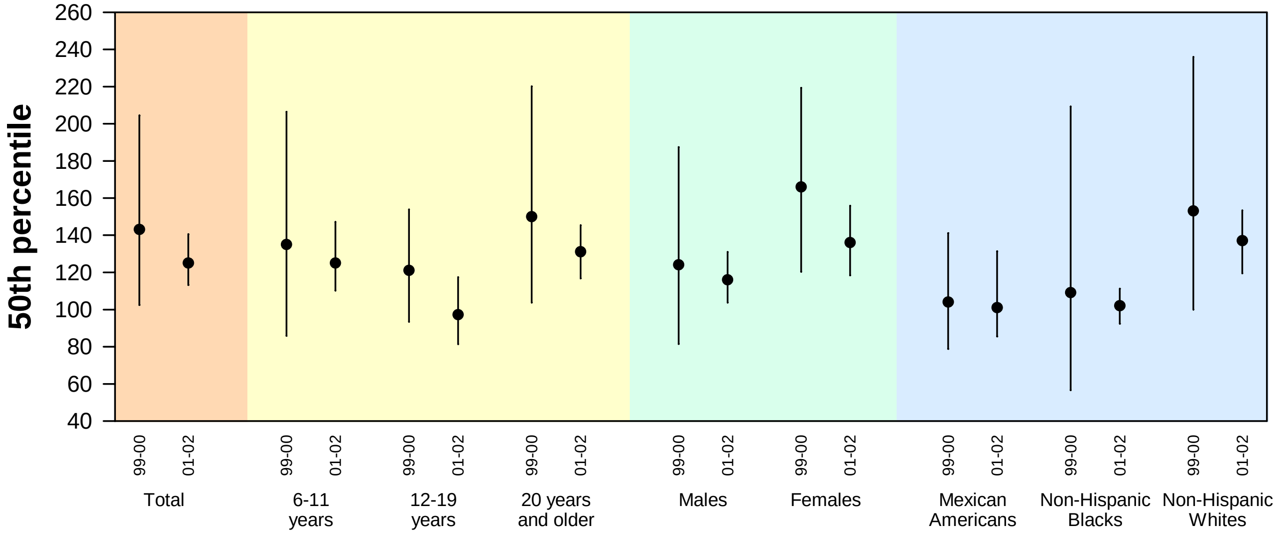
For adjusted geometric mean levels of urinary 3-hydroxyphenanthrene, in NHANES 2001-2002, higher levels were observed in the group aged 6-11 years than either of the groups age 12-19 years or 20 years and older. Non-Hispanic whites had higher levels than Mexican Americans.

For adjusted geometric mean levels of urinary 4-hydroxyphenanthrene, in NHANES 2001-2002, no demographic group differences were observed.

For adjusted geometric mean levels of urinary 9-hydroxyphenanthrene, in NHANES 2001-2002, non-Hispanic whites had higher levels than either non-Hispanic blacks or Mexican Americans. Also, Mexican Americans had higher levels than non-Hispanic blacks.

Figure 16. 1-Hydroxyphenanthrene (creatinine corrected)

Selected percentiles with 95% confidence intervals of urine concentrations (in ng/g of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2002.



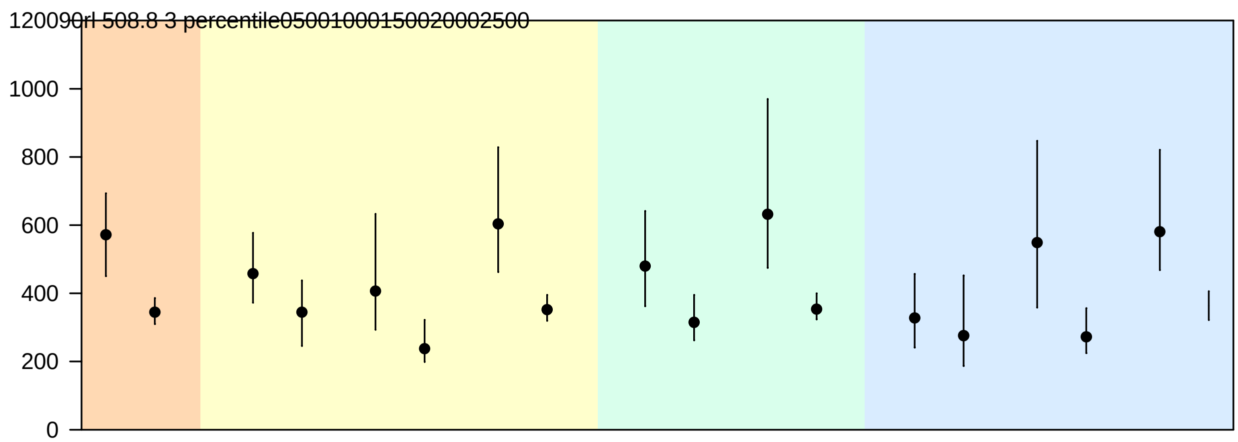


Table 64. 2-Hydroxyphenanthrene

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, 1999-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 6 and older	99-00	**98.3** (76.6-126)	**107** (79.7-141)	**240** (194-335)	**545** (448-689)	**828** (714-937)	2179
	01-02	**54.0** (46.0-63.5)	**57.0** (49.0-68.0)	**117** (102-140)	**240** (200-271)	**332** (299-377)	2742
Age group							
6-11 years	99-00	**79.6** (57.3-111)	**74.1** (45.8-113)	**189** (113-289)	**401** (283-585)	**698** (383-1140)	291
	01-02	**40.5** (34.3-47.7)	**45.0** (37.0-57.0)	**87.0** (71.0-101)	**170** (133-207)	**257** (195-320)	387
12-19 years	99-00	**109** (90.0-132)	**112** (92.6-139)	**233** (183-296)	**529** (427-615)	**767** (570-1250)	650
	01-02	**49.5** (37.3-65.7)	**51.0** (41.0-68.0)	**107** (90.0-122)	**210** (145-270)	**281** (214-524)	733
20 years and older	99-00	**99.3** (76.4-129)	**108** (81.2-148)	**253** (203-345)	**571** (454-721)	**864** (721-945)	1238
	01-02	**56.8** (48.1-66.9)	**60.0** (51.0-73.0)	**126** (104-152)	**249** (207-292)	**342** (308-398)	1622
Gender							
Males	99-00	**107** (81.9-140)	**109** (82.2-158)	**263** (199-382)	**592** (448-778)	**928** (702-1340)	1048
	01-02	**62.1** (53.3-72.5)	**67.0** (58.0-80.0)	**135** (109-161)	**274** (245-303)	**359** (329-414)	1345
Females	99-00	**90.6** (70.7-116)	**105** (72.7-132)	**226** (183-307)	**514** (402-632)	**797** (579-915)	1131
	01-02	**47.4** (39.1-57.5)	**50.0** (40.0-59.0)	**105** (88.0-128)	**200** (171-240)	**292** (236-357)	1397
Race/ethnicity							
Mexican Americans	99-00	**86.0** (69.6-106)	**92.3** (68.9-124)	**217** (163-285)	**432** (325-482)	**583** (433-913)	698
	01-02	**46.8** (32.7-66.8)	**51.0** (35.0-72.0)	**95.0** (72.0-137)	**191** (122-332)	**303** (187-652)	665
Non-Hispanic blacks	99-00	**131** (84.6-202)	**141** (69.6-250)	**370** (214-562)	**698** (476-1080)	**1080** (782-2310)	509
	01-02	**71.1** (58.0-87.1)	**74.0** (66.0-90.0)	**152** (123-182)	**260** (217-311)	**374** (284-560)	690
Non-Hispanic whites	99-00	**91.7** (67.2-125)	**103** (70.6-139)	**231** (177-339)	**514** (409-712)	**810** (680-906)	792
	01-02	**53.1** (43.6-64.6)	**57.0** (47.0-66.0)	**116** (98.0-144)	**242** (199-286)	**333** (303-385)	1204

Table 65. 2-Hydroxyphenanthrene (creatinine corrected)

	Survey years				Sample size
Total, age 6 and older	99-00	**90.3** (69.3-118)	**89.8** (67.8-119)	**188**	

Figure 17. 2-Hydroxyphenanthrene (creatinine corrected)

Selected percentiles with 95% confidence intervals of urine concentrations (in ng/g of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2002.

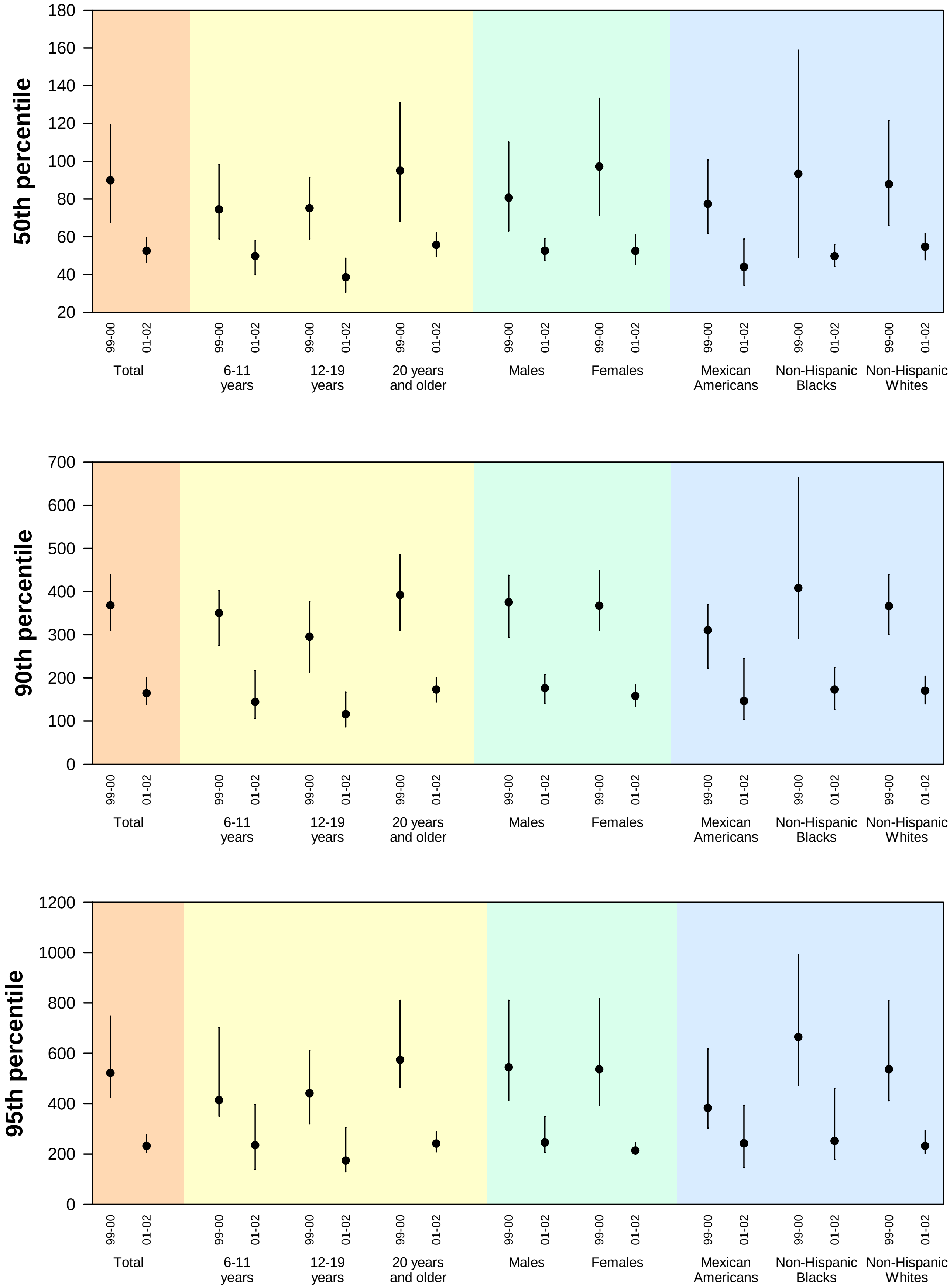


Table 66. 3-Hydroxyphenanthrene

	Survey years						Sample size
Total, age 6 and older	99-00	**127** (106-152)	**138** (113-165)	**256** (225-297)	**464** (399-547)	**657** (594-721)	2299
	01-02	**105** (92.5-118)	**105** (90.0-118)	**200** (178-225)	**400** (336-480)	**649** (542-747)	2741
Age group							

Figure 18. 3-Hydroxyphenanthrene (creatinine corrected)

Table 69. 4-Hydroxyphenanthrene **(creatinine corrected)**

Figure 19. 1-Hydroxypyrene (creatinine corrected)

Selected percentiles with 95% confidence intervals of urine concentrations (in ng/g of creatinine) for the U.S. population aged 6 years and older,

3-Hydroxybenzo[a]pyrene

CAS No. 13345-21-6

Metabolite of Benzo[a]pyrene, CAS No. 129-00-0

Interpreting Levels of Urinary 3-Hydroxybenzo[a]pyrene Reported in the Tables

Benzo[a]pyrene is considered a probable carcinogen by

Table 77. 1-Hydroxynaphthalene (creatinine corrected)

	Survey years						Sample size
Total, age 6 and older	01-02	**1910** (1700-2160)	**1560** (1370-1810)	**4160** (3550-5170)	**10500** (8470-12600)	**17800** (14500-20800)	2748
Age group							
6-11 years	01-02	**1600** (1320-1930)	**1370** (1040-1780)	**2880** (2140-384TT0 1 Tf-0.0077 Tc 6.8855 0 0 6.8855 487.98 45((5..9037 4f-02850)-8(0)]TJ/T			

Table 78. 2-Hydroxynaphthalene

	Survey years						Sample size
Total, age 6 and older	01-02	**2470** (2110-2890)	**2280** (1920-2640)	**5680** (4580-6830)	**14700** (12800-19500)	**26000** (22500-29700)	2748
Age group							
6-11 years	01-02	**1690** (1560-1840)	**1700** (1400-1950)	**3000** (2580-3470)	**5350** (3890-6700)	**7720** (6300-9540)	387
12-19 years	01-02	**2220** (1700-2900)	**2150** (1740-2530)	**4390** (3150-6110)	**11000** (6990-20400)	**22500** (13900-28400)	735
20 years and older	01-02	**2620** (2220-3100)	**2440** (1940-2950)	**6380** (5110-8110)	**17600** (14000-21100)	**28100** (23300-33700)	1626
Gender							
Males	01-02	**2750** (2360-3210)	**2510** (2090-2970)	**6040** (4820-7810)	**16400** (11900-23000)	**28100** (20800-35600)	1349
Females	01-02	**2220** (1860-2660)	**2060** (1650-2480)	**5240** (3890-6440)	**13900** (12300-17700)	**25100** (19700-28300)	1399
Race/ethnicity							
Mexican Americans	01-02	**2700** (2360-3080)	**2690** (2350-3260)	**5140** (4360-6150)	**9600** (8150-10600)	**13600** (10400-18700)	665
Non-Hispanic blacks	01-02	**3970** (3470-4540)	**3460** (3100-4020)	**9250** (6820-13200)	**22800** (16000-29100)		

Polychlorinated Dibenzo-p-dioxins, Polychlorinated Dibenzofurans, and Coplanar and Mono-ortho-substituted Polychlorinated Biphenyls

General Information

Polychlorinated dibenzo-*p*-dioxins and dibenzofurans are two similar classes of chlorinated aromatic chemicals that are produced as contaminants or byproducts. They have no known commercial or natural use. Dioxins are primarily produced during the incineration or burning of waste; the bleaching processes used in pulp and paper

Health effects of exposure to dioxins and furans in people have been observed as a result of industri5 T or]TJ0.0008 5c 0.0006 9w 0 T*(peaccident T e-2(8(sure tin)v)-75(ving larg

9.9 pg/g lipid (Papke et al., 1998). Levels at the 95th percentile in the NHANES 2001-2002 subsample reported here were 15.8 pg/g.

The three major hexachlorodibenzo-*p*-dioxins are assigned equal TEF values, but the 1,2,3,6,7,8-hexachlorodibenzo-*p*-dioxin often demonstrates multifold higher concentrations than the other two hexachlorodibenzo-*p*-dioxins, about six-fold higher in the NHANES 2001-2002 subsample. The geometric mean levels of 1,2,3,6,7,8-hexachlorodibenzo-*p*-dioxin in the 2001-2002 subsample are slightly higher than levels in either the German or New Zealand study mentioned above (Papke et al., 1998; Bates et al., 2004*b*). A small convenience sample of Japanese men and women aged 20-76 years studied during 1996-1997 also showed lower median levels of 17 pg/g and 18 pg/g lipid, respectively, than levels in the NHANES 2001-2002 subsample (Arisawa et al., 2003).

For TCDD levels in the NHANES 2001-2002 subsample, only the 95th percentiles in women and non-Hispanic blacks could be characterized, which were 6.4 and 7.4, picograms/gram (pg/g) of lipid, respectively (detection limit of 5.8 pg/g of lipid). The remainder of the U.S. population is likely to be below these levels of this hallmark dioxin. In 1996, the 95th percentile for lipid-adjusted serum TCDD levels in 139 Germans aged 18-71 years was 4.3 pg/g of lipid, with that percentile comprising mainly older individuals (Papke, 1998). The TCDD levels in this *Report* are much lower than those for chemical-production workers even when they were examined 15 years after workplace exposure had ceased (median serum TCDD concentration = 68 pg/g of lipid) (Calvert et al., 1996). TCDD levels of chemical-plant workers exposed to high concentrations have ranged as high as 2,000 pg/g lipid (World Health Organization/ IARC, 1997).

In the NHANES 2001-2002 subsample, the geometric mean levels of coplanar PCBs 126 and 169 for participants aged 20 years and older were similar or slightly lower than those reported from a representative pooled sample of New Zealanders in 1996-1997 (Bates et al., 2004*b*) and of a smaller sample of non-occupationally exposed men and women aged 20-76 years in Japan in 1999 (Arisawa et al., 2003). Of the mono-ortho-chlorine-substituted PCB congeners, the most frequently detected in general population studies are PCBs 118 and 156. Of these, PCB 118 levels were higher than PCB 156 in the NHANES 1999-2000 and 2001-2002 subsamples although PCB 156 contributes more to the TEQ because its TEF is five-fold greater than the TEF of PCB 118. Compared with levels in a convenience sample of the U.S. population in 1988 (Patterson et al., 1994), levels of PCB 118 are at least five-fold lower in the NHANES 1999-2002 subsamples. The PCB 156 levels in the NHANES data for 1999-2002 are slightly lower than those reported for a Canadian population study in 1994 (Longnecker et al., 2000). Levels of PCB 156 and PCB 118 were slightly higher in a Swedish study of 150 men than in the NHANES 1999-2002 subsample possibly due to higher fish intake in the Swedish population (Glynn et al., 2000). However, in fish-consuming Japanese men and women studied during 1996-1997, PCB 118 levels were similar to levels in the NHANES 2001-2002 subsample at the comparable 75th percentiles (Arisawa et al., 2003).

As was the case for TCDD, levels of other polychlorinated dibenzo-*p*-dioxins, dibenzofurans, coplanar and mono-ortho- substituted biphenyls in this *Report* are below levels associated with occupational or unintentional exposures that produce health effects. There are no firmly established relationships between serum lipid-based concentrations (mainly considering TCDD) and effects in people. Studies of industrial and accidental exposures suggest that concentrations of at least 800 pg/g of lipid might be necessary to induce chloracne, a specific effect, although levels in the thousands of pg/g of lipid do not always produce this effect (Mocarelli et al., 1991). The studies showing clinical effects in people after large unintentional exposures have demonstrated concentrations ranging from several hundred to the tens of thousands of pg/g of lipid (Masuda 2001; Masuda et al., 1998; Mocarelli et al., 1991).

Comparing Adjusted Geometric Means

For comparison of demographic groups in the NHANES 2001-2002 subsample, geometric means of whole weight-based serum measurements were adjusted for age, gender, race/ethnicity, log serum cotinine, and lipid level (data not shown). In NHANES 2001-2002, females had higher adjusted geometric mean levels than males for 1,2,3,4,6,7,8-heptachlorodibenzo-*p*-dioxin, and 3,3,4,4,5-pentachlorobiphenyl (PCB 126). However, males had higher levels than females for 3,3,4,4,5,5-hexachlorobiphenyl (PCB 169). In the previously mentioned study of Japanese adults, women demonstrated higher levels than men for the octachlorodibenzo-*p*-dioxin, 1,2,3,4,6,7,8-heptachlorodibenzo-*p*-dioxin and 1,2,3,7,8,9-hexachlorodibenzo-*p*-

Table 81. 1,2,3,4,6,7,8,9-Octachlorodibenzo-*p*-dioxin (OCDD) (lipid adjusted)

	Survey years						Sample size
Total, age 20 and older	99-00	*	**< LOD**	**445** (389-496)	**704** (624-802)	**948** (822-1080)	1254
	01-02	**346** (<LOD-394)	**333** (<LOD-399)	**571** (498-668)	**939** (780-1090)	**1260** (997-1610)	1171
Age group							
12-19 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**421** (363-517)	667
	01-02	†	†	†	†	†	†
20 years and older	99-00	*	**< LOD**	**445** (389-496)	**704** (624-802)	**948** (822-1080)	1254
	01-02	**346** (<LOD-394)	**333** (<LOD-399)	**571** (498-668)	**939** (780-1090)	**1260** (997-1610)	1171

Table 82. 1,2,3,4,6,7,8,9-Octachlorodibenzo-*p*-dioxin (OCDD) (whole weight)

	Survey years			Sample size

Table 83. 1,2,3,4,6,7,8-Heptachlorodibenzo-*p*-dioxin (HpCDD) (lipid adjusted)

	Survey years						Sample size
Total, age 20 and older	99-00	*	< LOD	**61.9** (57.1-66.7)	**92.0** (81.2-101)	**119** (102-139)	1237
	01-02	**39.0** (33.7-45.0)	**40.2** (34.9-46.7)	**68.7** (56.7-82.2)	**115** (88.2-138)	**147** (126-177)	1220
Age group							
12-19 years	99-00	*	< LOD	< LOD	< LOD	**63.6** (<LOD-75.6)	657
	01-02	†	†	†	†	†	†
20 years and older	99-00	*	< LOD	**61.9** (57.1-66.7)	**92.0** (81.2-101)	**119** (102-139)	1237
	01-02	**39.0** (33.7-45.0)	**40.2** (34.9-46.7)	**68.7** (56.7-82.2)	**115** (88.2-138)	**147**	

Table 84. 1,2,3,4,6,7,8-Heptachlorodibenzo-*p*-dioxin (HpCDD) (whole weight)

Geometric mean and selected percentiles of serum concentrations (in fg/g of serum or parts per quadrillion) for the U.S. popula

	Survey years						Sample size
Total, age 20 and older	99-00	*	< LOD	**385** (354-418)	**610** (534-677)	**802** (681-936)	1237
	01-02	**252** (219-289)	**265** (232-303)	**440** (376-529)	**779** (591-989)	**1030** (840-1290)	1220
Age group							
12-19 years	99-00	*	< LOD	< LOD	< LOD	**287** (239-340)	657
	01-02	†	†	†	†	†	†
20 years and older	99-00	*	< LOD	**385** (354-418)	**610** (534-677)	**802** (681-936)	1237
	01-02	**252** (219-289)	**265** (232-303)	**440** (376-529)	**779** (591-989)	**1030** (840-1290)	1220
Gender							
(20 years and older)							
Males	99-00	*	< LOD	**363** (310-397)	**501** (446-578)	**642** (543-716)	572
	01-02	**243** (211-279)	**244** (213-291)	**422** (349-527)	**765** (536-976)	**983** (766-1260)	553
Females	99-00	*	< LOD	**414** (354-462)	**707** (597-867)	**945** (825-1100)	665
	01-02	**260** (221-306)	**281** (236-324)	**464** (386-551)	**782** (621-997)	**1140** (849-1330)	667
Race/ethnicity							
(20 years and older)							
Mexican Americans	99-00	*	< LOD	**404** (364-472)	**646** (585-785)	**906** (677-1090)	330
	01-02	**254** (232-278)	**249** (229-286)	**403** (360-521)	**789** (643-929)	**988** (817-1240)	262
Non-Hispanic blacks	99-00	*	< LOD	**373** (297-428)	**592** (480-752)	**966** (610-1220)	224
	01-02	**258** (208-319)	**262** (180-339)	**469** (343-600)	**852** (578-1170)	**1160** (821-1660)	218
Non-Hispanic whites	99-00	*	< LOD	**391** (353-430)	**610** (511-679)	**758** (676-871)	567
	01-02	**255** (216-302)	**276** (228-328)	**442** (374-547)	**779** (551-1010)	**1020** (803-1290)	657

Table 86. 1,2,3,4,7,8-Hexachlorodibenzo-*p*-dioxin (HxCDD) (whole weight)

	Survey years						Sample size
Total, age 20 and older	01-02	*	**< LOD**	**< LOD**	**73.8** (54.3-90.7)	**105** (81.2-139)	1239
Age group							
12-19 years	01-02	†	†	†	†	†	†
20 years and older	01-02	*	**< LOD**	**< LOD**	**73.8** (54.3-90.7)	**105** (81.2-139)	1239
Gender							
(20 years and older)							
Males	01-02	*	**< LOD**	**< LOD**	**73.4** (52.6-90.7)	**105** (77.9-134)	566
Females	01-02	*	**< LOD**	**< LOD**	**73.8** (53.2-90.7)	**102** (78.0-152)	673
Race/ethnicity							
(20 years and older)							
Mexican Americans	01-02	*	**< LOD**	**< LOD**	**< LOD**	**70.2** (48.0-118)	263

Table 87. 1,2,3,6,7,8-Hexachlorodibenzo-*p*-dioxin (HxCDD) (lipid adjusted)

	Survey years						Sample size
Total, age 20 and older	99-00	*	**< LOD**	**36.1** (31.5-40.5)	**62.8** (53.6-69.1)	**75.6** (70.5-84.2)	1237
	01-02	**34.6** (29.6-40.6)	**39.2** (32.7-44.7)	**60.7** (50.3-74.2)	**95.2** (76.2-120)	**127**	

Table 90. 1,2,3,7,8,9-Hexachlorodibenzo-*p*-dioxin (HxCDD) (whole weight)

	Survey years						Sample size
Total, age 20 and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1228
	01-02	*	**< LOD**	**< LOD**	**86.5** (68.8-108)	**121** (99.5-146)	1238
Age group							
12-19 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	642
	01-02	†	†	†	†	†	†
20 years and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1228
	01-02	*	**< LOD**	**< LOD**	**86.5** (68.8-108)	**121** (99.5-146)	1238
Gender							
(20 years and older)							
Males	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	565
	01-02	*	**< LOD**	**< LOD**	**84.1** (62.7-104)	**108** (90.6-142)	567
Females	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	663
	01-02	*	**< LOD**	**< LOD**	**89.7** (67.9-121)	**123** (102-150)	671
Race/ethnicity							
(20 years and older)							
Mexican Americans	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	328
	01-02	*	**< LOD**	**< LOD**	**74.7** (50.5-104)	**104** (74.7-167)	262
Non-Hispanic blacks	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	223
	01-02	*	**< LOD**	**< LOD**	**92.6** (62.8-126)	**123** (82.6-169)	220
Non-Hispanic whites	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	562
	01-02	*	**< LOD**	**< LOD**	**88.1** (67.9-119)	**124** (96.6-152)	672

Table 91. 1,2,3,7,8-Pentachlorodibenzo-*p*-dioxin (PeCDD) (lipid adjusted)

	Survey years						Sample size
Total, age 20 and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1256
	01-02	*	**< LOD**	**< LOD**	**11.2** (9.30-13.3)	**15.8** (12.3-19.8)	1236
Age group							

Table 92. 1,2,3,7,8-Pentachlorodibenzo-*p*-dioxin (PeCDD) (whole weight)

	Survey years	mean					Sample size
Total, age 20 and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1256
	01-02	*	**< LOD**	**< LOD**	**77.8** (62.8-95.1)	**117** (90.3-133)	1236
Age group							
12-19 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	659
	01-02	†	†	†	†	†	†
20 years and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1256
	01-02	*	**< LOD**	**< LOD**	**77.8** (62.8-95.1)	**117** (90.3-133)	1236
Gender							
(20 years and older)							
Males	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	578
	01-02	*	**< LOD**	**< LOD**	**76.1** (54.7-93.7)	**107** (83.5-133)	564
Females	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	678
	01-02	*	**< LOD**	**37.8** (25.0-50.2)	**80.1** (62.9-107)	**121** (85.7-167)	672
Race/ethnicity							
(20 years and older)							
Mexican Americans	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	338
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**66.0** (43.3-111)	262
Non-Hispanic blacks	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	225
	01-02	*	**< LOD**	**43.0** (27.0-53.8)	**81.9** (58.2-117)	**123** (81.9-169)	218
Non-Hispanic whites	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	576
	01-02	*	**< LOD**	**< LOD**	**80.8** (61.6-107)	**119** (88.6-142)	672

< LOD means less than the limit of detection, which may vary for some chemicals by year and bi of detec 8.c (i)-6(m)-142(foN)s34.9601 Tmssomc 6]T//T02N6N 234.78015nrsN 234.78015

Table 94. 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin (TCDD) (whole weight)

Geometric mean and selected percentiles of serum concentrations (in fg/g of serum or parts per quadrillion) for the U.S. population National Health and Nutrition Examination Survey (1999-2000, aged 12 years and older; 2001-2002, aged 20 years and older).

