# 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 | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) 50th | 75th | 90th | 95th | Sample size |
|---|---|---|---|---|---|---|---|
| **Total, age 6 and older** | 99-00 | **.132** (.120-.145) | **.130** (.120-.140) | **.210** (.200-.230) | **.330** (.300-.350) | **.420** (.390-.460) | 2276 |
| | 01-02 | **.134** (.126-.142) | **.130** (.120-.130) | **.180** (.180-.190) | **.260** (.240-.300) | **.340** (.320-.390) | 2690 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **.176** (.154-.200) | **.190** (.160-.200) | **.260** (.230-.280) | **.350** (.300-.390) | **.400** (.320-.600) | 316 |
| | 01-02 | **.146** (.134-.160) | **.150** (.130-.160) | **.200** (.180-.210) | **.260** (.230-.310) | **.330** (.280-.380) | 368 |
| 12-19 years | 99-00 | **.158** (.141-.178) | **.170** (.150-.180) | **.230** (.210-.270) | **.340** (.290-.420) | **.460** (.350-.510) | 663 |
| | 01-02 | **.169** (.156-.184) | **.150** (.140-.180) | **.230** (.220-.250) | **.350** (.320-.400) | **.460** (.360-.480) | 762 |
| 20 years and older | 99-00 | **.123** (.112-.137) | **.110** (.100-.120) | **.190** (.180-.220) | **.310** (.280-.330) | **.420** (.390-.470) | 1297 |
| | 01-02 | **.128** (.119-.136) | **.120** (.120-.130) | **.170** (.160-.190) | **.240** (.220-.280) | **.330** (.280-.380) | 1560 |
| **Gender** | | | | | | | |
| Males | 99-00 | **.143** (.131-.157) | **.140** (.130-.150) | **.240** (.220-.250) | **.350** (.320-.370) | **.470** (.390-.570) | 1132 |
| | 01-02 | **.145** (.136-.154) | **.130** (.130-.150) | **.200** (.180-.200) | **.310** (.280-.330) | **.390** (.350-.430) | 1335 |
| Females | 99-00 | **.122** (.109-.137) | **.120** (.100-.130) | **.190** (.180-.220) | **.300** (.270-.330) | **.390** (.350-.460) | 1144 |
| | 01-02 | **.125** (.117-.133) | **.110** (.110-.120) | **.180** (.160-.190) | **.240** (.210-.260) | **.310** (.260-.350) | 1355 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **.132** (.108-.161) | **.130** (.110-.160) | **.200** (.180-.240) | **.300** (.250-.370) | **.410** (.330-.560) | 787 |
| | 01-02 | **.142** (.130-.154) | **.120** (.110-.130) | **.200** (.160-.220) | **.250** (.230-.300) | **.360** (.300-.390) | 683 |
| Non-Hispanic blacks | 99-00 | **.175** (.148-.207) | **.180** (.150-.200) | **.260** (.220-.290) | **.390** (.310-.470) | **.490** (.400-.620) | 554 |
| | 01-02 | **.180** (.164-.197) | **.160** (.150-.180) | **.250** (.210-.280) | **.350** (.320-.410) | **.450** (.370-.530) | 667 |
| Non-Hispanic whites | 99-00 | **.128** (.115-.144) | **.120** (.110-.140) | **.210** (.180-.220) | **.320** (.280-.350) | **.400** (.350-.500) | 768 |
| | 01-02 | **.126** (.117-.135) | **.120** (.120-.130) | **.180** (.170-.180) | **.240** (.220-.270) | **.340** (.310-.390) | 1132 |

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 (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 | **.124** (.108-.143) | **.119** (.102-.143) | **.185** (.163-.213) | **.274** (.233-.333) | **.382** (.333-.430) | 2276 |
| | 01-02 | **.126** (.119-.134) | **.120** (.115-.126) | **.173** (.162-.188) | **.265** (.242-.296) | **.364** (.320-.414) | 2689 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **.191** (.147-.248) | **.183** (.156-.220) | **.250** (.196-.414) | **.439** (.271-.741) | **.537** (.333-1.30) | 316 |
| | 01-02 | **.178** (.159-.200) | **.173** (.150-.193) | **.228** (.200-.272) | **.338** (.265-.480) | **.469** (.313-.727) | 368 |
| 12-19 years | 99-00 | **.121** (.104-.140) | **.119** (.095-.146) | **.176** (.146-.206) | **.259** (.206-.310) | **.310** (.228-.421) | 663 |
| | 01-02 | **.121** (.112-.131) | **.115** (.106-.127) | **.159** (.138-.186) | **.224** (.199-.245) | **.266** (.244-.310) | 762 |
| 20 years and older | 99-00 | **.118** (.104-.135) | **.111** (.096-.136) | **.174** (.149-.209) | **.263** (.227-.320) | **.352** (.320-.391) | 1297 |
| | 01-02 | **.122** (.115-.129) | **.115** (.108-.121) | **.167** (.153-.179) | **.265** (.241-.296) | **.364** (.318-.405) | 1559 |
| **Gender** | | | | | | | |
| Males | 99-00 | **.112** (.099-.127) | **.108** (.095-.127) | **.164** (.146-.181) | **.226** (.204-.268) | **.319** (.235-.391) | 1132 |
| | 01-02 | **.114** (.107-.123) | **.108** (.103-.115) | **.153** (.138-.171) | **.228** (.205-.250) | **.333** (.272-.421) | 1334 |
| Females | 99-00 | **.137** (.117-.161) | **.131** (.108-.164) | **.212** (.176-.247) | **.318** (.257-.400) | **.425** (.357-.485) | 1144 |
| | 01-02 | **.139** (.131-.148) | **.132** (.124-.140) | **.196** (.178-.211) | **.295** (.267-.317) | **.371** (.333-.444) | 1355 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **.120** (.107-.135) | **.114** (.105-.129) | **.167** (.148-.203) | **.249** (.207-.313) | **.333** (.280-.357) | 787 |
| | 01-02 | **.138** (.128-.149) | **.129** (.117-.143) | **.182** (.159-.203) | **.269** (.229-.308) | **.338** (.308-.429) | 682 |
| Non-Hispanic blacks | 99-00 | **.114** (.099-.133) | **.112** (.098-.130) | **.163** (.144-.183) | **.236** (.195-.338) | **.339** (.255-.425) | 554 |
| | 01-02 | **.123** (.113-.134) | **.115** (.106-.126) | **.163** (.150-.181) | **.232** (.208-.267) | **.300** (.248-.373) | 667 |
| Non-Hispanic whites | 99-00 | **.129** (.109-.152) | **.124** (.102-.152) | **.195** (.167-.225) | **.298** (.239-.352) | **.400** (.333-.444) | 768 |
| | 01-02 | **.127** (.117-.138) | **.120** (.113-.130) | **.176** (.159-.198) | **.280** (.241-.317) | **.380** (.318-.471) | 1132 |

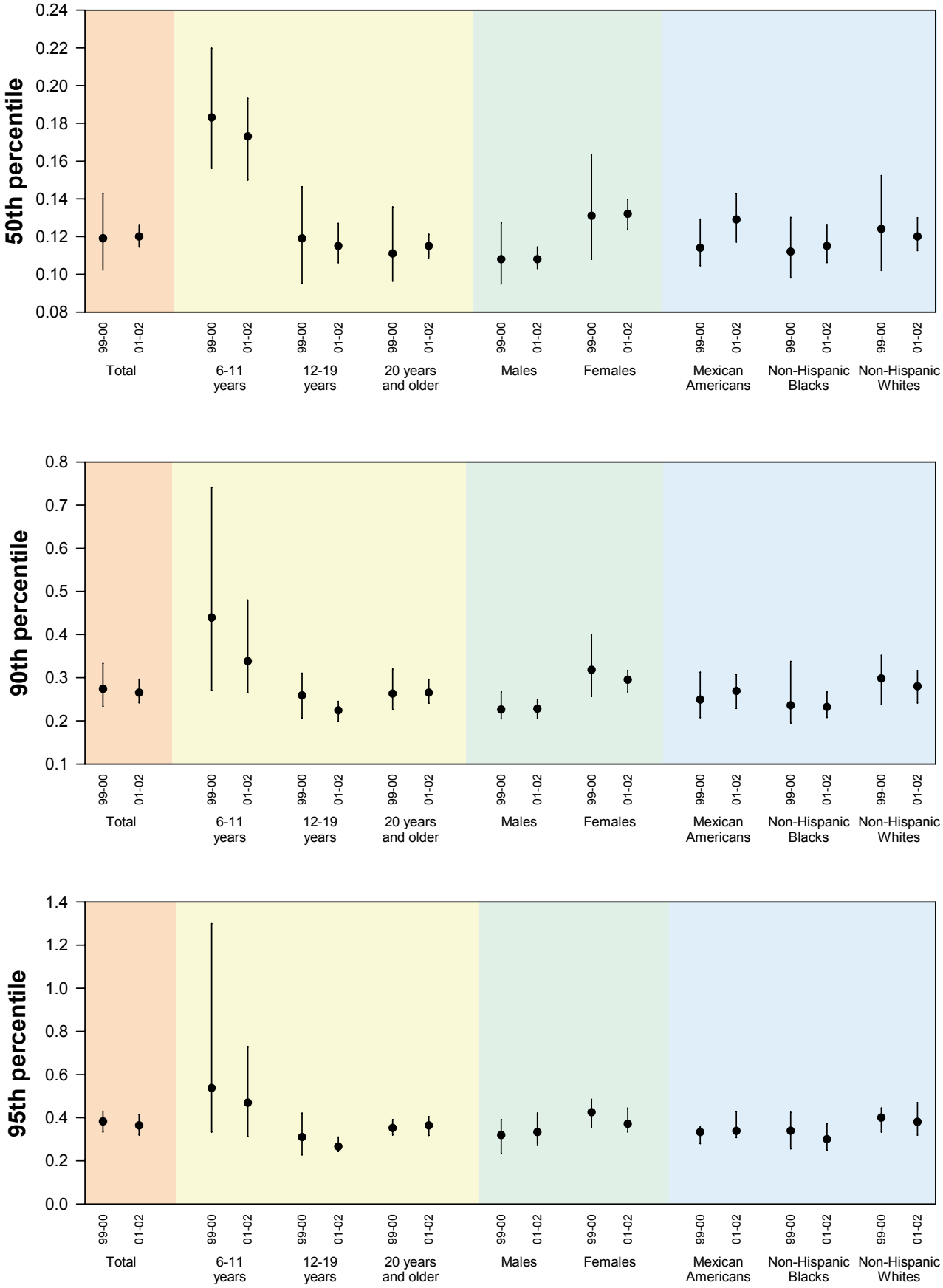
### Comparing Adjusted Geometric Means

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 urinary antimony were slightly higher for the group aged 6-11 years than for either groups aged 12-19 years or 20 years and older. The group aged 12-19 years had higher levels than the group aged 20 years and older. Mexican Americans had slightly higher levels than 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 antimony in urine does not mean that the level of antimony causes an adverse health effect. Whether antimony at the levels reported here is a cause for health concern is not yet known; more research is needed. These urine antimony data provide physicians with a reference range so that they can determine whether or not people have been exposed to higher levels of antimony than are found in the general population. These data will also help scientists plan and conduct research about exposure to antimony and health effects.

## 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 the various salts, approximately half are freely soluble in water, whereas the others are practically insoluble (notably barium sulfate and barium carbonate). Barium compounds are used by the oil and gas industries to make drilling muds. These compounds are also produced commercially for use in paint, bricks, tiles, glass, rubber, depilatories, fireworks, and ceramics. Medically, barium sulfate is used as a contrast medium for taking radiographs of the gastrointestinal tract. Barium salts are available for sale as rodenticides.

People can be exposed to barium in air, water, and food. Small amounts of barium can be released into the air during mining and other industrial processes. Workers employed by industries that make or use barium compounds are exposed to barium dust. Certain foods, such as brazil nuts, are exceptionally high in barium (Genter, 2001).

The health effects of exposure to barium compounds depend on the dose, chemical form, water solubility, and route of exposure. Toxicity from soluble barium salts is rare but occurs after intentional or accidental ingestion of barium carbonate in rodenticides (Genter, 2001). Barium blocks cellular efflux of potassium resulting in extracellular profound hypokalemia. Symptoms include perioral paresthesias, vomiting, diarrhea, weakness, paralysis, hypertension, and cardiac dysrhythmias. The lethal dose of barium by ingestion is reported to be between 0.8-0.9 grams (Jourdan et al., 2001).

### Table 5. Barium

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

| | 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 | **1.50** (1.35-1.66) | **1.50** (1.30-1.70) | **3.00** (2.70-3.40) | **5.40** (4.60-6.10) | **6.80** (6.20-8.40) | 2180 |
| | 01-02 | **1.52** (1.41-1.65) | **1.63** (1.50-1.75) | **3.12** (2.76-3.51) | **5.22** (4.73-5.74) | **7.48** (6.54-8.12) | 2690 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **2.15** (1.70-2.72) | **2.20** (1.80-2.30) | **3.90** (2.60-6.10) | **6.40** (5.20-8.30) | **8.30** (5.00-76.2) | 297 |
| | 01-02 | **1.80** (1.44-2.26) | **2.08** (1.74-2.49) | **3.62** (2.86-4.39) | **5.37** (4.26-7.38) | **6.88** (5.37-8.49) | 368 |
| 12-19 years | 99-00 | **1.97** (1.78-2.19) | **2.00** (1.60-2.30) | **3.50** (3.10-4.00) | **5.90** (4.80-7.00) | **9.70** (5.90-13.1) | 621 |
| | 01-02 | **2.03** (1.76-2.34) | **2.27** (1.96-2.53) | **4.09** (3.48-4.72) | **6.69** (5.55-7.87) | **9.00** (7.25-11.4) | 762 |
| 20 years and older | 99-00 | **1.36** (1.24-1.51) | **1.40** (1.30-1.70) | **2.70** (2.50-3.00) | **5.00** (4.20-5.50) | **6.40** (5.70-8.30) | 1262 |
| | 01-02 | **1.43** (1.32-1.54) | **1.50** (1.39-1.65) | **2.85** (2.55-3.26) | **4.86** (4.53-5.47) | **7.14** (6.08-8.12) | 1560 |
| **Gender** | | | | | | | |
| Males | 99-00 | **1.70** (1.54-1.88) | **1.80** (1.70-2.00) | **3.10** (2.80-3.40) | **5.50** (4.20-6.30) | **7.50** (5.90-9.40) | 1083 |
| | 01-02 | **1.64** (1.47-1.82) | **1.80** (1.63-1.98) | **3.15** (2.76-3.73) | **5.52** (4.82-6.35) | **7.87** (6.49-9.32) | 1335 |
| Females | 99-00 | **1.33** (1.15-1.53) | **1.50** (1.20-1.60) | **2.80** (2.30-3.10) | **5.10** (4.20-5.90) | **6.80** (5.60-10.4) | 1097 |
| | 01-02 | **1.43** (1.30-1.56) | **1.43** (1.28-1.63) | **3.10** (2.73-3.43) | **4.86** (4.44-5.88) | **7.15** (6.32-7.86) | 1355 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **1.35** (1.25-1.46) | **1.30** (1.20-1.50) | **2.60** (2.30-2.90) | **4.50** (4.00-5.10) | **6.30** (5.50-6.80) | 692 |
| | 01-02 | **1.21** (1.06-1.37) | **1.24** (1.08-1.45) | **2.55** (2.04-2.90) | **4.31** (3.65-5.49) | **6.08** (5.21-8.22) | 683 |
| Non-Hispanic blacks | 99-00 | **1.34** (1.12-1.62) | **1.30** (1.20-1.50) | **2.50** (2.20-2.80) | **5.10** (3.70-6.40) | **7.40** (5.40-13.9) | 540 |
| | 01-02 | **1.30** (1.14-1.48) | **1.41** (1.22-1.62) | **2.61** (2.31-2.82) | **4.28** (3.70-5.18) | **5.99** (4.87-7.26) | 667 |
| Non-Hispanic whites | 99-00 | **1.56** (1.36-1.80) | **1.70** (1.60-2.00) | **3.30** (2.80-3.70) | **5.40** (4.50-6.20) | **7.20** (6.20-8.80) | 765 |
| | 01-02 | **1.61** (1.46-1.77) | **1.67** (1.53-1.82) | **3.30** (2.86-3.73) | **5.66** (4.94-6.30) | **7.70** (6.61-8.49) | 1132 |

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 produced general health effects or evidence of cardiovascular risk (Brenniman and Levy, 1984; Wones et al., 1990). Workplace standards for external air exposure to various barium salts have been established by OSHA and a drinking water standard has been established by U.S. EPA. Barium is not rated for carcinogenicity. Information about external exposure 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 Barium Reported in the Tables

Urinary barium 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 urinary levels of barium in general populations have found values generally similar to those documented in this *Report* (Minoia et al., 1990; Paschal et al., 1998). In addition, levels determined in clinically submitted specimens are broadly comparable (Komaromy-Hiller et al., 2000). Median urinary levels of barium found in welders of barium-containing electrodes were 60 times higher than the median levels in this *Report* (Zschiesche et al., 1992) without obvious adverse effects. Urinary concentrations in acute poisonings are often hundreds to thousands times higher.

### Comparing Adjusted Geometric Means

Geometric mean levels of urinary barium 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 barium were higher for the group aged 6-11 years than either groups aged 12-19 years or aged 20 years and

**Table 6. Barium (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.

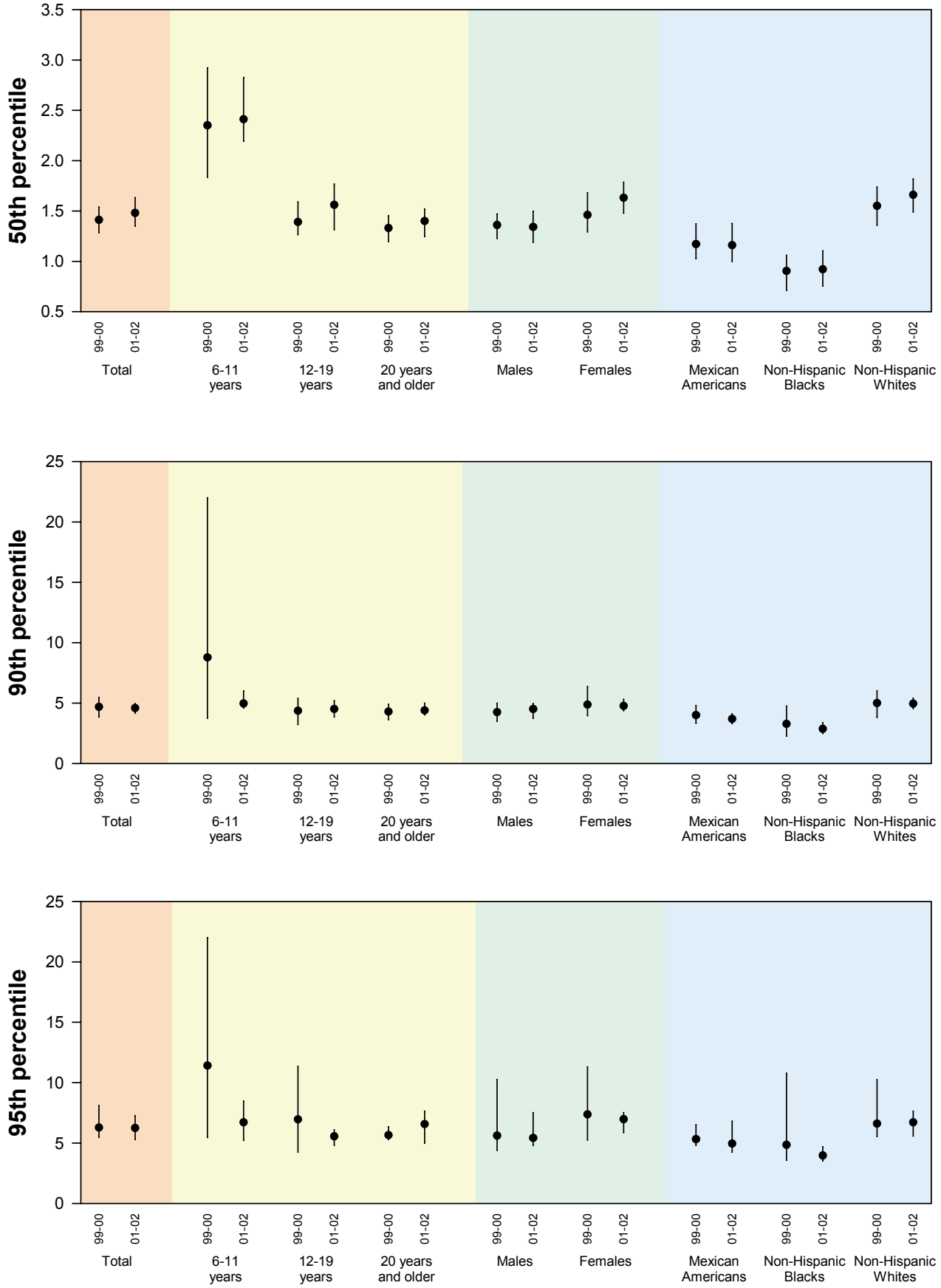
| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) 50th | 75th | 90th | 95th | Sample size |
|---|---|---|---|---|---|---|---|
| **Total, age 6 and older** | 99-00 | **1.40** (1.26-1.56) | **1.41** (1.28-1.54) | **2.54** (2.18-2.89) | **4.68** (3.85-5.47) | **6.27** (5.47-8.09) | 2180 |
| | 01-02 | **1.44** (1.31-1.58) | **1.48** (1.35-1.63) | **2.76** (2.51-3.03) | **4.58** (4.14-4.95) | **6.24** (5.28-7.27) | 2689 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **2.37** (1.68-3.32) | **2.35** (1.83-2.92) | **4.46** (2.55-6.46) | **8.77** (3.75-22.0) | **11.4** (5.45-22.0) | 297 |
| | 01-02 | **2.20** (1.91-2.52) | **2.41** (2.19-2.83) | **3.91** (3.29-4.51) | **4.96** (4.58-6.00) | **6.71** (5.20-8.47) | 368 |
| 12-19 years | 99-00 | **1.51** (1.34-1.70) | **1.39** (1.26-1.59) | **2.48** (1.97-3.06) | **4.36** (3.23-5.39) | **6.95** (4.24-11.4) | 621 |
| | 01-02 | **1.45** (1.33-1.59) | **1.56** (1.31-1.77) | **2.88** (2.68-3.12) | **4.50** (3.84-5.20) | **5.55** (4.81-6.10) | 762 |
| 20 years and older | 99-00 | **1.30** (1.19-1.42) | **1.33** (1.20-1.45) | **2.32** (2.08-2.62) | **4.29** (3.62-4.91) | **5.65** (5.28-6.33) | 1262 |
| | 01-02 | **1.37** (1.24-1.50) | **1.40** (1.24-1.52) | **2.53** (2.23-2.84) | **4.38** (4.02-5.00) | **6.55** (5.00-7.64) | 1559 |
| **Gender** | | | | | | | |
| Males | 99-00 | **1.32** (1.22-1.42) | **1.36** (1.23-1.47) | **2.39** (2.11-2.57) | **4.24** (3.48-5.00) | **5.61** (4.39-10.2) | 1083 |
| | 01-02 | **1.30** (1.16-1.45) | **1.34** (1.19-1.50) | **2.46** (2.14-2.83) | **4.50** (3.73-4.95) | **5.42** (4.81-7.51) | 1334 |
| Females | 99-00 | **1.49** (1.27-1.74) | **1.46** (1.29-1.68) | **2.65** (2.13-3.46) | **4.86** (3.96-6.38) | **7.36** (5.25-11.3) | 1097 |
| | 01-02 | **1.59** (1.45-1.75) | **1.63** (1.48-1.79) | **2.98** (2.75-3.30) | **4.76** (4.38-5.31) | **6.97** (5.86-7.52) | 1355 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **1.21** (1.10-1.33) | **1.17** (1.03-1.37) | **2.39** (2.10-2.59) | **4.00** (3.33-4.80) | **5.31** (4.80-6.51) | 692 |
| | 01-02 | **1.18** (1.03-1.34) | **1.16** (1.00-1.38) | **2.33** (1.90-2.61) | **3.68** (3.29-4.10) | **4.95** (4.24-6.80) | 682 |
| Non-Hispanic blacks | 99-00 | **.881** (.703-1.11) | **.904** (.710-1.06) | **1.64** (1.36-2.00) | **3.27** (2.26-4.76) | **4.84** (3.57-10.8) | 540 |
| | 01-02 | **.891** (.777-1.02) | **.920** (.754-1.11) | **1.64** (1.44-2.03) | **2.86** (2.48-3.37) | **3.96** (3.52-4.68) | 667 |
| Non-Hispanic whites | 99-00 | **1.56** (1.38-1.77) | **1.55** (1.36-1.74) | **2.72** (2.27-3.24) | **5.00** (3.81-6.02) | **6.60** (5.52-10.2) | 765 |
| | 01-02 | **1.62** (1.49-1.76) | **1.66** (1.49-1.82) | **3.04** (2.76-3.32) | **4.95** (4.55-5.41) | **6.71** (5.57-7.64) | 1132 |

older. Levels in the group aged 12-19 years were higher than the group aged 20 years and older. Levels in non-Hispanic whites were higher than in non-Hispanic blacks and 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 barium in urine does not mean that the level of barium causes an adverse health effect. Whether barium at the levels reported here is a cause for health concern is not yet known; more research is needed. These urine barium data provide physicians with a reference range so that they can determine whether people have been exposed to higher levels of barium than are found in the general population. These data will also help scientists plan and conduct research about exposure to barium and health effects.