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 20 and older	99-00	*	< LOD	< LOD	< LOD	< LOD	1240
	01-02	*	< LOD	< LOD	< LOD	< LOD	1228
Age group							
12-19 years	99-00	*	< LOD	< LOD	< LOD	< LOD	658
	01-02	†	†	†	†	†	†
20 years and older	99-00	*	< LOD	< LOD	< LOD	< LOD	1240
	01-02	*	< LOD	< LOD	< LOD	< LOD	1228
Gender							
(20 years and older)							
Males	99-00	*	< LOD	< LOD	< LOD	< LOD	572
	01-02	*	< LOD	< LOD	< LOD	< LOD	559
Females	99-00	*	< LOD	< LOD	< LOD	< LOD	668
	01-02	*	< LOD	< LOD	< LOD	**50.7** (29.2-74.3)	669
Race/ethnicity							
(20 years and older)							
Mexican Americans	99-00	*	< LOD	< LOD	< LOD	< LOD	336
	01-02	*	< LOD	< LOD	< LOD	< LOD	262
Non-Hispanic blacks	99-00	*	< LOD	< LOD	< LOD	< LOD	222
	01-02	*	< LOD	< LOD	< LOD	**52.1** (27.4-72.0)	217
Non-Hispanic whites	99-00	*	< LOD	< LOD	< LOD	< LOD	567
	01-02	*	< LOD	< LOD	< LOD	< LOD	665

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.

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

† Data not collected for this age group for these years.

Table 96. 1,2,3,4,6,7,8,9-Octachlorodibenzofuran (OCDF) (whole weight)

	Survey years				Sample size
Total, age 20 and older	99-00	*	< LOD	< LO026 Tc 0:*008 Tw 8.0494 0 0 8.0494 326.22 5020172	Tc -0.0032 4<3LO026 T

Table 97. 1,2,3,4,6,7,8-Heptachlorodibenzofuran (HpCDF)

Table 99. 1,2,3,4,7,8,9-Heptachlorodibenzofuran (HpCDF) (lipid adjusted)

Table 100. 1,2,3,4,7,8,9-Heptachlorodibenzofuran (HpCDF) (whole weight)

Geometric mean and selected percentiles of serum concentrations (in fg/g of serum or parts per quadrillion) for the U.S. population aged 20 years and older, National Health and Nutrition Examination Survey, 2001-2002.

	Survey years	Geometric	Selected percenti.0083 on				Sample size
			50th	75th	90th		
Total, age 20 and older	01-02	*	< LOD	< LOD	< LOD	< LOD	1224
Age group							
12-19 years	01-02	†	†	†	†	†	†
20 years and older	01-02	*	< LOD	< LOD	< LOD	< LOD	1224
Gender (20 years and older)							
Males	01-02	*	< LOD	< LOD	< LOD	< LOD	558
Females	01-02	*	< LOD	< LOD	< LOD	< LOD	666
Race/ethnicity (20 years and older)							
Mexican Americans	01-02	*	< LOD	< LOD	< LOD	< LOD	262
Non-Hispanic blacks	01-02	*	< LOD	< LOD	< LOD	< LOD	217
Non-Hispanic whites	01-02	*	< LOD	< LOD	< LOD	< LOD	661

Table 102. 1,2,3,4,7,8-Hexachlorodibenzofuran (HxCDF) (whole weight)

	Survey years					Sample size
Total, age 20 and older	99-00	*	< LOD	< LOD	< LOD	

Table 104. 1,2,3,6,7,8-Hexachlorodibenzofuran (HxCDF) (whole weight)

	Survey years						Sample size
Total, age 20 and older	99-00	*	< LOD	< LOD	< LOD	< LOD	1242
	01-02	*	< LOD	**46.0** (38.6-56.5)	**70.2** (58.3-90.2)	**101** (77.6-120)	1236
Age group							
12-19 years	99-00	*	< LOD	< LOD	< LOD	< LOD	656
	01-02	†	†	†	†	†	†

Table 106. 1,2,3,7,8,9-Hexachlorodibenzofuran (HxCDF) (whole weight)

	Survey years						Sample size
Total, age 20 and older	99-00	*	< LOD	< LOD	< LOD	< LOD	1230
	01-02	*	< LOD	< LOD	< LOD	< LOD	1223
Age group							
12-19 years	99-00	*	< LOD	< LOD	< LOD	< LOD	645
	01-02	†	†	†	†	†	†
20 years and older	99-00	*	< LOD	< LOD	< LOD	< LOD	1230
	01-02	*	< LOD	< LOD	< LOD	< LOD	1223
Gender (20 years and older)							
Males	99-00	*	< LOD	< LOD	< LOD	< LOD	564
	01-02	*	< LOD	< LOD	< LOD	< LOD	559
Females	99-00	*	< LOD	< LOD	< LOD	< LOD	666
	01-02	*	< LOD	< LOD	< LOD	< LOD	664
Race/ethnicity							

Table 107. 1,2,3,7,8-Pentachlorodibenzofuran (PeCDF) (lipid adjusted)

	Survey years						Sample size
Total, age 20 and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1259
	01-02	*	**< LOD**	**< LOD**	**< LOD**		

Table 108. 1,2,3,7,8-Pentachlorodibenzofuran (PeCDF) (whole weight)

	Survey years						Sample size
Total, age 20 and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1259
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1235
Age group							
12-19 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	663
	01-02	†	†	†	†	†	†
20 years and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1259
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1235
Gender							
(20 years and older)							
Males	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	578
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	565
Females	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	681
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	670
Race/ethnicity							
(20 years and older)							

Table 113. 2,3,7,8-Tetrachlorodibenzofuran (TCDF) (lipid adjusted)

	Survey years						Sample size
Total, age 20 and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1243
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1229
Age group							
12-19 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	660
	01-02	†	†	†	†	†	†
20 years and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1243
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1229
Gender (20 years and older)							
Males	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	574
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	558
Females	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	669
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	671
Race/ethnicity (20 years and older)							
Mexican Americans	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	335
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	262
Non-Hispanic blacks	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	226
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	217
Non-Hispanic whites	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	

Table 114. 2,3,7,8-Tetrachlorodibenzofuran (TCDF) (whole weight)

	Survey years						Sample size
Total, age 20 and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1243
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1229
Age group							
12-19 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	660
	01-02	†	†	†	†	†	†
20 years and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1243
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1229
Gender (20 years and older)							
Males	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	574
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	558
Females	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	669
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	671

Table 115. 2,4,4'-Trichlorobiphenyl (PCB 28) (lipid adjusted)

	Survey years			Sample size
Total, age 12 and older	99-00	*	90	

Table 116. 2,4,4'-Trichlorobiphenyl (PCB 28) (whole weight)

Table 117. 2,3',4,4'-Tetrachlorobiphenyl (PCB 66) (lipid adjusted)

	Survey years						Sample size
Total, age 12 and older	99-00	*	< LOD	< LOD	< LOD	< LOD	1931
	01-02	*	< LOD	< LOD	< LOD	< LOD	2250
Age group							
12-19 years	99-00	*	< LOD	< LOD	< LOD	< LOD	671
	01-02	*	< LOD	< LOD	< LOD	< LOD	724
20 years and older	99-00	*	< LOD	< LOD	< LOD		

Table 120. 2,4,4',5-Tetrachlorobiphenyl (PCB 74) (whole weight)

	Survey years			Sample size
Total, age 12 and older	99-00	*		

Table 124. 2,3,3',4,4'-Pentachlorobiphenyl (PCB 105)

	Survey years			Sample size
Total, age 12 and older	99-00	*		

Table 130. 2,3,3',4,4',5-Hexach31962.4xach3196bhe

Table 133. 2,3',4,4',5,5'-Hexachlorobiphenyl (PCB 167) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (in 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, 1999-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)				Sample size
			50th	75th	90th	95th	
Total, age 12 and older	99-00	*	< LOD	< LOD	< LOD	< LOD	1908
	01-02	*	< LOD	< LOD	< LOD	< LOD	2298
Age group							
12-19 years	99-00	*	< LOD	< LOD	< LOD	< LOD	666
	01-02	*	< LOD	< LOD	< LOD	< LOD	758
20 years and older	99-00	*	< LOD	< LOD	< LOD	< LOD	1242
	01-02	*	< LOD	< LOD	< LOD	< LOD	1540
Gender							
Males	99-00	*	< LOD	< LOD	< LOD	< LOD	908
	01-02	*	< LOD	< LOD	< LOD	< LOD	1069
Females	99-00	*	< LOD	< LOD	< LOD	< LOD	1000
	01-02	*	< LOD	< LOD	< LOD	< LOD	1229
Race/ethnicity							
Mexican Americans	99-00	*	< LOD	< LOD	< LOD	< LOD	627
	01-02	*	< LOD	< LOD	< LOD	< LOD	564
Non-Hispanic blacks	99-00	*	< LOD	< LOD	< LOD	< LOD	411
	01-02	*	< LOD	< LOD	< LOD	< LOD	515
Non-Hispanic whites	99-00	*	< LOD	< LOD	< LOD	< LOD	715
	01-02	*	< LOD	< LOD	< LOD	< LOD	1056

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.

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

Table 135. 3,3',4,4',5,5'-Hexachlorobiphenyl (PCB 169) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (in pg/g of lipid or parts per trillion on a lipid-weight basis)

aged 20 years and older).

	Survey years						Sample size
Total, age 20 and older	99-00	*	< LOD	< LOD	**36.4** (33.8-40.3)	**47.8** (42.8-51.0)	1240
	01-02	**17.9** (16.0-19.9)	**19.0** (16.8-21.9)	**33.1** (27.5-38.6)	**50.0** (43.9-55.0)	**60.7** (55.8-65.8)	1223
Age group							
12-19 years	99-00	*	< LOD	< LOD	< LOD	< LOD	648
	01-02	†	†	†	†	†	†
20 years and older	99-00	*	< LOD	< LOD	**36.4** (33.8-40.3)	**47.8** (42.8-51.0)	1240
	01-02	**17.9** (16.0-19.9)	**19.0** (16.8-21.9)	**33.1** (27.5-38.6)	**50.0** (43.9-55.0)	**60.7** (55.8-65.8)	1223
Gender							
(20 years and older)							
Males	99-00	*	< LOD	< LOD	**38.1** (33.8-42.3)	**45.7** (40.8-52.8)	572
	01-02	**20.2** (17.8-22.8)	**22.0** (18.5-25.3)	**36.0** (29.5-43.2)	**53.0** (45.8-56.9)	**60.6** (55.7-69.0)	559
Females	99-00	*	< LOD	< LOD	**34.6** (30.9-40.6)	**48.3** (39.4-52.0)	668
	01-02	**16.0** (14.2-18.1)	**16.8** (14.7-19.2)	**30.1** (24.5-36.5)	**46.0** (40.7-51.9)	**60.9** (52.2-70.0)	664
Race/ethnicity							
(20 years and older)							
Mexican Americans	99-00	*	< LOD	< LOD	< LOD	**33.6** (29.5-38.1)	335
	01-02	*	< LOD	**15.0** (11.3-18.3)	**24.6** (18.3-32.3)	**32.3** (26.3-39.6)	260
Non-Hispanic blacks	99-00	*	< LOD	< LOD	**41.3** (34.6-52.2)	**53.2** (44.3-65.6)	224
	01-02	**17.2** (15.4-19.1)	**18.3** (15.7-20.0)	**31.7** (25.8-35.4)	**47.3** (41.1-53.9)	**54.8** (48.3-64.5)	217
Non-Hispanic whites	99-00	*	< LOD	< LOD	**36.6** (33.5-41.8)	**48.1** (41.8-51.6)	568
	01-02	**19.5** (17.2-22.2)	**21.4** (17.4-24.7)	**36.0** (29.6-41.1)	**53.5** (47.0-58.3)	**64.3** (59.2-72.8)	662

Table 136. 3,3',4,4',5,5'-Hexachlorobiphenyl (PCB 169)

Table 137. 2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB 189) (lipid adjusted)

Survey

Table 138. 2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB 189) (whole weight)

Geometric mean and selected percentiles of serum concentrations (in ng/g of serum or parts per billion) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 2001-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 12 and older	01-02	*	< LOD	< LOD	< LOD	< LOD	2298
Age group							
12-19 years	01-02	*	< LOD	< LOD	< LOD	< LOD	752
20 years and older	01-02	*	< LOD	< LOD	< LOD	< LOD	1546
Gender							
Males	01-02	*	< LOD	< LOD	< LOD	< LOD	1070
Females	01-02	*	< LOD	< LOD	< LOD	< LOD	1228
Race/ethnicity							
Mexican Americans	01-02	*	< LOD	< LOD	< LOD	< LOD	564
Non-Hispanic blacks	01-02	*	< LOD	< LOD	< LOD	< LOD	514
Non-Hispanic whites	01-02	*	< LOD	< LOD	< LOD	< LOD	1057

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.
* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Non-dioxin-like Polychlorinated Biphenyls

pharmacokinetics, or the relationship of dose per body weight.

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 or not people have been exposed to higher levels of PCBs than levels found in the general population. Whether PCBs at the levels reported here are cause for health concern is not known; more research is needed.

Table 140. 2,2',5,5'-Tetrachlorobiphenyl (PCB 52) (lipid adjusted)

	Survey years			Sample size
Total, age 12 and older	99-00	*		

Table 141. 2,2',5,5'-Tetrachlorobiphenyl (PCB 52) (whole weight)

	Survey years						Sample size
Total, age 12 and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1912
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**.089** (.081-.097)	1537
Age group							
12-19 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	664
	01-02	*	**< LOD**	**< LOD**	**.079** (.048-.101)	**.104** (.083-.135)	291
20 years and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1248
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**.086** (.076-.092)	1246
Gender							
Males	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	908
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**.085** (.071-.104)	716
Females	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1004
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**.088** (.083-.094)	821
Race/ethnicity							

Table 142. 2,2',3,4,5'-Pentachlorobiphenyl (PCB 87) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (in 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, 2001-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)				Sample size
			50th	75th	90th	95th	
Total, age 12 and older	01-02	*	< LOD	< LOD	< LOD	< LOD	2298
Age group							
12-19 years	01-02	*	< LOD	< LOD	< LOD	< LOD	758
20 years and older	01-02	*	< LOD	< LOD	< LOD	< LOD	1540
Gender							
Males	01-02	*	< LOD	< LOD	< LOD	< LOD	1069
Females	01-02	*	< LOD	< LOD	< LOD	< LOD	1229
Race/ethnicity							
Mexican Americans	01-02	*	< LOD	< LOD	< LOD	< LOD	564
Non-Hispanic blacks	01-02	*	< LOD	< LOD	< LOD	< LOD	515
Non-Hispanic whites	01-02	*	< LOD	< LOD	< LOD	< LOD	1056

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.
* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 144. 2,2',4,4',5-Pentachlorobiphenyl (PCB 99) (lipid adjusted)

	Survey years						Sample size
Total, age 12 and older	99-00	*	**< LOD**	**< LOD**	**13.1** (<LOD-14.6)	**19.1** (16.2-20.6)	1897
	01-02	*	**< LOD**	**< LOD**	**17.6** (15.3-20.8)	**26.3** (22.1-30.5)	2281
Age group							
12-19 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	654
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	758
20 years and older	99-00	*	**< LOD**	**< LOD**	**13.9** (<LOD-16.0)	**19.9** (17.0-21.1)	1243
	01-02	*	**< LOD**	**10.8** (<LOD-12.3)	**19.4** (16.6-22.3)	**28.8** (23.2-32.1)	1523
Gender							
Males	99-00	*	**< LOD**	**< LOD**	**< LOD**	**16.7** (13.8-20.5)	905
	01-02	*	**< LOD**	**< LOD**	**16.7** (13.8-21.0)	**24.9** (19.8-30.1)	1061
Females	99-00	*	**< LOD**	**< LOD**	**13.9** (<LOD-16.2)	**20.0** (17.3-23.5)	992
	01-02	*	**< LOD**	**< LOD**	**18.0** (15.8-22.2)	**28.5** (22.5-33.2)	1220
Race/ethnicity							
Mexican Americans	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	624
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**13.4** (10.7-17.4)	562
Non-Hispanic blacks	99-00	*	**< LOD**	**< LOD**	**20.3** (17.0-31.1)	**31.5** (22.9-57.4)	400
	01-02	*	**< LOD**	**11.6** (10.6-13.1)	**22.4** (18.8-25.8)	**28.8** (23.0-37.2)	510
Non-Hispanic whites	99-00	*					

Table 146. 2,2',4,5,5'-Pentachlorobiphenyl (PCB 101) (lipid adjusted)

	Survey years						Sample size
Total, age 12 and older	99-00	*	< LOD	< LOD	< LOD	< LOD	1929
	01-02	*	< LOD	< LOD	< LOD	< LOD	2307
Age group							
12-19 years	99-00	*	< LOD				

Table 148. 2,3,3',4',6-Pentachlorobiphenyl (PCB 110) (lipid adjusted)

	Survey years						Sample size
Total, age 12 and older	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	2298
Age group							
12-19 years	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	758
20 years and older	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1540
Gender							
Males	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1069
Females	01-02	*					

Table 149. 2,3,3',4',6-Pentachlorobiphenyl (PCB 110) (whole weight)

Geometric mean and selected percentiles of serum concentrations (in ng/g of serum or parts per billion) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 2001-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 12 and older	01-02	*	< LOD	< LOD	< LOD	< LOD	2298
Age group							
12-19 years	01-02	*	< LOD	< LOD	< LOD	< LOD	758
20 years and older	01-02	*	< LOD	< LOD	< LOD	< LOD	1540
Gender							
Males	01-02	*	< LOD	< LOD	< LOD	< LOD	1069
Females	01-02	*	< LOD	< LOD	< LOD	< LOD	1229
Race/ethnicity							
Mexican Americans	01-02	*	< LOD	< LOD	< LOD	< LOD	564
Non-Hispanic blacks	01-02	*	< LOD	< LOD	< LOD	< LOD	515
Non-Hispanic whites	01-02	*	< LOD	< LOD	< LOD	< LOD	1056

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.

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

Table 150. 2,2',3,3',4,4'-Hexachlorobiphenyl (PCB 128) (lipid adjusted)

	Survey years						Sample size
Total, age 12 and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1927
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	2298
Age group							
12-19 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	668
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	758
20 years and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1259
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1540
Gender							
Males	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	917
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1069
Females	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1010
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1229
Race/ethnicity							
Mexican Americans	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	636
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	564
Non-Hispanic blacks	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	409
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	515
Non-Hispanic whites	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	725
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1056

Table 151. 2,2',3,3',4,4'-Hexachlorobiphenyl (PCB 128) (whole weight)

Geometric mean and selected percentiles of serum concentrations (in ng/g of serum or parts per billion) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 12 and older	99-00	*	< LOD	< LOD	< LOD	< LOD	1927
	01-02	*	< LOD	< LOD	< LOD	< LOD	2298
Age group							
12-19 years	99-00	*	< LOD	< LOD	< LOD	< LOD	668
	01-02	*	< LOD	< LOD	< LOD	< LOD	758
20 years and older	99-00	*	< LOD	< LOD	< LOD	< LOD	1259
	01-02	*	< LOD	< LOD	< LOD	< LOD	1540
Gender							
Males	99-00	*	< LOD	< LOD	< LOD	< LOD	917
	01-02	*	< LOD	< LOD	< LOD	< LOD	1069
Females	99-00	*	< LOD	< LOD	< LOD	< LOD	1010
	01-02	*	< LOD	< LOD	< LOD	< LOD	1229
Race/ethnicity							
Mexican Americans	99-00	*	< LOD	< LOD	< LOD	< LOD	636
	01-02	*	< LOD	< LOD	< LOD	< LOD	564
Non-Hispanic blacks	99-00	*	< LOD	< LOD	< LOD	< LOD	409
	01-02	*	< LOD	< LOD	< LOD	< LOD	515
Non-Hispanic whites	99-00	*	< LOD	< LOD	< LOD	< LOD	725
	01-02	*	< LOD	< LOD	< LOD	< LOD	1056

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.

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

Table 153. 2,2',3,4,4',5' and 2,3,3',4,4',6-Hexachlorobiphenyl (PCB 138 & 158) (whole weight)

Geometric mean and selected percentiles of serum concentrations (in ng/g of serum or parts per billion) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 12 and older	99-00	*	< LOD	< LOD	**.338** (.301-.369)	**.457** (.385-.532)	1930
	01-02	**.122** (.110-.135)	**.124** (.112-.139)	**.265** (.231-.292)	**.457** (.405-.508)	**.649** (.558-.698)	2293
Age group							
12-19 years	99-00	*	< LOD	< LOD	< LOD	< LOD	669
	01-02	*	< LOD	< LOD	**.085** (.064-.107)	**.113** (.086-.205)	748
20 years and older	99-00	*	< LOD	< LOD	**.357** (.323-.385)	**.489** (.399-.556)	1261
	01-02	**.148** (.133-.163)	**.152** (.136-.166)	**.292** (.264-.323)	**.505** (.453-.554)	**.676** (.605-.718)	1545
Gender							
Males	99-00	*	< LOD	< LOD	**.323** (.286-.370)	**.422** (.371-.528)	918
	01-02	**.125** (.112-.140)	**.125** (.111-.139)	**.262** (.228-.292)	**.456** (.374-.542)	**.627** (.509-.711)	1066
Females	99-00	*	< LOD	< LOD	**.344** (.303-.373)	**.485** (.385-.540)	1012
	01-02	**.119** (.107-.132)	**.123** (.111-.143)	**.265** (.231-.294)	**.457** (.418-.496)	**.656** (.588-.703)	1227
Race/ethnicity							
Mexican Americans	99-00	*	< LOD	< LOD	< LOD	< LOD	636
	01-02	*	< LOD	**.114** (.089-.151)	**.233** (.173-.334)	**.349** (.267-.431)	559
Non-Hispanic blacks	99-00	*	< LOD	< LOD	**.473** (.362-.666)	**.828** (.525-1.22)	412
	01-02	**.125** (.108-.146)	**.129** (.093-.157)	**.286** (.231-.347)	**.546** (.424-.675)	**.764** (.564-1.06)	513
Non-Hispanic whites	99-00	*	< LOD	< LOD	**.339** (.296-.371)	**.438** (.372-.532)	727
	01-02	**.133** (.119-.149)	**.136** (.119-.156)	**.280** (.254-.303)	**.464** (.420-.527)	**.647** (.548-.717)	1057

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.

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

Table 154. 2,2',3,4',5,5'-Hexachlorobiphenyl (PCB 146) (lipid adjusted)

	Survey years	mean (95% conf. interval)	50th (95% confidence interval)	75th	90th	95th	Sample size
Total, age 12 and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**13.3** (<LOD-15.2)	1923
	01-02	*	**< LOD**	**< LOD**	**11.0** (<LOD-12.4)	**15.3** (13.6-16.9)	2299
Age group							
12-19 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	667
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	758
20 years and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**14.2** (<LOD-17.1)	1256
	01-02	*	**< LOD**	**< LOD**	**11.8** (10.7-13.5)	**16.5** (14.6-17.9)	1541
Gender							
Males	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	915
	01-02	*	**< LOD**	**< LOD**	**11.0** (<LOD-12.9)	**15.3** (12.9-17.2)	1069
Females	99-00	*	**< LOD**	**< LOD**	**< LOD**	**13.4** (<LOD-16.3)	1008
	01-02	*	**< LOD**	**< LOD**	**11.0** (<LOD-12.2)	**15.2** (13.2-17.3)	1230
Race/ethnicity							
Mexican Americans	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	633
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	567
Non-Hispanic blacks	99-00	*	**< LOD**	**< LOD**	**16.9** (13.4-22.9)	**28.1** (20.2-42.2)	412
	01-02	*	**< LOD**	**< LOD**	**16.6** (12.7-21.4)	**23.8** (16.9-31.6)	515
Non-Hispanic whites	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	723
	01-02	*	**< LOD**	**< LOD**	**10.8** (<LOD-12.0)	**15.2** (12.8-16.8)	1054

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.

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

Table 155. 2,2',3,4',5,5'-Hexachlorobiphenyl (PCB 146) (whole weight)

	Survey years						Sample size
Total, age 12 and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**.082** (.074-.101)	1923
	01-02	*	**< LOD**	**< LOD**	**.073** (.067-.082)	**.104** (.092-.118)	2299
Age group							
12-19 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	667
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	758
20 years and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**.090** (.077-.116)	1256
	01-02	*	**< LOD**	**< LOD**	**.079** (.071-.087)	**.112** (.100-.123)	**1541**
Gender							

Table 158. 2,2',3,4',5',6-Hexachlorobiphenyl (PCB 149) (whole weight)

Geometric mean and selected percentiles of serum concentrations (in ng/g of serum or parts per billion) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 2001-2002.

	Survey years						Sample size
Total, age 12 and older	01-02	*	< LOD	< LOD	< LOD	< LOD	2307
Age group							
12-19 years	01-02	*	< LOD	< LOD	< LOD	< LOD	758
20 years and older	01-02	*	< LOD	< LOD	< LOD	< LOD	1549
Gender							
Males	01-02	*	< LOD	< LOD	< LOD	< LOD	1075
Females	01-02	*	< LOD	< LOD	< LOD	< LOD	1232
Race/ethnicity							
Mexican Americans	01-02	*	< LOD	< LOD	< LOD	< LOD	567
Non-Hispanic blacks	01-02	*	< LOD	< LOD	< LOD	< LOD	515
Non-Hispanic whites	01-02	*	< LOD	< LOD	< LOD	< LOD	1061

Table 159. 2,2',3,5,5',6-Hexachlorobiphenyl (PCB 151) (lipid adjusted)

	Survey years						Sample size
Total, age 12 and older	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	2307
Age group							
12-19 years	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	758
20 years and older	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1549
Gender							
Males	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1075
Females	01-02	*					

Table 160. 2,2',3,5,5',6-Hexachlorobiphenyl (PCB 151) (whole weight)

	Survey years						Sample size
Total, age 12 and older	01-02	*	< LOD	< LOD	< LOD	< LOD	2307
Age group							
12-19 years	01-02	*	< LOD	< LOD	< LOD	< LOD	758
20 years and older	01-02	*	< LOD	< LOD	< LOD	< LOD	1549
Gender							
Males	01-02	*	< LOD	< LOD	< LOD	< LOD	1075
Females	01-02	*	< LOD	< LOD	< LOD	< LOD	1232
Race/ethnicity							
Mexican Americans	01-02	*	< LOD	< LOD	< LOD	< LOD	567
Non-Hispanic blacks	01-02	*	< LOD	< LOD	< LOD		

Table 161. 2,2',4,4',5,5'-Hexachlorobiphenyl (PCB 153) **(lipid adjusted)**

	Survey years						Sample size
Total, age 12 and older	99-00	*	**< LOD**	**< LOD**	**77.8** (70.2-87.3)	**112** (91.8-130)	1926
	01-02	**27.2** (24.7-30.1)	**30.1** (26.1-34.1)	**57.7** (52.1-63.2)	**94.7** (86.5-104)	**126** (107-142)	2306
Age group							
12-19 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	668
	01-02	*	**< LOD**	**12.4** (11.1-14.1)	**21.2** (17.4-26.7)	**30.3** (23.1-64.7)	757
20 years and older	99-00	*	**< LOD**	**< LOD**	**83.2** (75.9-91.8)	**122** (98.7-139)	1258
	01-02	**32.6** (29.5-36.1)	**35.0** (31.1-39.0)	**62.8** (57.6-68.0)	**99.5** (90.7-110)	**132** (116-146)	1549
Gender							
Males	99-00	*	**< LOD**	**< LOD**	**75.0** (66.7-86.2)	**111** (87.7-128)	917
	01-02	**28.5** (25.5-32.0)	**31.5** (26.7-35.2)	**57.7** (48.2-65.5)	**97.5** (82.1-110)	**124** (104-146)	1074
Females	99-00	*	**< LOD**	**< LOD**	**79.0** (70.2-92.0)	**118** (91.4-142)	1009
	01-02	**26.1** (23.6-28.8)	**29.0** (25.1-33.4)	**57.8** (51.9-62.6)	**94.2** (87.8-98.2)	**126** (105-145)	1232
Race/ethnicity							
Mexican Americans	99-00	*	**< LOD**	**< LOD**	**< LOD**	**67.5** (59.5-71.8)	634
	01-02	**12.5**(25.1Tm(99-00))]<5 Tm(< L68s08.98 304.08n1e Tc 4 26Tm(99-00)T07 Tc 4.696 -0.96 68.8 Tm( )T0 6.9579 421.74 3					

Table 162. 2,2',4,4',5,5'-Hexachlorobiphenyl (PCB 153) (whole weight)

	Survey years						Sample size
Total, age 12 and older	99-00	*	< LOD	< LOD	**.530** (.493-.561)	**.749** (.613-.843)	1926
	01-02	**.167** (.151-.185)	**.186** (.166-.207)	**.378** (.337-.407)	**.621** (.563-.693)	**.851** (.754-.954)	2306
Age group							
12-19 years	99-00	*	< LOD	< LOD	< LOD	< LOD	668
	01-02	*	< LOD	**.064** (.054-.072)	**.104** (.084-.138)	**.147** (.111-.311)	757
20 years and older	99-00	*	< LOD	< LOD	**.561** (.505-.605)	**.786** (.670-.879)	1258
	01-02	**.206** (.187-.228)	**.218** (.197-.250)	**.407** (.379-.446)	**.667** (.595-.742)	**.898** (.815-1.04)	1549
Gender							
Males	99-00	*	< LOD	< LOD	**.531** (.474-.562)	**.691** (.576-.846)	917
	01-02	**.177** (.159-.198)	**.194** (.166-.214)	**.380** (.333-.429)	**.611** (.506-.726)	**.851** (.704-1.04)	1074
Females	99-00	*	< LOD	< LOD	**.530** (.480-.592)	**.759** (.612-.875)	1009
	01-02	**.158** (.142-.175)	**.176** (.150-.205)	**.375** (.335-.395)	**.626** (.565-.712)	**.860** (.756-.954)	1232
Race/ethnicity							
Mexican Americans	99-00	*	< LOD	< LOD	< LOD	**.468** (.384-.543)	634
	01-02	**.075** (.063-.089)	**.064** (.050-.078)	**.153** (.118-.207)	**.330** (.269-.415)	**.466** (.374-.541)	567

.064

Table 163. 2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB 170) (lipid adjusted)

	Survey years						Sample size
Total, age 12 and older	99-00	*	**< LOD**	**< LOD**	**23.6** (22.0-25.4)	**30.9** (28.1-35.1)	1798
	01-02	*	**< LOD**	**17.5** (15.6-19.3)	**26.7** (24.9-29.0)	**35.0** (32.4-37.3)	2301
Age group							
12-19 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	645
	01-02	* *	**< LOD**	**< LOD**	**< LOD**	**< LOD**	756
20 years and older	99-00	*	**< LOD**	**< LOD**	**24.9** (23.3-26.4)	**33.9** (29.6-37.5)	1153
	01-02	*	**11.1** (< LOD-12.0)	**19.1** (17.2-20.9)	**28.2** (26.2-30.9)	**36.8** (33.4-39.4)	1545
Gender							
Males	99-00	*					

Table 164. 2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB 170) (whole weight)

Geometric mean and selected percentiles of serum concentrations (in ng/g of serum or parts per billion) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2002.

	Survey years	Geometric	Selected percentile.95perc6(utritioD012(ea/l3d919 421.D01 6.4lc6(M				Sample size
Total, age 12 and older	99-00	*	**< LOD**	**< LOD**	**.158** (.141-.183)	**.212** (.199-.225)	1798
	01-02	*	**< LOD**	**.114** (.104-.122)	**.183** (.167-.202)	**.246** (.214-.271)	2301
Age group							
12-19 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	645
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	756
20 years and older	99-00	*	**< LOD**	**< LOD**	**.172** (.154-.192)	**.221** (.204-.252)	1153
	01-02	*	**.070** (.065-.077)	**.122** (.114-.133)	**.197** (.177-.213)	**.254** (.227-.286)	1545
Gender							
Males	99-00	*	**< LOD**	**< LOD**	**.169** (.140-.200)	**.215** (.199-.254)	863
	01-02	*	**.067** (.057-.074)	**.119** (.107-.134)	**.194** (.166-.207)	**.245** (.206-.281)	1073
Females	99-00	*	**< LOD**	**< LOD**	**.149** (.130-.167)	**.205** (.186-.229)	935
	01-02	*	**< LOD**	**.110** (.100-.117)	**.175** (.157-.196)	**.245** (.211-.281)	1228
Race/ethnicity							
Mexican Americans	99-00	*	**< LOD**	**< LOD**	**< LOD**	**.166** (.126-.187)	606
	01-02	*	**< LOD**	**< LOD**	**.104** (.082-.125)	**.154** (.116-.188)	565
Non-Hispanic blacks	99-00	*	**< LOD**	**< LOD**	**.188** (.147-.205)	**.258** (.194-.372)	382
	01-02	*	**< LOD**	**.112** (.094-.141)	**.211** (.151-.271)	**.276** (.209-.394)	514
Non-Hispanic whites	99-00	*	**< LOD**	**< LOD**	**.164** (.139-.197)	**.214** (.197-.242)	658
	01-02	*	**.067** (.058-.074)	**.119** (.112-.129)	**.187** (.171-.204)	**.247** (.207-.274)	1059

Table 165. 2,2',3,3',4,5,5'-Heptachlorobiphenyl (PCB 172) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (in 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, 1999-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 12 and older	99-00	*	< LOD	< LOD	< LOD	< LOD	1901
	01-02	*	< LOD	< LOD	< LOD	< LOD	2199
Age group							
12-19 years	99-00	*	< LOD	< LOD	< LOD	< LOD	660
	01-02	*	< LOD	< LOD	< LOD	< LOD	679
20 years and older	99-00	*	< LOD	< LOD	< LOD	< LOD	1241
	01-02	*	< LOD	< LOD	< LOD	< LOD	1520
Gender							
Males	99-00	*	< LOD	< LOD	< LOD	< LOD	911
	01-02	*	< LOD	< LOD	< LOD	< LOD	1027
Females	99-00	*	< LOD	< LOD	< LOD	< LOD	990
	01-02	*	< LOD	< LOD	< LOD	< LOD	1172
Race/ethnicity							
Mexican Americans	99-00	*	< LOD	< LOD	< LOD	< LOD	630
	01-02	*	< LOD	< LOD	< LOD	< LOD	519
Non-Hispanic blacks	99-00	*	< LOD	< LOD	< LOD	< LOD	409
	01-02	*	< LOD	< LOD	< LOD	< LOD	494
Non-Hispanic whites	99-00	*	< LOD	< LOD	< LOD	< LOD	706
	01-02	*	< LOD	< LOD	< LOD	< LOD	1027

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.
* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 166. 2,2',3,3',4,5,5'-Heptachlorobiphenyl (PCB 172) (whole weight)

Geometric mean and selected percentiles of serum concentrations (in ng/g of serum or parts per billion) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)				Sample size
			50th	75th	90th	95th	
Total, age 12 and older	99-00	*	< LOD	< LOD	< LOD	< LOD	1901
	01-02	*	< LOD	< LOD	< LOD	< LOD	2199
Age group							
12-19 years	99-00	*	< LOD	< LOD	< LOD	< LOD	660
	01-02	*	< LOD	< LOD	< LOD	< LOD	679
20 years and older	99-00	*	< LOD	< LOD	< LOD	< LOD	1241
	01-02	*	< LOD	< LOD	< LOD	< LOD	1520
Gender							
Males	99-00	*	< LOD	< LOD	< LOD	< LOD	911
	01-02	*	< LOD	< LOD	< LOD	< LOD	1027
Females	99-00	*	< LOD	< LOD	< LOD	< LOD	990
	01-02	*	< LOD	< LOD	< LOD	< LOD	1172
Race/ethnicity							
Mexican Americans	99-00	*	< LOD	< LOD	< LOD	< LOD	630
	01-02	*	< LOD	< LOD	< LOD	< LOD	519
Non-Hispanic blacks	99-00	*	< LOD	< LOD	< LOD	< LOD	409
	01-02	*	< LOD	< LOD	< LOD	< LOD	494
Non-Hispanic whites	99-00	*	< LOD	< LOD	< LOD	< LOD	706
	01-02	*	< LOD	< LOD	< LOD	< LOD	1027

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.

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

Table 167. 2,2',3,3',4,5',6'-Heptachlorobiphenyl (PCB 177) (lipid adjusted)

	Survey years			Sample size

Table 172 2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB 180) (whole weight)

	Survey years						Sample size
Total, age 12 and older	99-00	*	**< LOD**	**.245** (.224-.266)	**.414** (.373-.452)	**.535** (.493-.604)	1924
	01-02	**.118** (.106-.130)	**.140** (.120-.155)	**.278** (.253-.304)	**.458** (.401-.508)	**.605** (.541-.692)	2302
Age group							
12-19 years	930-304)em(nder( )T(99-6.248 -0.0.2 491.34 Tm(1924)65 52039 124/TT1 1 Tf0 Tc 6.2485.26.9039 Tc 0 Tw 0 6.9579 421.74 463.	*					

Table 173. 2,2',3,4,4',5',6-Heptachlorobiphenyl (PCB 183) (lipid adjusted)

	Survey years						Sample size
Total, age 12 and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1928
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	2306
Age group							

Table 174. 2,2',3,4,4',5',6-Heptachlorobiphenyl (PCB 183) (whole weight)

	Survey years					Sample size
Total, age 12 and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	

Table 176. 2,2',3,4',5,5',6-Heptachlorobiphenyl (PCB 187) (whole weight)

Geometric mean and selected percentiles of serum concentrations (in ng/g of serum or parts per billion) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 12 and older	99-00	*	< LOD	< LOD	.120 (.108-.134)	.166 (.143-.181)	1930
	01-02	*	< LOD	.080 (.072-.090)	.140 (.128-.159)	.198 (.177-.218)	2307
Age group							
12-19 years	99-00	*	< LOD	< LOD	< LOD	< LOD	667
	01-02	*	< LOD	< LOD	< LOD	< LOD	758
20 years and older	99-00	*	< LOD	< LOD	.128 (.112-.141)	.176 (.155-.191)	1263
	01-02	*	< LOD	.090 (.077-.100)	.149 (.132-.174)	.210 (.186-.231)	1549
Gender							
Males	99-00	*	< LOD	< LOD	.123 (.099-.139)	.178 (.141-.198)	917
	01-02	*	< LOD	.082 (.072-.098)	.144 (.130-.163)	.187 (.165-.230)	1075
Females	99-00	*	< LOD	< LOD	.116 (.106-.130)	.162 (.136-.179)	1013
	01-02	*	< LOD	.076 (.067-.086)	.134 (.119-.150)	.202 (.178-.217)	1232
Race/ethnicity							
Mexican Americans	99-00	*	< LOD	< LOD	< LOD	.118 (.100-.134)	636
	01-02	*	< LOD	< LOD	.078 (.058-.098)	.104 (.091-.121)	567
Non-Hispanic blacks	99-00	*	< LOD	.090 (.070-.132)	.203 (.164-.226)	.290 (.207-.531)	412
	01-02	*	< LOD	.102 (.074-.119)	.192 (.149-.258)	.286 (.187-.382)	515
Non-Hispanic whites	99-00	*	< LOD	< LOD	.112 (.099-.127)	.147 (.134-.168)	727
	01-02	*	< LOD	.081 (.072-.092)	.136 (.123-.157)	.191 (.167-.217)	1061

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.

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

Table 178. 2,2',3,3',4,4',5,5'-Octachlorobiphenyl (PCB 194) (whole weight)

	Survey years			Sample size
Total, age 12 and older	01-02	*	**< LOD**	

Table 181. 2,2',3,3',4,4',5,6' and 2,2',3,4,4',5,5',6-Octachlorobiphenyl (PCB 196 & 203) (lipid adjusted)

	Survey years						Sample size
Total, age 12 and older	01-02	*	**< LOD**	**< LOD**	**14.1** (13.0-15.7)	**19.2** (17.4-20.9)	2299
Age group							
12-19 years	01-02	*					

Table 183. 2,2',3,3',4,5,5',6'-Octachlorobiphenyl (PCB 199) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (in 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, 2001-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 12 and older	01-02	*	< LOD	< LOD	**17.0** (15.4-18.1)	**22.4** (19.9-25.9)	2292
Age group							
12-19 years	01-02	*	< LOD	< LOD	< LOD	< LOD	756
20 years and older	01-02	*	< LOD	**10.5** (<LOD-11.8)	**17.8** (16.2-19.2)	**24.4** (20.7-27.4)	1536
Gender							
Males	01-02	*	< LOD	< LOD	**17.3** (15.4-18.7)	**21.2** (19.2-24.5)	1066
Females	01-02	*	< LOD	< LOD	**16.1** (14.5-17.9)	**22.7** (19.4-27.3)	1226
Race/ethnicity							
Mexican Americans	01-02	*	< LOD	< LOD	< LOD	**12.1** (<LOD-14.2)	565
Non-Hispanic blacks	01-02	*	< LOD	**12.4** (<LOD-15.2)	**21.9** (17.0-28.1)	**30.7** (22.4-37.4)	513
Non-Hispanic whites	01-02	*	< LOD	< LOD	**17.2** (15.9-18.9)	**22.6** (19.8-26.3)	1051

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.
* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 184. 2,2',3,3',4,5,5',6'-Octachlorobiphenyl (PCB 199) (whole weight)

Geometric mean and selected percentiles of serum concentrations (in ng/g of serum or parts per billion) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 2001-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 12 and older	01-02	*	**< LOD**	**< LOD**	**.108** (.100-.126)	**.151** (.135-.168)	2292
Age group							
12-19 years	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	756
20 years and older	01-02	*	**< LOD**	**.069** (.060-.079)	**.122** (.105-.136)	**.158** (.139-.184)	1536
Gender							
Males	01-02	*	**< LOD**	**< LOD**	**.108** (.098-.133)	**.150** (.133-.179)	1066
Females	01-02	*	**< LOD**	**< LOD**	**.111** (.098-.125)	**.151** (.132-.167)	1226
Race/ethnicity							
Mexican Americans	01-02	*	**< LOD**	**< LOD**	**< LOD**	**.087** (.066-.107)	565
Non-Hispanic blacks	01-02	*	**< LOD**	**.069** (.054-.087)	**.135** (.104-.179)	**.182** (.133-.301)	513
Non-Hispanic whites	01-02	*	**< LOD**	**< LOD**	**.114** (.102-.130)	**.150** (.132-.170)	1051

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.

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

Table 185. 2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl (PCB 206) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (in 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, 2001-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 12 and older	01-02	*	< LOD	< LOD	< LOD	< LOD	2208
Age group							
12-19 years	01-02	*	< LOD	< LOD	< LOD	< LOD	723
20 years and older	01-02	*	< LOD	< LOD	< LOD	< LOD	1485
Gender							
Males	01-02	*	< LOD	< LOD	< LOD	< LOD	1033
Females	01-02	*	< LOD	< LOD	< LOD	< LOD	1175
Race/ethnicity							
Mexican Americans	01-02	*	< LOD	< LOD	< LOD	< LOD	533
Non-Hispanic blacks	01-02	*	< LOD	< LOD	< LOD	< LOD	483
Non-Hispanic whites	01-02	*	< LOD	< LOD	< LOD	< LOD	1034

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.

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

Table 186. 2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl (PCB 206) (whole weight)

	Survey years						Sample size
Total, age 12 and older	01-02	*	< LOD	< LOD	< LOD	< LOD	2208
Age group							
12-19 years	01-02	*	< LOD	< LOD	< LOD	< LOD	723
20 years and older	01-02	*	< LOD	< LOD	< LOD	< LOD	1485
Gender							
Males	01-02	*	< LOD	< LOD	< LOD	< LOD	1033
Females	01-02	*	< LOD	< LOD	< LOD	< LOD	1175
Race/ethnicity							

Phthalates

Phthalates

General Information

Phthalates are industrial chemicals that can act as plasticizers, which, when added to plastic, impart flexibility and resilience. Many consumer products contain phthalates. Among these products are vinyl flooring; adhesives; detergents; lubricating oils; solvents; automotive plastics; plastic clothing, such as raincoats; and personal-care products, such as soap, shampoo, deodorants, fragrances, hair spray, nail polish; and some medical pharmaceuticals. Phthalates are widely used in flexible polyvinyl chloride plastics, such as plastic bags, garden hoses, inflatable recreational toys, blood-storage bags, intravenous medical tubing, and children's toys. Soil and water contamination can be greatest in areas of industrial use and waste disposal.

People are exposed through direct contact with products that contain phthalates. For the general population, the oral route of exposure has been considered a major route. However, both population studies (Adibi et al., 2003) and occupational studies (Dirven et al., 1993; Liss et al., 1985; Nielsen et al., 1985) have shown that personal air-sample levels of phthalate diesters correlate modestly well with concentrations of urinary metabolites, suggesting that inhalation is an important route of exposure (Otake et al., 2004). In contrast, urinary levels in children did not correlate with home- dust measurements of phthalate content (Becker et al., 2004). Generally, phthalates are metabolized and excreted quickly and do not accumulate in the body (Anderson et al., 2001). Ingested phthalate diesters are initially hydrolyzed in the intestine to their corresponding monoester, which is then absorbed. (Albro et al., 1982; Albro and Lavenhar, 1989). Absorbed monoester metabolites may be further oxidized in the body. Table 188 shows the monoester metabolites and other oxidized metabolites of phthalates measured in this *Report* and also includes their commonly used abbreviations.

Several of the phthalates produce testicular injury, liver injury, liver cancer, and teratogenicity in rodent studies, but these effects either have not been demonstrated when tested in non-human primates or people or have not been investigated. The monoester metabolites are thought to mediate toxic effects for some of the phthalates. Phthalates have weak or no estrogenic, antiestrogenic, or androgenic activity *in vitro*, although not all metabolites have been tested (Jobling et al., 1995; Coldham et al., 1997; Harris et al., 1997; Parks et al., 2000; Okubo et al., 2003) and have shown no estrogenic activity *in vivo* (Zacharewski et al., 1998; Milligan et al., 1998). However, in animal studies, several phthalates show antiandrogenic activity and exposure to high doses of di-2-ethylhexyl phthalate (DEHP), dibutyl phthalate (DBP), and benzylbutyl phthalate (BzBP) during the fetal period have produced lowered testosterone levels, testicular atrophy, and Sertoli cell abnormalities in male animals and, at higher doses, ovarian abnormalities in female animals (see reviews by the Center for the Evaluation of Risks to Human Reproduction, 2000; McKee et al., 2004; and Jarfelt et al., 2005). Such effects may also be mediated through an inhibition of testicular, adrenal, or ovarian steroidogenesis. Phthalate levels in men from an infertility clinic have been associated with several parameters of sperm analysis (Duty et al., 2003; Duty et al., 2004; Duty et al., 2005).

Differences between human and rodent studies in the timing of dosages relative to critical developmental periods and in the amounts of putative metabolites generated in animals versus humans, as well as the large

Table 187. Phthalates and their metabolites

Phthalate name (CAS number)	**Abbreviation**	**Urinary metabolite** (CAS number)	**Abbreviation**
Dimethyl phthalate (131-11-3)	DMP	Mono-methyl phthalate (4376-18-5)	MMP
Diethyl phthalate (84-66-2)	DEP	Mono-ethyl phthalate (2306-33-4)	MEP
Dibutyl phthalates (84-74-2)	DBP	Mono-n-butyl phthalate (131-70-4)	MnBP
		Mono-isobutyl phthalate	MiBP
Benzylbutyl phthalate (85-68-7)	BzBP	Mono-benzyl phthalate (2528-16-7) (some mono-n-butyl phthalate)	MBzP
Dicyclohexyl phthalate (84-61-7)	DCHP	Mono-cyclohexyl phthalate (7517-36-4)	MCHP
Di-2-ethylhexyl phthalate (117-81-7)	DEHP	Mono-2-ethylhexyl phthalate (4376-20-9)	MEHP
		Mono-(2-ethyl-5-oxohexyl) phthalate	MEOHP
		Mono-(2-ethyl-5-hydroxyhexyl) phthalate	MEHHP
Di-n-octyl phthalate (117-84-0)	DOP	Mono-n-octyl phthalate (5393-19-1)	MOP
		Mono-(3-carboxypropyl) phthalate	MCPP
Di-isononyl phthalate (28553-12-0)	Di		

Table 189. Mono-methyl phthalate (creatinine corrected)

	Survey years						Sample size
Total, age 6 and older	01-02	**1.08** (.935-1.24)	**1.33** (1.13-1.54)	**2.62** (2.36-2.95)	**5.00** (3.96-6.00)	**7.97** (6.07-10.9)	2772
Age group							
6-11 years	01-02	**1.65** (1.28-2.13)	**2.32** (1.72-2.86)	**3.93** (3.27-4.71)	**6.77** (5.75-9.41)	**12.5** (7.60-22.5)	392
12-19 years	01-02	**1.23** (1.01-1.48)	**1.51** (1.32-1.81)	**2.84** (2.52-3.33)	**5.36** (3.68-6.39)	**7.27** (5.64-11.4)	742
20 years and older	01-02	**1.00** (.866-1.16)	**1.21** (1.04-1.40)	**2.44**			

388.74TT0 1 Tf6.9579 0 0 6.9579 208.98 406.02 Tm388.56742

Mono-ethyl Phthalate

CAS No. 2306-33-4

Metabolite of Diethyl Phthalate, CAS No. 84-66-2

General Information

Diethyl phthalate (DEP) is an industrial solvent used in many consumer products, particularly those containing fragrances. Products that may contain DEP include perfume, cologne, deodorant, soap, shampoo, and hand lotion. People exposed to DEP will excrete monoethyl phthalate (MEP) in their urine. Workplace air standards for external exposure to DEP have been established by ACGIH or recommended by NIOSH. It has not been completely classified with respect to its carcinogenicity by IARC and NTP.

Interpreting Levels of Urinary Mono-ethyl Phthalate in the Tables

MEP levels in the NHANES 2001-2002 subsample appear similar to levels in a small sample of pregnant women in New York City (Adibi et al., 2003). MEP levels found in a small sample of German residents (Koch et al., 2003) are slightly lower than levels documented in this *Report*.

Table 190. Mono-ethyl phthalate

Comparing Adjusted Geometric Means

Geometric mean levels of urinary MEP for the demographic groups were compared after adjusting for the covariates of race/ethnicity, age, gender, and urinary creatinine (data not shown). In NHANES 2001-2002, the adjusted geometric mean levels of urinary MEP were lower in the group aged 6-11 years than either of the other age groups and the group aged 12-19 was had lower levels than the group 20 years and older. This age-related trend is opposite the direction shown for other phthalates. Non-Hispanic whites had lower levels than non-Hispanic blacks or Mexican Americans. Levels in non-Hispanic blacks were not significantly higher than in Mexican Americans. It is unknown whether these differences associated with age or race/ethnicity represent differences in exposure, pharmacokinetics, or the relationship of dose per body weight.

Table 191. Mono-ethyl phthalate (creatinine corrected)

Survey

Mono-n-butyl Phthalate

CAS No. 131-70-4

Metabolite of Di-n-butyl Phthalate, CAS No. 84-74-2 and Benzylbutyl Phthalate, CAS No. 85-68-7

Mono-isobutyl Phthalate

Metabolite of Di-isobutyl Phthalates, CAS No. 84-74-2

General Information

Dibutyl phthalates (di-n-butyl, di-isobutyl) 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. Small amounts of mono-3-carboxypropyl phthalate are also produced from di-n-butyl phthalate. In addition, exposure to benzylbutyl phthalate (BzBP) will also result in small amounts of mono-n-butyl phthalate appearing in the urine (Anderson et al., 2001).

Workplace air standards for external exposure to dibutyl phthalate have been established by NIOSH and ACGIH. Dibutyl phthalates can produce reproductive toxicity in animals (Center for the Evaluation of Risks to Human Reproduction, 2003). Dibutyl phthalates have not been completely classified with respect to carcinogenicity by IARC or NTP.

Interpreting Levels of Urinary Mono-n-butyl and Mono-isobutyl Phthalates in the Tables

Mono-butyl phthalate (MBP) levels in the NHANES 1999-2000 subsample represented the sum of both

Table 192. Mono-n-butyl phthalate

mono-isobutyl phthalate (MiBP) and mono-n-butyl phthalate (MnBP), whereas in NHANES 2001-2002 it was possible to measure the concentrations of these two phthalates separately. Levels in the 1999-2000 and 2001-2002 subsamples appear roughly similar when the sum of the MiBP and MnBP levels in 2001-2002 are compared with the 1999-2000 MBP levels. Concentrations reported in these two subsamples are generally similar to those reported in U.S. residents (Blount et al., 2000) and in men from an infertility clinic (Duty et al., 2004). Levels reported for 1999-

Table 194. Mono-isobutyl phthalate

	Survey years			Sample size
Total, age 6 and older	years		S	a

Table 195. Mono-isobutyl phthalate (creatinine corrected)

	Survey years						Sample size
Total, age 6 and older	01-02	**2.53** (2.35-2.72)	**2.44** (2.26-2.67)	**4.50** (4.12-4.83)	**8.02** (7.60-8.66)	**12.0** (10.8-13.5)	2772
Age group							

Mono-benzyl Phthalate

CAS No. 2528-16-7

Metabolite of benzylbutyl phthalate, CAS No. 85-68-7

General Information

Benzylbutyl phthalate (BzBP) 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 BzBP will excrete MBzP and small amounts of mono-n-butyl phthalate in their urine. Workplace air standards for external exposures have not been established for BzBP. Like other phthalates, BzBP has low acute toxicity. It can produce reproductive toxicity in animals (Center for the Evaluation of Risks to Human Reproduction, 2000). BzBP is classified as a possible human carcinogen by U.S. EPA, but is considered not classifiable by IARC and unlisted by NTP.

Interpreting Levels of Urinary Mono-benzyl Phthalate in the Tables

The levels of MBzP in the NHANES 2001-2002 subsample appear generally similar to levels reported previously for U.S. residents (Blount et al., 2000), in a small sample of pregnant women in New York City (Adibi et al., 2003), in men from an infertility clinic (Duty et al., 2004), and in a small sample of German residents (Koch et al., 2003).

Comparing Adjusted Geometric Means

Geometric mean levels of urinary mono-benzyl phthalate for the demographic groups were compared after adjusting for the covariates of race/ethnicity, age, gender, and urinary creatinine (data not shown). In NHANES 2001-2002, adjusted geometric mean levels of urinary mono-benzyl phthalate were higher in children aged 6-11 years than in people aged 12-19 years and 20 years and older, and the group aged 12-19 years had higher levels than the group aged 20 years and older. Levels in females were higher than in males. Mexican Amercians had lower levels than non-Hispanic whites, but were not significantly different from non-Hispanic blacks. It is unknown whether these differences associated with age, gender, or race/ethnicity represent differences in exposure, pharmacokinetics, or the relationship of dose per body weight.

Table 197. Mono-benzyl phthalate (creatinine corrected)

	Survey years			Sample size
Total, age 6 and older				

Mono-cyclohexyl Phthalate

CAS No. 7517-36-4

Metabolite of Dicyclohexyl Phthalate, CAS No. 84-61-7

General Information

Dicyclohexyl phthalate (DCHP) is Used to stabilize some rubbers, resins, and polymers, including nitrocellulose, polyvinyl acetate, and polyvinyl chloride. People exposed to DCHP will excrete mono-cyclohexyl phthalate in their urine. Workplace air standards for external exposure have not been established for DCHP. It has not been completely classified as to its carcinogenicity by IARC and NTP.

In both the NHANES 1999-2000 and 2001-2002 subsamples, mono-cyclohexyl phthalate was characterized only at the 90^{th} and 95^{th} percentiles.

Mono-2-ethylhexyl Phthalate
CAS No. 4376-20-9

Mono-(2-ethyl-5-hydroxyhexyl) Phthalate

Mono-(2-ethyl-5-oxohexyl) Phthalate
CAS No. 40321-98-0

Metabolites of Di-2-ethylhexyl Phthalate, CAS No. 117-81-7

General Information

Di-2-ethylhexyl phthalate (DEHP) is primarily used to produce flexible plastics, mainly polyvinyl chloride, which is used for many home and garden products, toys, packaging film, and blood-product storage and intravenous delivery systems. Concentrations in plastic materials may reach 40% by weight. DEHP has been removed from or replaced in most children’s toys and food packaging in the United States. Other sources of exposure include foods and foods in contact with plastic containging DEHP.

the gastrointestinal tract and then absorbed. MEOHP and MEHHP are produced by the oxidative metabolism of MEHP and are present at roughly three- to ten-fold higher concentrations than MEHP in urine (Barr et al., 2003; Koch et al., 2003).

MEHP is considered a toxic metabolite of DEHP. Liver toxicity, decreased testicular weight, and testicular atrophy have been observed in animal studies at high or chronic doses (Center for the Evaluation of Risks to

atrophtoxicity, imal sTc s86 up5(ous 0.radiol-5(005 (tto005 nstudfe186 0 Tdley thre0 Tdtsc 0.0008 T

Figure 22. Mono-2n9.,hylhexyl phtal

Table 208. Mono-n-octyl phthalate

	Survey years						Sample size
Total, age 6 and older	99-00	*	< LOD	< LOD	**1.60** (1.20-2.00)	**2.90** (2.20-3.30)	2541
	01-02	*	< LOD	< LOD	< LOD	< LOD	2782
Age group							
6-11 years	99-00	*	< LOD	< LOD	**2.00** (.900-3.50)	**3.20** (1.70-4.30)	328
	01-02	*	< LOD	< LOD	< LOD	< LOD	393
12-19 years	99-00	*	< LOD	< LOD	**1.60** (.900-2.50)	**2.80** (2.00-4.20)	752
	01-02	*	< LOD	< LOD	< LOD	< LOD	742
20 years and older	99-00	*	< LOD	< LOD	**1.50** (1.10-1.90)	**2.90** (2.00-3.50)	1461
	01-02	*	< LOD	< LOD	< LOD	< LOD	1647
Gender							
Males	99-00	*	< LOD	< LOD	**1.60** (1.10-2.10)	**2.5e3 8Males0..Males099-00Males0.<**	

Mono-isononyl Phthalate

Phytoestrogens

Phytoestrogens

General Information

Phytoestrogens are naturally occurring chemical constituents of certain plants that may interact with estrogen receptors to produce estrogenic effects. Two major groups of phytoestrogens found in people's diets are isoflavones and lignans.