## Figure 2. Barium (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.



# 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 $\mu g/m^3$ 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 µg/L) (Hamilton et al., 1994). Apostoli and Schaller (2001) suggest that previous detection limits are inadequate to quantitate normal human exposure. In that study, urinary beryllium in workers correlated with air exposure measures, and when air levels were below the recommended threshold limit value, urinary beryllium concentrations ranged from 0.12 to 0.15 µg/L. The 95$^{th}$ percentiles in this *Report* for people aged 12-19 years and for males (0.14 µg/L and 0.13 µg/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 | 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 | 2689 |
| **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 | **.231** (.173-.273) | 762 |
| 20 years and older | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1406 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1559 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1227 |
| | 01-02 | * | < LOD | < LOD | < LOD | **.281** (.237-.333) | 1334 |
| 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 | 682 |
| 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.

detection limit documented in this *Report* was 0.13 µg/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 higher levels of beryllium than are found in the general population. These data will also help scientists plan and conduct research about exposure to beryllium and health effects.

# 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, such as secondary lead smelting, primary copper smelting, primary lead production, hazardous and municipal waste incineration, and petroleum refining (U.S. EPA, 1992).

Cadmium is absorbed via inhalation and ingestion. Inhalation of cigarette smoke is a predominant source in smokers. For nonsmokers who are not exposed to cadmium in the workplace, food is the largest source of cadmium intake and absorption. An analysis of food-intake rates and food-cadmium concentrations for the U.S. population recently estimated a geometric mean daily cadmium intake of 18.9 µg/day, or 0.4 µg/kg/day

### Table 9. Cadmium in blood

Geometric mean and selected percentiles of blood concentrations (in µg/L) for the U.S. population aged 1 year and older, National Health and Nutrition Examination Survey, 1999-2002.

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) 50th | 75th | 90th | 95th | Sample size |
|---|---|---|---|---|---|---|---|
| **Total, age 1 and older** | 99-00 | **.412** (.378-.449) | **.300** (.300-.400) | **.600** (.500-.600) | **1.00** (.900-1.00) | **1.30** (1.20-1.40) | 7970 |
| | 01-02 | * | **.300** (<LOD-.300) | **.400** (.400-.500) | **.900** (.900-1.10) | **1.30** (1.20-1.60) | 8945 |
| **Age group** | | | | | | | |
| 1-5 years | 99-00 | * | **< LOD** | **.300** (<LOD-.300) | **.400** (.300-.400) | **.400** (.300-.400) | 723 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.300** (<LOD-.300) | 898 |
| 6-11 years | 99-00 | * | **< LOD** | **.300** (<LOD-.300) | **.400** (.300-.400) | **.400** (.400-.500) | 905 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.400** (.300-.400) | 1044 |
| 12-19 years | 99-00 | **.333** (.304-.366) | **.300** (<LOD-.300) | **.300** (.300-.400) | **.800** (.600-.900) | **1.10** (.900-1.10) | 2135 |
| | 01-02 | * | **< LOD** | **.300** (<LOD-.300) | **.400** (.400-.500) | **.800** (.600-1.10) | 2231 |
| 20 years and older | 99-00 | **.468** (.426-.513) | **.400** (.300-.400) | **.600** (.600-.700) | **1.00** (1.00-1.10) | **1.50** (1.40-1.60) | 4207 |
| | 01-02 | * | **.300** (.300-.400) | **.600** (.500-.600) | **1.10** (.900-1.20) | **1.60** (1.30-1.80) | 4772 |
| **Gender** | | | | | | | |
| Males | 99-00 | **.403** (.368-.441) | **.400** (.300-.400) | **.600** (.500-.600) | **1.00** (.900-1.10) | **1.30** (1.20-1.50) | 3913 |
| | 01-02 | * | **.300** (<LOD-.300) | **.400** (.400-.500) | **.900** (.900-1.10) | **1.40** (1.20-1.80) | 4339 |
| Females | 99-00 | **.421** (.386-.460) | **.300** (.300-.400) | **.600** (.500-.600) | **1.00** (.800-1.00) | **1.30** (1.10-1.40) | 4057 |
| | 01-02 | * | **.300** (.300-.400) | **.500** (.500-.600) | **1.00** (.900-1.10) | **1.40** (1.20-1.60) | 4606 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **.395** (.367-.424) | **.400** (.300-.400) | **.400** (.400-.500) | **.700** (.700-.900) | **1.10** (.900-1.30) | 2742 |
| | 01-02 | * | **< LOD** | **.300** (.300-.400) | **.600** (.500-.700) | **1.00** (.700-1.30) | 2268 |
| Non-Hispanic blacks | 99-00 | **.393** (.361-.427) | **.300** (.300-.400) | **.600** (.500-.600) | **1.00** (.800-1.10) | **1.40** (1.10-1.50) | 1842 |
| | 01-02 | * | **< LOD** | **.400** (.400-.500) | **1.00** (.900-1.00) | **1.40** (1.20-1.50) | 2219 |
| Non-Hispanic whites | 99-00 | **.420** (.376-.470) | **.400** (.300-.400) | **.500** (.500-.600) | **1.00** (.900-1.10) | **1.30** (1.20-1.40) | 2716 |
| | 01-02 | * | **< LOD** | **.500** (.500-.600) | **.900** (.900-1.10) | **1.40** (1.20-1.80) | 3806 |

< 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.

(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 is manifested by irreversible proteinuria and progressive reductions in glomerular filtration rate (Roels et al., 1999). Increased urinary excretion of calcium and phosphorus and decreased hydroxylation of vitamin D metabolites that accompany advanced tubular damage may result in overt, and often painful, osteomalacia or osteoporosis, typified by a condition known as "Itai-Itai disease" that afflicted women living in a cadmium-polluted region of Japan. Several recent epidemiological investigations in Belgium (Staessen et al., 1996; Hotz et al., 1999; Staessen et al., 1999), Sweden (Jarup et al., 2000; Alfven et al., 2002; Olsson et al., 2002), Japan (Suwazono et al., 2000; Ezaki et al., 2003; Horiguchi et al., 2004*b*) China (Jin et al., 2004), and the United States (Noonan et al., 2002) have detected an association between relatively low-level environmental cadmium exposure and biomarkers of renal dysfunction or diminished bone mineral density. Environmental exposure from cadmium pollution has been linked to an increased rate of end-stage renal disease in a Swedish population residing in the vincinity of two battery manufacturing plants (Hellstrom et al., 2001). Although all the mechanisms of cadmium toxicity

## Table 10. Cadmium in urine

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 | **.193** (.169-.220) | **.232** (.214-.249) | **.475** (.436-.519) | **.858** (.763-.980) | **1.20** (1.06-1.33) | 2257 |
| | 01-02 | **.210** (.189-.235) | **.229** (.207-.255) | **.458** (.423-.482) | **.839** (.753-.919) | **1.20** (1.07-1.28) | 2690 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **.078** (.061-.101) | **.141** (.115-.173) | **.219** (.178-.233) | **.279** (.211-.507) | 310 |
| | 01-02 | **.061** (<LOD-.081) | **.077** (.067-.092) | **.140** (.112-.160) | **.219** (.184-.262) | **.282** (.260-.326) | 368 |
| 12-19 years | 99-00 | **.092** (.067-.126) | **.128** (.107-.148) | **.202** (.183-.232) | **.329** (.272-.372) | **.424** (.366-.596) | 648 |
| | 01-02 | **.109** (.087-.136) | **.135** (.114-.157) | **.210** (.189-.247) | **.327** (.289-.366) | **.442** (.366-.480) | 762 |
| 20 years and older | 99-00 | **.281** (.253-.313) | **.306** (.261-.339) | **.551** (.510-.621) | **.979** (.836-1.13) | **1.31** (1.13-1.57) | 1299 |
| | 01-02 | **.273** (.249-.299) | **.280** (.261-.308) | **.545** (.493-.607) | **.955** (.855-1.06) | **1.28** (1.20-1.43) | 1560 |
| **Gender** | | | | | | | |
| Males | 99-00 | **.199** (.165-.241) | **.227** (.193-.263) | **.462** (.381-.539) | **.892** (.748-1.15) | **1.41** (.980-1.83) | 1121 |
| | 01-02 | **.201** (.177-.229) | **.223** (.191-.257) | **.445** (.393-.481) | **.870** (.741-1.03) | **1.22** (1.12-1.38) | 1335 |
| Females | 99-00 | **.187** (.153-.229) | **.239** (.220-.255) | **.492** (.456-.540) | **.806** (.705-.980) | **1.10** (1.01-1.19) | 1136 |
| | 01-02 | **.219** (.192-.251) | **.234** (.202-.265) | **.466** (.433-.519) | **.817** (.733-.886) | **1.17** (.918-1.36) | 1355 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **.191** (.157-.233) | **.202** (.167-.221) | **.438** (.351-.551) | **.813** (.686-.977) | **1.12** (.886-1.38) | 780 |
| | 01-02 | **.160** (.135-.189) | **.181** (.171-.198) | **.321** (.285-.362) | **.559** (.430-.733) | **.766** (.633-1.15) | 683 |
| Non-Hispanic blacks | 99-00 | **.283** (.208-.387) | **.312** (.243-.412) | **.633** (.498-.806) | **1.22** (.892-1.38) | **1.48** (1.30-1.72) | 546 |
| | 01-02 | **.277** (.229-.336) | **.302** (.257-.354) | **.580** (.476-.713) | **1.04** (.843-1.38) | **1.51** (1.28-1.74) | 667 |
| Non-Hispanic whites | 99-00 | **.175** (.148-.206) | **.220** (.194-.246) | **.455** (.388-.510) | **.797** (.714-1.01) | **1.17** (.963-1.47) | 760 |
| | 01-02 | **.204** (.179-.231) | **.221** (.191-.255) | **.445** (.394-.479) | **.813** (.717-.875) | **1.17** (.989-1.24) | 1132 |

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

are uncertain, key factors may involve perturbation of zinc-dependent biochemical processes, induction of oxidative stress, aberrant gene expression, estrogenic effects (Johnson et al., 2003), or altered cell signaling and steroidogenesis (Misra et al., 2003; Waalkes, 2003; Henson and Chedrese, 2004).

Acute and heavy airborne exposure to dusts and fumes, as may occur from welding on cadmium-alloyed metals, may result in severe, potentially fatal pneumonitis (Fernandez et al., 1996). Chronic inhalation exposure to cadmium particulate has been associated with changes in pulmonary function and chest radiography consistent with emphysema (Davison et al., 1988). Among U.S. adult smokers and former smokers studied in NHANES III, increases in urinary cadmium were associated with obstructive changes in pulmonary function (Mannino et al., 2004). Workplace exposure to airborne cadmium particulate has been associated with decrements in olfactory function (Mascagni et al., 2003). Animal studies have demonstrated reproductive and teratogenic effects. Two recent small epidemiologic studies have noted a positive association of environmental cadmium levels in maternal urine or blood with gestational age (Nishijo et al., 2002) and birth height (Zhang et al., 2004). NTP has determined that cadmium is a known human carcinogen. Potential modes of action have recently been reviewed (Waalkes, 2003). 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 Cadmium in Blood and Urine Reported in the Tables

In the NHANES 2001-2002 sample, blood cadmium levels were measured in all participants aged 1 year and older, and urine cadmium levels were measured in a sample of people aged 6 years and older. Participants were selected to be a representative sample of the U.S.

**Table 11. Cadmium 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 | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) 50th | 75th | 90th | 95th | Sample size |
|---|---|---|---|---|---|---|---|
| **Total, age 6 and older** | 99-00 | **.181** (.157-.209) | **.219** (.199-.238) | **.423** (.391-.446) | **.712** (.645-.757) | **.933** (.826-1.07) | 2257 |
| | 01-02 | **.199** (.181-.218) | **.212** (.194-.232) | **.404** (.377-.440) | **.690** (.630-.754) | **.917** (.813-.998) | 2689 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **.085** (.063-.107) | **.147** (.123-.182) | **.210** (.171-.316) | **.300** (.184-.607) | 310 |
| | 01-02 | **.075** (.059-.094) | **.100** (.083-.112) | **.166** (.136-.192) | **.233** (.206-.281) | **.291** (.221-.440) | 368 |
| 12-19 years | 99-00 | **.071** (.051-.098) | **.093** (.084-.106) | **.147** (.130-.163) | **.215** (.204-.240) | **.283** (.222-.404) | 648 |
| | 01-02 | **.078** (.067-.091) | **.091** (.085-.101) | **.136** (.123-.143) | **.191** (.175-.234) | **.280** (.234-.321) | 762 |
| 20 years and older | 99-00 | **.267** (.247-.289) | **.288** (.261-.304) | **.484** (.433-.545) | **.769** (.727-.818) | **1.07** (.927-1.17) | 1299 |
| | 01-02 | **.261** (.236-.289) | **.273** (.247-.303) | **.481** (.426-.518) | **.776** (.691-.850) | **.979** (.874-1.12) | 1559 |
| **Gender** | | | | | | | |
| Males | 99-00 | **.154** (.131-.182) | **.174** (.158-.191) | **.329** (.293-.382) | **.617** (.537-.700) | **.788** (.696-.929) | 1121 |
| | 01-02 | **.159** (.143-.177) | **.168** (.157-.182) | **.334** (.304-.364) | **.532** (.491-.653) | **.757** (.690-.856) | 1334 |
| Females | 99-00 | **.211** (.170-.261) | **.267** (.239-.308) | **.473** (.423-.551) | **.783** (.690-.917) | **1.09** (.813-1.38) | 1136 |
| | 01-02 | **.245** (.216-.278) | **.263** (.228-.297) | **.479** (.414-.541) | **.792** (.687-.884) | **.985** (.876-1.16) | 1355 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **.175** (.137-.223) | **.181** (.144-.225) | **.331** (.266-.418) | **.612** (.441-.828) | **.843** (.674-1.13) | 780 |
| | 01-02 | **.156** (.136-.178) | **.170** (.150-.184) | **.282** (.263-.340) | **.501** (.388-.614) | **.693** (.507-.839) | 682 |
| Non-Hispanic blacks | 99-00 | **.183** (.140-.240) | **.201** (.168-.241) | **.414** (.343-.472) | **.658** (.516-.827) | **.873** (.722-.962) | 546 |
| | 01-02 | **.190** (.156-.232) | **.195** (.174-.225) | **.385** (.336-.449) | **.676** (.559-.850) | **.917** (.725-1.08) | 667 |
| Non-Hispanic whites | 99-00 | **.175** (.146-.209) | **.219** (.191-.250) | **.432** (.387-.470) | **.729** (.666-.783) | **1.00** (.826-1.16) | 760 |
| | 01-02 | **.205** (.184-.229) | **.224** (.208-.242) | **.421** (.382-.470) | **.719** (.668-.784) | **.931** (.806-1.05) | 1132 |

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

population. Blood cadmium reflects both recent and cumulative exposures. During typical environmental exposure, urinary cadmium predominantly reflects cumulative exposure and the concentration of cadmium in the kidney (Nordberg and Nordberg, 2001; Lauwerys and Hoet, 2001 Satarug et al., 2002).
A general population survey of approximately 4,700 adults in Germany in 1998 found levels of cadmium in blood and urine that were also similar or slightly higher than the adult values reported in the 1999-2000 and 2001-2002 samples (Becker et al., 2002; Becker et al., 2003). Creatinine-corrected urine cadmium values obtained in a study of 361 subjects from a U.S. community, where smelting activity had occurred in the past, and an unexposed comparison community were also similar to the corresponding values in this *Report* (Noonan et al., 2002). A general population survey of 10,753 adult Japanese women found geometric mean urinary cadmium levels that were approximately four-to five-fold higher than the levels found for U.S. adults in this *Report*. (Ezaki et al., 2003). People who are occupationally exposed may have blood and urine levels that are higher than levels in the general population. The 95$^{th}$ percentiles for blood cadmium levels in this *Report* are less than the OSHA criterion (OSHA, 29 CFR 1910.1027) for blood cadmium (5 µg/L), and the 95$^{th}$ percentile for urine cadmium is less than the OSHA criterion for urine cadmium (3 µg/gram of creatinine). Occupational criteria are provided here for comparison only, not to imply a safety level for general population exposure.

In recent studies, levels of urinary cadmium greater than or equal to 1 µg/gram of creatinine have been associated with increases in urinary protein markers of renal tubular function (Jarup et al., 2000; Moriguchi et al., 2004; Noonan et al., 2002). In addition, a decrease in bone density has been correlated with urinary cadmium excretion among middle-aged women with a mean urinary cadmium concentration of approximately 1 µg/gram creatinine (Staessen et al., 1999), and among women older than 60 years, the odds of low bone-mineral density increased by nearly three-fold when the blood cadmium level exceeded 1.1 µg/L (Alfven et al., 2002). In this *Report*, the urinary and blood cadmium levels at the 95$^{th}$ and 90$^{th}$ percentiles, respectively, approach these cited values associated with subclinical changes in renal function and bone mineral density. Further research is needed to address the public health consequences of such exposure in the United States.

### Comparing Adjusted Geometric Means

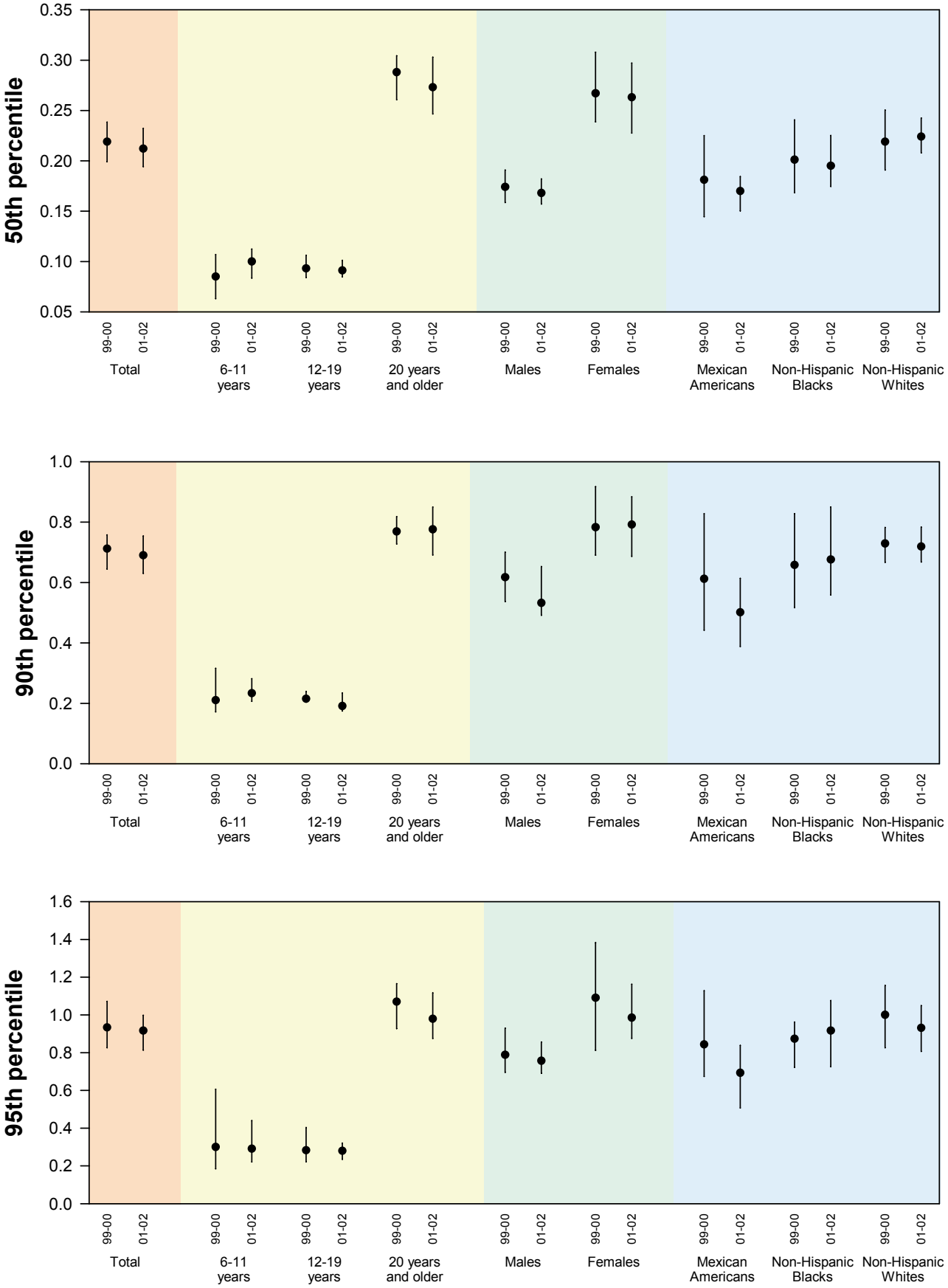
Geometric mean levels of blood cadmium in the NHANES 2001-2002 sample could not be calculated for this *Report* due to an insufficient number of samples with detectable levels of cadmium. The adjusted geometric mean levels of blood cadmium for the demographic groups were compared previously in the NHANES 1999-2000 sample after adjusting for the covariates of race/ethnicity, age, gender, log serum cotinine, and urinary creatinine (data not shown). Adjusted geometric mean levels of blood cadmium were slightly higher in the group aged 20 years and older than either of the groups aged 6-11 or the 12-19 years; and the group aged 12-19 years was higher than the group aged 6-11 years. Females had slightly higher blood cadmium levels than males. Mexican Americans had higher adjusted geometric mean levels of blood cadmium than non-Hispanic whites or non-Hispanic blacks; and non-Hispanic blacks had higher blood cadmium levels than non-Hispanic whites. Similar relationships for age and gender were found in a study of NHANES III participants (Paschal et al., 2000).