The major isoflavones include daidzein, genistein, O-desmethylangolensin, glycitein, and equol. Plant sources of isoflavones include legumes, with the largest contribution coming from soybeans and soy-based products. Soy flour and soy protein isolates are often added to processed meats, meat substitutes, breads, and protein food bars and can be a major source of isoflavones (Grace et al., 2004, Lampe et al., 1999). Formononectin and biochanin A are methylated isoflavones found in clovers and are metabolized in the body to daidzein and genistein. Daidzein is further metabolized to O-desmethylangolensin in the body and to equol by intestinal bacteria. The richest source of total isoflavones is mature red clover leaf (containing mainly biochanin A and formononetin, with lesser amounts of genistein, daidzein, and other related molecules), followed by kudzu root, and soy (richest source of the isoflavone genistein). Naringenin (precursor to genistein) and hesperetin are flavonoids found in higher amounts in citrus fruits.

Lignans include matairesinol, secoisolariciresinol, enterolactone, and enterodiol. The dietary lignans matairesinol and secoisolariciresinol are transformed by gut flora into enterolactone and enterodiol, respectively. Enterodiol may also interconvert with enterolactone. Lignans are found in flax seeds (richest source of secoisolariciresinol and matairesinol), and cereal grains. Other phytoestrogens are found in other plants. For example, the phytoestrogens resveratrol and *trans*-resveratrol are both found in grape skins and wine.

Diet is the major source of human exposure to phytoestrogens. The absorption and metabolism of phytoestrogens demonstrate large interindividual variability, which may relate to differences in both in human pharmacokinetics and metabolism by gut flora. Phytoestrogens are ingested in their natural beta-glycosidic forms, with the bioavailability of the glycosides exceeding the bioavailability of free aglycones. The beta-glycosidic forms are hydrolyzed to their aglycones in the intestine, absorbed, and then glucuronidated in the intestinal wall. The glucuronidated metabolites of isoflavones predominate in blood and urine (Setchell et al., 2001, Adlercreutz et al., 1995*b*).

Table 212. 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

Phytoestrogens persist in plasma for about 24 hours. The isoflavones are excreted in both urine and feces. (Setchell et al., 2001). Results of studies with flax seed show that plasma and urine concentrations increased in a dose-dependent manner (Nesbitt et al., 1999). Equol excretion may depend on diet and the type of intestinal flora present (Hutchins et al., 1995*a*,*b*; Karr et al., 1997; Setchell et al., 2001; Setchell and Cassidy, 1999).

Phytoestrogens preferentially bind to estrogen-beta receptors (ER-beta). Genistein binding to ER-beta produces a conformational change similar to that produced by the drug reloxifene (a selective estrogen receptor modulator prescribed for osteoporosis) but dissimilar to the binding of estradiol. Phytoestrogens decrease (by down-regulation) the number of ER-alpha receptors on breast and uterine tissue (Nikov et al., 2001). Generally, phytoestrogens are much less potent than the endogenously produced estrogens, but phytoestrogens can be present in much greater quantities (100 to 1000 times the concentration of endogenous estrogens). Additionally, phytoestrogens bind less tightly to steroid-hormone serum-transport proteins than do endogenous estrogens (Nagel et al., 1998). Soy-based infant formula can result in plasma concentrations of isoflavones in infants that are13,000-22,000 times higher than endogenous estrogen concentrations in infants (Setchell et al., 1997). Equol has more potent estrogen activity than its precursor, daidzein, and has been proposed to be most important in explaining the mechanism of action of isoflavones in disease prevention (Setchell et al., 2002).

Some actions of phytoestrogens are thought to occur through pathways other than interaction with estrogen receptors. These actions include inhibiting the transformation of estrone to estradiol and inhibiting enzymes important for steroid biosynthesis, as well as having antioxidant and anti-angiogenesis activity. (Adlercreutz et al., 1995*a*; Dixon and Ferreira, 2002).

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levels observed in Japanese men and women (Adlercreutz et al.,1991; Uehara et al., 2000*a*); Japane women (Arai et al., 2000); postmenopausal Ch women (Zheng et al., 1999); Singaporean women (Seow et al., 1998, Chen et al., 1999); and Japanese women living in Hawaii (Maskarinec et al., 1998). Genistein and daidzein levels in this *Report* were two-fold higher tha levels reported in people consuming a carotenoid diet but lower than levels found in people consuming a cruciferous diet, and O-desmethylangolensin levels wer seven times lower (Kirkman et al., 1995). Levels of genistein, daidzein, and O-desmethylangolensin for

Table 213. Daidzein

	Survey years			Sample

Table 214. Daidzein (creatinine corrected)

Figure 24. Enterodiol (creatinine corrected)

Selected percentiles with 95% confidence intervals of urine conc

Table 217. Enterolactone

	Survey years						Sample size
Total, age 6 and older	99-00	**239** (200-286)	**315** (245-381)	**726** (595-879)	**1970** (1440-2370)	**2790** (2480-3070)	2548
	01-02	**259** (233-287)	**348** (314-389)	**807** (739-873)	**1590** (1420-1820)	**2720** (1870-3430)	2794
Age group							
6-11 years	99-00	**308** (219-432)	**353** (243-474)	**721** (520-1320)	**1730** (973-2840)	**2840** (1700-3590)	331
	01-02	**288** (245-339)	**329** (271-412)	**680** (566-775)	**1380** (929-1620)	**2160** (1420-2550)	396
12-19 years	99-00	**250** (191-327)	**317** (242-410)	**670** (454-888)	**1760** (973-2480)	**2900** (1950-4330)	746
	01-02	**267** (231-308)	**321** (255-399)	**729** (617-856)	**1480** (1230-1800)	**2180** (1560-3310)	744
20 years and older	99-00	**230** (193-274)	**310** (242-375)	**728** (599-888)	**1980** (1490-2390)	**2790** (2510-3540)	1471
	01-02	**254** (223-289)	**355** (310-394)	**835** (760-914)	**1660** (1460-1890)	**2840** (1890-3610)	1654
Gender							
Males	99-00	**254** (212-304)	**351** (265-417)	**778** (579-1050)	**1980** (1580-2400)	**2730** (2430-3350)	1219
	01-02	**262** (233-295)	**340** (314-387)	**873** (769-957)	**1800** (1490-2470)	**3050** (1990-4070)	1375
Females	99-00	**226** (180-284)	**287** (236-339)	**684** (554-795)	**1880** (1200-2460)	**2830** (2100-4330)	1329
	01-02	**255** (226-288)	**355** (293-397)	**759** (680-840)	**1440** (1190-1700)	**2200** (1710-2950)	1419
Race/ethnicity							

Figure 25. Enterolactone (creatinine corrected)

Selected percentiles with 95% confidence intervals of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2002.

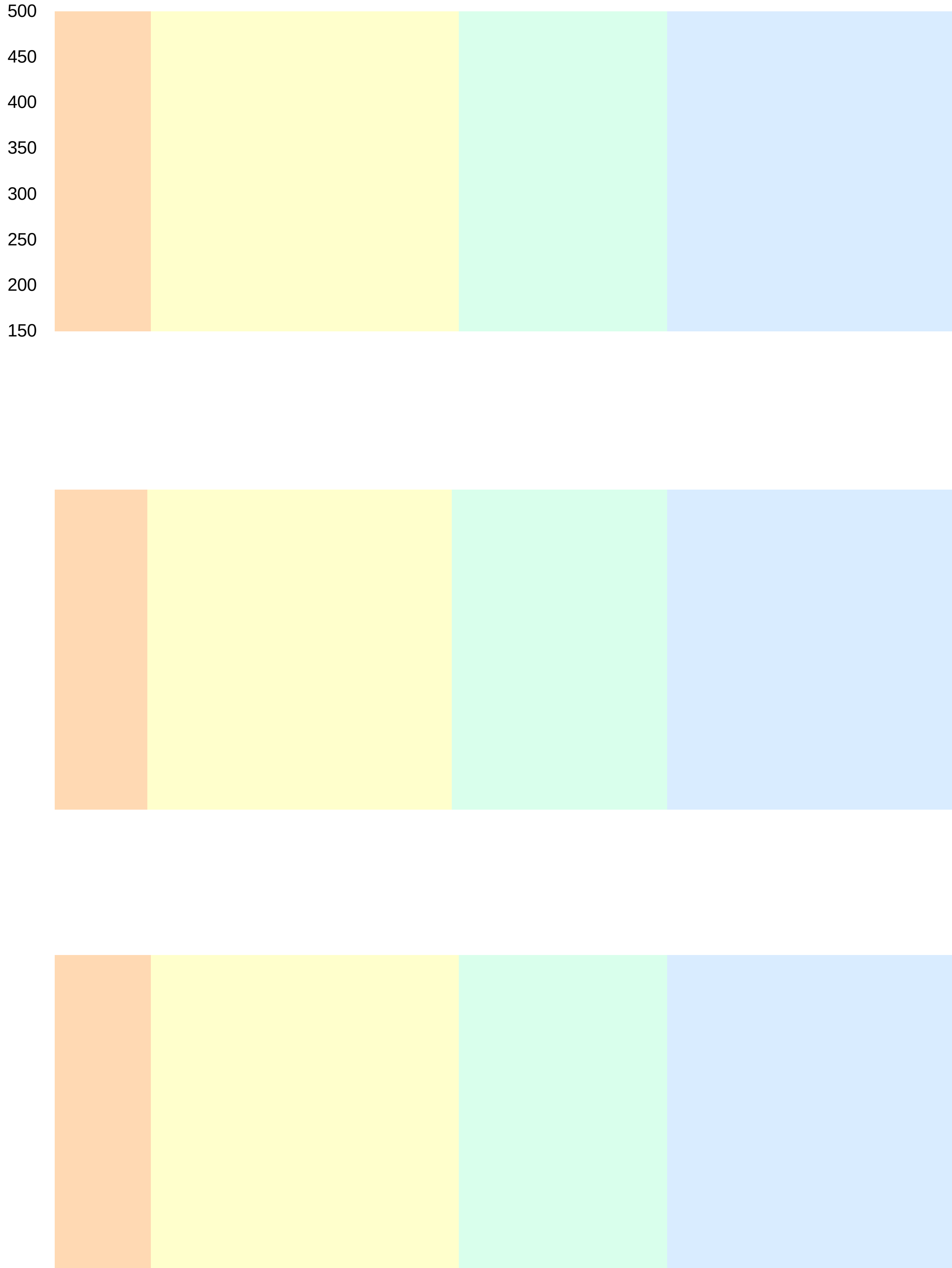


Table 219. Equol

	Survey years			Sample size

Table 220. Equol (creatinine corrected)

	Survey years				Sample size
Total, age 6 and older	99-00	**7.70** (6.82-8.70)	**7.96** (6.87-9.35)	**16.2** (13.2-18.6)	

Figure 26. Equol (creatinine corrected)

Selected percentiles with 95% confidence intervals of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2002.

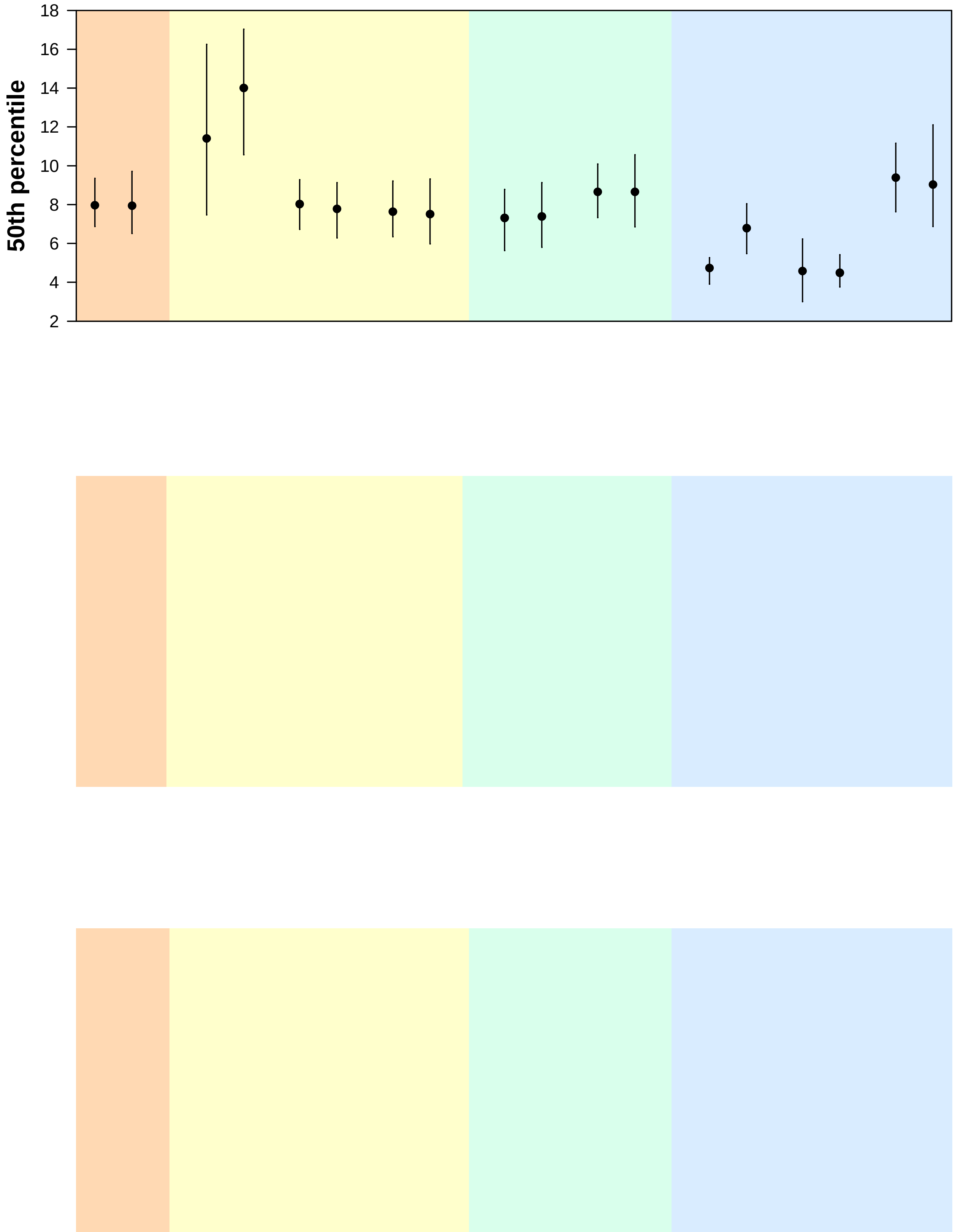


Table 221. Genistein

	Survey years					Sample size
Total, age 6 and older	99-00	**24.4** (19.7-30.3)	**27.0** (22.5-32.8)	**93.6** (75.8-118)	**284**	

Table 222. Genistein (creatinine corrected)

Geometric mean and selected percentiles of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 6 and older	99-00	**22.3** (17.7-28.1)	**23.8** (18.8-28.9)	**84.7** (67.2-105)	**222** (182-279)	**380** (334-497)	2557
	01-02	**30.9** (28.5-33.6)	**25.9** (23.7-29.1)	**83.1** (72.2-96.4)	**257** (211-296)	**427** (374-490)	2784
Age group							
6-11 years	99-00	**28.3** (21.1-37.9)	**27.8** (15.8-41.3)	**94.3** (60.5-145)	**206** (148-317)	**490** (279-895)	331
	01-02	**44.6** (37.1-53.6)	**37.7** (29.7-49.0)	**110** (76.5-146)	**250** (173-371)	**487** (252-713)	395
12-19 years	99-00	**29.4** (22.3-38.8)	**32.0** (23.8-41.6)	**83.2** (64.1-104)	**181** (130-295)	**336** (184-816)	754
	01-02	**26.3** (21.3-32.5)	**21.0** (17.8-26.5)	**66.2** (47.9-91.5)	**200** (149-298)	**321** (261-435)	744
20 years and older	99-00	**20.6** (16.3-26.2)	**21.6** (17.7-26.2)	**83.1** (64.9-107)	**234** (190-287)	**381** (325-562)	1472
	01-02	**30.4** (27.6-33.4)	**24.7** (21.9-30.0)	**83.1** (68.5-99.0)	**269** (208-328)	**435** (374-518)	1645
Gender							
Males	99-00	**23.3** (16.8-32.3)	**23.8** (17.5-32.2)	**86.1** (64.7-115)	**234** (178-330)	**523** (323-889)	1222
	01-02	**26.2** (23.1-29.8)	**22.0** (19.4-26.0)	**67.6** (57.5-77.0)	**186** (145-237)	**350** (278-418)	1371
Females	99-00	**21.3** (17.5-26.0)	**22.9** (17.5-29.3)	**83.1** (57.2-106)	**209** (154-283)	**357** (283-398)	1335
	01-02	**36.2** (32.8-39.8)	**29.6** (25.5-33.8)	**107** (87.9-129)	**321** (269-356)	**571** (427-729)	1413
Race/ethnicity							
Mexican Americans	99-00	**28.4** (23.3-34.7)	**27.9** (22.5-35.0)	**109** (91.5-137)	**257** (209-380)	**562** (257-981)	819
	01-02	**26.6** (21.6-32.7)	**20.8** (16.1-28.5)	**60.1** (50.5-73.4)	**208** (162-270)	**371** (271-479)	676
Non-Hispanic blacks	99-00	**17.1** (12.4-23.7)	**19.5** (15.7-26.1)	**59.0** (43.1-93.7)	**178** (132-245)	**299** (222-446)	608
	01-02	**26.4** (19.3-36.1)	**22.7** (16.4-33.6)	**69.4** (42.2-115)	**206** (140-317)	**384** (217-747)	705
Non-Hispanic whites	99-00	**23.2** (18.5-29.0)	**24.9** (19.0-31.7)	**86.1** (68.4-105)	**232** (178-295)	**381** (325-523)	917
	01-02	**30.6** (28.3-33.2)	**25.4** (22.7-29.6)	**82.0** (68.3-96.3)	**248** (204-320)	**426** (365-518)	1217

Figure 27. Genistein (creatinine corrected)

Table 223. O-Desmethylangolensin

	Survey years						Sample size
Total, age 6 and older	99-00	**4.39** (3.37-5.73)	**4.98** (3.65-6.77)	**22.7** (18.7-30.2)	**100** (74.8-141)	**222** (182-250)	2271
	01-02	**4.08** (3.53-4.73)	**3.30** (2.60-4.00)	**19.7** (16.6-24.6)	**96.0** (70.1-135)	**260** (153-435)	2794
Age group							
6-11 years	99-00	**5.60** (3.85-8.15)	**7.52** (3.43-15.2)	**36.1** (20.3-45.0)	**78.5** (43.4-191)	**168** (74.8-264)	287
	01-02	**6.19** (4.51-8.49)	**5.70** (3.80-9.30)	**26.2** (15.7-52.1)	**116** (61.5-215)	**281** (161-466)	396
12-19 years	99-00	**6.04** (3.76-9.70)	**7.58** (5.13-13.5)	**36.4** (22.0-57.3)	**106** (63.4-165)	**194** (107-238)	667
	01-02	**5.92** (4.46-7.87)	**5.20** (3.60-7.50)	**33.6** (18.0-56.8)	**125** (91.2-172)	**249** (172-435)	744
20 years and older	99-00	**4.05** (3.12-5.26)	**4.46** (3.31-5.64)	**19.8** (16.0-26.5)	**101** (80.8-150)	**228** (179-259)	1317
	01-02	**3.65** (3.08-4.32)	**2.70** (2.20-3.60)	**17.0** (13.9-22.4)	**81.5** (63.0-128)	**259** (135-493)	1654
Gender							
Males	99-00	**4.97** (3.71-6.66)	**5.62** (4.12-8.73)	**29.1** (19.8-42.9)	**121** (74.1-190)	**235**	

Results by Chemical Group

Organochlorine Pesticides

Organochlorine Pesticides

General Information

Organochlorine pesticides, including DDT, are effective against a variety of insects. Some organochlorines, including hexachlorobenzene and pentachlorophenol, have been used primarily as fungicides and antimicrobials. These chemicals were introduced in the 1940s, and many of their uses have been restricted by the U.S. EPA because of their persistence in the environment. Although many of these chemicals are no longer widely used in the United States, other countries continue to use them.

Organochlorine pesticides can enter the environment[(includina3.2 8 Tc06 Tw 0 -1.153 TDfr So9(dirnse appl8(inatioadin)d runo
iiGenetor40s, anreleasffeass aser aent[(inclu0006 Tc 0.0008 Tw T*pntroduer t(ese cfe)-hem)8(fe)-bials. Se2(organochlorine pest

Once exposure to HCB occurs, the chemical is distributed throughout the body and accumulates in fatty tissues. HCB can persist in body fat for many years and is eliminated very slowly from the body. Age-dependent detection (on a lipid adjusted basis) in this *Report*. HCB was detected in only 4.9% of people in the 1976-1980 NHANES subsample (Stehr-Green et al., 1989). Mean levels in small sample of males and females in Spain were about 100 and 20 fold higher, respectively, than the detection limit in this *Report* (To-Figueras et al., 1997).

Finding a measurable amount of hexachlorobenzene in serum does not mean that the level of the hexachlorobenzene will result in an adverse health effect. These data will help scientists plan and conduct research about exposure to hexachlorobenzene and health effects. These data also provide physicians with a reference range so that they can determine whether or not other people have been exposed to higher levels of hexachlorobenzene than levels found in the general population.

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 also may be formed during the synthesis of lindane. Technical-grade HCH contains all four isomers but mostly the alpha isomer. In 1985, many agricultural uses of lindane were cancelled in the United States. Lindane has had limited registration hexachlorocyclohexane isomers as reasonably anticipated to be human carcinogens. More information about external exposure (i.e., environmental levels) and health effects is available from the U.S. EPA's IRIS Web site at http://www.epa.gov/iris and from ATSDR's Toxicological Profiles at http://www.atsdr.cdc.gov global change in levels over time.

Age-related increases in the levels of beta-HCH have previously been observed by the German Commission on Biological Monitoring (Ewers et al., 1999). In addition, such an age relationship was observed previously in both a nonrandom 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 than in males also had been observed for beta-HCH levels in serum (Stehr-Green et al., 1989), but not in adipose tissue (Burns, 1974).

In the NHANES 1999-2000 and 2001-2002 subsamples, serum levels of gamma-HCH were generally below the limit of detection, and detection limits were lower than values reported in studies of people in other countries including Spain (Botella et al., 2004) and India (Bhatnagar et al., 2004). 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.

Serum lindane levels in workers involved in the manufacture, processing, application, or formulation of HCH were found to be several-fold 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 United Kingdom's benchmark guidance value for workers with lindane exposure is 35 nanomoles per liter (approximately 1,700 ng/gram of lipid) in whole blood or 70 nanomoles per liter in plasma (Wilson, 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 Forschungsgemeinchaft, 2000).

Finding a measurable amount of HCH isomers in serum does not mean that the level will result in an adverse health effect. These data will help scientists plan and conduct research about the relation between exposure to HCH isomers and health effects. These data also provide physicians with a reference range so that they can determine whether or not other people have been exposed to higher levels of HCH isomers than levels found in the general population.

Table 230. gamma Hexachlorocylclohexane (lipid adjusted)

	Survey years						Sample size
Total, age 12 and older	99-00	*	< LOD	< LOD	< LOD	< LOD	1799
	01-02	*	< LOD	< LOD	< LOD	< LOD	2280
Age group							
12-19 years	99-00	*	< LOD	< LOD	< LOD	< LOD	660
	01-02	*	< LOD	< LOD	< LOD	< LOD	758
20 years and older	99-00	*	< LOD	< LOD	< LOD	< LOD	1139
	01-02	*	< LOD	< LOD	< LOD	< LOD	1522
Gender							

< LOD

Interpreting Levels of Urinary Pentachlorophenol Reported in the Tables

6-59 years. Participants were selected within the specified age range to be a representative sample of the U.S. population. In the current NHANES 2001-2002 subsample, urinary 2,4,6-TCP levels at the 95th percentile were several times higher than a nonrandom subsample from NHANES III during 1988-1994 (Hill et al., 1995) and several times higher than 95th percentile values reported in a study of German adults aged 18-69 years (Becker et al., 2003). Urinary levels of 2,4,5-TCP at the 95th percentile were similar to values reported in a nonrandom subsample from NHANES III during 1988-1994 (Hill et al., 1995) and several times higher than 95th percentile values reported in a study of German adults aged 18-69 years (Becker et al., 2003).

Comparing Adjusted Geometric Means

Geometric mean levels of urinary 2,4,5-TCP in the 1999-2000 and 2001-2002 subsamples and 2,4,6-TCP in the 2001-2002 subsample could not be calculated due to an insufficient detection rate. Geometric mean levels of urinary 2,4,6-TCP for the demographic 0012 Tc 0.Iups8( )(H]TJ]TJ0006 Tc 0.0701 Tw 0 -Ts 1024.72 59(p6ercentiand 23(5(si)-

Table 236. 2,4,6-Trichlorophenol

	Survey years						Sample size
Total, age 6 and older	99-00	**2.85** (2.55-3.18)	**2.45** (2.40-2.60)	**4.80** (3.80-7.60)	**14.8** (7.70-25.0)	**25.0** (15.0-39.0)	1989
	01-02	*	**1.68** (<LOD-2.43)	**5.94** (4.89-6.63)	**10.8** (9.98-11.7)	**14.9** (13.4-17.9)	2503
Age group							
6-11 years	99-00						

Table 237. 2,4,6-Trichlorophenol (creatinine corrected)

Figure 29. 2,4,6-Trichlorophenol (creatinine corrected)

Dichlorodiphenyltrichloroethane

CAS No. 50-29-3

General Information

Dichlorodiphenyltrichloroethane (DDT) is an insecticide that was used in the 1940s by the military against mosquitoes that carried vector-borne diseases (e.g., malaria). The U.S. EPA banned the use of DDT in the United States in 1973, and it is no longer being applied in this country. However, DDT is still used in other countries. Commercially available DDT (technical grade) contains three chemical forms of DDT: *p,p*'-DDT, *o,o*'-DDT, and *o,p*'-DDT.

DDT is converted in the environment to other more stable chemical forms, including 1,1'-(2,2-dichlorohundred times greater than concentrations in other tissues. DDE persists longer in the body than DDT. Previous studies have reported that levels of DDT and DDE increase as a person ages.

DDT and its metabolites can cause adverse effects through different mechanisms—by interfering with the movement of ions through cells in the nervous system or by mimicking or blocking the action of reproductive hormones. 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). In people, elevations of liver enzymes in serum have been observed after large accidental or workplace exposures; acute overdoses may cause tremors, gait disturbances, fatigue, headache, and vomiting (Hayes, 1976). The association of DDT with breast cancer has been studied, and a causal link is uncertain (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.

More information about external exposure (i.e., environmental levels) and health effects is available from the U.S. EPA's IRIS Web site at http://www.epa.gov/iris and from ATSDR's Toxicological Profiles at http://www.atsdr.cdc. gov/toxprofiles.

Interpreting Levels of Lipid-Adjusted Serum DDT and DDE Reported in the Tables

Serum levels of *p,p*'-DDT, *o,p*'-DDT and *p,p*'-DDE were measured in a subsample of NHANES participants aged 12 years and older. Participants were selected within the specified age range to be a representative sample of the U.S. population. Geometric mean levels of *p,p*'-DDE in the NHANES 2001-2002 subsample were similar to measurements reported in a previous study of adults in Germany (Becker et al., 2002). The *p,p*'-DDE levels in the NHANES 2001-2002 subsample were approximately three-fold lower than serum *p,p*'-DDE measurements

Table 239. *p,p'*-DDT (whole weight)

reported in studies of adults in New Zealand (Bates et al., 2004*b*) and ten times lower than serum measurements whether these differences associated with age or race/ethnicity represent differences in exposure, pharmacokinetics, or the relationship of dose per body weight.

There were no significant differences in serum *p,p*'-DDE levels between males and females in NHANES 2001-2002; 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).

Finding a measurable amount of *p,p*'-DDT or *p,p*'-DDE in serum does not mean that the level of the *p,p*'-DDT or *p,p*'-DDE will result in an adverse health effect. These data will help scientists plan and conduct research about the relation between exposure to DDT or DDE and health effects. These data also provide physicians with a reference range so that they can determine whether or not other people have been exposed to higher levels of DDT or DDE than levels found in the general population.