Due to a recently demonstrated interference from molybdenum oxide when measuring low-level urinary cadmium using the ICP-MS method, both the 1999-2000 and 2001-2002 data were corrected for this interference based on the molybdenum measurement and expected proportion of molybdenum oxide. Geometric mean levels of urinary cadmium for the demographic groups were compared after adjusting for the covariates of race/ethnicity, age, gender, log serum cotinine, and urinary creatinine. In the NHANES 2001-2002 sample, the group aged 20 years and older had higher adjusted geometric mean levels of urinary cadmium than in either of the groups aged 6-11 or 12-19 years. Females had higher urinary cadmium levels than males. Higher urinary cadmium values in females than in males have been observed in other general population studies (Olsson et al., 2002) and, as noted previously, may be a possible consequence of increased gastrointestinal absorption of cadmium in females. 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.

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

## Figure 3. Cadmium 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.



# 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. Radioactive $^{137}Cs$ has been used medically to treat cancer.

Most human exposure to cesium occurs through the diet. For absorbed cesium salts, the body half-life is estimated to be 70-109 days based on $^{137}Cs$ exposures. Little is known about the health effects of this metal although cesium is generally of low toxicity when given to animals. However, cesium hydroxide is corrosive and irritating when concentrations are high. Workplace air standards for external exposure for certain cesium salts are recommended by NIOSH on the basis of these irritant effects. It is not known whether cesium compounds are carcinogenic.

## Interpreting Levels of Urinary Cesium Reported in the Tables

Urinary cesium 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. In one study of clinically submitted specimens (Komaromy-Hiller et al., 2000), mean urinary cesium concentrations were slightly lower than those reported here. In a small population study of Europeans, Minoia et al. (1990) found average urinary cesium levels to be comparable to levels in this *Report*. Median values in the NHANES 1999-2000 and 2001-2002 subsamples are more than

### Table 12. Cesium

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

| | 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 | **4.35** (4.00-4.74) | **4.80** (4.40-5.30) | **7.10** (6.50-7.70) | **9.60** (8.80-10.3) | **11.4** (10.2-12.9) | 2464 |
| | 01-02 | **4.81** (4.40-5.26) | **5.49** (5.09-5.89) | **7.91** (7.47-8.39) | **10.4** (9.56-11.4) | **12.6** (11.1-13.8) | 2690 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **4.87** (4.08-5.81) | **5.60** (4.60-6.70) | **7.30** (6.70-8.00) | **9.00** (7.90-10.1) | **9.70** (8.90-10.4) | 340 |
| | 01-02 | **4.87** (4.08-5.82) | **5.61** (4.69-6.52) | **7.96** (6.77-8.84) | **9.79** (8.64-10.6) | **11.1** (10.2-12.4) | 368 |
| 12-19 years | 99-00 | **4.55** (4.09-5.05) | **5.10** (4.30-5.60) | **6.80** (6.10-7.70) | **8.80** (8.00-9.40) | **10.4** (8.90-12.3) | 718 |
| | 01-02 | **5.22** (4.57-5.95) | **5.62** (5.13-6.12) | **7.55** (7.13-8.04) | **9.71** (9.12-11.1) | **12.0** (10.0-15.0) | 762 |
| 20 years and older | 99-00 | **4.26** (3.94-4.62) | **4.80** (4.40-5.30) | **7.10** (6.50-7.60) | **9.80** (8.80-10.5) | **11.6** (10.2-13.2) | 1406 |
| | 01-02 | **4.74** (4.32-5.20) | **5.43** (5.05-5.87) | **7.96** (7.43-8.52) | **10.6** (9.73-11.5) | **12.8** (11.2-14.2) | 1560 |
| **Gender** | | | | | | | |
| Males | 99-00 | **4.84** (4.35-5.38) | **5.50** (4.60-5.90) | **7.50** (6.90-8.20) | **9.70** (8.60-10.7) | **11.6** (10.3-13.0) | 1226 |
| | 01-02 | **5.34** (4.89-5.84) | **6.11** (5.61-6.64) | **8.26** (7.84-9.08) | **10.8** (10.1-12.1) | **12.8** (11.3-15.0) | 1335 |
| Females | 99-00 | **3.95** (3.63-4.29) | **4.50** (4.10-4.80) | **6.60** (6.20-7.30) | **9.10** (8.30-9.90) | **11.1** (9.90-12.9) | 1238 |
| | 01-02 | **4.36** (3.95-4.81) | **4.87** (4.45-5.25) | **7.29** (6.71-8.01) | **9.77** (9.07-11.0) | **12.4** (10.4-13.8) | 1355 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **4.32** (3.82-4.89) | **4.70** (4.20-5.10) | **6.60** (6.20-7.10) | **9.10** (8.00-9.80) | **10.9** (9.50-12.6) | 884 |
| | 01-02 | **4.63** (4.10-5.24) | **5.29** (4.59-5.89) | **7.08** (6.42-7.99) | **9.13** (7.86-11.3) | **11.3** (8.81-14.9) | 683 |
| Non-Hispanic blacks | 99-00 | **4.94** (4.33-5.64) | **5.40** (4.80-6.30) | **7.40** (6.80-8.20) | **9.80** (8.80-10.8) | **11.5** (9.80-13.1) | 568 |
| | 01-02 | **4.93** (4.70-5.17) | **5.31** (5.05-5.63) | **7.36** (6.97-7.59) | **9.44** (8.71-9.68) | **10.7** (10.1-12.3) | 667 |
| Non-Hispanic whites | 99-00 | **4.25** (3.83-4.72) | **4.70** (4.20-5.50) | **7.10** (6.50-7.80) | **9.60** (8.80-10.4) | **11.7** (10.3-13.3) | 821 |
| | 01-02 | **4.77** (4.27-5.32) | **5.46** (4.97-6.03) | **7.97** (7.43-8.55) | **10.4** (9.54-11.4) | **12.6** (11.0-13.8) | 1132 |

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. These data will also help scientists plan and conduct research about exposure to cesium and health effects.

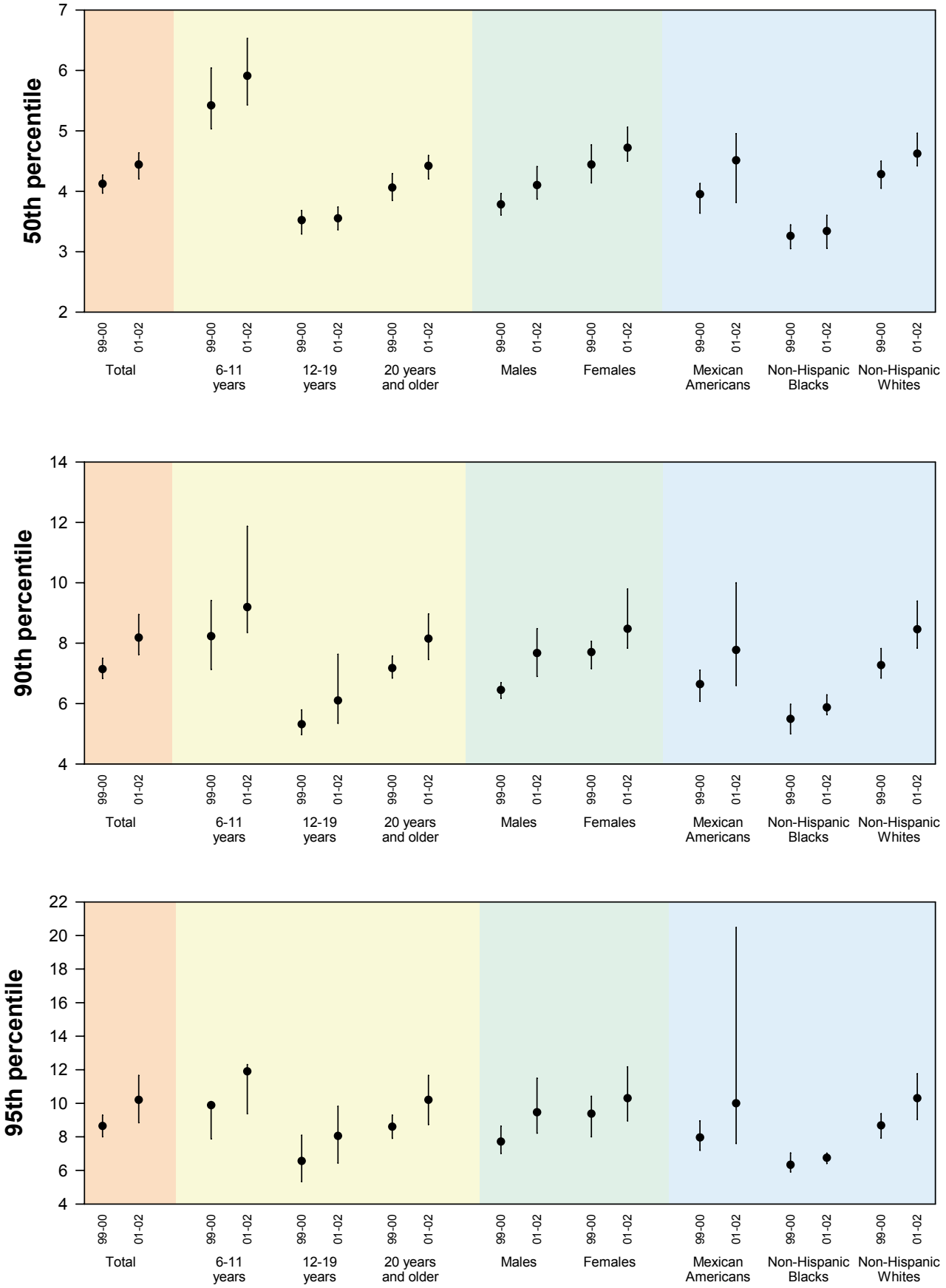
### Table 13. Cesium (creatinine corrected)

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 | **4.10** (3.96-4.25) | **4.12** (3.97-4.27) | **5.41** (5.21-5.70) | **7.14** (6.83-7.50) | **8.64** (8.00-9.30) | 2464 |
| | 01-02 | **4.54** (4.30-4.79) | **4.44** (4.20-4.64) | **6.06** (5.66-6.47) | **8.18** (7.62-8.95) | **10.2** (8.84-11.7) | 2689 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **5.34** (5.03-5.67) | **5.42** (5.03-6.04) | **6.63** (6.18-7.13) | **8.23** (7.13-9.41) | **9.89** (7.88-10.1) | 340 |
| | 01-02 | **5.95** (5.48-6.46) | **5.91** (5.43-6.53) | **7.77** (7.00-8.28) | **9.19** (8.35-11.9) | **11.9** (9.38-12.3) | 368 |
| 12-19 years | 99-00 | **3.43** (3.29-3.58) | **3.52** (3.29-3.68) | **4.35** (4.17-4.56) | **5.31** (4.97-5.79) | **6.56** (5.33-8.09) | 718 |
| | 01-02 | **3.73** (3.41-4.08) | **3.55** (3.36-3.74) | **4.74** (4.40-5.13) | **6.10** (5.35-7.63) | **8.05** (6.44-9.82) | 762 |
| 20 years and older | 99-00 | **4.08** (3.88-4.29) | **4.06** (3.85-4.29) | **5.38** (5.04-5.85) | **7.17** (6.84-7.58) | **8.60** (7.91-9.30) | 1406 |
| | 01-02 | **4.54** (4.30-4.78) | **4.42** (4.20-4.59) | **5.94** (5.64-6.40) | **8.15** (7.46-8.97) | **10.2** (8.74-11.7) | 1559 |
| **Gender** | | | | | | | |
| Males | 99-00 | **3.78** (3.65-3.91) | **3.78** (3.60-3.96) | **4.96** (4.72-5.20) | **6.45** (6.18-6.70) | **7.71** (7.01-8.64) | 1226 |
| | 01-02 | **4.22** (3.96-4.51) | **4.10** (3.87-4.41) | **5.60** (5.27-6.03) | **7.67** (6.90-8.48) | **9.46** (8.22-11.5) | 1334 |
| Females | 99-00 | **4.43** (4.20-4.68) | **4.44** (4.14-4.77) | **5.92** (5.36-6.47) | **7.70** (7.16-8.06) | **9.38** (8.00-10.4) | 1238 |
| | 01-02 | **4.86** (4.58-5.16) | **4.72** (4.50-5.06) | **6.54** (5.93-7.00) | **8.47** (7.84-9.79) | **10.3** (8.95-12.2) | 1355 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **3.99** (3.73-4.25) | **3.95** (3.64-4.13) | **5.09** (4.79-5.38) | **6.64** (6.08-7.10) | **7.96** (7.20-8.95) | 884 |
| | 01-02 | **4.51** (4.00-5.08) | **4.51** (3.82-4.95) | **5.91** (5.31-6.64) | **7.77** (6.60-10.0) | **10.0** (7.60-20.5) | 682 |
| Non-Hispanic blacks | 99-00 | **3.21** (2.90-3.56) | **3.26** (3.05-3.44) | **4.30** (4.00-4.55) | **5.49** (5.00-5.98) | **6.33** (5.91-7.04) | 568 |
| | 01-02 | **3.38** (3.19-3.57) | **3.34** (3.05-3.60) | **4.41** (4.15-4.78) | **5.87** (5.63-6.29) | **6.75** (6.41-7.03) | 667 |
| Non-Hispanic whites | 99-00 | **4.26** (4.07-4.47) | **4.28** (4.05-4.50) | **5.63** (5.26-6.05) | **7.27** (6.84-7.83) | **8.68** (7.93-9.38) | 821 |
| | 01-02 | **4.81** (4.55-5.08) | **4.62** (4.42-4.96) | **6.33** (5.91-6.68) | **8.46** (7.84-9.39) | **10.3** (9.04-11.8) | 1132 |

## Figure 4. Cesium 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.



# 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 exhaust. Usual human exposure is from food sources. Cobalt may be released into the systemic circulation of patients who receive joint prostheses that are fabricated from cobalt alloys (Lhotka et al., 2003). Exposure in the workplace may come from electroplating, the refining or processing of alloys, the grinding of tungsten carbide-type, hard-metal cutting tools, and the use of diamond-polishing wheels containing cobalt metal. Workplace standards for external air exposure to cobalt and several of its compounds have been established by OSHA and ACGIH.

## Table 14. Cobalt

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

| | 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 | **.375** (.336-.419) | **.400** (.360-.440) | **.630** (.570-.670) | **.940** (.890-1.03) | **1.32** (1.16-1.48) | 2465 |
| | 01-02 | **.379** (.355-.404) | **.410** (.380-.430) | **.610** (.570-.660) | **.930** (.860-1.00) | **1.27** (1.15-1.44) | 2690 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **.499** (.427-.583) | **.520** (.430-.600) | **.740** (.610-.900) | **1.03** (.860-1.12) | **1.22** (1.03-1.50) | 340 |
| | 01-02 | **.452** (.377-.543) | **.510** (.430-.610) | **.710** (.660-.810) | **1.07** (.940-1.21) | **1.28** (1.17-1.53) | 368 |
| 12-19 years | 99-00 | **.519** (.463-.581) | **.520** (.480-.550) | **.810** (.670-.890) | **1.16** (1.01-1.47) | **1.52** (1.26-2.56) | 719 |
| | 01-02 | **.515** (.469-.564) | **.520** (.470-.570) | **.750** (.690-.840) | **1.23** (1.07-1.32) | **1.59** (1.37-1.99) | 762 |
| 20 years and older | 99-00 | **.343** (.305-.386) | **.360** (.320-.410) | **.560** (.510-.640) | **.880** (.800-.950) | **1.28** (1.07-1.39) | 1406 |
| | 01-02 | **.352** (.333-.373) | **.370** (.350-.400) | **.550** (.520-.590) | **.860** (.790-.930) | **1.15** (1.04-1.42) | 1560 |
| **Gender** | | | | | | | |
| Males | 99-00 | **.371** (.331-.416) | **.400** (.360-.440) | **.580** (.530-.630) | **.810** (.730-.890) | **1.01** (.900-1.12) | 1227 |
| | 01-02 | **.367** (.338-.399) | **.390** (.360-.410) | **.540** (.510-.590) | **.780** (.740-.840) | **1.05** (.960-1.14) | 1335 |
| Females | 99-00 | **.379** (.333-.431) | **.410** (.340-.460) | **.670** (.590-.790) | **1.17** (.930-1.36) | **1.49** (1.28-1.98) | 1238 |
| | 01-02 | **.390** (.364-.417) | **.430** (.390-.440) | **.660** (.620-.700) | **1.05** (.980-1.16) | **1.44** (1.22-1.81) | 1355 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **.418** (.348-.502) | **.470** (.370-.530) | **.660** (.620-.760) | **1.05** (.950-1.19) | **1.47** (1.25-1.67) | 884 |
| | 01-02 | **.398** (.373-.424) | **.420** (.400-.450) | **.640** (.600-.710) | **.950** (.850-1.03) | **1.20** (1.06-1.48) | 683 |
| Non-Hispanic blacks | 99-00 | **.434** (.405-.465) | **.420** (.390-.470) | **.680** (.620-.750) | **1.15** (1.02-1.25) | **1.45** (1.23-2.04) | 568 |
| | 01-02 | **.435** (.388-.487) | **.410** (.380-.440) | **.650** (.540-.810) | **1.15** (.840-1.63) | **1.75** (1.32-2.22) | 667 |
| Non-Hispanic whites | 99-00 | **.369** (.316-.431) | **.400** (.340-.450) | **.620** (.550-.700) | **.930** (.820-1.07) | **1.29** (1.02-1.65) | 822 |
| | 01-02 | **.359** (.327-.394) | **.380** (.350-.430) | **.580** (.520-.650) | **.870** (.800-.930) | **1.16** (1.04-1.32) | 1132 |

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 distinction should be made between soluble cobalt and insoluble (oxides and metallic) cobalt (Christensen and Poulsen, 1994; Lison et al., 1994). Exposure to soluble cobalt salts will produce proportionately higher urinary levels because of better absorption. Correlations between air-exposure levels and urinary cobalt levels in hard-metal fabricators are well documented (Ichikawa et al., 1985; Linnainmaa and Kiilunen, 1997; ACGIH 2001; Kraus et al., 2001; Lauwerys and Hoet, 2001).

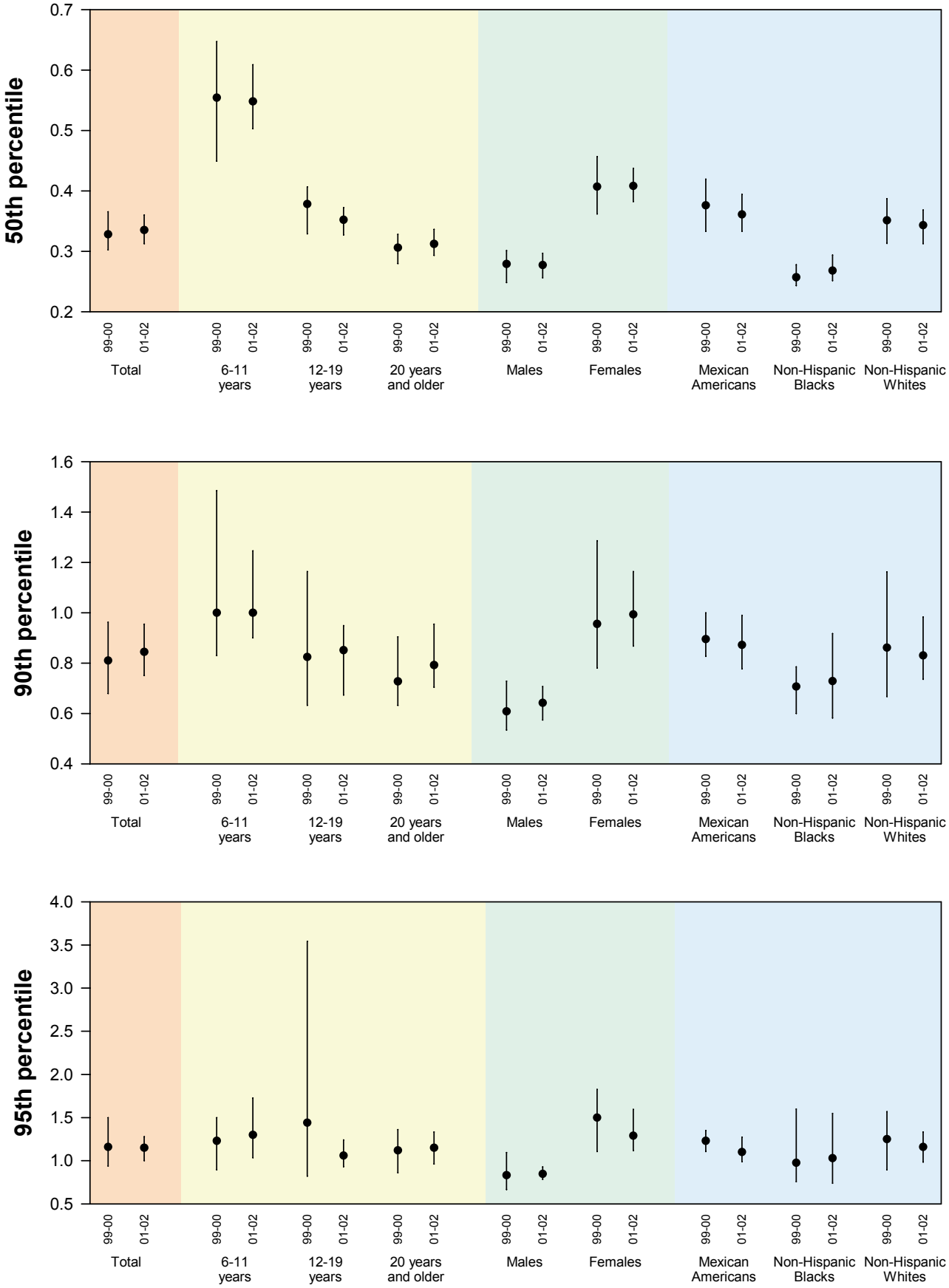
### Comparing Adjusted Geometric Means

Geometric mean levels of urinary cobalt 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 cobalt were slightly higher for children aged 6-11 years than for people aged 12-19 years, with both age groups having higher levels than people aged 20 years and older. Urinary cobalt levels in females were higher than in males, and levels in non-Hispanic blacks were slightly lower than in either Mexican Americans or non-Hispanic whites. Relative higher urinary cobalt levels in females than in males have been noted in other investigations and may reflect increased cobalt uptake by premenopausal women (Kristiansen et al., 1997). 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.

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

## 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 exposure still exist, including lead-glazed ceramic pottery; pewter utensils and drinking vessels; plumbing systems with lead-soldered joints or lead pipes; lead-based painted surfaces undergoing renovation or demolition; lead-containing folk remedies; bullet fragments retained in human tissue; lead-contaminated

### Table 16. Lead in blood

Geometric mean and selected percentiles of blood concentrations (in µg/dL) for the U.S. population aged 1 year and older, National Health and Nutrition Examination Survey, 1999-2002.

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) 50th | 75th | 90th | 95th | Sample size |
|---|---|---|---|---|---|---|---|
| **Total, age 1 and older** | 99-00 | **1.66** (1.60-1.72) | **1.60** (1.50-1.60) | **2.40** (2.30-2.60) | **3.80** (3.60-3.90) | **4.90** (4.60-5.30) | 7970 |
| | 01-02 | **1.45** (1.39-1.51) | **1.40** (1.30-1.40) | **2.20** (2.10-2.20) | **3.40** (3.10-3.50) | **4.40** (4.20-4.70) | 8945 |
| **Age group** | | | | | | | |
| 1-5 years | 99-00 | **2.23** (1.96-2.53) | **2.20** (1.90-2.50) | **3.30** (2.80-3.80) | **4.80** (4.00-6.60) | **7.00** (6.10-8.30) | 723 |
| | 01-02 | **1.70** (1.55-1.87) | **1.50** (1.40-1.70) | **2.50** (2.20-2.80) | **4.10** (3.40-5.00) | **5.80** (4.70-6.90) | 898 |
| 6-11 years | 99-00 | **1.51** (1.36-1.66) | **1.30** (1.20-1.50) | **2.00** (1.70-2.40) | **3.30** (2.70-3.60) | **4.50** (3.40-6.20) | 905 |
| | 01-02 | **1.25** (1.14-1.36) | **1.10** (1.00-1.30) | **1.60** (1.50-1.80) | **2.70** (2.40-3.00) | **3.70** (3.00-4.70) | 1044 |
| 12-19 years | 99-00 | **1.10** (1.04-1.17) | **1.00** (.900-1.10) | **1.40** (1.30-1.60) | **2.30** (2.10-2.30) | **2.80** (2.60-3.00) | 2135 |
| | 01-02 | **.942** (.899-.986) | **.800** (.800-.900) | **1.20** (1.20-1.30) | **1.90** (1.80-2.00) | **2.70** (2.30-2.90) | 2231 |
| 20 years and older | 99-00 | **1.75** (1.68-1.81) | **1.70** (1.60-1.70) | **2.50** (2.50-2.60) | **3.90** (3.70-4.00) | **5.20** (4.80-5.50) | 4207 |
| | 01-02 | **1.56** (1.49-1.62) | **1.60** (1.50-1.60) | **2.20** (2.20-2.30) | **3.60** (3.30-3.70) | **4.60** (4.20-4.90) | 4772 |
| **Gender** | | | | | | | |
| Males | 99-00 | **2.01** (1.93-2.09) | **1.80** (1.80-1.90) | **2.90** (2.80-3.00) | **4.40** (4.10-4.80) | **6.00** (5.40-6.40) | 3913 |
| | 01-02 | **1.78** (1.71-1.86) | **1.70** (1.70-1.80) | **2.70** (2.50-2.80) | **3.90** (3.70-4.10) | **5.30** (5.00-5.50) | 4339 |
| Females | 99-00 | **1.37** (1.32-1.43) | **1.30** (1.20-1.30) | **1.90** (1.90-2.10) | **3.00** (2.90-3.20) | **4.00** (3.70-4.20) | 4057 |
| | 01-02 | **1.19** (1.14-1.25) | **1.10** (1.10-1.20) | **1.80** (1.70-1.80) | **2.60** (2.40-2.70) | **3.60** (3.00-3.80) | 4606 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **1.83** (1.75-1.91) | **1.80** (1.60-1.80) | **2.70** (2.60-2.90) | **4.20** (3.90-4.50) | **5.80** (5.10-6.60) | 2742 |
| | 01-02 | **1.46** (1.34-1.60) | **1.50** (1.30-1.60) | **2.20** (2.00-2.60) | **3.60** (3.30-4.00) | **5.40** (4.40-6.60) | 2268 |
| Non-Hispanic blacks | 99-00 | **1.87** (1.75-2.00) | **1.70** (1.60-1.90) | **2.80** (2.50-2.90) | **4.20** (4.00-4.60) | **5.70** (5.20-6.10) | 1842 |
| | 01-02 | **1.65** (1.52-1.80) | **1.60** (1.40-1.70) | **2.50** (2.30-2.80) | **4.20** (3.80-4.60) | **5.70** (5.30-6.50) | 2219 |
| Non-Hispanic whites | 99-00 | **1.62** (1.55-1.69) | **1.60** (1.50-1.60) | **2.40** (2.30-2.40) | **3.60** (3.40-3.70) | **5.00** (4.40-5.70) | 2716 |
| | 01-02 | **1.43** (1.37-1.48) | **1.40** (1.30-1.40) | **2.10** (2.10-2.20) | **3.10** (3.00-3.40) | **4.10** (3.90-4.50) | 3806 |

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 subperiosteal surface and matrix of bone. Lead also undergoes transplacental transport and poses a potential hazard to the fetus. The kinetics of lead clearance from the body are characterized by a multi-compartmental model, predominantly composed of the blood and soft tissues, with a half-life of 1 to 2 months, and the skeleton, with a half-life of years to decades. Approximately 70% of lead excretion occurs via the urine, with lesser amounts eliminated via the feces, and scant amounts through sweat, hair, and nails (Leggett, 1993; O'Flaherty, 1993). The fraction of absorbed lead not undergoing prompt excretion, which is approximately half of the absorbed lead, may be incorporated into bone, the site of about 90% of the body lead burden in most adults.

Lead exerts multisystemic toxic effects through a variety of mechanisms, including interference in the function of essential cations such as calcium, zinc, and iron; inhibition of certain enzymes; binding to ion channels and regulatory proteins; generation of reactive oxygen species; and alteration in gene expression. Large amounts of lead in the body can cause clinical anemia, kidney injury, abdominal pain, seizures, encephalopathy, and paralysis. An increased prevalence of anemia has been observed with blood lead levels (BLLs) in excess of 25 µg/dL in children (Schwartz et al., 1990), or higher than 50 µg/dL in adults (Lilis et al., 1977). Kidney toxicity associated with chronic high-dose lead exposure includes interstitial and peritubular fibrosis, but low-level environmental lead exposure also can be associated with

## Table 17. Lead in urine

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 | **.766** (.708-.828) | **.800** (.700-.800) | **1.30** (1.30-1.40) | **2.10** (2.00-2.30) | **2.90** (2.60-3.20) | 2465 |
| | 01-02 | **.677** (.637-.718) | **.600** (.600-.700) | **1.20** (1.10-1.20) | **2.00** (1.80-2.00) | **2.60** (2.50-2.80) | 2690 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **1.07** (.955-1.20) | **1.00** (.900-1.20) | **1.50** (1.40-1.60) | **2.40** (1.80-3.00) | **3.40** (2.40-5.00) | 340 |
| | 01-02 | **.753** (.661-.857) | **.800** (.600-.800) | **1.20** (1.00-1.30) | **2.00** (1.60-2.40) | **2.60** (2.10-3.60) | 368 |
| 12-19 years | 99-00 | **.659** (.579-.749) | **.600** (.500-.800) | **1.10** (.900-1.20) | **1.70** (1.40-2.10) | **2.20** (1.90-2.50) | 719 |
| | 01-02 | **.564** (.526-.605) | **.600** (.500-.600) | **.900** (.800-1.10) | **1.50** (1.40-1.70) | **1.90** (1.70-2.10) | 762 |
| 20 years and older | 99-00 | **.752** (.691-.818) | **.700** (.700-.800) | **1.40** (1.20-1.50) | **2.10** (1.90-2.30) | **2.90** (2.50-3.20) | 1406 |
| | 01-02 | **.688** (.641-.738) | **.700** (.600-.700) | **1.20** (1.10-1.20) | **1.90** (1.80-2.10) | **2.80** (2.50-2.90) | 1560 |
| **Gender** | | | | | | | |
| Males | 99-00 | **.923** (.822-1.04) | **.900** (.800-.900) | **1.60** (1.40-1.80) | **2.40** (2.20-2.90) | **3.40** (2.90-3.70) | 1227 |
| | 01-02 | **.808** (.757-.862) | **.700** (.700-.800) | **1.30** (1.30-1.50) | **2.40** (2.20-2.70) | **3.20** (2.90-3.50) | 1335 |
| Females | 99-00 | **.642** (.589-.701) | **.600** (.600-.700) | **1.20** (1.10-1.30) | **1.90** (1.60-2.10) | **2.40** (2.00-2.90) | 1238 |
| | 01-02 | **.573** (.535-.613) | **.500** (.500-.600) | **1.00** (1.00-1.10) | **1.50** (1.40-1.70) | **2.20** (1.90-2.40) | 1355 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **1.02** (.915-1.13) | **1.00** (.900-1.20) | **1.70** (1.60-1.90) | **2.80** (2.50-3.40) | **4.10** (3.10-5.40) | 884 |
| | 01-02 | **.833** (.745-.931) | **.900** (.700-1.00) | **1.50** (1.20-1.70) | **2.40** (2.00-2.90) | **3.20** (2.70-3.70) | 683 |
| Non-Hispanic blacks | 99-00 | **1.11** (1.00-1.23) | **1.10** (1.00-1.20) | **1.90** (1.50-2.00) | **2.90** (2.40-3.50) | **4.20** (3.30-5.70) | 568 |
| | 01-02 | **.940** (.833-1.06) | **.900** (.800-.900) | **1.50** (1.30-1.80) | **2.60** (2.00-3.20) | **3.70** (2.90-4.80) | 667 |
| Non-Hispanic whites | 99-00 | **.695** (.625-.773) | **.700** (.600-.700) | **1.30** (1.10-1.40) | **1.90** (1.70-2.20) | **2.60** (2.30-3.00) | 822 |
| | 01-02 | **.610** (.572-.651) | **.600** (.600-.700) | **1.00** (1.00-1.10) | **1.80** (1.70-2.00) | **2.40** (2.10-2.50) | 1132 |

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 | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) 50th | 75th | 90th | 95th | 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** (1.40-1.61) | **2.00** (1.85-2.19) | 1559 |
| **Gender** | | | | | | | |
| Males | 99-00 | **.720** (.679-.763) | **.693** (.645-.734) | **1.10** (.991-1.22) | **1.68** (1.50-2.09) | **2.43** (2.15-3.03) | 1227 |
| | 01-02 | **.639** (.607-.673) | **.638** (.586-.684) | **1.01** (.957-1.08) | **1.55** (1.41-1.61) | **2.06** (1.88-2.43) | 1334 |
| Females | 99-00 | **.722** (.681-.765) | **.706** (.667-.746) | **1.11** (1.05-1.16) | **1.74** (1.50-2.02) | **2.38** (2.03-2.88) | 1238 |
| | 01-02 | **.639** (.594-.688) | **.625** (.571-.670) | **1.03** (.938-1.11) | **1.50** (1.39-1.61) | **1.98** (1.85-2.15) | 1355 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **.940** (.876-1.01) | **.882** (.796-1.02) | **1.43** (1.36-1.56) | **2.38** (2.08-2.77) | **3.31** (2.78-4.18) | 884 |
| | 01-02 | **.810** (.731-.898) | **.769** (.702-.893) | **1.28** (1.09-1.44) | **2.05** (1.75-2.50) | **2.78** (2.55-3.33) | 682 |
| Non-Hispanic blacks | 99-00 | **.722** (.659-.790) | **.667** (.583-.753) | **1.11** (.988-1.20) | **1.98** (1.56-2.51) | **2.83** (2.20-3.88) | 568 |
| | 01-02 | **.644** (.559-.742) | **.606** (.510-.710) | **.962** (.853-1.19) | **1.79** (1.36-2.33) | **2.75** (2.04-3.98) | 667 |
| Non-Hispanic whites | 99-00 | **.696** (.668-.725) | **.677** (.645-.718) | **1.07** (.997-1.14) | **1.66** (1.50-1.83) | **2.31** (1.94-2.82) | 822 |
| | 01-02 | **.615** (.579-.654) | **.621** (.571-.667) | **1.00** (.930-1.06) | **1.46** (1.37-1.52) | **1.88** (1.61-2.00) | 1132 |

### 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).

### Comparing Adjusted Geometric Means

Geometric mean BLLs for the demographic groups were compared after adjusting for the covariates of race/ethnicity, age, gender, and log serum cotinine (data not shown). In NHANES 2001-2002, adjusted geometric mean BLLs were higher in children aged 1-5 years than in children aged 6-11 years, and both these age groups had higher levels than did those aged 12-19 years. BLLs in adults aged 20 years and older were higher than BLLs in the group aged 12-19 years. BLLs for males were higher than those for females. Non-Hispanic whites had lower BLLs than non-Hispanic blacks.

For urinary lead in NHANES 2001-2002, adjusted geometric mean levels of urinary lead in the group aged 6-11 years were higher than either the group aged 12-19 years or the group aged 20 years and older. The group aged 20 years and older had higher levels than the group aged 12-19 years. Mexican Americans had higher urinary levels than either non-Hispanic blacks or whites. Non-Hispanic blacks had higher levels than non-Hispanic whites. Males had slightly higher levels than females.

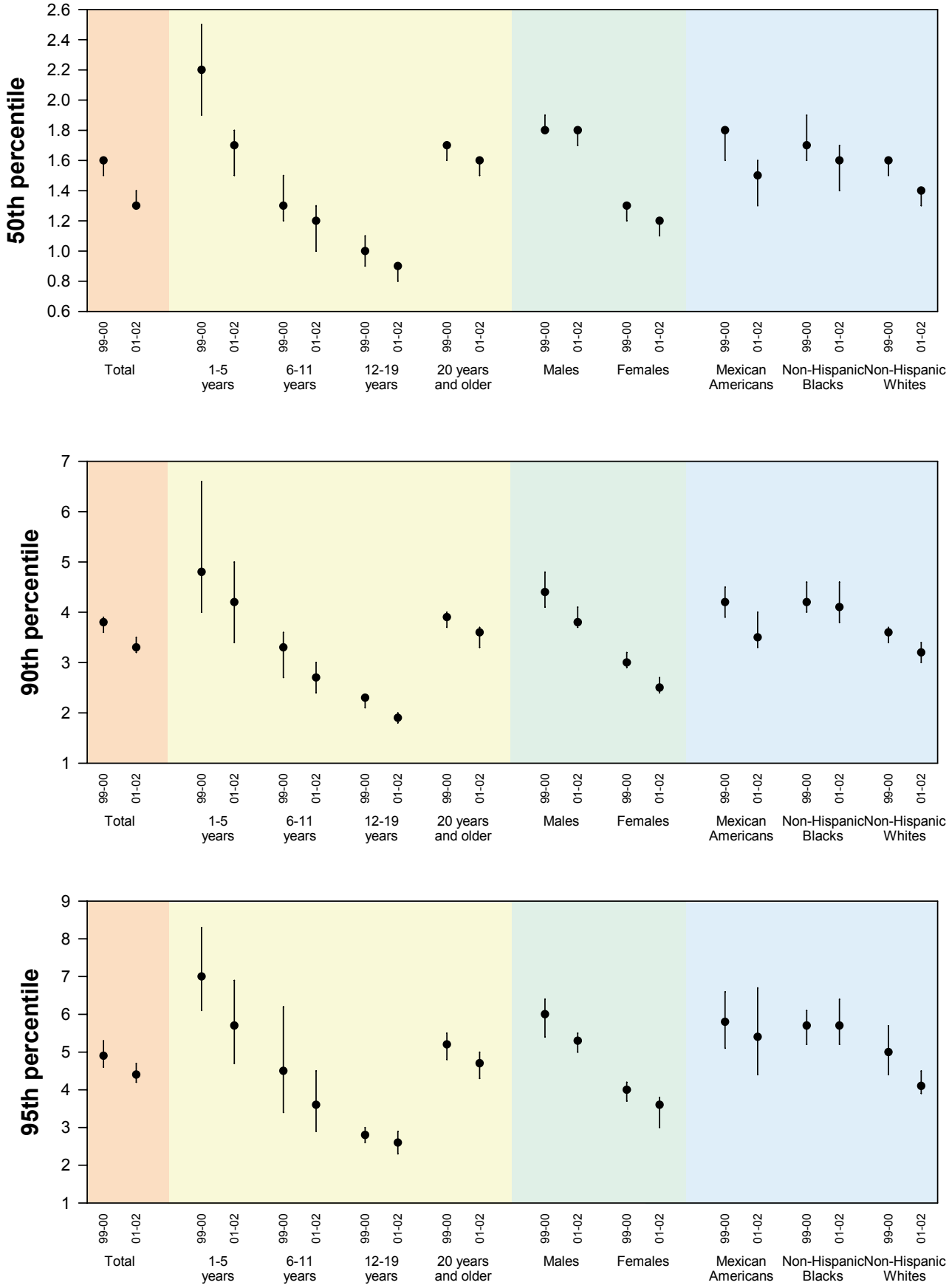
It is unknown whether these differences associated with age, gender or race/ethnicity represent differences in exposure, pharmacokinetics, or the relationship of dose per body weight. For instance, to account for the decreasing BLLs observed with increasing ages during childhood, several explanations are possible, including

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.

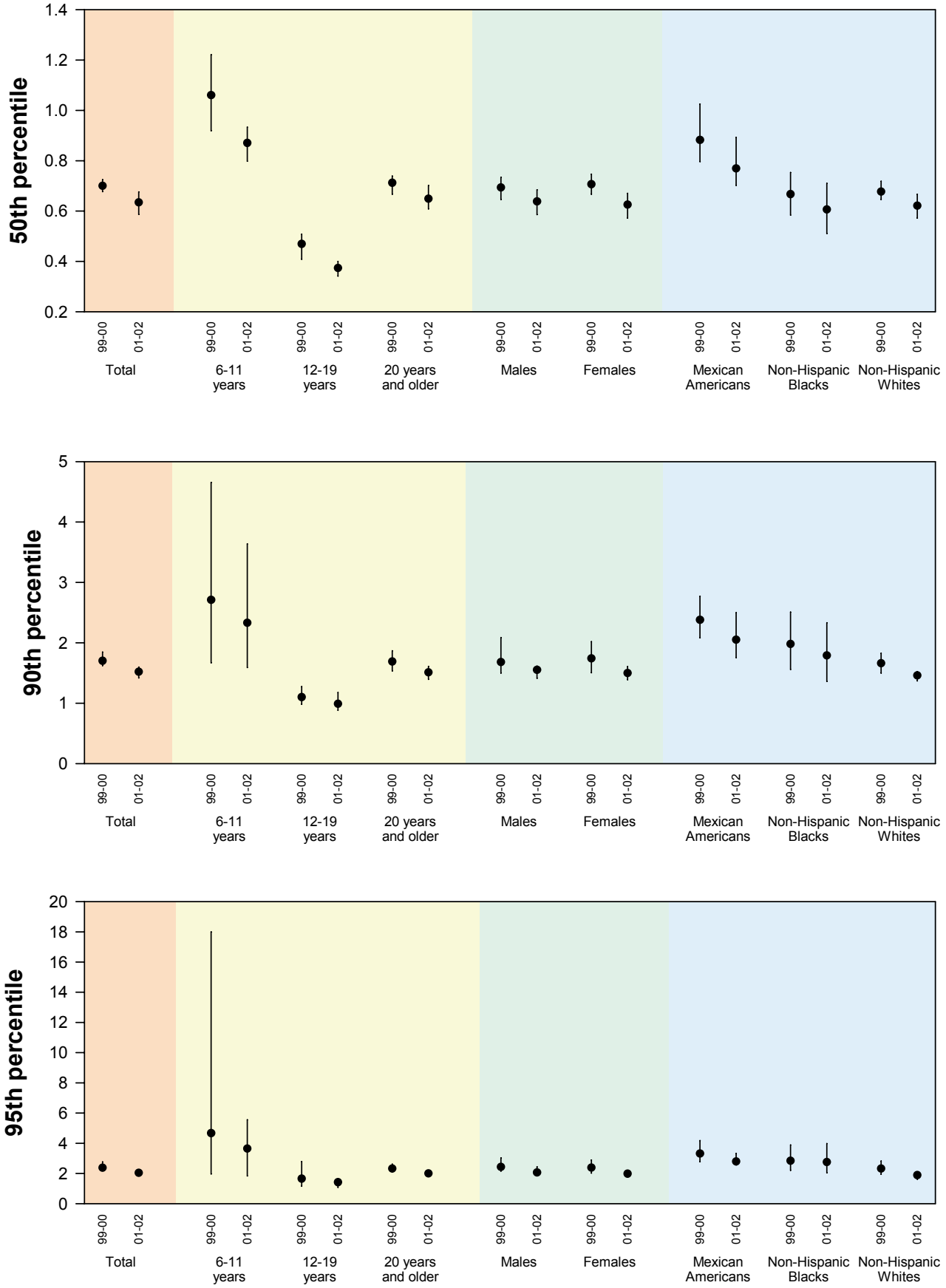
## Figure 6. Lead in blood

Selected percentiles with 95% confidence intervals of blood concentrations (in µg/dL) for the U.S. population aged 1 year and older, National Health and Nutrition Examination Survey, 1999-2002.