Table 241. *p,p'*-DDE (whole weight)

	Survey years						Sample size
Total, age 12 and older	99-00	**1.54** (1.33-1.79)	**1.31** (1.09-1.66)	**3.49** (2.97-4.27)	**7.49** (6.14-9.25)	**11.6** (9.25-14.8)	1964
	01-02	**1.81** (1.64-2.01)	**1.57** (1.37-1.72)	**3.97** (3.43-4.59)	**8.81** (7.85-10.1)	**15.4** (12.9-17.6)	2298
Age group							
12-19 years	99-00	**.561** (.488-.646)	**.518** (.433-.603)	**.872** (.682-1.18)	**1.52** (1.13-2.25)	**2.31** (1.76-3.56)	686
	01-02	**.623** (.534-.726)	**.592** (.495-.727)	**.997** (.819-1.22)	**1.65** (1.39-2.07)	**2.30** (1.91-3.14)	758
20 years and older	99-00	**1.83** (1.56-2.14)	**1.61** (1.26-2.07)	**4.17** (3.48-4.66)	**8.12** (6.37-10.6)	**12.3** (9.87-16.7)	1278
	01-02	**2.14** (1.91-2.39)	**1.76** (1.61-2.04)	**4.59** (4.10-5.26)	**9.75** (8.34-11.5)	**16.8** (13.7-19.1)	1540
Gender							
Males	99-00	**1.49** (1.30-1.70)	**1.25** (1.10-1.44)	**3.01** (2.56-3.74)	**6.43** (5.40-8.00)	**9.63** (6.63-15.6)	937
	01-02	**1.77** (1.57-2.01)	**1.59** (1.36-1.76)	**3.40** (3.03-4.10)	**7.48** (6.43-8.75)	**13.1** (9.66-17.6)	1069
Females	99-00	**1.59** (1.32-1.92)	**1.38** (1.03-1.99)	**4.05** (3.15-4.79)	**8.12** (6.36-11.5)	**13.2** (9.81-18.5)	1027
	01-02	**1.85** (1.66-2.06)	**1.49** (1.32-1.75)	**4.57** (3.81-5.47)	**10.1** (9.01-11.9)	**16.8** (13.4-19.7)	1229
Race/ethnicity							
Mexican Americans	99-00	**3.92** (3.40-4.51)	**3.52** (3.17-3.91)	**8.20** (7.26-10.4)	**22.0** (12.2-32.2)	**31.5** (19.7-48.1)	657
	01-02	**3.92** (3.37-4.57)	**3.53** (2.68-4.34)	**9.33** (7.31-12.5)	**26.6** (17.9-38.3)	**40.9** (26.8-90.5)	566

Table 42. *o,p'*-DDT (lipid adjusted)

	Survey years					Sample size
Total, a… 12 and older	99…0	< LOD	< LOD	< LOD	< LOD	1669
	01…2	< LOD	< LOD	< LOD	< LOD	<2279
Age gro…						

Chlordane

CAS No.12789-03-6 and 57-74-9

women. Indoor inhalational exposure to chlordane may occur for decades after the termite treatment of a females in Sweden (Glynn et al., 2003), and two-fold lower than levels reported for women in New York (Wolff et al., 2000). Compared with serum levels in the NHANES 2001-2002 subsample, higher serum levels of *trans*-nonachlor were reported in an Inuit population in Greenland (Van Oostdam et al., 2004). Levels of heptachlor epoxide in both the 1999-2000 and the 2001-2002 subsamples approximately ten-fold lower at the corresponding 90th percentile for a historical cohort of women studied during the period 1963-1967 (James et al., 2002).

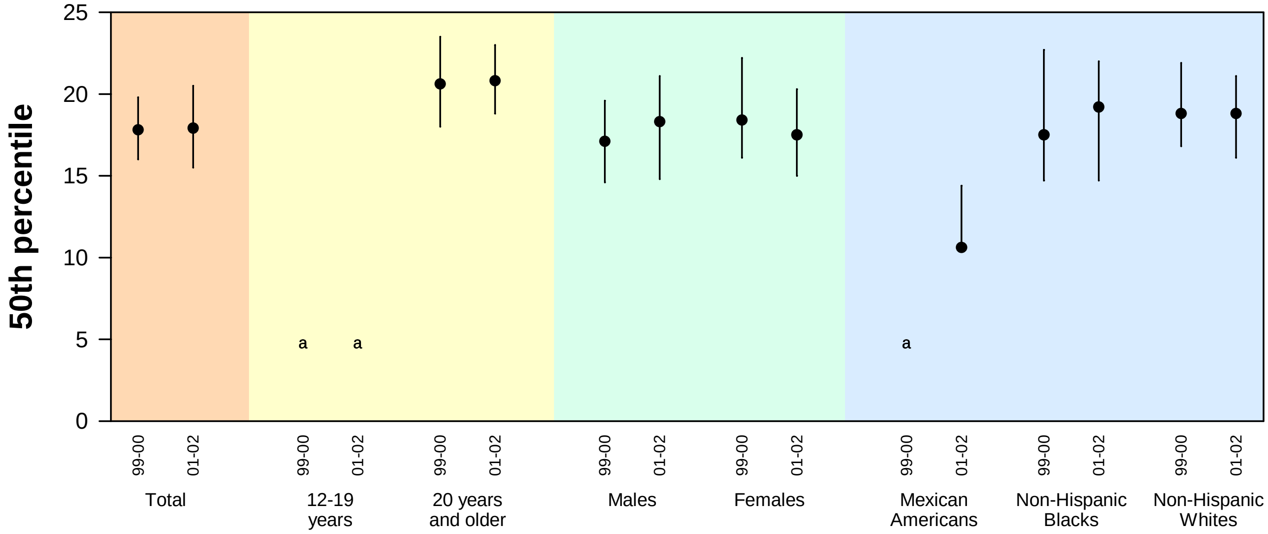
Comparing Adjusted Geometric Means

Table 247. *trans*-Nonachlor (whole weight)

	Survey years			Sample size
Total, age 12 and older				

Figure 31. *trans*-Nonachlor (lipid adjusted)

Selected percentiles with 95% confidence intervals of serum concentrations (in 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, 1999-2002.



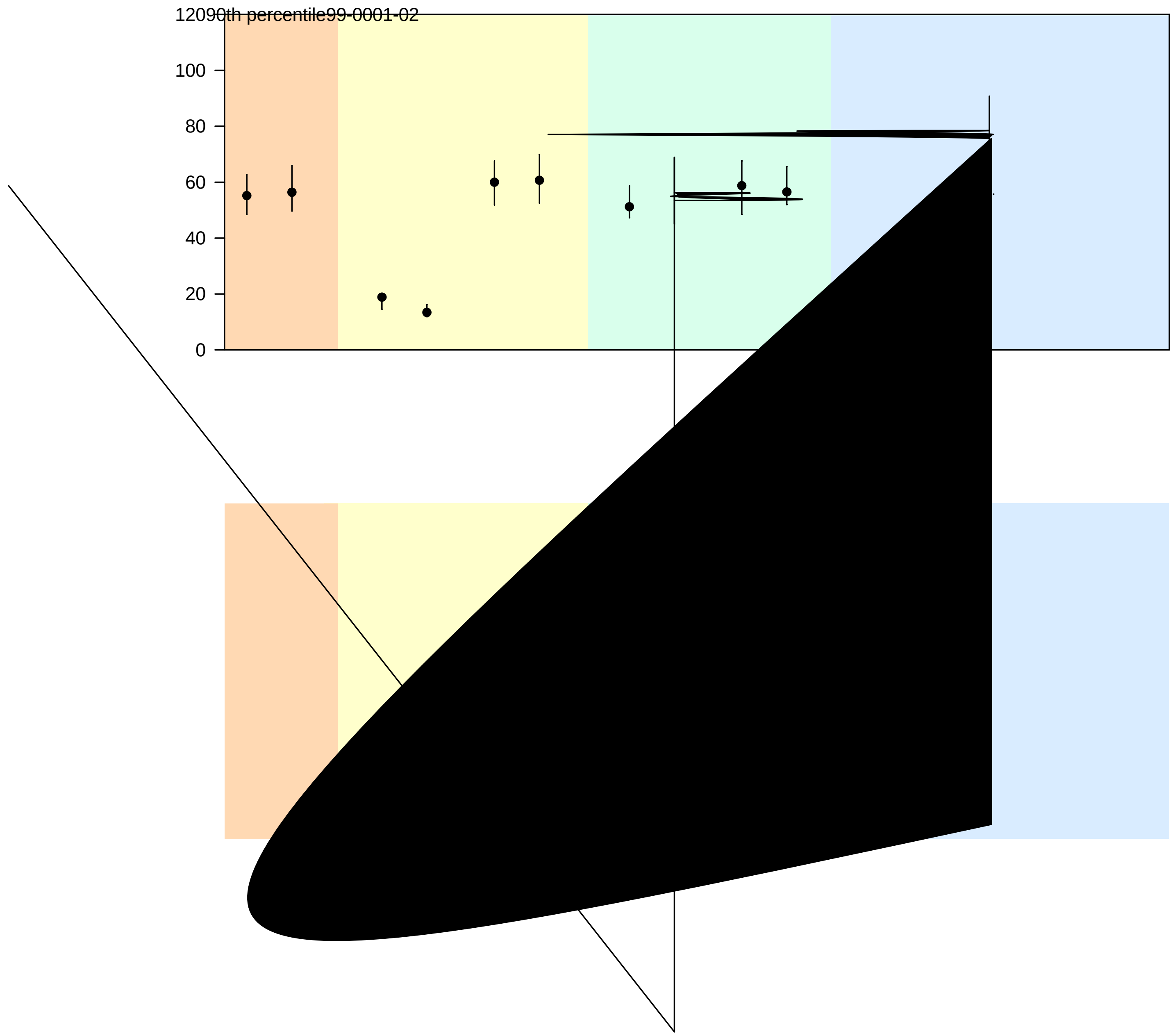


Table 248. Heptachlor epoxide (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (in 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, 1999-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 12 and older	99-00	*	< LOD	< LOD	**15.3** (<LOD-19.8)	**23.9** (15.1-38.8)	1589
	01-02	*	< LOD	< LOD	**14.8** (13.0-17.8)	**21.6** (18.1-26.2)	2259
Age group							
12-19 years	99-00	*	< LOD	< LOD	< LOD	< LOD	638
	01-02	*	< LOD	< LOD	< LOD	< LOD	741
20 years and older	99-00	*	< LOD	< LOD	**17.8** (<LOD-23.9)	**27.1** (16.8-46.1)	951
	01-02	*	< LOD	< LOD	**15.7** (13.6-18.8)	**23.1** (19.1-29.1)	1518
Gender							
Males	99-00	*	< LOD	< LOD	< LOD	**19.2** (<LOD-27.2)	760
	01-02	*	< LOD	< LOD	**13.9** (12.0-17.3)	**20.8** (15.9-25.3)	1047
Females	99-00	*	< LOD	< LOD	**18.2** (<LOD-25.2)	**27.0** (16.0-54.3)	829
	01-02	*	< LOD	< LOD	**15.5** (13.3-18.2)	**23.2** (18.9-29.8)	1212
Race/ethnicity							
Mexican Americans	99-00	*	< LOD	< LOD	**15.2** (<LOD-23.6)	**21.6** (<LOD-62.3)	598
	01-02	*	< LOD	< LOD	**13.2** (<LOD-16.3)	**16.6** (13.8-23.1)	553
Non-Hispanic blacks	99-00	*	< LOD	< LOD	< LOD	**19.4** (<LOD-32.4)	336
	01-02	*	< LOD	< LOD	**14.6** (11.7-19.0)	**21.0** (18.2-27.3)	503
Non-Hispanic whites	99-00	*	< LOD	< LOD	**16.5** (<LOD-21.8)	**25.2** (<LOD-54.3)	539
	01-02	*	< LOD	< LOD	**15.3** (12.9-19.1)	**22.8** (18.9-29.8)	1041

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.
* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 249. Heptachlor epoxide (whole weight)

	Survey years						Sample size
Total, age 12 and older	99-00	*	**< LOD**	**< LOD**	**.110** (.091-.144)	**.177** (.109-.220)	1589
	01-02	*	**< LOD**	**< LOD**	**.102** (.089-.121)	**.153** (.125-.179)	2259
Age group							
12-19 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	638
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	s8.0105 0 0 8.*0104

as well as in a subsample of NHANES II (1976-1980) participants, serum mirex levels were generally below the limits of detection (Stehr-Green, 1989). In the NHANES 2001-2002 subsample, only mirex levels at the 90th and 95th percentiles were characterized. In a study of fishermen in New York who consumed sport fish, median levels of lipid-adjusted serum mirex were lower than the 95th percentile values in this 2001-2002 subsample (Bloom et al., 2005).

Finding a measurable amount of mirex in serum does not mean that the level will result in an adverse health effect. These data will help scientists plan and conduct research about the relation between exposure to mirex and health effects. These data also provide physicians with a reference range so that they can determine whether or not other people have been exposed to higher levels of mirex than levels found in the general population.

Table 251. Mirex (whole weight)

Geometric mean and selected percentiles of serum concentrations (in ng/g of serum or parts per billion) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 1999-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 12 and older	99-00	*	< LOD	< LOD	< LOD	< LOD	1853
	01-02	*	< LOD	< LOD	.101 (.049-.468)	.414 (.080-1.73)	2257
Age group							
12-19 years	99-00	*	< LOD	< LOD	< LOD	< LOD	659
	01-02	*	< LOD	< LOD	< LOD	< LOD	728
20 years and older	99-00	*	< LOD	< LOD	< LOD	< LOD	1194
	01-02	*	< LOD	< LOD	.137 (.053-.687)	.468 (.089-1.92)	1529
Gender							
Males	99-00	*	< LOD	< LOD	< LOD	< LOD	887
	01-02	*	< LOD	< LOD	.111 (.055-.468)	.368 (.089-1.37)	1052
Females	99-00	*	< LOD	< LOD	< LOD	< LOD	966
	01-02	*	< LOD	< LOD	.087 (.043-.513)	.419 (.072-1.79)	1205
Race/ethnicity							
Mexican Americans	99-00	*	< LOD	< LOD	< LOD	< LOD	617
	01-02	*	< LOD	< LOD	< LOD	< LOD	548
Non-Hispanic blacks	99-00	*	< LOD	< LOD	.087 (.044-.221)	.221 (.124-.449)	398
	01-02	*	< LOD	.085 (.031-.240)	.293 (.092-1.41)	.826 (.166-3.02)	500
Non-Hispanic whites	99-00	*	< LOD	< LOD	< LOD	< LOD	688
	01-02	*	< LOD	< LOD	.098 (.047-.609)	.449 (.077-1.79)	1049

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.
* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

In the NHANES 2001-2002 subsample, serum levels of aldrin were below the limit of detection, which is consistent with findings of NHANES II (1976-1980) (Stehr-Green, 1989). As well, levels of aldrin were not

Table 255. Dieldrin (whole weight)

Geometric mean and selected percentiles of serum concentrations (in ng/g of serum or parts per billion) for the U.S. population aged 12 years and older, National Health and Nutrition Examination Survey, 2001-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentilesA for LODs. (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 12 and older	01-02	*	< LOD	< LOD	.109 (.099-.121)	.146 (.129-.164)	2159
Age group							
12-19 years	01-02	*	< LOD	< LOD	< LOD	< LOD	716
20 years and older	01-02	*	< LOD	.067 (.062-.075)	.117 (.105-.127)	.158 (.141-.178)	1443
Gender							
Males	01-02	*	< LOD	< LOD	.114 (.102-.129)	.156 (.126-.190)	1007
Females	01-02	*	< LOD	< LOD	.097 (.089-.111)	.141 (.123-.157)	1152
Race/ethnicity							
Mexican Americans	01-02	*	< LOD	< LOD	.083 (.068-.103)	.119 (.086-.144)	539
Non-Hispanic blacks	01-02	*	< LOD	< LOD	.085 (.071-.113)	.118 (.086-.190)	484
Non-Hispanic whites	01-02	*	< LOD	< LOD	.109 (.100-.124)	.153 (.131-.175)	980

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.

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

Table 257. Endrin (whole weight)

	Survey years						Sample size
Total, age 12 and older	01-02	*	**< LOD**	**< LOD**	**< LOD**	**.021** (.020-.021)	2187
Age group							
12-19 years	01-02	*	**< LOD**	**< LOD**	**.021** (.020-.021)	**.021** (.020-.021)	730
20 years and older	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1457
Gender							
Males	01-02	*	**< LOD**	**< LOD**	**< LOD**	**.020** (.020-.021)	1022
Females	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1165
Race/ethnicity							
Mexican Americans	01-02	*	**< LOD**	**< LOD**	**< LOD**	**.021** (.020-.021)	547
Non-Hispanic blacks	01-02	*	**< LOD**	**< LOD**	**< LOD**	**.021** (.020-.021)	487
Non-Hispanic whites	01-02	*	**< LOD**	**< LOD**	**< LOD**	**.021** (.020-.021)	1000

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.

Results by Chemical Group

Organophosphate Pesticides: Dialkyl Phosphate Metabolites

Organophosphate Pesticides: Dialkyl Phosphate Metabolites

General Information

Organophosphate pesticides, which are active against a broad spectrum of insects, account for about half of all insecticides used in the United States. Although organophosphates are still used for insect control on many food crops, most residential uses are being phased out in the United States as a result of implementation of the Food Quality Protection Act of 1996. Certain organophosphates (i.e., malathion, naled) are registered for public health applications (mosquito control) in the United States. About 73 million pounds of organophosphate pesticides were used in the United States in 2001 (70% of all insecticides) (U.S. EPA, 2004). Approximately 40 organophosphate insecticides are registered for use in the United States by the U.S. EPA. Some chemicals in this class are also used in

Table 258. 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						

Table 259. Dimethylphosphate

	Survey years			Sample size
Total, age 6 and older	99-00	*	.740	

Figure 32. Dimethylphosphate (creatinine corrected)

Selected percentiles with 95% confidence intervals of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6-59 years, National Health and Nutrition Examination Survey, 1999-2002.

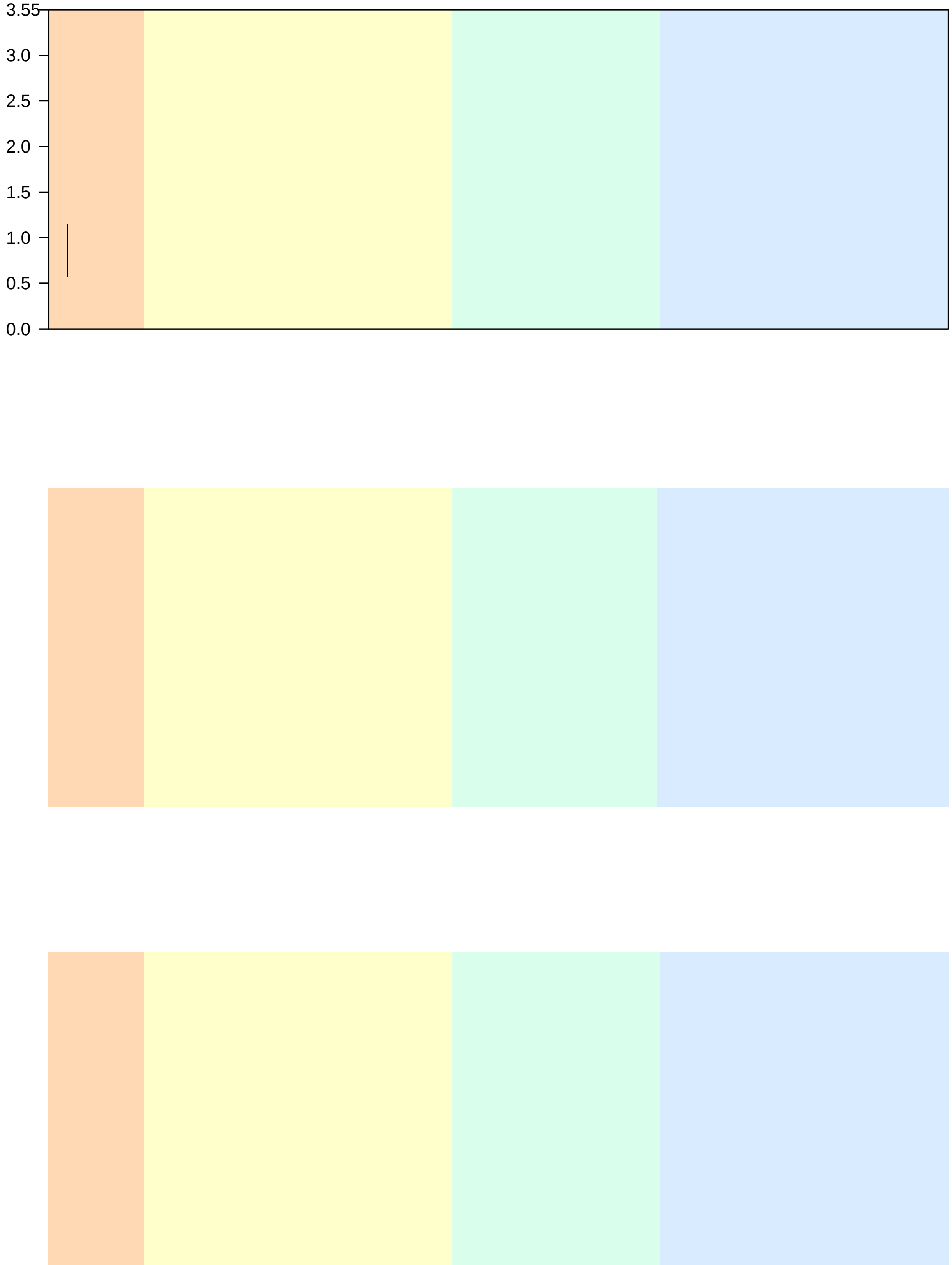


Table 262. Dimethylthiophosphate (creatinine corrected)

Geometric mean and selected percentiles of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6-59 years,

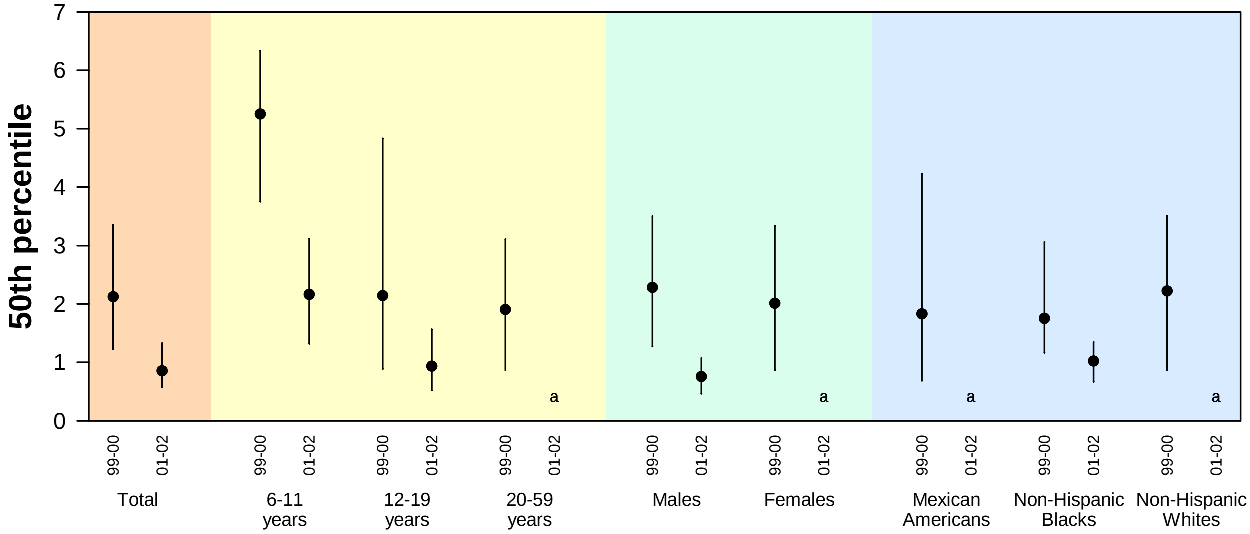
	Survey years	mean (95% conf. interval)		(95% confidence interval)			Sample size
Total, age 6 and older	99-00	**1.64** (1.22-2.20)	**2.12** (1.22-3.35)	**9.57** (6.59-15.8)	**32.0** (23.8-41.1)	**51.0** (39.0-70.1)	1948
	01-02	*	**.854** (.571-1.33)	**3.79** (2.50-5.19)	**13.2** (10.9-18.8)	**27.2** (21.7-37.7)	2517
Age group							
6-11 years	99-00	**2.95** (2.25-3.86)	**5.25** (3.75-6.33)	**18.7** (12.1-28.0)	**45.2** (32.1-60.3)	**65.9** (50.9-95.0)	471
	01-02	*	**2.16** (1.32-3.12)	**10.6** (7.84-13.6)	**28.7** (18.8-45.0)	**47.2** (33.4-71.1)	575
12-19 years	99-00	**1.71** (1.07-2.75)	**2.14** (.886-4.83)	**13.4** (6.46-22.6)	**36.0** (25.6-51.4)	**61.5** (41.7-109)	664
	01-02	*	**.933** (.519-1.56)	**3.56** (2.38-5.57)	**12.2** (8.96-16.0)	**22.4** (13.2-34.7)	821
20-59 years	99-00	**1.47** (1.07-2.02)	**1.90** (.867-3.11)	**8.09** (5.19-14.6)	**27.0** (19.8-37.6)	**47.4** (34.2-70.1)	813
	01-02	*	**< LOD**	**3.16** (1.99-4.62)	**11.8** (7.79-17.2)	**25.2** (15.9-37.0)	1121
Gender							
Males	99-00	**1.61** (1.11-2.34)	**2.28** (1.27-3.51)	**9.27** (6.00-16.9)	**28.9** (19.0-40.4)	**41.1** (34.9-52.9)	952
	01-02	*	**.753** (.466-1.08)	**3.35** (2.26-4.60)	**12.4** (8.54-15.9)	**24.0** (14.6-38.9)	1187
Females	99-00	**1.66** (1.26-2.18)	**2.01** (.866-3.33)	**10.0** (6.67-16.0)	**34.5** (26.2-47.1)	**69.5** (39.0-118)	996
	01-02	*	**< LOD**	**4.22** (2.40-7.00)	**15.6** (11.3-22.6)	**29.6** (24.8-43.8)	1330
Race/ethnicity							
Mexican Americans	99-00	**1.60** (.899-2.86)	**1.83** (.684-4.23)	**10.4** (5.95-16.9)	**37.0** (23.1-63.1)	**112** (40.5-190)	671
	01-02	*	**< LOD**	**3.55** (2.52-4.93)	**13.2** (9.61-22.7)	**30.2** (22.7-47.7)	678
Non-Hispanic blacks	99-00	**1.45** (1.03-2.06)	**1.75** (1.17-3.06)	**8.21** (4.36-13.4)	**25.5** (15.4-39.3)	**52.1** (25.5-97.6)	509
	01-02	*	**1.02** (.667-1.35)	**3.58** (2.33-5.18)	**13.4** (9.69-18.8)	**22.6** (17.5-43.8)	694
Non-Hispanic whites	99-00	**1.68** (1.16-2.43)	**2.22** (.867-3.51)	**9.27** (5.58-17.0)	**32.5** (20.5-49.4)	**51.0** (39.0-71.1)	595
	01-02	*	**< LOD**	**3.82** (2.19-6.38)	**14.1** (10.1-22.1)	**27.4** (21.7-43.8)	947

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.

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

Figure 33. Dimethylthiophosphate (creatinine corrected)

Selected percentiles with 95% confidence intervals of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6-59 years, National Health and Nutrition Examination Survey, 1999-2002.



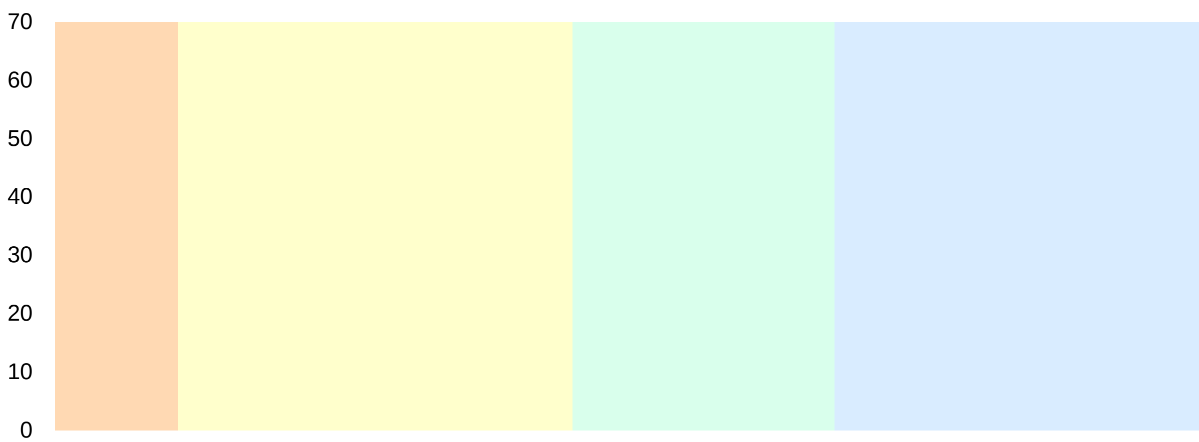


Table 264. Dimethyldithiophosphate (creatinine corrected)

Geometric mean and selected percentiles of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6-59 years, National Health and Nutrition Examination Survey, 1999-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 6 and older	99-00	*	< LOD	**1.86** (.974-3.86)	**10.1** (5.31-18.3)	**21.7** (12.8-33.7)	1949
	01-02	*	< LOD	**.667** (.333-1.07)	**2.60** (1.85-3.69)	**5.80** (4.23-7.75)	2517
Age group							
6-11 years	99-00	*	**.788** (.186-1.60)	**4.07** (2.31-7.18)	**16.2** (8.22-27.0)	**30.8** (20.2-38.9)	471
	01-02	*	< LOD	**1.35** (.805-2.31)	**3.76** (2.67-6.24)	**6.98** (4.40-12.8)	575
12-19 years	99-00	*	< LOD	**1.52** (.623-3.47)	**9.42** (4.04-16.8)	**18.5** (9.48-42.3)	664
	01-02	*	< LOD	**.543** (.306-.773)	**1.99** (1.49-2.40)	**3.13** (2.51-4.67)	820
20-59 years	99-00	*	< LOD	**1.71** (.847-3.56)	**8.46** (4.00-19.1)	**19.2** (8.57-40.7)	814
	01-02	*	< LOD	**.595** (.292-1.05)	**2.56** (1.64-4.03)	**6.03** (3.96-8.17)	1122
Gender							
Males	99-00	*	**.150** (.085-.351)	**1.64** (.840-3.97)	**11.0** (4.62-17.4)	**17.8** (7.51-44.7)	952
	01-02	*	< LOD	**.583** (.269-.824)	**2.01** (1.40-2.67)	**4.43** (2.90-6.80)	1187
Females	99-00	*	< LOD	**1.99** (.940-4.00)	**9.30** (4.96-25.5)	**27.0** (9.66-47.5)	997
	01-02	*	< LOD	**.820** (.368-1.43)	**2.91** (2.29-4.56)	**6.93** (4.44-11.9)	1330
Race/ethnicity							
Mexican Americans	99-00	*	**.265** (.087-.658)	**1.35** (.857-2.53)	**6.55** (3.83-11.8)	**16.7** (6.25-38.8)	672
	01-02	*	< LOD	**.800** (.543-1.11)	**2.59** (1.88-3.22)	**4.86** (3.32-6.37)	678
Non-Hispanic blacks	99-00	*	**.235** (.071-.698)	**2.39** (.690-5.44)	**9.41** (4.81-17.8)	**17.8** (11.4-40.7)	509
	01-02	*	< LOD	**.426** (.140-.933)	**1.79** (.828-3.50)	**3.65** (2.33-5.91)	694
Non-Hispanic whites	99-00	*	< LOD	**1.75** (.778-4.02)	**11.3** (4.07-21.5)	**21.5** (11.3-34.8)	595
	01-02	*	< LOD	**.711** (.304-1.31)	**2.85** (1.91-4.96)	**6.98** (4.25-9.47)	947

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.