## 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.



# Mercury

CAS No. 7439-97-6

## General Information

Mercury is a naturally occurring metal that has elemental (metallic), inorganic, and organic forms. Elemental mercury is a shiny, silver-white liquid (quicksilver) obtained predominantly from the refining of mercuric sulfide in cinnabar ore. Elemental mercury is used to produce chlorine gas and caustic soda for industrial applications. Other major uses include electrical equipment (e.g., thermostats and switches), electrical lamps, thermometers, sphygmomanometers and barometers, and dental amalgam. Inorganic mercury exists in two oxidative states (mercurous and mercuric) that combine with other elements, such as chlorine (e.g., mercuric chloride), sulfur, or oxygen, to form inorganic mercury compounds or salts. Inorganic mercury compounds such as mercuric oxide are used in the production of batteries and pigments. Pharmaceutical applications of mercury have been declining, although certain organomercury compounds are still used as preservatives (e.g., thimerosal, phenylmercuric acetate) or topical antiseptics (e.g., merbromin). Some cosmetic skin creams from countries other than the U.S. may contain mercury. Folk medicines may contain mercury compounds, and elemental mercury is used ritually in some Latin American and Caribbean communities.

Elemental mercury is released into the air from the combustion of fossil fuels (primarily coal), solid-waste incineration, and mining and smelting. Through biogeochemical cycling, some atmospheric elemental mercury is deposited on land and water. In addition, water can be contaminated by the direct release of elemental and inorganic mercury from industrial processes. Metabolism of mercury by microorganisms in sediments creates methyl mercury, an organomercurial compound, which can bioaccumulate in terrestrial and especially aquatic food chains. The ingestion of methyl mercury, predominantly from fish and other seafood, constitutes the main source of dietary mercury exposure in the general population. Using the 1999-2000 NHANES data, it was estimated that women 16 to 49 years of age ingest a geometric

### Table 19. Mercury in blood

Geometric mean and selected percentiles of blood concentrations (in µg/L) for males and females aged 1 to 5 years and females aged 16 to 49 years in the U.S. population, National Health and Nutrition Examination Survey, 1999-2002.

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) 50th | 75th | 90th | 95th | Sample size |
|---|---|---|---|---|---|---|---|
| **Age Group** | | | | | | | |
| 1-5 years (females and males) | 99-00 | **.343** (.297-.395) | **.300** (.200-.300) | **.500** (.500-.600) | **1.40** (1.00-2.30) | **2.30** (1.20-3.50) | 705 |
| | 01-02 | **.318** (.268-.377) | **.300** (.200-.300) | **.700** (.500-.800) | **1.20** (.900-1.60) | **1.90** (1.40-2.90) | 872 |
| Females | 99-00 | **.377** (.299-.475) | **.200** (.200-.300) | **.800** (.500-1.10) | **1.60** (1.00-2.80) | **2.70** (1.30-5.50) | 318 |
| | 01-02 | **.329** (.265-.407) | **.300** (.200-.300) | **.700** (.500-.800) | **1.30** (1.00-2.10) | **2.60** (1.30-4.90) | 432 |
| Males | 99-00 | **.317** (.269-.374) | **.200** (.200-.300) | **.500** (.500-.600) | **1.10** (.800-1.60) | **2.10** (1.10-3.50) | 387 |
| | 01-02 | **.307** (.256-.369) | **.300** (.200-.300) | **.600** (.400-.700) | **1.30** (.900-1.70) | **1.70** (1.40-2.00) | 440 |
| 16-49 years (females only) | 99-00 | **1.02** (.825-1.27) | **.900** (.800-1.20) | **2.00** (1.50-3.00) | **4.90** (3.70-6.30) | **7.10** (5.30-11.3) | 1709 |
| | 01-02 | **.833** (.738-.940) | **.700** (.700-.800) | **1.70** (1.40-1.90) | **3.00** (2.70-3.50) | **4.60** (3.70-5.90) | 1928 |
| **Race/ethnicity** (females, 16-49 years) | | | | | | | |
| Mexican Americans | 99-00 | **.820** (.664-1.01) | **.900** (.700-1.00) | **1.40** (1.20-2.00) | **2.60** (2.00-3.60) | **4.00** (2.70-5.50) | 579 |
| | 01-02 | **.667** (.541-.824) | **.700** (.500-.800) | **1.10** (1.00-1.40) | **2.10** (1.70-3.00) | **3.50** (2.30-4.40) | 527 |
| Non-hispanic blacks | 99-00 | **1.35** (1.06-1.73) | **1.30** (1.10-1.70) | **2.60** (1.80-3.40) | **4.80** (3.30-6.60) | **5.90** (4.20-11.7) | 370 |
| | 01-02 | **1.06** (.871-1.29) | **1.10** (.800-1.20) | **1.80** (1.50-2.20) | **3.20** (2.20-3.90) | **4.10** (3.30-6.00) | 436 |
| Non-hispanic whites | 99-00 | **.944** (.726-1.23) | **.900** (.700-1.10) | **1.90** (1.30-3.30) | **5.00** (3.00-6.90) | **6.90** (4.50-12.0) | 588 |
| | 01-02 | **.800** (.697-.919) | **.800** (.700-.800) | **1.50** (1.30-2.00) | **3.00** (2.20-3.70) | **4.60** (3.30-6.80) | 806 |

## Table 20. Mercury in urine

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

| | 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 | **.719** (.622-.831) | **.760** (.610-.910) | **1.62** (1.43-1.94) | **3.15** (2.55-3.92) | **5.00** (3.59-5.79) | 1748 |
| | 01-02 | **.606** (.553-.665) | **.580** (.500-.670) | **1.37** (1.23-1.55) | **2.91** (2.53-3.17) | **3.99** (3.50-4.63) | 1960 |
| **Race/ethnicity** (females, 16-49 years) | | | | | | | |
| Mexican Americans | 99-00 | **.724** (.656-.799) | **.650** (.560-.810) | **1.69** (1.45-2.07) | **3.68** (3.10-4.45) | **5.62** (4.91-7.38) | 595 |
| | 01-02 | **.592** (.502-.699) | **.560** (.420-.710) | **1.35** (1.09-1.76) | **2.84** (2.32-3.85) | **4.13** (2.81-6.24) | 531 |
| Non-Hispanic blacks | 99-00 | **1.06** (.832-1.35) | **1.03** (.850-1.51) | **2.30** (1.83-3.03) | **4.81** (3.41-6.18) | **6.98** (5.04-10.3) | 381 |
| | 01-02 | **.772** (.616-.966) | **.740** (.540-.930) | **1.76** (1.30-2.37) | **3.50** (2.57-4.97) | **5.18** (3.61-6.92) | 442 |
| Non-Hispanic whites | 99-00 | **.657** (.557-.774) | **.710** (.520-.870) | **1.50** (1.31-1.77) | **2.84** (2.39-3.32) | **4.05** (3.16-5.52) | 594 |
| | 01-02 | **.565** (.501-.637) | **.540** (.450-.650) | **1.31** (1.09-1.56) | **2.70** (2.22-3.16) | **3.62** (3.13-4.54) | 826 |

mean of 1.22 micrograms of mercury per day from fish/seafood (approximately 85% as methyl mercury) (Mahaffey et al., 2004). Inhalation of mercury volatilized from dental amalgam is another major source of mercury exposure in the general population and is estimated to result in a daily intake of 1-5 µg per day (U.S. DHHS, 1993). Accidental spills of elemental mercury, which create the potential for subsequent volatization and inhalation of mercury vapor, have often required public health intervention (Zeitz et al., 2002).

The kinetics of the different forms of mercury vary considerably. Elemental mercury, absorbed mainly through inhalation of volatilized vapor, undergoes distribution to most tissues, with the highest concentrations occurring in the kidney (Hursh et al., 1980; Barregard et al., 1999). After absorption of elemental mercury, blood concentrations decline initially with a rapid half-life of approximately 1-3 days followed by a slower half-life of approximately 1 week to 3 weeks (Barregard et al., 1992; Sandborgh-Englund et al., 1998). The slow-phase half-life may be several weeks longer in people with chronic occupational exposure (Sallsten et al., 1993). After exposure to elemental mercury, excretion of mercury occurs predominantly through the kidney (Sandborgh-Englund et al., 1998), and peak urine mercury levels can lag behind peak blood levels by days to a few weeks (Barregard et al., 1992); thereafter, for both acute and chronic exposures, urinary mercury levels decline with a half-life of approximately 1-3 months (Roels et al., 1991; Jonsson et al., 1999).

About 15% of inorganic mercury is absorbed from the human gastrointestinal tract (Rahola et al., 1973). Lesser penetration of inorganic mercury occurs through the blood-brain barrier than occurs with either elemental or methyl mercury (Hattula and Rahola, 1975; Vahter et al., 1994). The half-life of inorganic mercury in blood is similar to the slow-phase half-life of mercury after inhalation of elemental mercury. Excretion occurs by renal and fecal routes.

The fraction of methyl mercury absorped from the gastrointestinal tract is about 95% (Aberg et al., 1969; Miettinen et al., 1971). Methyl mercury enters the brain and other tissues (Vahter et al., 1994) and then undergoes slow dealkylation to inorganic mercury. Human pharmacokinetic studies indicate that methyl mercury declines in blood and the whole body with a half-life of approximately 50 days (Sherlock et al., 1984; Smith et al., 1994; Smith and Farris, 1996). After exposure to methyl mercury, greater than two-thirds of the mercury is excreted via the feces, with a relatively minor amount eliminated as inorganic mercury in the urine (Smith et al., 1994; Smith and Farris, 1996). Small fractions of inorganic mercury and methyl mercury are incorporated into hair (Suzuki et al., 1993), which has been used in epidemiologic studies as a biomarker of exposure to methyl mercury (McDowell et al., 2004).

## 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 |

Inorganic mercury and methyl mercury are also distributed into human breast milk, although the process may be more efficient for inorganic mercury (Grandjean et al., 1995; Oskarsson et al., 1996). Transplacental transport of methyl mercury and elemental mercury has been demonstrated in animal models. In a recent human study, concentrations of mercury in umbilical cord blood were correlated with mercury concentrations in maternal hair, maternal fish/seafood consumption, and maternal dental amalgam (Bjornberg et al., 2003). A recent meta-analysis of human studies of the ratio of mercury in umbilical cord blood to maternal blood produced an estimate of 1.7 (Stern and Smith, 2003).

The health effects of mercury are diverse and can depend on the form of the mercury to which a person is exposed and the severity and length of exposure. Acute, high-dose exposure to elemental mercury vapor may cause severe pneumonitis. At levels below those that cause acute lung injury, overt signs and symptoms of chronic inhalation may include tremor; gingivitis; and neurocognitive and behavioral disturbances, particularly irritability, depression, short-term memory loss, fatigue, anorexia, and sleep disturbance (Bidstrup et al., 1951; Smith et al., 1970; Smith et al., 1983). Subclinical neurological effects of low-level occupational exposure to elemental mercury have been found in some investigations (Chapman et al., 1990; Bittner et al., 1998), but an impact of low-level environmental exposure, such as that resulting from dental amalgam, has not been established (Factor-Litvak et al., 2003; Bates et al., 2004*a*).

Exposure to inorganic mercury usually occurs by ingestion. The most prominent effect is on the kidneys, where mercury accumulates, and leads to tubular necrosis. In addition, there may be an irritant or corrosive effect on the gastrointestinal tract (Sanchez-Sicilia et al., 1963). Occupational exposure to elemental mercury vapor has been associated with subclinical effects on biomarkers of renal dysfunction (Cardenas et al., 1993). Acrodynia, a sporadic and predominantly pediatric syndrome in which the constellation of findings may include anorexia, insomnia, irritability, hypertension, maculopapular rash, pain in the extremities and pinkish discoloration of the hands and feet, has been associated with a variety of exposures to elemental mercury and inorganic mercury compounds (Tunnessen et al., 1987).

Overt poisoning from methyl mercury primarily affects the central nervous system, causing parasthesias, ataxia, dysarthria, hearing impairment, and progressive constriction of the visual fields, typically after a latent period of weeks to months. Methyl mercury has well-characterized adverse reproductive effects. High-level prenatal exposure may result in a constellation of developmental deficits that include mental retardation, cerebellar ataxia, dysarthria, limb deformities, altered physical growth, sensory impairments, and cerebral

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 1990s, had an average blood mercury concentration of 2.55 µg/L (Kingman et al., 1998).

Blood mercury levels in both the 1999-2000 and 2001-2002 subsamples are below levels considered associated with known health effects. When blood mercury levels rise to about 100 µg/L following recent inorganic or elemental mercury poisoning, abnormal renal function tests may occur with low frequency. Total blood mercury levels in this *Report* were also well below levels established as occupational exposure guidelines. ACGIH recommends that the blood levels of inorganic mercury in workers not exceed 15 µg/L (six participants in the survey had higher levels, although these levels were unlikely to be due to inorganic forms of mercury). Information about the biological exposure indices (BEIs) is provided here for comparison, not to imply that the BEI is a safety level for general population exposure.

Clinically observable signs of ataxia and paresthesias occur with low frequency when blood mercury levels rise to about 100 µg/L following recent methyl mercury poisoning. However, the developing fetus may be the most susceptible to the effects of ongoing methyl mercury exposure (National Research Council, 2000). A cord blood mercury level of 85 µg/L (lower 95% confidence bound = 58 µg/L) is associated with a 5% increase in the prevalence of an abnormal Boston Naming Test (NRC, 2000). *Report* data for the period 1999-2002 show that all women of childbearing age had levels below 58 µg/L, a concentration associated with neurologic effects in the fetus. These data show that 5.7% of women of childbearing age had levels between 5.8 and 58 µg/L; that is, levels within a factor of 10 of those associated with neurological effects. Better defining safe levels of mercury in maternal blood is a priority area for additional research. EPA has set an oral reference dose (RfD, a daily dose considered to be safe) for methyl mercury of 0.1µg/kg/day, derived in part from this and other associated blood levels in outcome studies. A specific value for the blood mercury concentration that corresponds to the RfD has not been established (Rice, 2004).

Urinary mercury levels in recent German (Becker et al., 2003), Czech (Benes et al., 2002), and Italian (Apostoli et al., 2002*b*) adult population surveys were roughly similar to the values found for women in the 2001–2002 NHANES subsample. An expert-panel

report recently prepared for the U.S. Department of Health and Human Services (U.S. DHHS) noted that several studies have observed a modest, reversible increase in urinary N-acetyl-glucosaminidase, a biomarker of perturbation in renal tubular function, among workers with urinary mercury concentrations of greater than or equal to 25-35 µg/L (Life Sciences Research Office, 2004). The ACGIH (2001) currently recommends that urinary inorganic mercury in workers not exceed 35 µg/gram of creatinine.

### Comparing Adjusted Geometric Means

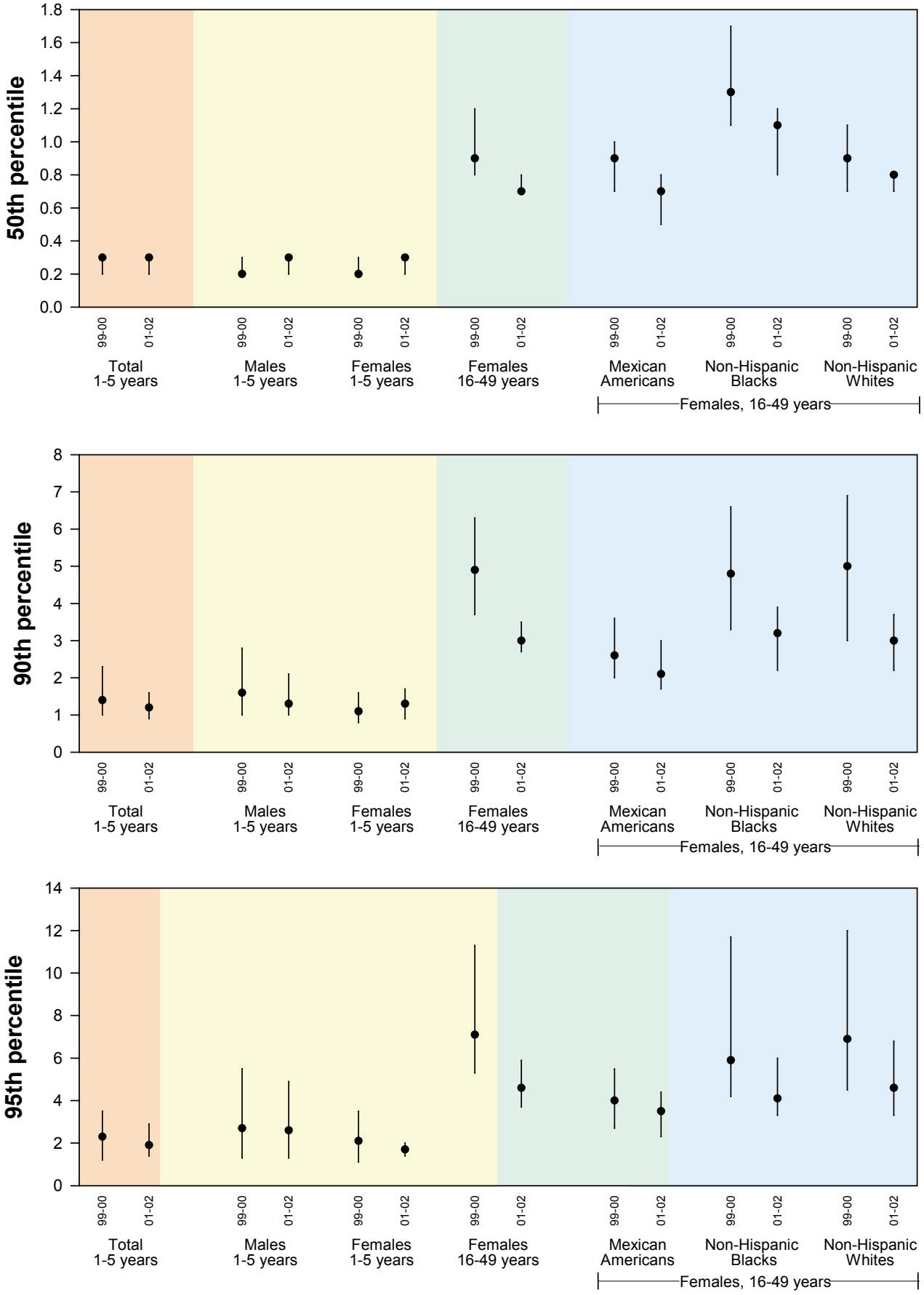
Geometric mean levels of blood mercury for the demographic groups were compared after adjusting for the covariates of race/ethnicity, age, gender, creatinine, and log serum cotinine (data not shown). In NHANES 2001-2002, non-Hispanic black females aged 16-49 years had higher levels than non-Hispanic white and Mexican-American females aged 16-49 years. Non-Hispanic white females aged 16-49 years had higher levels than Mexican American females aged 16-49 years. 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.

For urinary mercury levels, there were no differences of the adjusted geometric means among the three race/ethnicity groups.

Finding a measurable amount of mercury in blood or urine does not mean that the level of mercury causes 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 mercury than are found in the general population. These data will also help scientists plan and conduct research about mercury exposure and health effects.

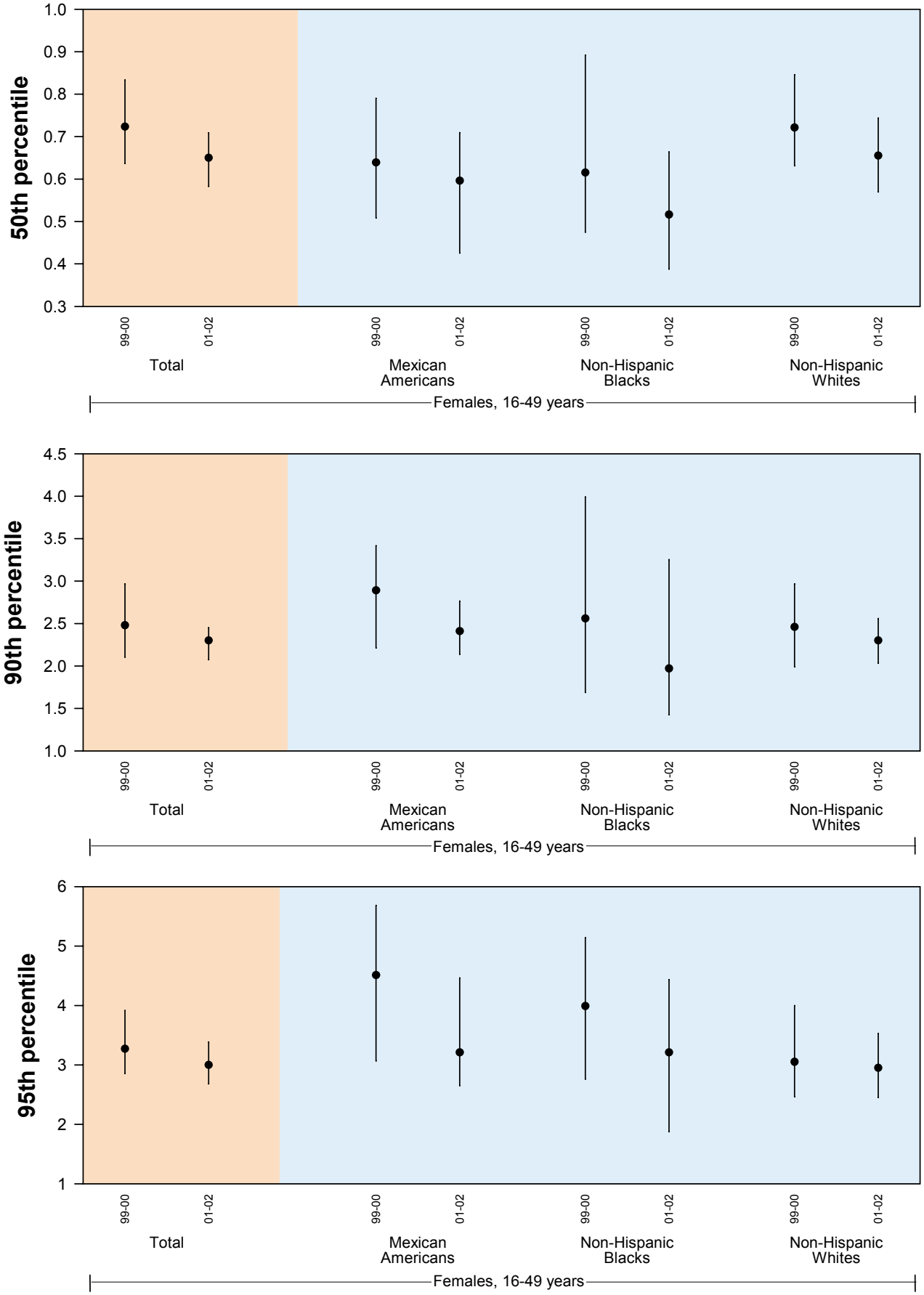
## Figure 8. Mercury in blood

Selected percentiles with 95% confidence intervals of blood concentrations (in µg/L) for males and females aged 1 to 5 years and females aged 16 to 49 years in the U.S. population, National Health and Nutrition Examination Survey, 1999-2002.