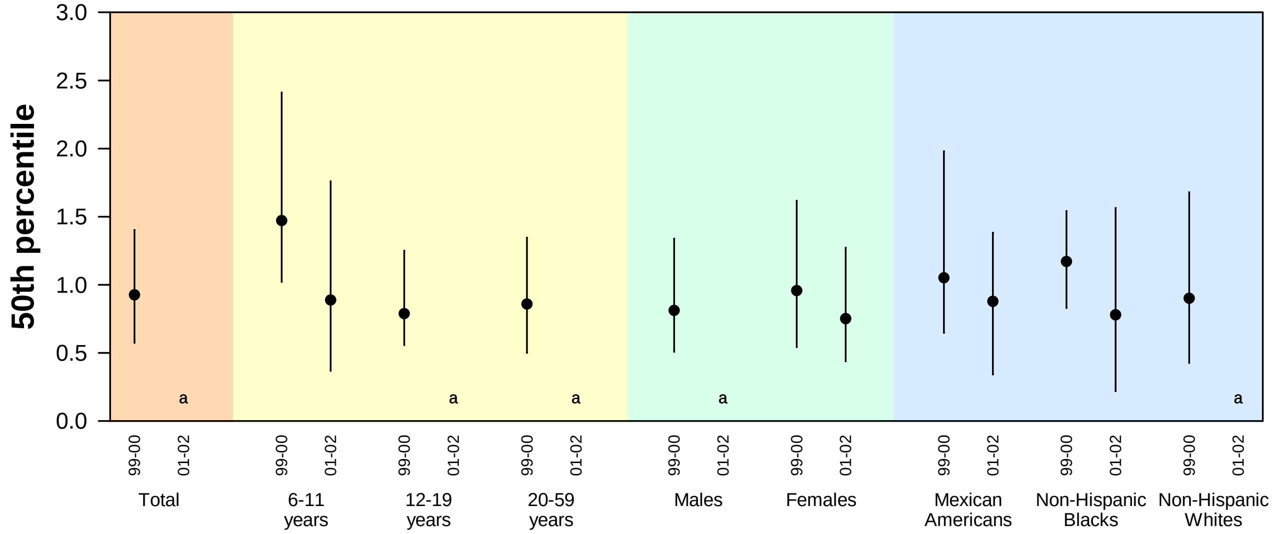
* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 265. Diethylphosphate

	Survey years						Sample size
Total, age 6 and older	99-00	**1.03** (.670-1.58)	**1.20** (.720-1.60)	**3.10** (2.30-4.70)	**7.50** (5.00-12.0)	**13.0** (7.60-22.0)	1949
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]-12.5)	2520 .
Age group		9( )8)					

Figure 34. Diethylphosphate (creatinine corrected)

Selected percentiles with 95% confidence intervals of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6-59 years, National Health and Nutrition Examination Survey, 1999-2002.



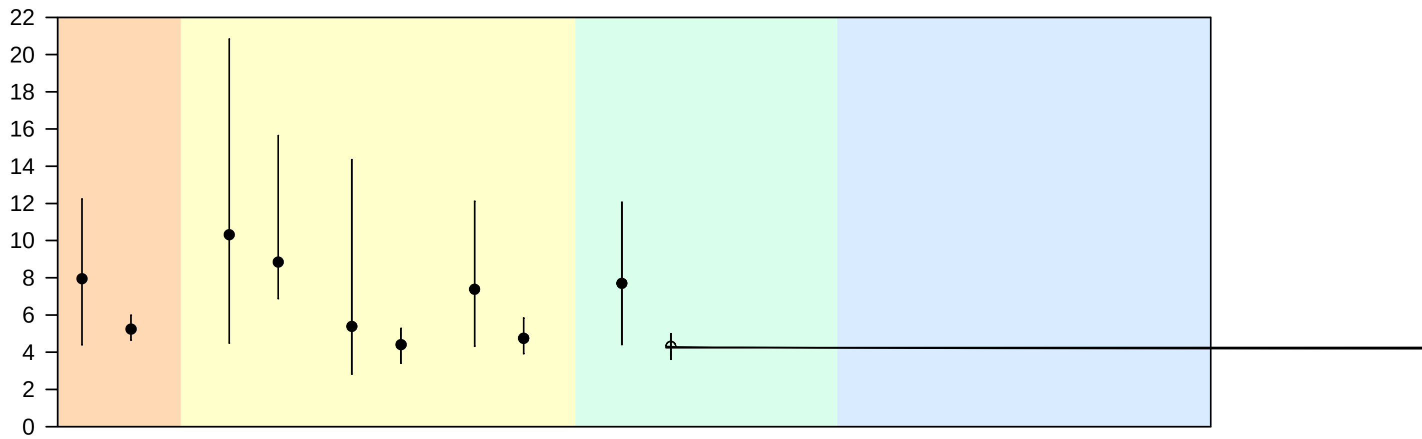


Table 267. Diethylthiophosphate

	Survey years						Sample size
Total, age 6 and older	99-00	*	**.490** (<LOD-.680)	**.760** (.610-1.10)	**1.30** (1.10-1.70)	**2.20** (1.70-2.80)	1949
	01-02	**.457** (.353-.592)	**.570** (.390-.860)	**1.48** (1.25-1.79)	**2.46** (2.22-3.02)	**3.94** (3.17-4.95)	2519
Age group							
6-11 years	99-00	*	**.590** (<LOD-.800)	**.900** (.710-1.30)	**1.70** (1.10-2.90)	**3.13** (1.70-7.30)	471
	01-02	**.453** (.350-.585)	**.540** (.350-.850)	**1.58** (1.32-2.01)	**2.74** (2.22-3.38)	**4.08** (2.95-5.16)	575
12-19 years	99-00	*	**.210** (<LOD-.710)	**.780** (.600-1.20)	**1.40** (1.10-2.20)	**2.20** (1.60-3.10)	664
	01-02	**.505** (.388-.657)	**.690** (.440-.960)	**1.61** (1.31-1.93)	**2.57** (2.23-3.39)	**4.08** (2.73-5.86)	822
20-59 years	99-00	*	**.480** (<LOD-.660)	**.740** (.600-.930)	**1.30** (.960-1.60)	**2.00** (1.50-2.50)	814
	01-02	**.449** (.340-.592)	**.540** (.380-.880)	**1.44** (1.19-1.77)	**2.46** (2.11-3.17)	**3.79** (2.96-5.34)	1122
Gender							
Males	99-00	*	**.500** (<LOD-.680)	**.790** (.680-1.10)	**1.40** (1.20-1.90)	**2.70** (1.90-4.10)	952
	01-02	**.459** (.359-.587)	**.560** (.370-.850)	**1.49** (1.28-1.76)	**2.54** (2.16-3.34)	**3.83** (2.76-5.86)	1187
Females	99-00	*	**< LOD**	**.720** (.560-1.00)	**1.24** (.910-1.60)	**1.70** (1.30-2.70)	997
	01-02	**.455** (.336-.618)	**.550** (.370-.940)	**1.48** (1.14-1.89)	**2.44** (2.11-3.21)	**3.91** (2.68-5.49)	1332

Race/et1a*8m(13 Tf6.958oTf-0.004 Tc 6.9579 0 0 6.9579 208.98 330.20 8.4.2 0/TT2 4(99C 6.9 4(99CTd[(.)-9(450 1 Tf6.9579 0 0 6.9579 492

Table 268. Diethylthiophosphate (creatinine corrected)

Geometric mean and selected percentiles of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6-59 years, National Health and Nutrition Examination Survey, 1999-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 6 and older	99-00	*	**.254** (.079-.478)	**.706** (.456-1.07)	**1.70** (1.17-2.32)	**2.64** (2.08-3.06)	1949
	01-02	**.453** (.348-.590)	**.515** (.332-.760)	**1.33** (1.04-1.66)	**2.84** (2.22-3.76)	**4.61** (3.42-6.65)	2518
Age group							
6-11 years	99-00	*	**.470** (.136-.869)	**1.08** (.797-1.32)	**1.73** (1.44-2.36)	**2.45** (2.04-5.32)	471
	01-02	**.591** (.471-.742)	**.628** (.389-1.00)	**1.63** (1.31-1.94)	**3.20** (2.72-4.16)	**5.70** (3.84-6.80)	575
12-19 years	99-00	*	**.176** (.051-.404)	**.509** (.318-.821)	**1.07** (.723-1.61)	**1.97** (1.07-3.92)	664
	01-02	**.393** (.300-.515)	**.534** (.313-.735)	**1.23** (.978-1.53)	**2.11** (1.61-3.07)	**3.14** (2.25-3.97)	821
20-59 years	99-00	*	**.250** (.081-.462)	**.685** (.443-1.08)	**1.79** (1.08-2.39)	**2.75** (2.02-3.22)	814
	01-02	**.447** (.335-.597)	**.494** (.316-.742)	**1.31** (.986-1.71)	**2.87** (2.08-3.95)	**4.61** (3.20-7.81)	1122
Gender							
Males	99-00	*	**.267** (.077-.471)	**.672** (.515-.835)	**1.34** (1.08-2.17)	**2.66** (1.67-3.23)	952
	01-02	**.372** (.285-.485)	**.454** (.268-.692)	**1.11** (.939-1.33)	**2.05** (1.55-3.11)	**3.31** (2.47-4.71)	1187
Females	99-00	*	**< LOD**	**.790** (.382-1.50)	**1.89** (1.07-2.52)	**2.52** (1.89-3.75)	997
	01-02	**.552** (.412-.739)	**.580** (.368-.906)	**1.60** (1.18-2.42)	**3.67** (2.77-4.99)	**6.57** (3.92-8.82)	1331
Race/ethnicity							
Mexican Americans	99-00	*	**.335** (.063-.786)	**.829** (.545-1.20)	**1.69** (1.20-2.43)	**2.71** (1.75-3.78)	672
	01-02	**.509** (.377-.688)	**.551** (.376-.844)	**1.27** (1.03-1.67)	**2.55** (1.77-3.72)	**3.67** (2.58-6.30)	678
Non-Hispanic blacks	99-00	*	**.300** (.076-.579)	**.717** (.514-.848)	**1.35** (1.03-2.10)	**2.89** (1.49-4.24)	509
	01-02	**.535** (.444-.645)	**.705** (.553-.925)	**1.43** (1.32-1.60)	**2.69** (2.30-2.98)	**3.89** (3.05-4.99)	694
Non-Hispanic whites	99-00	*	**.230** (.062-.548)	**.705** (.387-1.22)	**1.88** (1.05-2.58)	**2.58** (2.08-3.07)	595
	01-02	**.448** (.318-.630)	**.508** (.269-.800)	**1.38** (.995-1.88)	**3.08** (2.29-4.23)	**5.77** (3.42-8.44)	948

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.

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

Figure 35. Diethylthiophosphate

Organophosphate Pesticides: Specific Metabolites

representative sample of the U.S. population. For the NHANES 1999-2000 subsample, urinary levels of malathion dicarboxylic acid at the 95th percentile in children aged 6-11 years are several-fold 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. Of 382 pregnant women living in an agricultural community, 30% had detectable levels dn()8(a)0011 TcTc 0.0002 Twf 382 pregTwfg dn(93 Tda de6 0 002 liy)-

para-Nitrophenol

CAS No. 100-02-7

Metabolite of Methyl Parathion, CAS No.298-00-0 and Ethyl Parathion, CAS No. 56-38-2

Symptoms of an acute overdose of methyl or ethyl parathion may include nausea, vomiting, cholinergic effects, weakness, paralysis, and seizures. Delayed peripheral neuropathy has been reported after chronic occupational exposure and acute overdose. The metabolite, *para*-nitrophenol, does not inhibit acetylcholinesterase enzymes. IARC does not consider ethyl parathion and methyl parathion classifiable as human carcinogens.

Interpreting Levels of Urinary *para*-Nitrophenol Reported in the Tables

Urinary levels of *para*-nitrophenol were measured in a subsample of NHANES participants aged 6-59 years. Participants were selected within the specified age range to be a representative sample of the U.S. population. In general, urinary *para*-nitrophenol levels in the NHANES 2001-2002 subsample appeared roughly similar to values in a nonrandom subsample of NHANES III (1988-1994) participants (Hill et al., 1995).

Considerably higher levels of *para*-nitrophenol have been measured in urine samples obtained from children and adults living in residences where methyl parathion was illegally applied indoors (Barr et al., 2002). The geometric mean concentration of *para*-nitrophenol in these individuals was approximately nine times higher than the 95th percentile values for the 2001-2002 NHANES subsample. In a study of workers who handle parathion, end-of-shift urinary *para*-nitrophenol levels ranged from 190-410 µg/gram of creatinine (Leng and Lewalter, 1999), a range of values that is much higher than the 95th percentile values in this *Report*. ACGIH (2001) recommends a BEI of 0.5 mg (500 µg)/g creatinine for workers at the end of shift.

Finding a measurable amount of *para*-nitrophenol in urine does not mean that the level will result in an adverse health effect. These data will help scientists plan and conduct research about the relation between exposure to methyl or ethyl parathion and health effects.

Table 275. *para*-Nitrophenol (creatinine corrected)

Geometric mean and selected percentiles of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6-59 years, National Health and Nutrition Examination Survey, 1999-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 6 and older	99-00	*	< LOD	< LOD	**2.08** (1.33-3.91)	**4.20** (2.15-10.2)	1989
	01-02	*	< LOD	**.968** (.826-1.10)	**1.91** (1.72-2.03)	**2.89** (2.44-3.23)	2476
Age group							
6-11 years	99-00	*	< LOD	**.938** (.609-1.95)	**2.80** (1.94-4.00)	**4.20** (3.33-6.70)	479
	01-02	*	**.715** (.543-.870)	**1.59** (1.30-1.82)	**2.74** (2.31-3.11)	**3.67** (3.11-4.61)	565
12-19 years	99-00	*	< LOD	< LOD	**1.79** (1.08-3.04)	**4.00** (1.57-7.29)	680
	01-02	*	**.372** (.250-.503)	**.839** (.790-.951)	**1.59** (1.37-1.78)	**2.09** (1.78-2.43)	812
20-59 years	99-00	*	< LOD	< LOD	**2.00** (1.17-4.08)	**4.29** (2.13-12.3)	830
	01-02	*	< LOD	**.875** (.693-1.07)	**1.79** (1.56-2.05)	**2.89** (2.35-3.33)	1099
Gender							
Males	99-00	*	< LOD	< LOD	**1.90** (1.01-3.39)	**3.39** (1.77-7.55)	971
	01-02	*	**.430** (.307-.535)	**.983** (.854-1.08)	**1.87** (1.57-2.09)	**2.97** (2.14-3.57)	1164
Females	99-00	*	< LOD	< LOD	**2.22** (1.48-4.88)	**6.90** (2.76-14.1)	1018
	01-02	*	< LOD	**.933** (.735-1.23)	**1.96** (1.78-2.15)	**2.81** (2.44-3.06)	1312
Race/ethnicity							
Mexican Americans	99-00	*	< LOD	**1.53** (.759-3.17)	**4.80** (2.21-21.9)	**17.4** (3.94-47.7)	695
	01-02	*	**.402** (.219-.543)	**.928** (.717-1.20)	**1.87** (1.41-2.60)	**3.04** (2.38-3.84)	660
Non-Hispanic blacks	99-00	*	< LOD	**.667** (.314-1.79)	**2.07** (1.33-3.71)	**3.71** (1.98-7.20)	518
	01-02	*	**.436** (.167-.636)	**1.01** (.801-1.31)	**1.71** (1.60-2.21)	**2.97** (2.16-4.30)	678
Non-Hispanic whites	99-00	*	< LOD	< LOD	**1.94** (1.07-4.29)	**3.75** (1.97-10.2)	603
	01-02	*	< LOD	**.967** (.786-1.13)	**1.96** (1.67-2.26)	**2.93** (2.35-3.45)	941

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.
* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

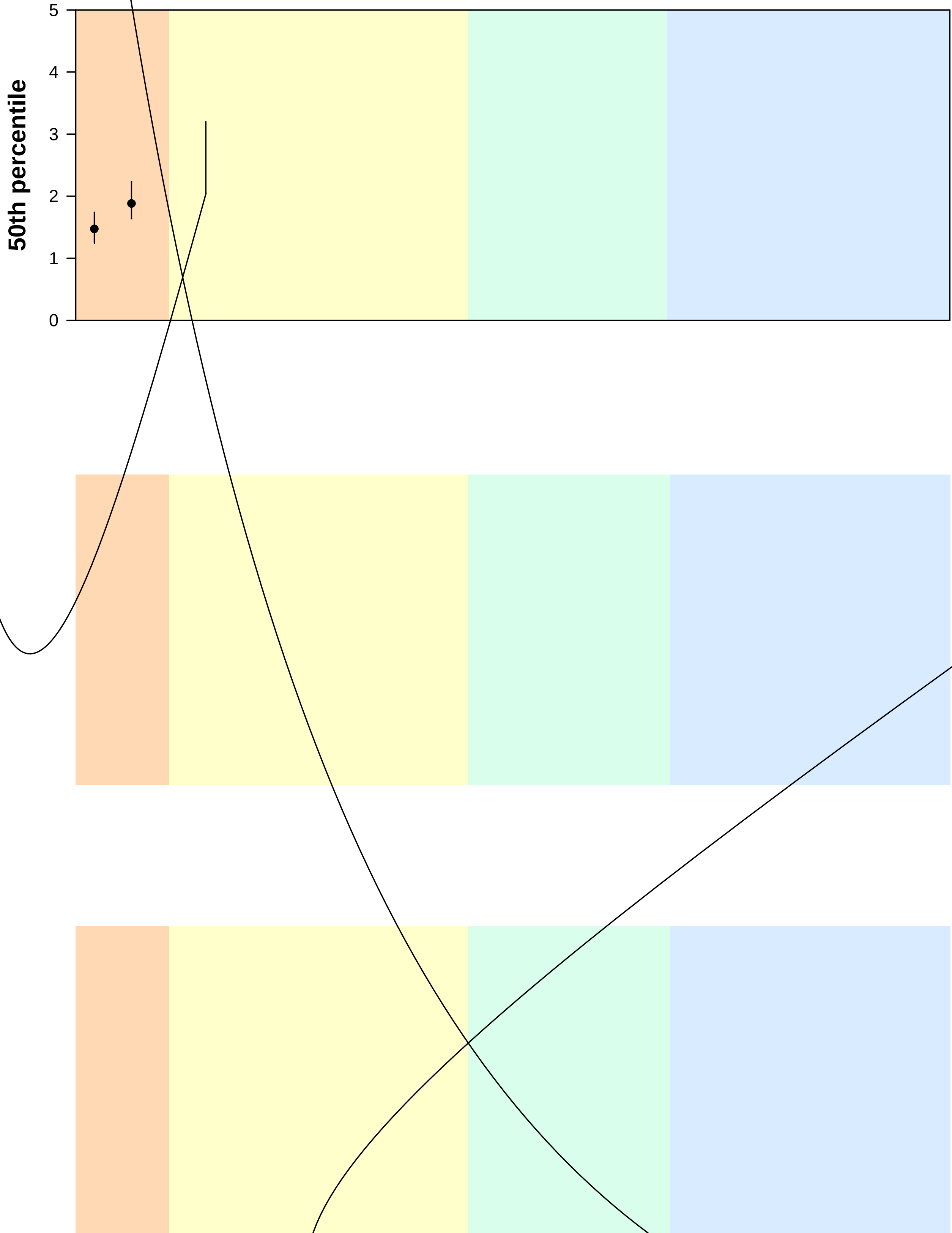
These data also provide physicians with a reference range so that they can determine whether or not other people have been exposed to higher levels of methyl and ethyl parathion than those levels found in the general population.

3,5,6-Trichloro-2-pyridinol
CAS No. 6515-38-4

Interpreting Levels of Urinary TCPy Reported in the Tables

Urinary TCPy levels were measured in a subsample of NHANES participants aged 6-59 years. Participants were selected within the specified age range to be a with age represent differences in exposure, pharmacokinetics, or the relationship of dose per body weight.

Finding a measurable amount of TCPy in urine does not mean that the level will result in an adverse health effect. These data will help scientists plan and conduct research about the relation between exposure to chlorpyrifos or chlorpyrifos-methyl and health effects. These data also provide physicians with a reference range so that they can determine whether or not other people have been exposed to higher levels of chlorpyrifos or chlorpyrifos-methyl than those levels found in the general population.


50th percentile
0
1
2
3
4
5

2-Isopropyl-4-methyl-6-hydroxypyrimidine

CAS No. 2814-20-2

Metabolite of Diazinon, CAS No. 333-41-5

General Information

The specific metabolite of diazinon is 2-isopropyl-4-methyl-6-hydroxypyrimidine. Diazinon is an organophosphate insecticide that is used to control pests on certain agricultural commodities (including almonds and fruits that contain stones or pits). It is also used as a veterinary insecticide on cattle. Approximately 13 million pounds of diazinon are used annually on agricultural sites in the United States, but diazinon is no longer registered for indoor residential use.

In addition to being a metabolite of diazinon in the body, 2-isopropyl-4-methyl-6-hydroxypyrimidine can also occur in the environment from the breakdown of the parent compound. Thus, the detection of 2-isopropyl-4-methyl-6 hydroxypyrimidine in a person's urine may also reflect exposure to the metabolite if it was present in a person's food or environment.

Diazinon is not well-absorbed through the skin but is rapidly absorbed in the body once ingested. Experimental diazinon exposure in people has shown a rapid elimination from the body, as inferred from dialkyl phosphate excretion (Garfitt et al., 2002). Diazinon and other organophosphates share a common mechanism of toxicity, inhibiting the activity of acetylcholinesterase enzymes in the nervous system. The metabolite 2-isopropyl-4-methyl-6-hydroxypyrimidine does not inhibit acetylcholinesterase enzymes.

Table 278. 2-Isopropyl-4-methyl-6-hydroxypyrimidine

	Survey years						Sample size
Total, age 6 and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1842
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	2535
Age group							
6-11 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	454
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**1.45** (<LOD-3.11)	580
12-19 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	

Interpreting Levels of Urinary 2-Isopropyl-4-methyl-6-hydroxypyrimidine Reported in the Tables

Urinary levels of 2-isopropyl-4-methyl-6-hydroxypyrimidine were measured in a subsample of NHANES participants aged 6-59 years. Participants were selected within the specified age range to be a representative sample of the U.S. population. In the NHANES 2001-2002 subsample, most of the measurements of 2-isopropyl-4-methyl-6-hydroxypyrimidine in urine were below the limit of detection. In a previous nonrandom sample of adults and children in the United States, 2-isopropyl-4-methyl-6-hydroxypyrimidine levels in urine ranged from non-detectable to 10 g/L (Baker et al., 2000).

Finding a measurable amount of 2-isopropyl-4-methyl-6-hydroxypyrimidine in urine does not mean that the level will result in an adverse health effect. These data will help scientists plan and conduct research about the relation between exposure to diazinon and health effects. These data also provide physicians with a reference range so that they can determine whether or not other people have been exposed to higher levels of diazinon than those levels found in the general population.

Table 279. 2-Isopropyl-4-methyl-6-hydroxypyrimidine (creatinine corrected)

Geometric mean and selected percentiles of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6-59 years, National Health and Nutrition Examination Survey, 1999-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)				Sample size
			50th	75th	90th	95th	
Total, age 6 and older	99-00	*	< LOD	< LOD	< LOD	< LOD	1842
	01-02	*	< LOD	< LOD	< LOD	< LOD	2534
Age group							
6-11 years	99-00	*	< LOD	< LOD	< LOD	< LOD	454
	01-02	*	< LOD	< LOD	< LOD	**2.58** (1.75-4.45)	580
12-19 years	99-00	*	< LOD	< LOD	< LOD	< LOD	632
	01-02	*	< LOD	< LOD	< LOD	< LOD	828
20-59 years	99-00	*	< LOD	< LOD	< LOD	< LOD	756
	01-02	*	< LOD	< LOD	< LOD	< LOD	1126
Gender							
Males	99-00	*	< LOD	< LOD	< LOD	< LOD	894
	01-02	*	< LOD	< LOD	< LOD	< LOD	1191
Females	99-00	*	< LOD	< LOD	< LOD	< LOD	948
	01-02	*	< LOD	< LOD	< LOD	< LOD	1343
Race/ethnicity							
Mexican Americans	99-00	*	< LOD	< LOD	< LOD	< LOD	644
	01-02	*	< LOD	< LOD	< LOD	< LOD	678
Non-Hispanic blacks	99-00	*	< LOD	< LOD	< LOD	< LOD	484
	01-02	*	< LOD	< LOD	< LOD	**1.76** (1.07-3.48)	699
Non-Hispanic whites	99-00	*	< LOD	< LOD	< LOD	< LOD	554
	01-02	*	< LOD	< LOD	< LOD	< LOD	956

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.
* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

2-(Diethylamino)-6-methylpyrimidin-4-ol/one

Metabolite of Pirimiphos-methyl, CAS No. 29232-93-7

General Information

The chemical 2-(diethylamino)-6-methylpyrimidin-4-ol/one is a specific metabolite of the organophosphate insecticide pirimiphos-methyl. Pirimiphos-methyl has limited applications in agriculture but is used as a veterinary insecticide. It is not registered for residential use in the United States.

In addition to being a metabolite of pirimiphos-methyl in the body, 2-(diethylamino)-6-methylpyrimidin-4-ol/one can also occur in the environment. Thus, the detection of 2-(diethylamino)-6-methylpyrimidin-4-ol/one may also reflect exposure to the metabolite if it was present in a person's food or environment. Pirimiphos-methyl and other organophosphate pesticides share a common mechanism of toxicity, inhibiting the activity of acetylcholinesterase enzymes in the nervous system. Pirimiphos-methyl has generally been shown to be of low acute toxicity. The metabolite 2-(diethylamino)-6-methylpyrimidin-4-ol/one does not inhibit acetylcholinesterase enzymes.

Interpreting Levels of Urinary 2-(Diethylamino)-6-methylpyrimidin-4-ol/one Reported in the Tables

Urinary levels of 2-(diethylamino)-6-methylpyrimidin-4-ol/one were measured in a subsample of NHANES participants aged 6 years and older. Participants were selected within the specified age range to be a representative sample of the U.S. population. In the NHANES 2001-2002 subsample, most urinary levels of 2-(diethylamino)-6-methylpyrimidin-4-ol/one were below the limit of detection. In a study of urine specimens obtained from a nonrandom sample of adults and children in the United States, Olsson et al. (2003) found that the geometric mean concentration of 2-(diethylamino)-6-methylpyrimidin-4-ol/one was 4.1 ng/mL urine, with values ranging from non-detectable to 37 ng/mL.

Finding a measurable amount of 2-(diethylamino)-6-methylpyrimidin-4-ol/one in urine does not mean that the level will result in an adverse health effect. These data will help scientists plan and conduct research about the relation between exposure to pirimiphos-methyl and health effects. These data also provide physicians with a reference range so that they can determine whether or not other people have been exposed to higher levels of pirimiphos-methyl than levels found in the general population.

Table 281. 2-(Diethylamino)-6-methylpyrimidin-4-ol/one (creatinine corrected)

Geometric mean and selected percentiles of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6-59 years, National Health and Nutrition Examination Survey, 2001-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 6 and older	01-02	*	< LOD	< LOD	< LOD	**.778** (.700-.933)	2481
Age group							
6-11 years	01-02	*	< LOD	< LOD	**.680** (.560-.953)	**1.17** (.737-1.27)	567
12-19 years	01-02	*	< LOD	< LOD	< LOD	**.667** (.467-1.31)	810
20-59 years	01-02	*	< LOD	< LOD	< LOD	**.764** (.667-.875)	1104
Gender							
Males	01-02	*	< LOD	< LOD	< LOD	**.732** (.572-.986)	1165
Females	01-02	*	< LOD	< LOD	< LOD	**.778** (.667-1.00)	1316
Race/ethnicity							
Mexican Americans	01-02	*	< LOD	< LOD	< LOD	**.778** (.556-1.21)	669
Non-Hispanic blacks	01-02	*	< LOD	< LOD	< LOD	< LOD	687
Non-Hispanic whites	01-02	*	< LOD	< LOD	< LOD	**.778** (.700-.933)	929

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.