## 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, National Health and Nutrition Examination Survey, 1999-2002.



# 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 | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) 50th | 75th | 90th | 95th | 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) | **114** (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 |
| | 01-02 | **51.0** (46.6-55.7) | **56.9** (51.8-62.6) | **88.5** (81.6-96.5) | **130** (120-141) | **169** (145-194) | 1335 |
| Females | 99-00 | **40.4** (34.8-46.8) | **45.5** (40.4-52.0) | **77.2** (71.0-85.7) | **118** (105-138) | **154** (132-180) | 1136 |
| | 01-02 | **39.9** (37.2-42.9) | **45.7** (42.7-49.0) | **78.4** (72.6-82.9) | **114** (104-128) | **158** (130-177) | 1355 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **47.0** (42.1-52.4) | **53.2** (49.0-59.0) | **80.3** (73.7-91.7) | **120** (103-139) | **152** (120-217) | 780 |
| | 01-02 | **49.3** (46.5-52.3) | **55.7** (50.4-61.0) | **86.3** (80.8-94.1) | **133** (113-155) | **177** (142-207) | 683 |
| Non-Hispanic blacks | 99-00 | **57.7** (51.0-65.2) | **61.8** (55.0-71.5) | **97.7** (85.0-110) | **151** (126-188) | **202** (150-274) | 546 |
| | 01-02 | **53.2** (49.9-56.7) | **60.3** (54.2-63.1) | **89.9** (81.0-101) | **130** (121-147) | **166** (147-170) | 667 |
| Non-Hispanic whites | 99-00 | **44.5** (37.0-53.4) | **48.5** (41.1-59.8) | **85.0** (76.7-95.9) | **135** (119-154) | **178** (146-223) | 760 |
| | 01-02 | **42.2** (38.5-46.2) | **48.9** (44.2-53.2) | **80.7** (71.9-85.8) | **117** (108-129) | **152** (134-180) | 1132 |

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 NHANES 2001-2002 subsample are broadly comparable to levels reported for adults in recent smaller European population surveys (Minoia et al., 2002; White and Sabbioni, 1998; Iversen et al., 1998). Among infants, urinary molybdenum concentrations may be slightly lower than other age groups (Sievers et al., 2001).

## Table 23. Moylbdenum (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 | **43.2** (40.0-46.6) | **41.5** (38.5-45.2) | **63.5** (59.3-68.8) | **108** (97.3-115) | **144** (125-171) | 2257 |
| | 01-02 | **42.5** (39.9-45.2) | **42.2** (40.1-45.2) | **62.0** (58.4-66.4) | **98.8** (90.1-109) | **130** (120-149) | 2689 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **85.9** (73.7-100) | **78.9** (71.6-88.4) | **122** (107-133) | **173** (130-243) | **213** (154-1040) | 310 |
| | 01-02 | **77.2** (73.1-81.5) | **77.5** (71.8-84.5) | **109** (99.4-120) | **154** (129-170) | **185** (165-219) | 368 |
| 12-19 years | 99-00 | **41.9** (39.3-44.6) | **40.5** (37.7-44.4) | **57.3** (51.5-62.5) | **85.0** (67.4-107) | **109** (78.4-185) | 648 |
| | 01-02 | **43.4** (40.8-46.1) | **44.1** (40.8-47.2) | **60.6** (57.6-63.7) | **85.5** (79.7-93.8) | **106** (94.8-118) | 762 |
| 20 years and older | 99-00 | **39.6** (36.9-42.6) | **38.5** (36.1-41.0) | **56.4** (53.5-60.7) | **92.5** (83.1-100) | **120** (116-147) | 1299 |
| | 01-02 | **39.3** (36.8-42.0) | **39.6** (36.4-42.1) | **57.2** (52.9-61.0) | **86.7** (75.2-96.8) | **122** (109-139) | 1559 |
| **Gender** | | | | | | | |
| Males | 99-00 | **40.8** (37.5-44.3) | **38.5** (37.2-40.4) | **62.4** (55.9-68.4) | **101** (83.9-118) | **131** (112-179) | 1121 |
| | 01-02 | **40.3** (37.1-43.8) | **40.2** (36.3-43.3) | **60.4** (54.8-66.3) | **91.3** (83.4-106) | **123** (107-155) | 1334 |
| Females | 99-00 | **45.5** (41.5-50.0) | **43.7** (39.5-48.8) | **64.4** (59.5-70.5) | **111** (95.2-121) | **149** (122-181) | 1136 |
| | 01-02 | **44.6** (42.2-47.1) | **45.1** (42.2-46.9) | **63.6** (59.5-69.4) | **107** (92.5-119) | **136** (117-169) | 1355 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **42.9** (40.6-45.4) | **43.2** (40.9-45.6) | **61.6** (57.2-65.5) | **89.0** (80.0-103) | **115** (93.7-137) | 780 |
| | 01-02 | **48.1** (44.3-52.2) | **48.4** (44.8-52.3) | **71.5** (66.4-76.0) | **103** (90.0-120) | **129** (109-155) | 682 |
| Non-Hispanic blacks | 99-00 | **37.2** (33.4-41.6) | **37.0** (33.0-41.2) | **55.9** (49.6-63.3) | **88.2** (69.1-112) | **117** (88.3-141) | 546 |
| | 01-02 | **36.5** (34.1-39.0) | **37.5** (35.1-38.9) | **57.1** (49.7-62.4) | **78.3** (71.5-92.0) | **109** (81.1-127) | 667 |
| Non-Hispanic whites | 99-00 | **44.5** (40.2-49.2) | **42.1** (38.8-47.3) | **65.3** (58.9-71.3) | **116** (101-126) | **172** (131-195) | 760 |
| | 01-02 | **42.5** (39.3-46.0) | **41.9** (39.3-45.6) | **61.2** (57.1-67.2) | **104** (88.7-120) | **138** (120-163) | 1132 |

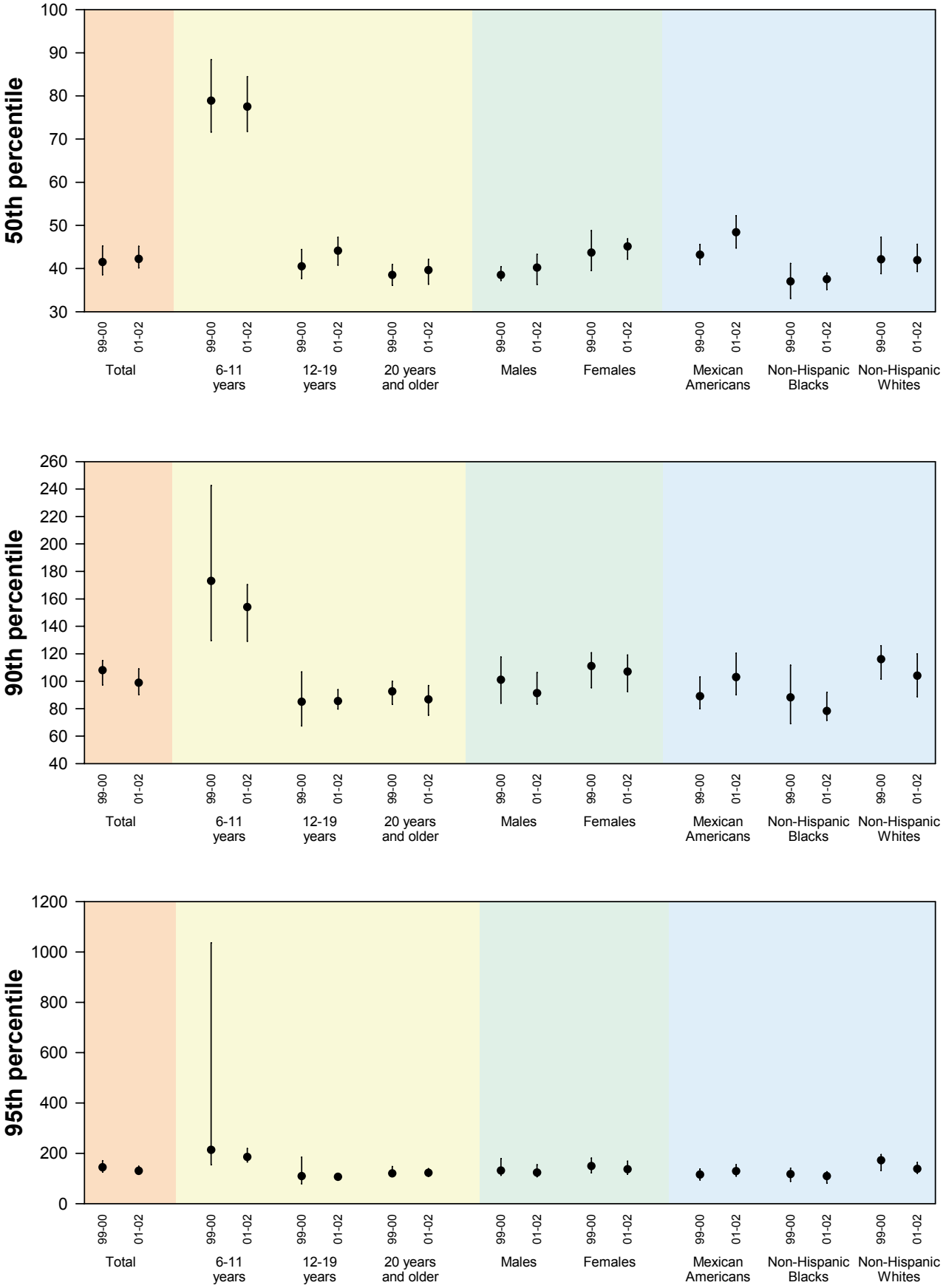
### Comparing Adjusted Geometric Means

Geometric mean levels of urinary molybdenum for the demographic groups were compared after adjusting for the covariates of race/ethnicity, age, gender, creatinine, and log serum cotinine (data not shown). In NHANES 2001-2002, adjusted geometric mean levels of urinary molybdenum were higher for children aged 6-11 years than for people aged 12-19 years or aged 20 years and older. The group aged 12-19 years had higher levels than the group aged 20 years and older. Non-Hispanic blacks had slightly lower levels than non-Hispanic whites and Mexican Amercians. 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.

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

## Figure 10. Molybdenum (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.



# Platinum

CAS No. 7440-06-4

## General Information

Platinum is a silver-gray, lustrous metal found naturally in extremely low amounts in the earth's crust and typically is associated with sulfide-ore bodies of nickel, copper, and iron. Important properties of platinum are its resistance to corrosion, strength at high temperatures, and high catalytic activity.

Platinum compounds are also used in electrodes and jewelry, as oxidation catalysts in chemical manufacturing, in thick-film circuits printed on ceramic substrates, and as drugs (e.g., cisplatin, carboplatin) in the treatment of cancer. Platinum-rhodium and platinum-palladium crystals are used as catalysts in petroleum refining and in the control of automobile-exhaust emissions. Platinum-rhodium compounds are also used in glass and glass-fiber manufacture and in high-temperature thermocouples. Higher environmental soil concentrations of platinum have been associated with nearby roadways due to vehicular emissions (Farago et al., 1998), although the ambient air concentrations of platinum associated with its use in automotive engine catalytic converters are estimated to be 10,000 times lower than occupational exposure limits.

The acute and chronic toxic effects of exposure to platinum are highly dependent on the type of compound (e.g., metallic, inorganic salt, or organometallic), the route of exposure (e.g., intravenous (medicinal use), inhalational, cutaneous, oral), and duration of exposure. Platinum metal is considered biologically inert, whereas platinum compounds (e.g., salts) can cause acute and chronic irritant and immune-mediated hypersensitivity reactions, such as bronchitis and asthma following inhalational exposure. Also, contact dermatitis following

### Table 24. Platinum

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

| | 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 | 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 | < LOD | 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 | < LOD | 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.

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 http://www.inchem.org).

### Interpreting Levels of Urinary Platinum Reported in the Tables

Urinary platinum 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. In the NHANES 2001-2002 subsample, as in the previously tested 1999-2000 subsample, urinary platinum levels were detectable in only a few percent of the sample (detection limit was 0.04 µg/L). Older studies reporting measurements in general populations have found detectable and higher values than the value of the detection limit reported in this *Report* (Vaughan et al., 1992; Paschal et al., 1998), which may be due to methodologic, population, or exposure differences. Recently, several studies have shown that background concentrations in general populations are usually less than 0.005 µg/L (Iavicoli et al., 2004; Wilhelm et al., 2003) or less than 0.01 µg/L (Becker et al., 2003; Herr et al., 2003).

One study found that traffic-control police had no greater urinary platinum concentrations than office-based control subjects (Iavicoli et al., 2004). Gold-platinum alloys used for dental fillings also may contribute to urinary platinum concentrations (Schierl, 2001; Herr et al., 2003).

**Table 25. Platinum (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 2465 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 2689 |
| **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 | < LOD | 762 |
| 20 years and older | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1406 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1559 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1227 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1334 |
| 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 | 682 |
| 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.

Platinum-industry and precious-metal workers can have urinary concentrations 1,000 times higher than general populations (Schierl et al., 1998). The handling of cisplatin and carboplatin by pharmacy and other hospital personnel has been associated with modest (ten-fold or less) elevations in urinary platinum concentrations (Ensslin et al., 1997; Pethran et al., 2003).

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

# Thallium

CAS No. 7440-28-0

## General Information

Elemental thallium is a blue-white metal found in small amounts in soil and in sulfide-based minerals. In the past, thallium was obtained as a by-product of the smelting of other metals; however, it has not been specifically mined or refined in the United States since 1984. It is still used in relatively small amounts in pharmaceutical and electronics manufacturing, the latter being the current major industrial consumer of thallium in this country. In the United States, thallium has been restricted from pesticidal (rodenticidal, insecticidal, and fungicidal) or cosmetic (depilatory) uses.

Thallium exposure occurs primarily from industrial processes such as coal-burning and smelting. From these and other sources, thallium is produced in a fine particulate form that can be absorbed through inhalation or ingestion. Thallium disappears from the blood with a half-life of several days representing distribution into other tissues. In addition, thallium readily crosses the placenta and also distributes into breast milk. Elimination from the body tissues is slow, occurring via urine and feces.

Thallium produces toxicity by replacing intracellular potassium in the body, though additional mechanisms of action are possible. Since thallium salts are colorless, odorless, and tasteless, there is potential for undetected malevolent use. Severe accidental thallium poisoning has involved the ingestion of rat poisons that contain water-soluble thallium salts. Relatively high-dose intentional or accidental ingestion can result in gastrointestinal symptoms followed by multi-organ failure, neurologic injury, and death. Peripheral neuropathy and alopecia are well-documented effects of acute and chronic exposures.

### Table 26. Thallium

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

| | 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 | **.176** (.162-.192) | **.200** (.180-.210) | **.280** (.260-.310) | **.400** (.370-.420) | **.450** (.420-.470) | 2413 |
| | 01-02 | **.165** (.154-.177) | **.180** (.170-.200) | **.270** (.260-.290) | **.360** (.350-.380) | **.440** (.410-.470) | 2653 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **.201** (.167-.243) | **.200** (.150-.260) | **.300** (.250-.350) | **.410** (.330-.450) | **.440** (.350-.590) | 336 |
| | 01-02 | **.172** (.147-.202) | **.200** (.160-.220) | **.290** (.230-.330) | **.340** (.330-.360) | **.380** (.360-.420) | 362 |
| 12-19 years | 99-00 | **.202** (.181-.225) | **.210** (.200-.240) | **.290** (.270-.340) | **.410** (.390-.430) | **.460** (.430-.510) | 697 |
| | 01-02 | **.200** (.182-.220) | **.210** (.190-.240) | **.300** (.290-.320) | **.360** (.340-.390) | **.460** (.400-.500) | 746 |
| 20 years and older | 99-00 | **.170** (.157-.183) | **.180** (.170-.200) | **.290** (.260-.310) | **.400** (.370-.420) | **.450** (.420-.470) | 1380 |
| | 01-02 | **.159** (.147-.173) | **.190** (.170-.200) | **.270** (.250-.290) | **.380** (.350-.400) | **.440** (.400-.490) | 1545 |
| **Gender** | | | | | | | |
| Males | 99-00 | **.197** (.179-.217) | **.220** (.190-.240) | **.310** (.280-.350) | **.390** (.360-.440) | **.440** (.420-.480) | 1200 |
| | 01-02 | **.184** (.173-.196) | **.200** (.190-.220) | **.290** (.270-.290) | **.380** (.350-.390) | **.420** (.390-.460) | 1313 |
| Females | 99-00 | **.159** (.145-.175) | **.180** (.150-.200) | **.270** (.240-.290) | **.380** (.340-.410) | **.450** (.410-.490) | 1213 |
| | 01-02 | **.149** (.137-.163) | **.150** (.150-.170) | **.250** (.230-.280) | **.370** (.330-.400) | **.430** (.400-.500) | 1340 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **.172** (.150-.196) | **.190** (.160-.220) | **.260** (.240-.290) | **.370** (.320-.420) | **.450** (.370-.520) | 861 |
| | 01-02 | **.160** (.148-.173) | **.180** (.150-.190) | **.250** (.240-.270) | **.330** (.310-.360) | **.400** (.350-.440) | 675 |
| Non-Hispanic blacks | 99-00 | **.217** (.197-.239) | **.220** (.200-.240) | **.340** (.300-.380) | **.440** (.390-.510) | **.550** (.460-.620) | 561 |
| | 01-02 | **.202** (.187-.218) | **.210** (.200-.230) | **.290** (.270-.330) | **.400** (.380-.440) | **.520** (.440-.590) | 657 |
| Non-Hispanic whites | 99-00 | **.170** (.153-.188) | **.200** (.160-.220) | **.280** (.250-.320) | **.400** (.360-.420) | **.440** (.420-.480) | 801 |
| | 01-02 | **.159** (.147-.172) | **.180** (.160-.190) | **.270** (.250-.290) | **.350** (.320-.380) | **.430** (.390-.460) | 1114 |

Workplace air standards for external exposure are generally established by OSHA and ACGIH. Chronic high-level exposures have been associated with weight loss, arthralgias, and polyneuropathy. IARC and NTP consider the evidence for the carcinogenicity of thallium as inadequate or unclassifiable. 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 Thallium Reported in the Tables

Urinary thallium 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 have suggested that normal background urinary thallium concentrations are less than 1 µg/L (Schaller et al., 1980; Brockhaus et al., 1981; Minoia et al., 1990), which are consistent with levels documented in this NHANES 2001-2002 subsample and the previous 1999-2000 subsample. Other population surveys have demonstrated urinary levels of roughly similar magnitude (White and Sabbioni, 1998; Minoia et al., 1990; Paschal et al., 1998).

Urinary concentrations of 100 µg/L in asymptomatic workers (500 times higher than median levels observed in this *Report*) are thought to correspond to workplace exposures at the threshold limit value of 0.1 mg/m$^3$ (Marcus, 1985). Brockhaus et al. (1981) studied 1,265 people living near a thallium-emitting cement plant in Germany. Nearby residents were exposed by eating garden plants on which thallium had been deposited. Seventy-eight percent of the urine specimens in that study contained more than 1 µg/L, with concentrations ranging up to 76.5 µg/L. There was no increase in the prevalence of symptoms at levels less than 20 µg/L and only a slight increase in nonspecific symptoms above 20 µg/L.

**Table 27. Thallium (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 | **.166** (.159-.173) | **.168** (.162-.176) | **.224** (.217-.233) | **.297** (.273-.319) | **.366** (.338-.387) | 2413 |
| | 01-02 | **.156** (.151-.162) | **.156** (.148-.164) | **.215** (.208-.222) | **.287** (.278-.300) | **.348** (.337-.365) | 2652 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **.221** (.197-.248) | **.221** (.196-.236) | **.292** (.229-.356) | **.375** (.318-.469) | **.424** (.356-.600) | 336 |
| | 01-02 | **.211** (.198-.226) | **.207** (.198-.221) | **.286** (.257-.321) | **.370** (.333-.402) | **.411** (.389-.456) | 362 |
| 12-19 years | 99-00 | **.153** (.146-.160) | **.154** (.146-.162) | **.205** (.191-.219) | **.257** (.231-.278) | **.321** (.265-.364) | 697 |
| | 01-02 | **.143** (.137-.150) | **.145** (.135-.152) | **.196** (.184-.207) | **.269** (.250-.289) | **.307** (.299-.333) | 746 |
| 20 years and older | 99-00 | **.162** (.153-.171) | **.167** (.154-.176) | **.217** (.207-.230) | **.285** (.271-.300) | **.364** (.325-.389) | 1380 |
| | 01-02 | **.153** (.147-.159) | **.152** (.144-.161) | **.210** (.200-.217) | **.277** (.263-.292) | **.342** (.313-.362) | 1544 |
| **Gender** | | | | | | | |
| Males | 99-00 | **.154** (.147-.161) | **.156** (.149-.164) | **.202** (.192-.214) | **.269** (.254-.297) | **.338** (.300-.364) | 1200 |
| | 01-02 | **.146** (.140-.153) | **.148** (.141-.156) | **.192** (.184-.204) | **.259** (.245-.278) | **.307** (.291-.342) | 1312 |
| Females | 99-00 | **.178** (.167-.189) | **.182** (.169-.196) | **.244** (.226-.259) | **.313** (.281-.366) | **.380** (.333-.462) | 1213 |
| | 01-02 | **.167** (.158-.176) | **.167** (.153-.179) | **.233** (.217-.250) | **.313** (.282-.348) | **.375** (.348-.402) | 1340 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **.158** (.147-.170) | **.159** (.148-.175) | **.212** (.200-.234) | **.282** (.266-.304) | **.338** (.306-.389) | 861 |
| | 01-02 | **.156** (.145-.169) | **.155** (.145-.167) | **.204** (.190-.221) | **.286** (.250-.315) | **.361** (.301-.424) | 674 |
| Non-Hispanic blacks | 99-00 | **.142** (.133-.152) | **.140** (.129-.151) | **.200** (.184-.214) | **.277** (.244-.307) | **.383** (.286-.462) | 561 |
| | 01-02 | **.138** (.128-.150) | **.136** (.125-.146) | **.194** (.170-.212) | **.256** (.238-.278) | **.321** (.271-.387) | 657 |
| Non-Hispanic whites | 99-00 | **.169** (.160-.179) | **.173** (.167-.181) | **.226** (.215-.240) | **.300** (.271-.325) | **.364** (.333-.377) | 801 |
| | 01-02 | **.161** (.155-.167) | **.161** (.153-.171) | **.220** (.214-.231) | **.291** (.278-.304) | **.347** (.327-.375) | 1114 |

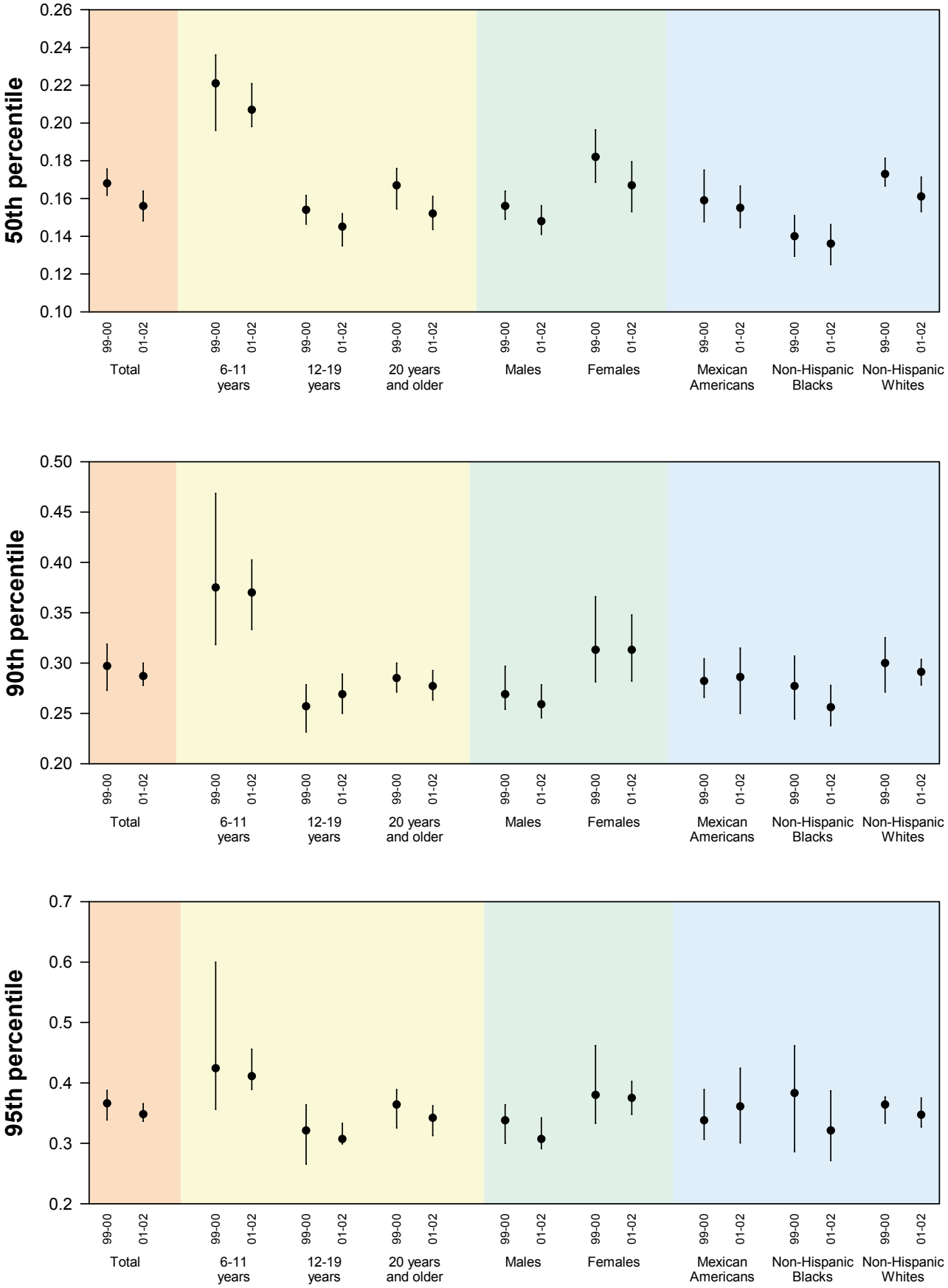
### Comparing Adjusted Geometric Means

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 established by ACGIH or recommended by NIOSH. Evidence is lacking for the carcinogenicity of tungsten; it has not been classified with respect to its carcinogenicity by either IARC or NTP.

Only limited information is available on the toxicity of tungsten. Human illness from low-level environmental or occupational exposure has not been well established. Although workers occupationally exposed to tungsten carbide may develop serious lung disease ("hard metal" disease), their illness may stem from co-exposure to cobalt mixed with tungsten carbide rather than to tungsten itself.

## Table 28. Tungsten

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

| | 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 | **.093** (.087-.100) | **.090** (.080-.090) | **.180** (.160-.190) | **.320** (.280-.360) | **.500** (.420-.550) | 2338 |
| | 01-02 | **.082** (.073-.092) | **.060** (.060-.080) | **.150** (.130-.180) | **.300** (.260-.340) | **.450** (.370-.560) | 2652 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **.158** (.123-.204) | **.160** (.100-.200) | **.260** (.210-.330) | **.490** (.380-.560) | **.590** (.510-.950) | 320 |
| | 01-02 | **.137** (.110-.170) | **.140** (.100-.160) | **.250** (.200-.340) | **.450** (.360-.690) | **.770** (.510-1.53) | 363 |
| 12-19 years | 99-00 | **.113** (.097-.132) | **.110** (.090-.120) | **.200** (.170-.230) | **.360** (.300-.430) | **.530** (.380-.800) | 679 |
| | 01-02 | **.113** (.095-.135) | **.100** (.090-.130) | **.210** (.180-.240) | **.390** (.310-.520) | **.570** (.430-.710) | 744 |
| 20 years and older | 99-00 | **.084** (.078-.091) | **.070** (.060-.080) | **.150** (.130-.180) | **.270** (.250-.320) | **.440** (.360-.520) | 1339 |
| | 01-02 | **.073** (.065-.082) | **.060** (.050-.060) | **.130** (.110-.160) | **.250** (.210-.300) | **.370** (.300-.490) | 1545 |
| **Gender** | | | | | | | |
| Males | 99-00 | **.107** (.096-.120) | **.100** (.080-.110) | **.210** (.180-.230) | **.380** (.310-.470) | **.530** (.470-.650) | 1160 |
| | 01-02 | **.088** (.074-.105) | **.080** (.060-.090) | **.160** (.130-.210) | **.330** (.260-.390) | **.490** (.380-.580) | 1307 |
| Females | 99-00 | **.082** (.077-.087) | **.070** (.060-.070) | **.140** (.130-.160) | **.270** (.240-.290) | **.390** (.320-.470) | 1178 |
| | 01-02 | **.076** (.069-.084) | **.060** (.050-.060) | **.140** (.120-.170) | **.280** (.230-.320) | **.430** (.330-.530) | 1345 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **.113** (.095-.133) | **.100** (.090-.120) | **.190** (.160-.240) | **.390** (.300-.520) | **.550** (.420-.830) | 790 |
| | 01-02 | **.101** (.093-.109) | **.090** (.080-.110) | **.180** (.170-.200) | **.370** (.310-.430) | **.560** (.450-.670) | 680 |
| Non-Hispanic blacks | 99-00 | **.113** (.101-.126) | **.090** (.080-.110) | **.200** (.170-.240) | **.360** (.290-.460) | **.550** (.420-.810) | 562 |
| | 01-02 | **.096** (.080-.116) | **.080** (.060-.110) | **.150** (.120-.230) | **.310** (.270-.400) | **.460** (.390-.580) | 649 |
| Non-Hispanic whites | 99-00 | **.092** (.084-.100) | **.070** (.060-.090) | **.170** (.150-.190) | **.310** (.270-.380) | **.460** (.380-.520) | 802 |
| | 01-02 | **.076** (.066-.088) | **.050** (.040-.070) | **.150** (.120-.170) | **.290** (.230-.350) | **.430** (.330-.560) | 1117 |

### Interpreting Levels of Urinary Tungsten Reported in the Tables

Urinary tungsten 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. 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 al., 2001). The application of the technique of neutron activation analysis to a control group of non-metal workers showed mean urinary tungsten levels similar to levels at the 95th percentile of the NHANES 1999-2000 subsample, whereas the tungsten-worker group had mean urine levels 35 times higher (Nicolaou et al., 1987). Patients with medically-inserted tungsten embolization coils showed elevated tungsten levels in blood, urine, and hair (Bachthaler et al., 2004). Urinary tungsten levels in these patients were often hundreds-fold higher than demonstrated in this *Report*.

### Comparing Adjusted Geometric Means

Geometric mean levels of urinary tungsten 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 2002-2002, the group aged 6-11 years had higher adjusted geometric mean levels of urinary tungsten than either of the groups aged 12-19 years or 20 years and older. The group aged 12-19 years had higher

## Table 29. Tungsten (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.

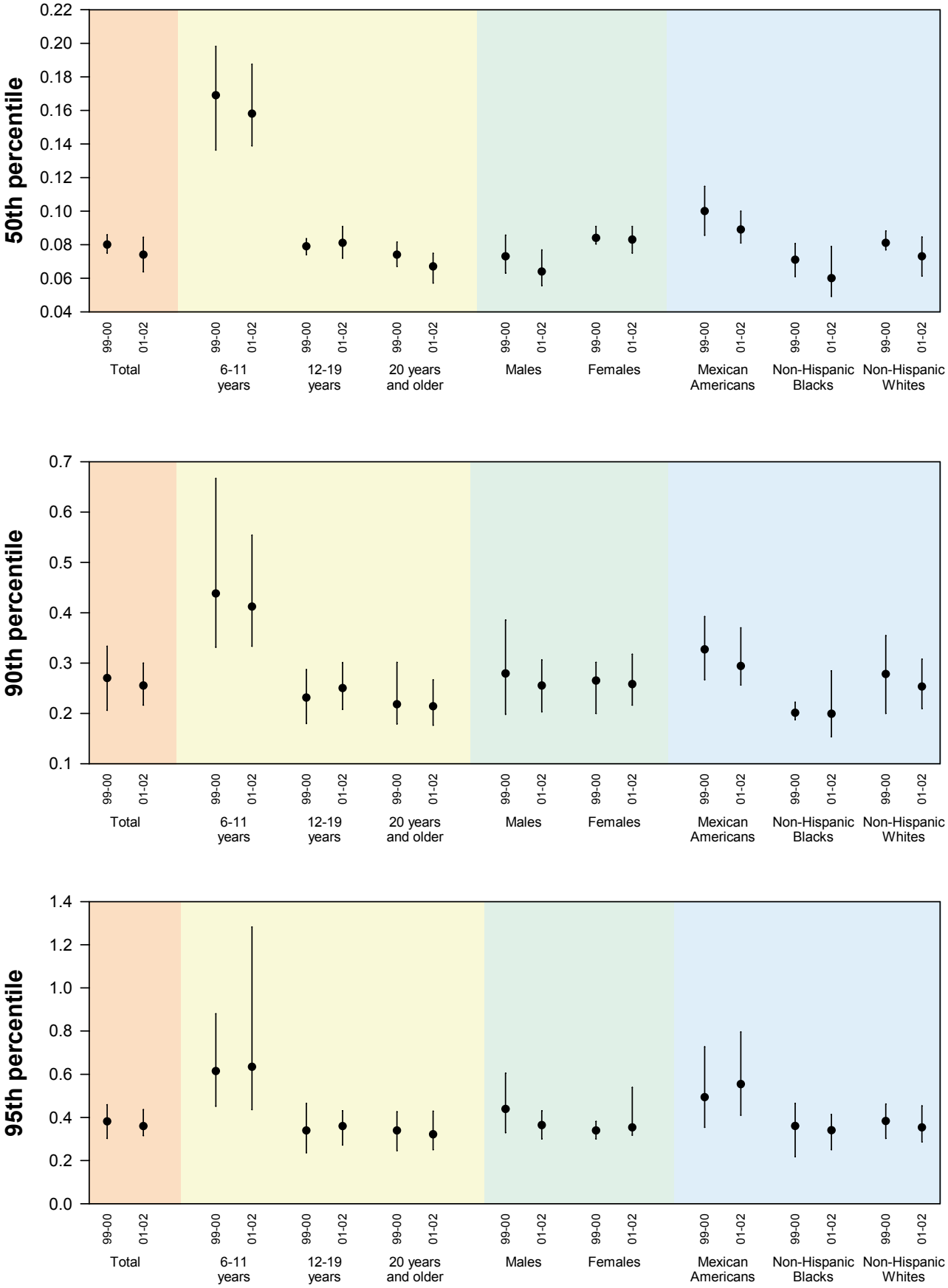
| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) 50th | 75th | 90th | 95th | Sample size |
|---|---|---|---|---|---|---|---|
| **Total, age 6 and older** | 99-00 | **.087** (.080-.095) | **.080** (.075-.086) | **.146** (.136-.158) | **.270** (.206-.333) | **.381** (.302-.459) | 2338 |
| | 01-02 | **.078** (.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 |
| 20 years and older | 99-00 | **.080** (.072-.089) | **.074** (.067-.082) | **.130** (.115-.143) | **.218** (.179-.301) | **.339** (.245-.426) | 1339 |
| | 01-02 | **.070** (.063-.079) | **.067** (.057-.075) | **.119** (.099-.139) | **.214** (.176-.267) | **.321** (.250-.429) | 1544 |
| **Gender** | | | | | | | |
| Males | 99-00 | **.083** (.074-.094) | **.073** (.063-.086) | **.146** (.126-.165) | **.279** (.198-.386) | **.439** (.329-.605) | 1160 |
| | 01-02 | **.071** (.060-.083) | **.064** (.056-.077) | **.125** (.098-.152) | **.255** (.203-.306) | **.364** (.300-.431) | 1306 |
| Females | 99-00 | **.091** (.085-.098) | **.084** (.080-.091) | **.145** (.136-.158) | **.265** (.200-.301) | **.339** (.300-.381) | 1178 |
| | 01-02 | **.085** (.077-.094) | **.083** (.075-.091) | **.143** (.128-.162) | **.258** (.216-.317) | **.353** (.317-.538) | 1345 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **.106** (.093-.120) | **.100** (.086-.115) | **.184** (.152-.214) | **.327** (.267-.392) | **.493** (.354-.727) | 790 |
| | 01-02 | **.098** (.090-.108) | **.089** (.081-.100) | **.163** (.143-.187) | **.294** (.256-.370) | **.554** (.410-.797) | 679 |
| Non-Hispanic blacks | 99-00 | **.073** (.064-.083) | **.071** (.061-.081) | **.124** (.109-.154) | **.201** (.188-.222) | **.360** (.217-.465) | 562 |
| | 01-02 | **.066** (.056-.077) | **.060** (.049-.079) | **.109** (.090-.125) | **.199** (.153-.285) | **.340** (.250-.414) | 649 |
| Non-Hispanic whites | 99-00 | **.091** (.083-.100) | **.081** (.077-.088) | **.149** (.135-.167) | **.278** (.200-.354) | **.383** (.302-.462) | 802 |
| | 01-02 | **.078** (.068-.088) | **.073** (.061-.085) | **.138** (.120-.156) | **.253** (.209-.308) | **.353** (.286-.453) | 1117 |

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

## 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 | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) 50th | 75th | 90th | 95th | 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** (.025-.049) | 368 |
| 12-19 years | 99-00 | **.009** (.008-.011) | **.009** (.008-.010) | **.014** (.012-.018) | **.025** (.020-.043) | **.043** (.028-.072) | 719 |
| | 01-02 | **.010** (.008-.012) | **.009** (.008-.012) | **.017** (.012-.023) | **.030** (.021-.042) | **.041** (.027-.088) | 762 |
| 20 years and older | 99-00 | **.008** (.006-.009) | **.007** (.005-.008) | **.012** (.009-.016) | **.026** (.021-.038) | **.045** (.035-.054) | 1405 |
| | 01-02 | **.009** (.007-.010) | **.007** (.006-.009) | **.014** (.011-.016) | **.030** (.022-.039) | **.046** (.034-.059) | 1560 |
| **Gender** | | | | | | | |
| Males | 99-00 | **.009** (.008-.011) | **.007** (.007-.010) | **.015** (.012-.020) | **.036** (.024-.046) | **.053** (.040-.067) | 1227 |
| | 01-02 | **.009** (.008-.011) | **.008** (.007-.010) | **.014** (.012-.019) | **.033** (.023-.043) | **.046** (.035-.065) | 1335 |
| Females | 99-00 | **.007** (.006-.008) | **.006** (.005-.007) | **.011** (.009-.014) | **.023** (.016-.032) | **.035** (.026-.050) | 1237 |
| | 01-02 | **.008** (.007-.010) | **.008** (.006-.009) | **.013** (.011-.016) | **.027** (.018-.037) | **.040** (.029-.062) | 1355 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **.017** (.012-.023) | **.015** (.011-.021) | **.032** (.019-.053) | **.059** (.040-.127) | **.113** (.054-.279) | 883 |
| | 01-02 | **.013** (.010-.016) | **.011** (.009-.015) | **.022** (.016-.027) | **.039** (.031-.054) | **.054** (.045-.067) | 683 |
| Non-Hispanic blacks | 99-00 | **.009** (.007-.011) | **.007** (.006-.010) | **.013** (.010-.019) | **.028** (.018-.045) | **.049** (.030-.067) | 568 |
| | 01-02 | **.008** (.007-.009) | **.007** (.007-.009) | **.012** (.010-.013) | **.020** (.017-.027) | **.030** (.023-.037) | 667 |
| Non-Hispanic whites | 99-00 | **.007** (.006-.009) | **.007** (.005-.007) | **.012** (.008-.014) | **.023** (.016-.033) | **.041** (.027-.051) | 822 |
| | 01-02 | **.008** (.007-.009) | **.006** (.006-.008) | **.012** (.010-.014) | **.026** (.018-.034) | **.036** (.028-.049) | 1132 |

24 hours after exposure. Following exposure to soluble uranium salts, the initial half-life of uranium is considered to be about 15 days (Bhattacharyya et al., 1992), representing distribution and excretion, with a much slower elimination from bone. After inhalation exposure of insoluble uranium, the half-life for disappearance from the lung is several years (Durakovic et al., 2003).

Health effects from uranium exposure occur from chemical toxicity. Radiation risks from exposure to natural uranium are very low. Nephrotoxicity, the primary toxic effect attributed to chronic uranium exposure in people, manifests as tubular damage and appears reversible with decreasing exposure. Workplace air standards for external exposure to soluble and insoluble uranium compounds have been established by OSHA and ACGIH. Although older evaluations suggested the carcinogenicity of uranium among smokers, the U.S. EPA has withdrawn its classification for carcinogenicity; IARC and NTP have no ratings.

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 Uranium Reported in the Tables

Urine uranium 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. The analytical method measures only levels of the $^{238}$U isotope and not levels of the $^{235}$U isotope ($^{235}$U is higher in enriched uranium used as nuclear fuel). More than 99% of naturally occurring uranium is $^{238}$U.

A previous nonrandom subsample from NHANES III (n = 499) showed concentrations that are essentially similar to those in this *Report* (Ting et al., 1999). Dang et

**Table 31. Uranium (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 | **.007** (.006-.009) | **.007** (.006-.009) | **.013** (.010-.016) | **.024** (.019-.030) | **.034** (.027-.053) | 2464 |
| | 01-02 | **.008** (.007-.010) | **.007** (.006-.009) | **.014** (.011-.018) | **.026** (.020-.033) | **.040** (.028-.054) | 2689 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **.009** (.007-.012) | **.008** (.006-.010) | **.015** (.010-.024) | **.030** (.016-.044) | **.037** (.030-.077) | 340 |
| | 01-02 | **.010** (.008-.011) | **.010** (.008-.012) | **.015** (.013-.019) | **.027** (.018-.032) | **.033** (.027-.048) | 368 |
| 12-19 years | 99-00 | **.007** (.006-.008) | **.006** (.005-.008) | **.010** (.009-.014) | **.020** (.014-.030) | **.030** (.019-.074) | 719 |
| | 01-02 | **.007** (.006-.008) | **.007** (.006-.008) | **.012** (.009-.016) | **.020** (.014-.026) | **.026** (.020-.042) | 762 |
| 20 years and older | 99-00 | **.007** (.006-.009) | **.007** (.005-.008) | **.013** (.010-.016) | **.024** (.019-.029) | **.034** (.025-.051) | 1405 |
| | 01-02 | **.008** (.007-.010) | **.007** (.006-.009) | **.014** (.011-.019) | **.027** (.020-.039) | **.043** (.030-.063) | 1559 |
| **Gender** | | | | | | | |
| Males | 99-00 | **.007** (.006-.009) | **.006** (.005-.008) | **.011** (.009-.015) | **.021** (.017-.028) | **.035** (.024-.056) | 1227 |
| | 01-02 | **.007** (.006-.008) | **.007** (.006-.008) | **.012** (.010-.015) | **.022** (.018-.028) | **.033** (.025-.047) | 1334 |
| Females | 99-00 | **.008** (.007-.010) | **.007** (.006-.009) | **.013** (.010-.017) | **.024** (.019-.033) | **.034** (.027-.054) | 1237 |
| | 01-02 | **.009** (.008-.011) | **.009** (.007-.011) | **.016** (.012-.021) | **.029** (.021-.042) | **.045** (.031-.067) | 1355 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **.015** (.011-.022) | **.015** (.011-.020) | **.028** (.016-.058) | **.059** (.027-.146) | **.100** (.042-.270) | 883 |
| | 01-02 | **.012** (.010-.016) | **.012** (.009-.016) | **.021** (.015-.028) | **.033** (.024-.053) | **.049** (.033-.077) | 682 |
| Non-Hispanic blacks | 99-00 | **.006** (.004-.007) | **.005** (.004-.006) | **.008** (.006-.013) | **.017** (.011-.028) | **.028** (.018-.048) | 568 |
| | 01-02 | **.005** (.005-.006) | **.005** (.005-.006) | **.008** (.007-.010) | **.013** (.011-.014) | **.017** (.014-.029) | 667 |
| Non-Hispanic whites | 99-00 | **.007** (.006-.009) | **.007** (.006-.009) | **.012** (.010-.015) | **.021** (.017-.027) | **.030** (.024-.050) | 822 |
| | 01-02 | **.008** (.007-.009) | **.007** (.006-.009) | **.013** (.011-.016) | **.025** (.018-.032) | **.034** (.025-.051) | 1132 |

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, other studies have demonstrated urinary uranium concentrations that are consistent with levels documented in this *Report*, in that the reported levels were below their respective detection limits (Hamilton et al., 1994; Komaromy-Hiller et al., 2000; Byrne et al., 1991).