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

3-Chloro-7-hydroxy-4-methyl-2H-chromen-2-one/ol

Metabolite of Coumaphos
CAS No.56-72-4

General Information

Results by Chemical Group

Herbicides

Herbicides

General Information

Herbicides are chemicals used to control undesirable weeds and plants in agricultural, residential, and aquatic environments. More herbicides are used annually than insecticides, with about 553 million pounds used in the

2,4,5-Trichlorophenoxyacetic Acid

CAS No. 93-76-5

General Information

The herbicide 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) is a chlorophenoxy acid herbicide that was once registered for use in the United States. Concern about its contamination with 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) led to the discontinuation of 2,4,5-T in 1985.

Although 2,4,5-T is rapidly absorbed via oral and inhalation routes, it is not well absorbed through the skin. Once absorbed into the body, 2,4,5-T distributes widely and then is rapidly eliminated unchanged in the urine, with an elimination half-life of approximately 19 hours (Kohli et al., 1974

and 0 Tc -The herbs.20012v66.6 Tm( )TjETEMC /P 8MCID 6 BDC BT/TT2 1 Tf0 Tc 7.98 0 0 7.98521.5 706.36 Tm( )TjETEMC /P

In the NHANES 2001-2002 subsample, urinary levels of 2,4,5-T were generally below the limit of detection. This finding is similar to the findings in the NHANES 1999-2000 subsample and is consistent with results of NHANES II (1976-1980), which showed that urinary levels of 2,4,5-T were below the limit of detection (Kutz et al., 1992). In contrast, detectable levels of 2,4,5-T were reported among asymptomatic herbicide applicators when measured after a day of exposure, with urinary levels ranging 1-11   g/mL (Kolmodin-Hedman and Erne, 1980).

Finding a measurable amount of 2,4,5-T in urine does not mean that the level of the 2,4,5-T will result in an adverse health effect. These data will help scientists plan and conduct research about the relation of exposure to 2,4,5-T and health effects. These data also provide physicians with a reference range so that they can determine whether other people have been exposed to higher levels of 2,4,5-T than levels found in the general population.

Table 286. 2,4,5-Trichlorophenoxyacetic acid (creatinine corrected)

	Survey years			Sample size
Total, age 6 and older	99-00	*		

2,4-Dichlorophenoxyacetic Acid

CAS No. 94-75-7

95th percentile value from a nonrandom subsample from

2,4-Dichlorophenol

CAS No. 120-83-2

General Information

The chemical 2,4-dichlorophenol is a minor metabolite of the herbicide 2,4-dichlorophenoxyacetic acid (2,4-D) that can also result from the metabolism of several other environmental chemicals or can be formed as a byproduct during the manufacture of many chemicals.

A lipid-soluble chemical, 2,4-dichloro12 Tc 0.0002 Tu be formed as a

Comparing Adjusted Geometric Means

Geometric mean levels of urinary 2,4-dichlorphenol levels could not be calculated for the 2001-2002 subsample due to the insufficient rate of detection. Geometric mean levels for the previous 1999-2000 subsample were compared after adjusting for the covariates of race/ethnicity, age, gender, and urine creatinine (data not shown). Non-Hispanic whites had a lower adjusted geometric mean levels of urinary 2,4-dichlorphenol than Mexican Americans. It is unknown whether these differences associated with race/ethnicity represent differences in exposure, pharmacokinetics, or the relationship of dose per body weight.

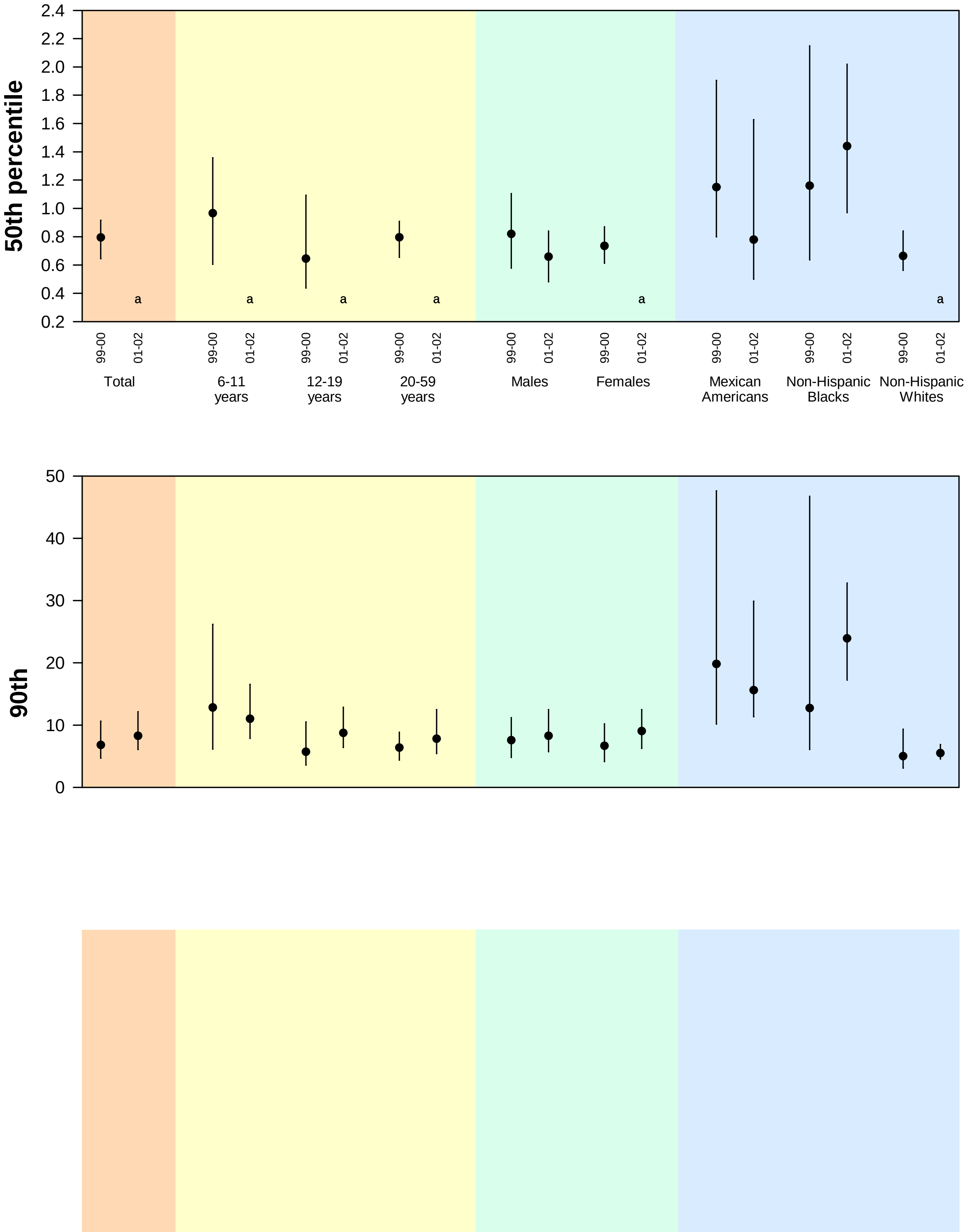
Finding a measurable amount of 2,4-dichlorophenol in urine does not mean that the level of the 2,4-dichlorophenol will result in an adverse health effect. These data will help scientists plan and conduct research about the relation between exposure to 2,4-dichlorophenol and health effects. These data also provide physicians with a reference range so that they can determine whether other people have been exposed to higher levels of 2,4-dichlorophenol than levels found in the general population.

Table 290. 2,4-Dichlorophenol (creatinine corrected)

	Survey years						Sample size
Total, age 6 and older	99-00	**.994** (.790-1.25)	**.794** (.645-.917)	**2.15** (1.31-3.64)	**6.79** (4.68-10.6)	**13.9** (9.89-23.7)	1990
	01-02	*	< LOD	**2.62** (2.09-3.17)	**8.24** (6.06-12.1)	**18.0** (12.5-26.2)	2502
Age group							
6-11 years	99-00	**1.37** (.932-2.01)	**.966** (.605-1.36)	**3.15** (1.82-6.79)	**12.8** (6.12-26.2)	**25.3** (11.5-76.9)	481
	01-02	*	< LOD	**3.01** (1.75-5.49)	**11.0** (7.88-16.5)	**26.4** (12.5-58.4)	574
12-19 years	99-00	**.877** (.629-1.22)	**.645** (.438-1.09)	**2.19** (1.22-4.19)	**5.70** (3.55-10.5)	**10.3** (5.19-20.8)	679
	01-02	*	< LOD	**2.59** (1.89-3.54)	**8.72** (6.40-12.9)	**17.7** (14.6-22.5)	819
20-59 years	99-00	**.967** (.784-1.19)	**.795** (.654-.909)	**1.95** (1.23-3.42)	**6.36** (4.35-8.84)	**11.6** (8.70-26.5)	830
	01-02	*	< LOD	**2.58** (1.95-3.20)	**7.77** (5.41-12.5)	**17.2** (10.6-26.8)	1109
Gender							
Males	99-00	**1.04**1109110m[((,-0.0039 Tc 110m[(Tc 1 42.96 0 6.9553 492.5999 257.8201 Tm((8.70-26.5))Tj-0.0078P>6 .)-9(6)]TJ/TT7					

Figure 37. 2,4-Dichlorophenol (creatinine corrected)

Selected percentiles with 95% confidence intervals of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6-59 years, National Health and Nutrition Examination Survey, 1999-2002.



Atrazine Mercapturate

Metabolite of Atrazine, CAS No. 1912-24-9

General Information

Atrazine, one of the most widely used herbicides in the United States, inhibits photosynthesis in broadleaf and some grassy weeds. An estimated of 65-75 million pounds of atrazine are applied in the United States each year. It is used in agricultural and forestry applications and on recreational turfs. Atrazine is registered for use on corn, sorghum, sugarcane, and certain other agricultural commodities. Use on corn accounts for 86% of its use. Atrazine is also registered for use on golf courses and, in some regions of the United States, on residential lawns (U.S. EPA, 2003*a*). Atrazine takes several days to have toxicity similar to atrazine. Atrazine is listed as “not classifiable” by IARC and as “not likely to be a human carcinogen” by the U.S. EPA.

Interpreting Levels of Urinary Atrazine Mercapturate Reported in the Tables

Urinary levels of atrazine mercapturate were measured in a subsample of NHANES participants aged 6-59 years. Participants were selected within the specified age range to be a representative sample of the U.S. population.

In the both NHANES 1999-2000 and 2001-2002 subsamples, urinary levels of atrazine mercapturate were below the limit of detection. A low frequency of detection for atrazine mercapturate in urine was previously reported in the U.S. population (Macintosh et al., 1999) and in a study of children 3-13 years of age (Adgate et al., 2001). In contrast, atrazine has been detected more frequently among farmers who apply this herbicide. For example, atrazine was detected at a mean concentration of 14.2 µg/L in a study of farmers (Perry et al., 2000).

Finding a measurable amount of atrazine mercapturate in urine does not mean that the level will result in an adverse health effect. These data will help scientists plan and conduct research about the relation between exposure to atrazine and health effects. These data also provide physicians with a reference range so that they can determine whether other people have been exposed to higher levels of atrazine mercapturate than levels found in the general population.

Table 292. Atrazine mercapturate (creatinine corrected)

	Survey years						Sample size
Total, age 6 and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1878
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	2476
Age group							
6-11 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	449
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	568
12-19 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	639
	01-02	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	808
20-59 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	790
*							

Alachlor Mercapturate

Metabolite of Alachlor, CAS No. 15972-60-8

General Information

Alachlor is a restricted-use herbicide that is used for weed control on certain agricultural commodities including corn, soybeans, sorghum, peanuts, and beans. In animal studies, alachlor has generally been shown to be of low acute toxicity. The U.S. EPA has classified alachlor as not likely to be carcinogenic in humans at low doses.

Interpreting Levels of Urinary Alachlor Mercapturate Reported in the Tables

Urinary levels of alachlor mercapturate were measured in a subsample of NHANES participants aged 6-59 years. Note that data are not available for 2001-2002. Participants were selected within the specified age range to be a representative sample of the U.S. population. In the NHANES 1999-2000 subsample, urinary levels of alachlor mercapturate were generally not detectable. A study of herbicide applicators detected alachlor mercapturate in 60% of urine samples at concentrations ranging from 1.98-9.1 µg/L (Hines et al., 2003).

Finding a measurable amount of alachlor mercapturate in urine does not mean that the level will result in an adverse health effect. These data will help scientists plan and conduct research about the relation between exposure to alachlor and health effects. These data also provide physicians with a reference range so that they can determine whether other people have been exposed to higher levels of alachlor mercapturate than levels found in the general population.

Table 293. Alachlor mercapturate

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

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 6 and older	99-00	*	< LOD	< LOD	< LOD	< LOD	1942
Age group							
6-11 years	99-00	*	< LOD	< LOD	< LOD	< LOD	463
12-19 years	99-00	*	< LOD	< LOD	< LOD	< LOD	662
20-59 years	99-00	*	< LOD	< LOD	< LOD	< LOD	817
Gender							
Males	99-00	*	< LOD	< LOD	< LOD	< LOD	950
Females	99-00	*	< LOD	< LOD	< LOD	< LOD	992
Race/ethnicity							
Mexican Americans	99-00	*	< LOD	< LOD	< LOD	< LOD	679
Non-Hispanic blacks	99-00	*	< LOD	< LOD	< LOD	< LOD	507
Non-Hispanic whites	99-00	*	< LOD	< LOD	< LOD	< LOD	586

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.
* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

Table 294. Alachlor mercapturate (creatinine corrected)

	Survey years						Sample size
Total, age 6 and older	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	1942
Age group							
6-11 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	463
12-19 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	662
20-59 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	817
Gender							
Males	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	950
Females	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	

Acetochlor Mercapturate

Metabolite of Acetochlor, CAS No. 34256-82-1

Table 298. Metolachlor mercapturate (creatinine corrected)

Pyrethroid Pesticides

4-Fluoro-3-phenoxybenzoic Acid

CAS No. 77279-89-1

Metabolite of Cyfluthrin, CAS No.68359-37-5

General Information

The chemical 4-fluoro-3-phenoxybenzoic acid is a specific metabolite of the pyrethroid insecticide cyfluthrin. Exposure to cyfluthrin may occur from the diet (including from certain fruits, vegetables, and grains), residential applications in homes and gardens, and from other indoor or outdoor locations where this pesticide is used.

Cyfluthrin is rapidly metabolized and eliminated from the body. The mean elimination half-life of cyfluthrin was 16 hours after an indoor application of this pesticide (Williams et al., 2003).

Interpreting Levels of Urinary 4-Fluoro-3-Phenoxybenzoic Acid Reported in the Tables

Urinary levels of 4-fluoro-3-phenoxybenzoic acid were measured in a subsample of NHANES participants aged 6 years and older. Participan

dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid in 30% of urine samples obtained from adults and children in the general population (Heudorf and Angerer, 2001*d*). In that study, urinary metabolite levels in adults and children were similar. Higher levels of *cis*-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid (up to 12.8 µg/L) have been measured in urine samples obtained from pyrethroid insecticide applicators (Leng et al., 2003).

Finding a measurable amount of *cis*-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid in urine does not mean that the level will result in an adverse health effect. These data will help scientists plan and conduct research about the relation between exposure to pyrethroid insecticides and health effects. These data also provide physicians with a reference range so that they can determine whether or not other people have been exposed to higher levels of pyrethroids than levels found in the general population.

Table 303. *cis*-3-(2,2-Dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid (creatinine corrected)

	Survey years			Sample size
Total, age 6 and older	01-02	*		

cis-3-(2,2-Dibromovinyl)-2,2-dimethylcyclopropane Carboxylic Acid

CAS No. 63597-73-9

Metabolite of Deltamethrin, CAS No. 52918-63-5

General Information

Cis-3-(2,2-dibromovinyl)-2,2-dimethylcyclopropane carboxylic acid is a specific metabolite of the pyrethroid insecticide deltamethrin. Exposure to deltamethrin may occur from the diet and its application in indoor or outdoor locations, including homes and gardens.

The metabolic transformation of deltamethrin to *cis*-3-(2,2-dibromovinyl)-2,2-dimethylcyclopropane carboxylic acid can also occur in the environment (International Programme on Chemical Safety, 1990). Thus, in addition to reflecting exposure to deltamethrin, the detection of *cis*-3-(2,2-dibromovinyl)-2,2-dimethylcyclopropane carboxylic acid in the urine may also reflect exposure to the metabolite if it was present in a person's food or environment. Deltamethrin is not considered a persistent pesticide in the body.

Interpreting Levels of Urinary *cis*-3-(2,2-Dibromovinyl)-2,2-Dimethylcyclopropane Carboxylic Acid Reported in the Tables

Urinary levels of *cis*-3-(2,2-dibromovinyl)-2,2-dimethylcyclopropane carboxylic acid were measured in a subsample of NHANES participants aged 6 years and older. Participants were selected within the specified age range to be a representative sample of the U.S. population. In the NHANES 2001-2002 subsample, urinary levels of *cis*-3-(2,2-dibromovinyl)-2,2-dimethylcyclopropane carboxylic acid were below the limit of detection. In a previous analysis of 217 urine specimens from a nonrandom sample of individuals in the United States that included cases of possible exposure to residential insecticides, the geometric mean concentration of *cis*-3-(2,2-dibromovinyl)-2,2-dimethylcyclopropane carboxylic acid was 0.39 µg/L (Baker et al., 2004). Results of a study of German children and adults showed that the mean urinary concentration of *cis*-3-(2,2-dibromovinyl)-2,2-dimethylcyclopropane carboxylic acid was 0.08 µg/gram creatinine (Heudorf and Angerer, 2001*d*). In another German study, *cis*-3-(2,2-dibromovinyl)-2,2-dimethylcyclopropane carboxylic acid was detected in 19% of urine samples obtained from adults and children in the general population (Heudorf and Angerer, 2001*d*) with adults and children having similar levels of urinary metabolite.

Table 306. *cis*-3-(2,2-Dibromovinyl)-2,2-dimethylcyclopropane carboxylic acid

Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6-59 years, National Health and Nutrition Examination Survey, 2001-2002.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total, age 6 and older	01-02	*	< LOD	< LOD	< LOD	< LOD	2539
Age group							
6-11 years	01-02	*	< LOD	< LOD	< LOD	< LOD	580
12-19 years	01-02	*	< LOD	< LOD	< LOD	< LOD	831
20-59 years	01-02	*	< LOD	< LOD	< LOD	< LOD	1128
Gender							
Males	01-02	*	< LOD	< LOD	< LOD	< LOD	1193
Females	01-02	*	< LOD	< LOD	< LOD	< LOD	1346
Race/ethnicity							
Mexican Americans	01-02	*	< LOD	< LOD	< LOD	< LOD	680
Non-Hispanic blacks	01-02	*	< LOD	< LOD	< LOD	< LOD	701
Non-Hispanic whites	01-02	*	< LOD	< LOD	< LOD	< LOD	957

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.
* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

3-Phenoxybenzoic Acid

CAS No. 3739-38-6

Metabolite of Cypermethrin, CAS No.52315-07-8, Deltamethrin, CAS No. 52918-63-5; and Permethrin, CAS No. 52645-53-1

General Information

The chemical 3-phenoxybenzoic acid is a metabolite of cypermethrin, deltamethrin, permethrin, and possibly other pyrethroid insecticides. Thus, the detection of this metabolite in the urine may reflect multiples sources of environmental exposure to different pyrethroid insecticides. The metabolic transformation of certain pyrethroids to 3-phenoxybenzoic acid occurs in the body as well as in the environment. Thus, in addition to reflecting exposure to certain pyrethroids, so detecting 3-phenoxybenzoic acid in the urine may also reflect exposure to the metabolite if it was present in a person's food or environment.

Interpreting Levels of Urinary 3-Phenoxybenzoic Acid Reported in the Tables

Urinary levels of 3-phenoxybenzoic acid were measured in a subsample of NHANES participants aged 6 years and older. Participants were selected within the specified age range to be a representative sample of the U.S. population.

In the NHANES 2001-2002 subsample, the median concentration 3-phenoxybenzoic acid in urine was similar to measurements reported in a study of German adults aged 17-61 years (Schettgen et al., 2002*b*). In a previous analysis of 217 urine specimens from a nonrandom sample of individuals in the United States that included cases of possible exposure to residential insecticides, geometric mean levels of 3-phenoxybenzoic acid were approximately six-fold higher than levels in the NHANES 2001-2002 subsample (Baker et al., 2004).

A previous study of adults and children in the United States reported the detection of 3-phenoxybenzoic acid in 12% of urine samples at concentrations of up to 30 g/g creatinine (Baker et al., 2000). In a study by Leng et al. (2003), 3-phenoxybenzoic acid was detected in 25% of urine samples obtained from adult pest-control operators applying pyrethroid insecticides, and metabolite concentrations were observed to increase during the first 48 hours after an application. In that study, 3-phenoxy-benzoic acid levels in urine ranged 0.1-11.5 g/L.

Table 308. 3-Phenoxybenzoic acid

	Survey years						Sample size
Total, age 6 and older	01-02	**.321** (.276-.374)	**.280** (.220-.340)	**.690** (.560-.810)	**1.69** (1.41-2.33)	**3.32** (2.52-5.25)	2539
Age group							
6-11 years	01-02	**.325** (.260-.406)	**.300** (.200-.410)	**.750** (.560-1.03)	**1.81** (1.34-2.69)	**3.28** (2.25-4.12)	580
12-19 years	01-02	**.353** (.288-.434)	**.290** (.250-.390)	**.800** (.560-1.13)	**1.85** (1.48-2.35)	**3.45** (2.14-6.69)	831
20-59 years	01-02	**.314**	**.290**.254-.390)				

dermal study in animals using OPP and found no evidence of carcinogenicity.

2,5-Dichlorophenol

CAS No. 583-78-8

Metabolite of para-*Dichlorobenzene, CAS No. 106-47-7*

General Information

The chemical 2,5-dichlorophenol is a metabolite of *para*-dichlorobenzene (*p*-dichlorobenzene), which is used in moth balls, some room deodorizers, and previously as an insecticidal fumigant. *Para*-dichlorobenzene can be absorbed through oral, dermal, or pulmonary exposure. Absorbed *p*-dichlorobenzene can be excreted unchanged in the urine. Once metabolized in the body to 2,5-dichlorophenol, it is conjugated to glutathione and excreted in the urine.

Eye and respiratory irritation may occur at air levels higher than levels encountered with normal uses. Liver necrosis has been observed in workers after prolonged heavy applications of *p*-dichlorobenzene (Cotter, 1953).

The NTP considers *p*-dichlorobenzene as possibly carcinogenic to humans, and IARC considers *p*-dichlorobenzene as reasonably anticipated to be a human carcinogen. Information about external exposure (i.e., environmental levels) and health effects is available from the U.S. EPA's IRIS Web site at http://www.epa.gov/iris and from ATSDR's Toxicological Profiles at http://www.atsdr.cdc. gov/toxprofiles.

Interpreting Levels of Urinary 2,5-Dichlorophenol Reported in the Tables

Urinary levels of 2,5-dichlorophenol were measured in a subsample of NHANES participants aged 6-59 years. Participants were selected within the specified age range to be a representative sample of the U.S. population.

Table 314. 2,5-Dichlorophenol

	Survey years	mean (95% conf. interval)		(95% confidence interval)		19405.04ref41	Sample size
Total, age 6 and older	99-00	**6.01** (4.19-8.64)	**6.50** (5.00-9.10)	**37.8** (24.0-47.0)	**144** (88.0-240)	**440** (290-620)	1989
	01-02	*	**2.04** (<LOD-6.48)	**28.8** (20.5-40.2)	**194** (115-255)	**657** (301-1150)	2502
Age group							
6-11 years	99-00	**7.57** (4.62-12.4)	**9.00** (4.70-12.0)	**46.0** (27.0-90.8)	**240** (130-610)	**630** (400-750)	480
	01-02	*	**1.62** (<LOD-11.5)	**34.5** (19.6-107)	**265** (151-536)	**683** (326-1790)	574
12-19 years	99-00	**5.85** (3.80-9.00)	**4.80** (4.10-6.80)	**32.0** (18.0-45.0)	**130** (66.0-280)	**382** (150-950)	680
	01-02	*	**3.51** (<LOD-12.4)	**32.9** (21.6-56.3)	**194** (106-323)	**733** (389-1140)	820
20-59 years	99-00	**5.82** (4.05-8.37)	**6.60** (5.30-9.30)	**36.7** (24.0-45.0)	**130** (86.0-200)	**420** (240-590)	829
	01-02	*	**1.86** (<LOD-6.09)	**27.3** (16.9-42.0)	**186** (99.7-281)	**641** (256-1190)	1108
Gender							
Males	99-00	**6.84** (4.73-9.89)	**7.90** (5.70-11.0)	**37.0** (21.0-55.0)	**150** (88.0-280)	**440** (210-550)	970
	01-02	*	**2.41** (<LOD-8.94)	**31.9** (24.7-44.8)	**189** (108-316)	**663** (251-1210)	1178
Females	99-00	**5.30** (3.34-8.42)	**5.40** (3.80-7.90)	**37.8** (23.0-46.0)	**150** (82.0-260)	**490** (250-740)	1019
	01-02	*	**1.41** (<LOD-5.78)	**24.6** (14.6-40.8)	**194** (95.5-278)	**624** (256-1320)	1324
Race/ethnicity							
Mexican Americans	99-00	**14.3** (5.24-38.8)	**13.0** (7.90-26.0)	**110** (24.0-500)	**660** (210-1200)	**1100** (510-2800)	695
	01-02	*	**12.7** (5.02-27.3)	**97.7** (53.2-195)	**532** (300-1040)	**1550** (641-2980)	677
Non-Hispanic blacks	99-00	**15.8** (9.92-25.2)	**19.0** (11.0-29.0)	**110** (61.0-160)	**460** (290-620)	**770** (470-1200)	517
	01-02	*	**31.5** (24.2-40.2)	**242** (145-404)	**1210** (774-1680)	**2520** (1600-4500)	696
Non-Hispanic whites	99-00	**3.81** (2.38-6.09)	**4.40** (3.00-5.80)	**19.0** (13.0-24.0)	**75.0** (55.0-100)	**170** (120-320)	603
	01-02	*	**< LOD**	**15.2** (7.54-25.1)	**67.9** (40.8-103)	**194** (109-289)	930

< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.

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

Levels of 2,5-dichlorophenol in a nonrandom subsample of NHANES III (1988-1994) participants were 5-15 times higher than the levels published in this *Report* (Hill et al., 1995). In the 1999 German Environmental Survey for people aged 16-69 years, median 2,5-dichlorophenol levels were similar to the median in the 2001-2002 subsample, but the 90th percentile was 17-fold lower than the NHANES 2001-2002 value, possibly indicating a wider range of exposures in the United States. Urinary levels of 2,5-dichlorophenol have been shown to correlate with environmental air-exposure levels in a convenience sample of Japanese citizens (Yoshida et al., 2002).

Worker exposure to p-dichlorobenzene has resulted in urinary 2,5-dichlorophenol levels that are much higher than levels in either of the two NHANES subsamples. At a mean air concentration of 25 parts per million (ppm), the corresponding urinary level of 2,5-dichlorophenol was 50 mg (50,000 µg)/gram of creatinine (Pagnotto and Walkley, 1965).

Comparing Adjusted Geometric Means

Geometric mean levels of urinary 2,5-dichlorphenol could not be calculated on the 2001-2002 subsample due to an insufficient detection rate. Geometric mean levels of 2,5-dichlorophenol for the demographic groups in the 1999-2000 subsample were compared after adjusting for the covariates of race/ethnicity, age, gender, and urinary creatinine (data not shown). The group aged 6-11 years had higher adjusted geometric mean levels of urinary 2,5-dichlorophenol than the group aged 12-19 years. Non-Hispanic whites had lower levels than either non-Hispanic blacks or Mexican Americans. It is unknown whether these differences associated with age or race/ethnicity represent differences in exposure, pharmacokinetics, or the relationship of dose per body weight.

Finding a measurable amount of 2,5-dichlorophenol in urine does not mean that the level will result in an adverse health effect. These data will help scientists plan

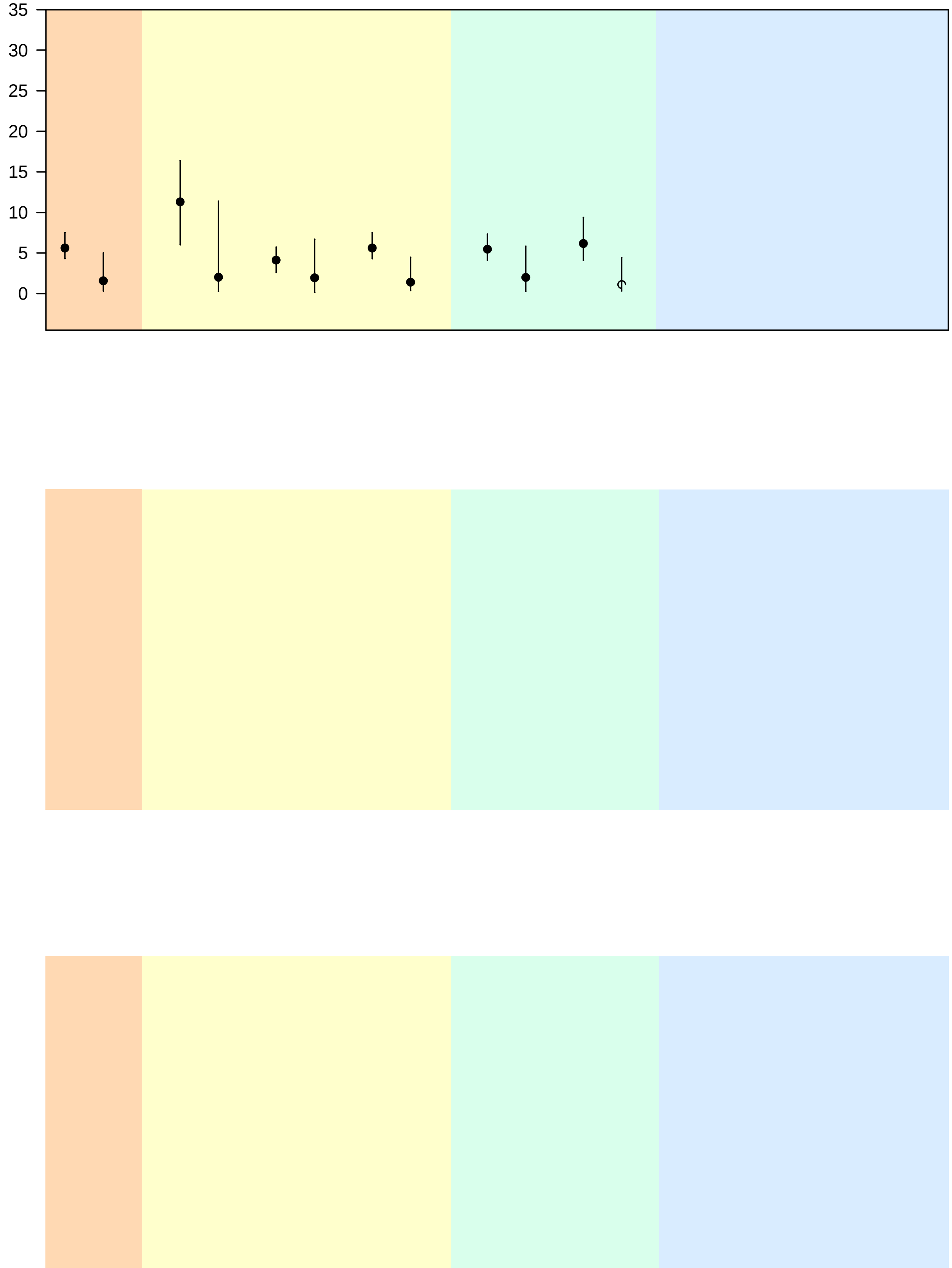
Table 315. 2,5-Dichlorophenol (creatinine corrected)

	Survey years						Sample size
Total, age 6 and older	99-00	**5.38** (3.76-7.68)	**5.60** (4.30-7.54)	**26.0** (19.6-34.5)	**125** (72.8-213)	**299** (238-426)	1989
	01-02	*	**1.56** (.333-5.00)	**23.9** (15.9-31.8)	**133** (97.0-238)	**527** (268-860)	2501
Age group							
6-11 years							

and conduct research about the relation between exposure to *p*-dichlorobenzene and health effects. These data also provide physicians with a reference range so that they can determine whether or not other people have been exposed to higher levels of *p*-dichlorobenzene than those levels found in the general population.

Figure 38. 2,5-Dichlorophenol **(creatinine corrected)**

Geometric mean and selected percentiles of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6-59 years, National Health and Nutrition Examination Survey, 1999-2002.



Carbamate Insecticides

Carbamate Insecticides

General Information

N-methyl carbamate insecticides are widely used as insecticides in the United States and throughout the world. The estimated annual worldwide use for all

Alfven T, Jarup L, Elinder CG. Cadmium and lead in blood in relation to low bone mineral density and tubular proteinuria. Environ Health Perspect 2002;110:699-702.

Allain P, Berre S, Premel-Cabic A, Mauras Y, Cledes A, Cournot A. Urinary elimination of molybdenum by healthy subjects as determined by inductively coupled plasma mass spectrometry. Magnesium and Trace Elements 1991-1992;10(1):47-50.

Ambrose AM, Yost DH. Pharmacologic and toxicologic studies of N,N-diethyltoluamide. II. N,N-Diethyl-o-toluamide and N,N-diethyl-p-toluamide. Toxicol Appl Pharmacol 1965; 7(6):772-80.

American Conference of Government Industrial Hygienists (ACGIH). Documentation of biological exposure indices. 7th edition. Cincinnati (OH): ACGIH Worldwide; 2001.

Anderson HA, Falk C, Hanrahan L, Olson J, Burse VW, Needham LL, et al. Profiles of Great Lakes critical pollutants: a sentinel analysis of human blood and urine. The Great Lakes Consortium. Environ Health Perspect 1998;106(5):279-89.

Anderson WA, Castle L, Scotter MJ, Massey RC, Springall C. A biomarker approach to measuring human dietary exposure to certain phthalate diesters. Food Addit Contam 2001;18(12):1068-74.

Angerer J, Heinzow B, Schaller K H, Weltle D, Lehnert G. Determination of environmentally caused chlorophenol levels in urine of the general population. Fresenius' Journal of Analytical Chemistry 1992;342(4-5):433-8.

Angerer J, Maass R, Heinrich R. Occupational exposure to hexachlorocyclohexane. VI. Metabolism of gamma-hexachlorocyclohexane in man. Int Arch Occup Environ Health 1983;52(1):59-67.

Angerer J, Ritter A. Determination of metabolites of pyrethroids in human urine using solid-phase extraction and gas chromatography-mass spectrometry. J Chromatogr B Biomed Sci Appl 1997;695(2):217-26.

Apostoli P, Baj A, Bavazzano P, Ganzi A, Neri A, Ronchi L, et al. Blood lead reference values: the results of an Italian polycentric study. Sci Total Environ 2002*a*;287:1-11.

Apostoli P, Cortesi I, Mangili A, Elia G, Drago I, Gagliardi T, et al. Assessment of reference values for mercury in urine: the results of an Italian polycentric study. Sci Total Environ 2002*b*;289:13-24.

Apostoli P, Schaller KH. Urinary beryllium--a suitable tool for assessing occupational and environmental beryllium exposure. Int Arch Occup Environ Health 2001;74:162-6.

Aprea C, Betta A, Catenacci G, Lotti A, Magnaghi S, Barisano A, et al. Reference values of urinary 3,5,6-trichloro-2-pyridinol in the Italian population--validation of analytical method and preliminary results (multicentric study). J AOAC Int 1999;82:305-12.

Aprea C, Sciarra G, Orsi D, Boccalon P, Sartorelli P, Sartorelli E. Urinary excretion of alkylphosphates in the general population (Italy). Sci Total Environ 1996;177:37-41.

Aprea C, Strambi M, Novelli MT, Lunghini L, Bozzi N. Biologic monitoring of exposure to organophosphorus pesticides in 195 Italian children. Environ Health Perspect 2000;4a70;4a70;ocRi-5(eca15(eca1c(ec)-5(I(e)6(g)-5(e)-1(n)-5(e)5(ral)

Bailly R, Lauwerys R, Buchet JP, Mahieu P, Konings J. Experimental and human studies on antimony metabolism: their relevance for the biological monitoring of workers exposed to inorganic antimony. British Journal of Industrial Medicine 1991;48:93-7.

Baker DB, Loo S, Barker J. Evaluation of human exposure to the heptachlor epoxide contamination of milk in Hawaii. Hawaii Med J 1991;50(3):108-12,118.

Baker SE, Barr DB, Driskell WJ, Beeson MD, Needham LL. Quantification of selected pesticide metabolites in human urine using isotope dilution high-performance liquid chromatography/tandem mass spectrometry. J Expo Anal Environ Epidemiol 2000;10:789-98.

Baker SE, Olsson AO, Barr DB. Isotope dilution high-performance liquid chromatography-tandem mass spectrometry method for quantifying urinary metabolites of synthetic pyrethroid insecticides. Arch Environ Contam Toxicol 2004;46:281-8.

Balluz L, Philen R, Ortega L, Rosales C, Brock J, Barr D, et al. Investigation of systemic lupus erythematosus in Nogales, Arizona. Am J Epidemiol 2001;154(11):1029-36.

Barr DB, Wilder LC, Caudill SP, Gonzalez AJ, Needham LL, Pirkle JL. Urinary creatinine concentrations in the U.S. population: implications for urinary biologic monitoring measurements. Environ Health Perspect 2005;113(2):192-200.

Barr DB, Silva MJ, Kato K, Reidy JA, Malek NA, Hurtz D, et al. Assessing human exposure to phthalates using monoesters and their oxidized metabolites as biomarkers. Environ Health Perspect 2003;111(9):1148-51.

Barr DB, Turner WE, DiPietro E, McClure PC, Baker SE, Barr JR, et al. Measurement of p-nitrophenol in the urine of residents who5 TduGns in esH1Pux

Bhatnagar VK, Kashyap R, Zaidi SS, Kulkarni PK, Saiyed HN. Levels of DDT, HCH, and HCB residues in human blood in Ahmedabad, India. Bull Environ Contam Toxicol 2004;72:261-5.

Bhattacharyya MH, Breitenstein BD, Metivier H, Muggenburg, BA, Stradling GN, Volf V. Guidebook for the treatment of accidental internal radionuclide contamination of workers. In: Gerber GB, Thomas RG, eds. Radiation protection dosimetry. Vol. 41 (1). Kent (England): Nuclear Technology Publishing; 1992. p. 1-49.

Bidstrup PL, Bonnell JA, Harvey DG, Locket S. Chronic mercury poisoning in men repairing direct-current meters.

Dang HS, Pullat VR, Pillai KC. Determining the normal concentration of uranium in urine and application of the data to its biokinetics. Health Phys 1992;62:562-6.

Das YT, Taskar PK, Brown HD, Chattopadhyay SK. Exposure

Ejnik JW, Carmichael AJ, Hamilton MM, McDiarmid M, Squibb K, Boyd P, et al. Determination of the isotopic composition of uranium in urine by inductively coupled plasma mass spectrometry. Health Phys 2000;78:143-6.

Elinder CG, Friberg L. Antimony. GcvctiT Friberg L, Nordberg GF, Vouk VB, eds. Handbook on the toxicology of metals. 2nd ed. New YorkiT Elsevier; 1986i. p. 26-4i2.

Ensslin AS, Huber R, Pethran A, Rommelt H, Schierl R, Kulka U, et al. Biological monitoring of hospital pharmacy personnel occupationally exposed to cytostatic drugs: urinary excretion and cytogenetic studies. Int Arch Occup Ecvctviron Health 1997;70(3):205-8.

Eriksson P, Archer T, Fredriksson A. Altered behaviour in adult mice exposed to a single low dose of DDT and its fatty acid conjugate as neonates. Brain Res 1990;514(1):141-2.

Eskenazi B, Mocarelli P, Warner M, Samuels S, Vercellini P, Olive D, et al. Serum dioxin concentrations and endometriosis: a cohort study in Seveso, Italy. Environ Health Perspect 2002;110(7):629-34.

Eskenazi B, Harley K, Bradman A, Weltzien E, Jewell NP, Barr DB, et al. Association of in utero organophosphate pesticide exposure and fetal growth and length of gestation in an agricultural population. Environ Health Perspect 2004;112(10):1116-24.

Esteban E, Rubin C, Hill R, Olson D, Pearce K. Association between indoor residential contamination with methyl parathion and urinary para-nitrophenol. J Expo Anal Environ Epidemiol 1996;6(3):375-87.

European Commission. Scientific Committee for Toxicity, Ecotoxicity and the Environment (CSTEE). Opinion on the results of a second risk assessment of: Bis(2-ethylhexyl) phthalate (DEHP) human health part [online]. 2004. Available from URL: http://europa.eu.int/comm/health/ph_risk/committees/sct/documents/out214_en.pdf, 03/17/05.

Ewers U, Krause C, Schulz C, Wilhelm M. Reference values and human biological monitoring values for environmental toxins. Report on the work and recommendations of the Commission on Human Biological Monitoring of the German Federal Environmental Agency. Int Arch Occup Environ Health 1999;72(4):255-60.

Ezaki T, Tsukahara T, Moriguchi J, Furuki K, et al. No clear-cut evidence for cadmium-induced renal tubular dysfunction among over 10,000 women in the Japanese general population: a nationwide large-scale survey. Int Arch Occup Environ Health 2003;76:186-96.

Fabro S, McLachlan JA, Dames

toxicology. 5th ed. New York: John Wiley & Sons, Inc.; 2001. p. 221-52

George DA. Permethrin and its two metabolite residues in seven agricultural crops. J AOAC 1985;68(6):1160-3.

Geyer HJ, Schramm KW, Feicht EA, Behechti A, Steinberg C, Bruggemann R, et al. Half-lives of tetra-, penta-, hexa-, hepta-, and octachlorodibenzo-p-dioxin in rats, monkeys, and humans—a critical review. Chemosphere 2002;48(6):631-44.

Glynn AW, Granath F, Aune M, Atuma S, Darnerud PO, Bjerselius R, et al. Organochlorines in Swedish women: determinants of serum concentrations. Environ Health Perspect 2003;111:349-55.

Glynn AW, Wolk A, Aune M, Atuma S, Zettermark S, Maehle-Schmid M, et al. Serum concentrations of organochlorines in men: a search for markers of exposure. Sci Total Environ 2000; 263(1-3):197-208.

Goen T, Gundel J, Schaller KH, Angerer J. The elimination of 1-hydroxypyrene in the urine of the general population and workers with different occupational exposures to PAH. Sci Total Environ 1995;163(1-3):195-201.

Goldberg MA, Dunning SP, Bunn HF. Regulation of the erythropoietin gene: evidence that the oxygen sensor is a heme protein. Science 1988;242:1412-5.

Grace PB, Taylor JI, Low Y, Luben RN, Mulligan AA, Botting NP, et al. Phytoestrogen concentrations in serum and spot urine as biomarkers for dietary phytoestrogen intake and their relation to breast cancer risk in European prospective investigation of cancer and nutrition Norfolk. Cancer Epidemiol Biomarkers and Prev 2004;13:698-708.

Grandjean P, Weihe P, Needham LL, Burse VW, Patterson DG Jr, Sampson EJ, et al. Relation of a seafood diet to mercury, selenium, arsenic, and polychlorinated biphenyl and other organochlorine concentrations in human milk. Environ Res 1995;71(1):29-38.

exposure to the herbicide atrazine at low ecologically relevant doses. Proceedings of the National Academy of Sciences USAWashington, DC: PNAS; 2002 Apr 16; 99(8):5476-80.

Hayes WJ Jr. Mortality in 1969 from pesticides, including aerosols. Arch Environ Health 1976;31:61-72.

Hedge AG, Thakker DM, Bhat IS. Long-term clearance of inhaled ^{60}Co. Health Phys 1979;36:732-4.

Howe GR, Hirohata T, Hislop

Jarvis JQ, Hammond E, Meier R, Robinson C. Cobalt cardiomyopathy. A report of two cases from mineral assay laboratories and a review of the literature. Journal of Occupational Medicine 1992;34:620-6.

Jauhiainen A, Kangas J, Laitinen S, Savolainen K. Biological monitoring of workers exposed to mevinphos in greenhouses. Bull Environ Contam Toxicol 1992;49(1):37-43.

Jefferson JA, Escudero E, Hurtado ME, Pando J, Tapia R, Swenson ER, et al. Excessive erythrocytosis, chronic mountain sickness, and serum cobalt levels. Lancet 2002;359:407-8.

Jemal A, Graubard BI, Devesa SS, Flegal KM. The association of blood lead level and cancer mortality among whites in the United States. Environ Health Perspect 2002;110(4):325-9.

Kerper LE, Ballatori N, Clarkson TW. Methyl mercury transport across the blood-brain barrier by an amino acid carrier. Am J Physiol 1992;262:RF 761-RF 5.

Kessler W, Numtip W, Grote K, Csanády G, Chahoud I, Filser J (2004). Blood burden of di(2-ethylhexylphthalate (DEHP) and its primary metabolite mono(2-ethylhexyl) phthalate

Lhotka C, Szekeres T, Steffan I, Zhuber K, Zweymuller K. Four-year study of cobalt and chromium blood levels in patients managed with two different metal-on-metal total hip replacements. J Orthop Res 2003;21(2):189-95.

Li N, Hao M, Phalen RF, Hinds WC, Nel AE. Particulate air pollutants and asthma. A paradigm for the role of oxidative

Marcus RL. Investigation of a working population exposed to thallium. Journal for the Society of Occupational Medicine. 1985;35(1):4-9.

Martin SA Jr, Harlow SD, Sowers MF, Longnecker MP, Garabrant D, Shore DL, et al. DDT metabolite and androgens in African-American farmers. Epidemiology 2002;1:454-8.

Mascagni P, Consonni D, Bregante G, Chiappino G, Toffoletto F. Olfactory function in workers exposed to moderate airborne cadmium levels. Neurotoxicology 2003;24:717-24.

Maskarinec G, Singh S, Meng L, Franke AA. Dietary soy intake and urinary isoflavone excretion among women from a multiethnic population. Cancer Epidemiol Biomarkers and Prev 1998;7:613-9.

Masuda Y. Fate of PCDF/PCB congeners and change of clinical symptoms in patients with Yusho PCB poisoning for 30 years. Chemosphere 2001:43(4-7):925-30.

Masuda Y, Schecter A, Papke O. Concentrations of PCBs, PCDFs and PCDDs in the blood of Yusho patients and their toxic equivalent contribution. Chemosphere 1998;37(9-12):1773-80.

Matsuura N, Uchiyama T, Tada H, Nakamura Y, Kondo N, Morita M. Effects of dioxins and polychlorinated biphenyls (PCBs) on thyroid function in infants born in Japan–the second report from research on environmental health. Chemosphere 2001;45(8):1167-71.

McDiarmid MA, Squibb K, Engelhardt SM. Biologic monitoring for urinary uranium in Gulf War I veterans. Health Phys 2004;87:51-6.

McDowell MA, Dillon CF, Osterloh J, Bolger PM, Pellizzari E, Fernando R, et al. Hair mercury levels in U.S. children and women of childbearing age: reference range data from NHANES 1999-2000. Environ Health Perspect 2004;112(11):1165-71.

McKee RH, Butala JH, David RM, Gans G. NTP center for the evaluation of risks to human reproduction reports on phthalates: addressing the data gaps [review]. Reprod Toxicol 2004;18(1):1-22.

McKee RH, El Hawari M, Stoltz M, Pallas F, Lington AW. Absorption, disposition and metabolism of Di-isononyl phthalate (DINP) in F-344 rats. J Appl Toxicol 2002;22:293-302.

Melnick RL. Is peroxisome proliferation an obligatory precursor step in the carcinogenicity of di (2-ethylhexyl) phthalate (DEHP)? Environ Health Perspect 2001;109(5):437-42.

Merlo F, Andreassen A, Weston A, Pan CF, Haugen A, Valerio F, et al. Urinary excretion of 1-hydroxypyrene as a marker for exposure to urban air levels of polycyclic aromatic

Epidemiol. 2004 Sep 15; [Epub ahead of print] doi:10.1038/sj.jea.7500406

Moriguchi J, Ezaki T, Tsukahara T, Furuki K, Fukui Y, Okamoto S, et al. Alpha1-Microglobulin as a promising marker of cadmium-induced tubular dysfunction, possibly better than beta2-microglobulin. Toxicol Lett. 2004;148(1-2):11-20.

Mosconi G, Bacis M, Vitali MT, Leghissa P, Sabbioni E. Cobalt excretion in urine: results of a study on workers producing diamond grinding tools and on a control group. Sci Total Environ 1994;150(1-3):133-9.

Moulin JJ, Wild P, Romazini S, Lasfargues G, Peltier A, Bozec C, et al. Lung cancer risk in hard-metal workers. Am J Epidemiol 1998;148:241-8.

Mukherjee S, Palmer LJ, Kim JY, Aeschliman DB, Houk RS, Woodin MA, et al. Smoking status and occupational exposure affects oxidative DNA injury in boilermakers exposed to metal fume and residual oil fly ash. Cancer Epidemiol Biomarkers Prev 2004;13(3):454-60.

Muntner P, Vupputyuri S, Coresh J, Batuman V. Blood lead and chronic kidney disease in the general United States population: results from NHANES III. Kidney Int 2003;63:104-50.

Murkies A, Dalais FS, Briganti EM, Burger HG, Healy DL, Wahlqvist MLLe84(Le84Phy)4(4(L)o5(un25w -22 Tc(1f(NESaip9-1.Pn50(d l)4(ecl United) 6M l)4(.00E)l70022 e2320021 Tc -0.0006 Tw)-

Ritchie KA, Gilmour WH, Macdonald EB, Burke FJ, McGowan DA, Dale IM, et al. Health and neuropsychological functioning of dentists exposed to mercury. Occup Environ Med 2002;59(5):287-93.

Robbins PJ, Cherniack MG. Review of the biodistribution and toxicity of the insect repellent N,N-diethyl-m-toluamide (DEET). J Toxicol Environ Health 1986;18(4):503-25.

Roels HA, Boeckx M, Ceulemans E, Lauwerys RR. Urinary excretion of mercury after occupational exposure to mercury vapor and influence of the chelating agent meso-2,3-dimercaptosuccinic acid (DMSA). British Journal of Industrial Medicine 1991;48:247-53.

Roels HA, Hoet P, Lison D. Usefulness of biomarkers of exposure to inorganic mercury, lead, or cadmium in controlling occupational and environmental risks of nephrotoxicity. Ren Fail 1999;21(3-4):251-62.

Schwartz J. Lead, blood pressure and cardiovascular disease in men. Arch Environ Health 1995; 50:31-7.

Schwartz J, Landrigan PJ, Baker EL, Orenstein WA, von Lindern IH. Lead induced anemia: dose-response relationships and evidence for a threshold. Am J Public Health 1990;80:165-8.

Seifert B, Becker K, Helm D, Krause C, Schulz C, Seiwert M.

Smith T, Edmonds CJ, Barnaby CF. Absorption and retention of cobalt in man by whole-body counting. Health Phys 1972;22:359-67.

Soderlund DM, Clark JM, Sheets LP, Mullin LS, Piccirillo VJ, Sargent D, et al. Mechanisms of pyrethroid neurotoxicity: implications for cumulative risk assessment. Toxicology 2002;171:3-59.

Soldin OP, Hanak B, Soldin SJ. Blood lead concentrations in children: new ranges. Clin Chim Acta 2003;327:109-13.

Staessen JA, Buchet JP, Ginucchio G, Lauwerys R, Lijnen P, column-switching high performance liquid chromatography with fluorescence detection. Analyst 2003;128(6):605-10.

To-Figueras J, Sala M, Otero R, Barrot C, Santiago-Silva M, Rodamilans M, et al. Metabolism of hexachlorobenzene in humans: association between serum levels and urinary metabolites in a highly exposed population. Environ Health Perspect 1997;105(1):78-83.

Tsai HT, Wu MT, Hauser R, Rodrigues E, Ho CK, Liu CL, et al. Exposure to environmental tobacco smoke and urinary 1-hydroxypyrene levels in preschool children. Kaohsiung J Med Sci 2003;19(3):97-104.

Tsai PJ, Shih TS, Chen HL, Lee WJ, Lai CH, Liou SH. Urinary 1-hydroxypyrene as an indicator for assessing the exposures of booth attendants of a highway toll station to polycyclic aromatic hydrocarbons. Environ Sci Technol 2004;38(1):56-61.

Tsongas TA, Meglen RR, Walravens PA, Chappell WR. Molybdenum in the diet: an estimate of average daily intake in the United States. Am J Clin Nutr 1980;33(5):1103-7.

Tunnessen WW, McMahon KJ, Baser M. Acrodynia: exposure to mercury from fluorescent light bulbs. Pediatrics 1987;79:786-9.

Turnlund JR, Keyes WR, Peiffer GL. Molybdenum absorption, excretion, and retention studied with stable isotopes in young men at five intakes of dietary molybdenum. Am J Clin Nutr 1995;62(4):790-6.

Uehara M, Lapcik O, Hampl R, Al-maharik N, Makela T, Wahala K, et al. Rapid analysis of phytoestrogens in human by time-resolved fluoroimmunoassay. Journal of Steroid Biochemistry and Molecular Biology (Oxford) 2000*b*;72:273-82.

Uehara M, Arai Y, Watanabe S, Adlercreutz H. Comparison of plasma and urinary phytoestrogens in Japanese and Finnish women by time-resolved fluoroimmunoassay. Biofactors 2000*a*;12:217-25.

Umweltbundesamt [Federal Environmental Agency]. German Environmental Survey 1998 (GerES III). Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. Germany. 2002 [online]. 2002. Available from URL: http://www.umweltbundesamt.de/survey-e/us98/blut.htm, 02/22/05.

U.S. Department of Health and Human Services (U.S. DHHS). Public Health Service. Subcommittee on Risk Management. Dental amalgam: a scientific review and recommended Public Health Service strategy for research, education, and regulation. Washington (DC): DHHS; January 1993.

U.S. Environmental Protection Agency (U.S. EPA). Deposition of air pollutants to the Great Waters – 3rd Report to Congress, 2000 [online]. Available from URL: http://www.epa.gov/air/oaqps/gr8water/2ndrpt/chap2.pdf, 2/22/05.

U.S. Environmental Protection Agency (U.S. EPA). Hexachlorobenzene health advisory. EPA/820K87110. Washington (DC): U.S. EPA; March 1987.

U. S. Environmental Protection Agency (U.S. EPA). Methyl mercury. Integrated Risk Information System (IRIS). Revised 07/27/2001 [online]. Available from URL: www.epa.gov/

U.S. Geological Survey (U.S.GS). Cadmium. Mineral commodity summary [online]. 2004. Available from URL: http://minerals.usgs.gov/minerals/pubs/commodity/cadmium/cadmimcs04.pdf,03/18/05.

U.S. Nuclear Regulatory Commission (U.S. NRC). U.S. Nuclear Regulatory Commission (NRC) Guide 8.22–Bioassay at uranium mills. Washington (DC): NRC; July 1978.

Vahter M, Mottet NK, Friberg L, Lind B, Shen DD, Burbacher T. Speciation of mercury in the primate blood and brain following long-term exposure to methyl mercury. Tox Appl Pharmacol 1994;124:221-9.

Valentin-Blasini L, Blount B, Caudill S, ,Needham L. Urinary and serum concentrations of seven phytoestrogens in a human reference population subset. J Expos Anal Environ Epidemiol 2003;13:276-82.

Van Oostdam JC, Dewailly E, Gilman A, Hansen JC, Odland JO, Chashchin V, et al. Circumpolar maternal blood contaminant survey, 1994-1997 organochlorine compounds. Sci Total Environ 2004;330:55-70.

van Wijnen JH, Slob R, Jongmans-Liedekerken G, van de Weerdt RH, Woudenberg F. Exposure to polycyclic aromatic hydrocarbons among Dutch children. Environ Health Perspect 1996;104(5):530-4.

Vaughan GT, Florence TM. Platinum in the human diet, blood, hair and excreta. Sci Total Environ 1992;111(1):47-58.

World Health Organization (WHO). Molybdenum. In: Trace elements in human nutrition and health. Geneva: WHO; 1996. p. 144-54.

Xu X, Duncan AM, Wangen KE, Kurzer MS. Soy consumption alters endogenous estrogen metabolism in postmenopausal women. Cancer Epidemiol Biomarkers Prev 2000;9(8):781-6.

Yang M, Kim S, Lee E, Cheong HK, Chang SS, Kang D, et al. Sources of polycyclic aromatic hydrocarbon exposure in non-occupationally exposed Koreans. Environ Mol Mutagen 2003;42(4):250-7.

Yoshida T, Andoh K, Fukuhara M. Urinary 2,5-dichlorophenol as biological index for p-dichlorobenzene exposure in the general population. Arch Environ Contam Toxicol. 2002;43(4):481-5.

Zacharewski TR, Meek MD, Clemons JH, Wu ZF, Fielden MR, Matthews JB. Examination of the in vitro and in vivo estrogenic activities of eight commercial phthalate esters.

Appendix A. Limit of Detection Table

The analytical limit of detection (LOD) for each of the different chemical measurements is presented in the table below. The LOD is the level at which the measurement has a 95% probability of being greater than zero (Taylor, 1987). For most chemicals, the LOD is constant for each sample analyzed. However, for dioxins, furans, PCBs, organochlorine pesticides, and some other pesticides, each individual sample has its own

Appendix A: Limit of Detection Table

Phthalate Metabolites

Blount BC, Milgram KE, Silva M, Malek N, Reidy J, Needham LL, et al. Quantitative detection of eight phthalate

Appendix C. Confidence Interval Estimation for Percentiles

A common practice to calculate confidence intervals from survey data is to use large-sample normal approximations. Ninety-five percent 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. Further, 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 and Graubard (1998) to compute Clopper-Pearson 95% confidence intervals about percentile estimates. We describe the method

Appendix D. Abbreviations and Acronyms