In one study, 105 people exposed to well water containing natural uranium in the range of 1.8 to 7770 µg/L (median 157 µg/L) had urinary levels of uranium as high as 9.55 µg/L (median 0.162 µg/L)(Orloff et al., 2003). Eighty-five percent of the levels were above the 95$^{th}$ percentile of the NHANES 1999-2000 subsample. In another study of people drinking well water with high natural uranium concentrations, the median urinary concentration was 0.078 µg/L (ranging up to 5.65 µg/L), and a subtle effect of uranium on calcium and phosphate fractional clearance was indicated (within the normal range of these measures), but without effects on other biochemical or traditional markers of renal function (Kurttio et al., 2002). The urinary uranium levels reported here for the NHANES 2001-2002 subsample are well below any of these aforementioned levels.

The U.S. Nuclear Regulatory Commission (U.S. NRC) has set an action level of 15 µg/L for uranium in urine to protect people who are occupationally exposed to uranium (U.S. NRC, 1978). Six workers in a depleted uranium program had concentrations of 0.110 to 45 µg/L (Ejnik et al., 2000). Several recent studies have investigated urinary uranium levels in veterans who served during the 1991 Gulf War. In one study, 17 soldiers with embedded shrapnel had a median urinary uranium concentration of 2.61 µg/g creatinine and 28 soldiers who may have been exposed to DU by inhalation, ingestion, or wound contamination, but in whom no shrapnel was embedded, had a mean urinary uranium concentration of 0.066 µg/g creatinine (Gwiazda et al., 2004). In a much larger study of a group of 446 Gulf War veterans who were concerned about past exposure to DU, the geometric mean urinary uranium concentration was 0.011 µg/L (McDiarmid, et al., 2004).

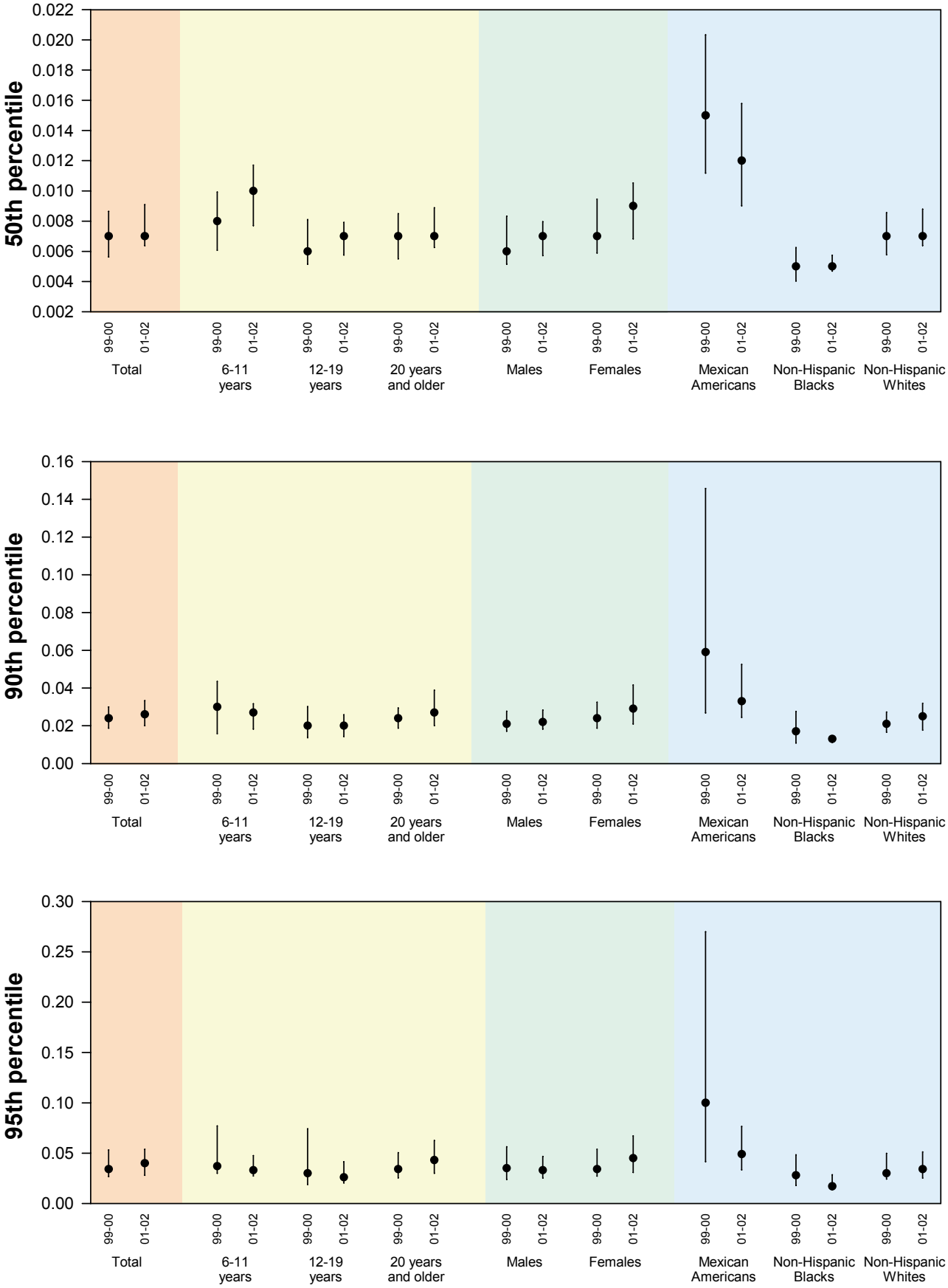
### Comparing Adjusted Geometric Means

Geometric mean levels of urinary uranium 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 uranium in the group aged 6-11 years were higher than the groups aged 12-19 years. Mexican Americans had higher levels than either non-Hispanic blacks or non-Hispanic whites, and non-Hispanic whites had higher levels than non-Hispanic blacks. Females had slightly higher adjusted geometric mean levels of urinary uranium than males. 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.

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

## 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.



# Results by Chemical Group

## Tobacco Smoke

# Cotinine

CAS No. 486-56-6

## General Information

Tobacco use is the most important preventable cause of premature morbidity and mortality in the United States. The consequences of smoking and of using smokeless tobacco products are well known and include an increased risk for cancer, emphysema, cardiovascular disease, and possibly other disorders.

Inhalation of tobacco smoke is the main source of nicotine exposure for the general population. Cigarettes contain about 1.5% nicotine by weight (Kozlowski et al., 1998), producing roughly 1-2 mg of bioavailable nicotine per cigarette (Institute of Medicine, 2001). Nicotine can also be absorbed from the gastrointestinal tract and skin as a result of chewing tobacco or chewing gum or using skin patches that contain nicotine. Workers who harvest tobacco can be exposed to nicotine and intoxicated as a result of the transdermal absorption of nicotine contained in the plant. Some other plants also contain nicotine in smaller amounts. Nicotine has been used previously as an insecticide and is still available for that purpose in its sulfate and alkaloid forms.

Up to 92% of the nicotine delivered in smoke is absorbed from the lungs into the blood stream (Armitage et al., 1975; Iwase et al., 1991). Air concentrations of nicotine in public spaces where smoking is allowed are about 1-10 µg/m$^3$. Once absorbed, nicotine has a half-life in blood plasma of several hours (Benowitz, 1996). Cotinine is a metabolite of nicotine and is currently regarded as the best biomarker in active smokers and in nonsmokers exposed to environmental tobacco smoke (ETS). Measuring cotinine is preferred over measuring

### Table 32. Cotinine

Geometric mean and selected percentiles of serum concentrations (in ng/mL) for the non-smoking U.S. population aged 3 years and older, National Health and Nutrition Examination Survey, 1999-2002.

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) 50th | 75th | 90th | 95th | Sample size |
|---|---|---|---|---|---|---|---|
| **Total, age 3 and older** | 99-00 | * | **.059** (<LOD-.070) | **.236** (.190-.300) | **1.02** (.750-1.25) | **1.96** (1.60-2.62) | 5999 |
| | 01-02 | **.062** (.050-.077) | † | **.163** (.123-.224) | **.932** (.737-1.17) | **2.19** (1.83-2.44) | 6813 |
| **Age group** | | | | | | | |
| 3-11 years | 99-00 | * | **.109** (.063-.180) | **.500** (.259-1.09) | **1.88** (.997-3.44) | **3.37** (1.42-4.79) | 1174 |
| | 01-02 | **.110** (.076-.160) | **.071** (<LOD-.124) | **.570** (.306-1.01) | **2.23** (1.60-2.78) | **3.21** (2.53-4.01) | 1414 |
| 12-19 years | 99-00 | * | **.107** (.080-.160) | **.540** (.428-.660) | **1.65** (1.48-1.92) | **2.56** (2.09-3.39) | 1773 |
| | 01-02 | **.086** (.059-.126) | **.051** (<LOD-.109) | **.352** (.189-.580) | **1.53** (1.09-2.12) | **3.12** (2.47-3.99) | 1902 |
| 20 years and older | 99-00 | * | **< LOD** | **.167** (.140-.193) | **.630** (.530-.810) | **1.48** (1.28-1.66) | 3052 |
| | 01-02 | **.052** (<LOD-.063) | † | **.113** (.090-.150) | **.623** (.465-.770) | **1.38** (1.11-1.84) | 3497 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **.080** (.059-.109) | **.302** (.220-.394) | **1.20** (.950-1.49) | **2.39** (1.66-3.22) | 2789 |
| | 01-02 | **.075** (.059-.095) | † | **.230** (.165-.316) | **1.17** (.932-1.42) | **2.44** (2.23-2.97) | 3149 |
| Females | 99-00 | * | **< LOD** | **.179** (.148-.220) | **.850** (.597-1.14) | **1.85** (1.33-2.45) | 3210 |
| | 01-02 | **.053** (<LOD-.066) | † | **.123** (.092-.180) | **.711** (.537-.990) | **1.76** (1.32-2.16) | 3664 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **.138** (.110-.176) | **.506** (.370-.726) | **1.21** (.900-1.70) | 2241 |
| | 01-02 | **.060** (<LOD-.084) | † | **.157** (.080-.308) | **.727** (.452-1.19) | **2.11** (1.14-2.98) | 1877 |
| Non-Hispanic blacks | 99-00 | * | **.131** (.111-.150) | **.505** (.400-.625) | **1.43** (1.18-1.75) | **2.34** (1.84-3.50) | 1333 |
| | 01-02 | **.164** (.136-.197) | **.132** (.106-.161) | **.570** (.436-.760) | **1.77** (1.54-2.01) | **3.12** (2.47-4.25) | 1599 |
| Non-Hispanic whites | 99-00 | * | **.050** (<LOD-.070) | **.210** (.150-.310) | **.950** (.621-1.40) | **1.92** (1.48-3.02) | 1950 |
| | 01-02 | **.052** (<LOD-.068) | † | **.119** (.087-.180) | **.800** (.571-1.11) | **1.88** (1.49-2.30) | 2845 |

< 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.

† 83% of measurements had a LOD of 0.015 ng/mL and 17% of measurements had a LOD of 0.050 ng/mL. See note in text.

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 (50$^{th}$ 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 50$^{th}$ percentile (as is the case for cotinine). For completeness, we list here, for 2001-2002, the computed 50$^{th}$ 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

shown). Both groups aged 3-11 years and 12-19 years had higher adjusted geometric mean levels of cotinine than the group aged 20 years and older. Males had higher levels than females. Non-Hispanic whites and Mexican Americans both had lower levels than non-Hispanic blacks. Higher levels of cotinine have previously been reported for non-Hispanic blacks (Caraballo et al., 1998). It is unknown whether these age, gender, and race/ethnicity differences represent differences in exposure, pharmacokinetics, or the relationship of dose per body weight.

These serum cotinine data will help public health officials determine whether or not people have been exposed to higher levels of ETS than are found in the general population. These data will also help scientists plan and conduct research about exposure to ETS and health effects.

# 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 coal, oil, gas, wood, garbage, or other organic substances, such as tobacco and charbroiled meat. Exposure to these chemicals usually occurs as exposure to mixtures and not to individual chemicals. Exposure can occur through air, water, soil, or food. PAHs enter the air from motor vehicle exhaust, residential and industrial furnaces, tobacco smoke, volcanoes, agricultural burning, residential wood burning, and wildfires. Seasonal variations in exposure to PAHs are known to occur. The soil and water near industrialized areas can contain elevated concentrations of PAHs. Foods that contain PAHs include smoked, charcoal-broiled, and roasted foods and plant foods that become contaminated by atmospheric deposition. Cereal products (e.g., wheat, corn, oats, and barley) may contain PAHs because of methods used to dry them.

Workers in certain occupational settings are exposed to PAHs from the burning or coking of petroleum products. Workplace situations include coke production, coal gasification and gas refinery, iron or steel production, roofing tar and asphalt application, chimney sweeping, waste incineration, and aluminum smelting. Coal tar is composed of PAHs and can be used as a medical therapy for psoriasis. OSHA have developed criteria on the allowable levels of these chemicals in the workplace. The U.S. EPA and The U.S. Food and Drug Administration (U.S. FDA) have only limited or preliminary standards for a few PAHs in water or food.

PAHs can be absorbed through the skin, respiratory tract, and gastrointestinal tract (Ramesh et al., 2004). In cells, some PAHs can bind and stimulate the Ah receptor, which in turn induces a greater metabolism of the PAHs themselves to products that can interact with DNA and promote cancer (Nebert et al., 2004) Lung, genito-urinary, and skin cancers have been reported in occupational settings, where the amount of exposure is greater than it is in the general population (Lloyd, 1971; Redmond et al., 1976; Boffetta et al., 1997; Bostrom et al., 2002; Armstrong et al., 2004). Additionally, PAH exposure may affect the immune system (Li et al., 2003) and reduce fetal growth (Dejmek et al., 2000; Perera et al., 2003). Early studies have been limited by the inability to evaluate the isolated effects of individual PAHs and other contributing carcinogens, such as those in tobacco smoke. IARC classifies benz[a]anthracene and benzo[a]pyrene as probable human carcinogens, and

**Table 33. Polycyclic Aromatic Hydrocarbons (PAHs) and their metabolites**

| **PAH** (CAS number) | **Urinary hydroxylated metabolite** (CAS number) |
|---|---|
| Benz[a]anthracene (56-55-3) | 1-Hydroxybenz[a]anthracene (69847-26-3)<br>3-Hydroxybenz[a]anthracene (4834-35-9)<br>and 9-Hydroxybenz[a]anthracene |
| Benzo[c]phenanthrene (195-19-7) | 1-Hydroxybenzo[c]phenanthrene<br>2-Hydroxybenzo[c]phenanthrene (22717-94-8)<br>3-Hydroxybenzo[c]phenanthrene |
| Chrysene (218-01-9) | 1-Hydroxychrysene(63019-38-5)<br>2-Hydroxychrysene (65945-06-4)<br>3-Hydroxychrysene (63019-39-6)<br>4-Hydroxychrysene (63019-40-9)<br>6-Hydroxychrysene (37515-51-8) |
| Fluoranthene (206-44-0) | 3-Hydroxyfluoranthrene |
| Fluorene (86-73-7) | 2-Hydroxyfluorene (2443-58-5)<br>3-Hydroxyfluorene (6344-67-8)<br>9-Hydroxyfluorene (484-17-3) |
| Phenanthrene (85-01-8) | 1-Hydroxyphenanthrene (2433-56-9)<br>2-Hydroxyphenanthrene<br>3-Hydroxyphenanthrene (605-87-8)<br>4-Hydroxyphenanthrene (7651-86-7)<br>9-Hydroxyphenanthrene (484-17-3) |
| Pyrene (129-00-0) | 1-Hydroxypyrene (5315-79-7) |
| Benzo[a]pyrene (50-32-8) | 3-Hydroxybenzo[a]pyrene (13345-21-6) |
| Naphthalene (91-20-3) | 1-Hydroxynapthalene (90-15-3)<br>2-Hydroxynapthalene (135-19-3) |

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 classi-fiable 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.

Information about external exposure (i.e., environmental levels) and health effects is available in several reviews (Bostrom et al., 2002, Armstrong et al., 2004) as well as from ATSDR's Toxicological Profiles at http://www.atsdr.cdc.gov/toxprofiles.

### Interpreting Levels of Urinary PAH Metabolites Reported in the Tables

Urinary levels of hydroxylated metabolites of PAHs 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.

Measurement of these 22 metabolites reflects exposure to PAHs that has occurred within the previous few days. Some of the parent PAHs can produce more than one measureable urinary metabolite. Table 34 shows the relation between PAHs and their metabolites. The hydroxylated metabolites of the PAHs are excreted in human urine both as free hydroxylated metabolites and as hydroxylated metabolites conjugated to glucuronic acid and sulfate. Measurements provided in this *Report* include both free and conjugated forms of the hydroxylated metabolites.

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

# 1-Hydroxybenz[a]anthracene and 3- 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]-anthracene, exceeding five- to ten-fold the concentrations measured in the NHANES 1999-2002 subsamples (Chuang et al., 1999). Workers manufacturing fireproof stone had 3-hydroxybenz[a]anthracene levels that were 10-100 times higher than the levels that were found in the NHANES 1999-2002 subsamples (Gundel et al., 2000).

### Table 34. 1-Hydroxybenz[a]anthracene

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

| | 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** | 2084 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **30.0** (22.0-36.0) | 2748 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 276 |
| | 01-02 | * | **< LOD** | **< LOD** | **13.0** (<LOD-30.0) | **45.0** (19.0-56.0) | 387 |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 626 |
| | 01-02 | * | **< LOD** | **< LOD** | **4.00** (<LOD-19.0) | **38.0** (10.0-68.0) | 735 |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1182 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **26.0** (21.0-34.0) | 1626 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1004 |
| | 01-02 | * | **< LOD** | **< LOD** | **10.0** (<LOD-20.0) | **30.0** (23.0-39.0) | 1349 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1080 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **30.0** (15.0-40.0) | 1399 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **6.80** (<LOD-10.9) | 667 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **21.0** (<LOD-38.0) | 665 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **5.20** (<LOD-7.20) | 465 |
| | 01-02 | * | **< LOD** | **< LOD** | **30.0** (13.0-42.0) | **59.0** (30.0-89.0) | 692 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 779 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **27.0** (20.0-37.0) | 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 35. 1-Hydroxybenz[a]anthracene (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 2084 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **27.0** (19.6-32.4) | 2748 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 276 |
| | 01-02 | * | **< LOD** | **< LOD** | **21.5** (10.0-28.0) | **34.0** (27.0-50.5) | 387 |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 626 |
| | 01-02 | * | **< LOD** | **< LOD** | **12.4** (6.83-24.8) | **28.0** (14.8-38.0) | 735 |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1182 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **24.5** (18.4-31.1) | 1626 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1004 |
| | 01-02 | * | **< LOD** | **< LOD** | **12.7** (10.2-17.0) | **24.8** (18.4-33.8) | 1349 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1080 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **27.0** (17.5-33.9) | 1399 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **15.7** (9.43-18.3) | 667 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **21.5** (14.1-33.3) | 665 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **7.36** (5.41-11.0) | 465 |
| | 01-02 | * | **< LOD** | **< LOD** | **17.5** (10.7-28.1) | **33.9** (17.5-61.6) | 692 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 779 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **28.0** (18.7-32.7) | 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 36. 3- and 9-Hydroxybenz[a]anthracene

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

| | 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** | **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 |
| | 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) | **11.6** (7.30-19.0) | 488 |
| | 01-02 | * | **< LOD** | **< LOD** | **18.0** (15.0-25.0) | **35.0** (22.0-46.0) | 692 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **7.60** (5.60-10.3) | **11.8** (7.70-18.0) | 793 |
| | 01-02 | * | **< LOD** | **< LOD** | **11.0** (<LOD-18.0) | **23.0** (18.0-36.0) | 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 37. 3- and 9-Hydroxybenz[a]anthracene (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** | **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** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **9.77** (8.09-12.7) | **14.7** (10.7-19.0) | 1033 |
| | 01-02 | * | **< LOD** | **< LOD** | **18.7** (15.6-21.9) | **26.3** (21.5-35.3) | 1349 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **14.1** (12.3-16.5) | **21.1** (16.5-22.4) | 1119 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **33.8** (29.8-39.8) | 1399 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **10.8** (8.84-15.5) | **18.1** (11.9-21.6) | 688 |
| | 01-02 | * | **< LOD** | **< LOD** | **21.5** (17.2-28.4) | **32.3** (27.3-36.3) | 665 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **6.77** (5.76-9.05) | **10.9** (7.45-14.1) | 488 |
| | 01-02 | * | **< LOD** | **< LOD** | **17.6** (14.5-22.2) | **28.4** (21.5-41.2) | 692 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **13.1** (10.3-16.5) | **19.0** (16.5-22.4) | 793 |
| | 01-02 | * | **< LOD** | **< LOD** | **23.7** (20.9-25.6) | **33.8** (29.6-37.4) | 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.

# 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.

## Table 38. 1-Hydroxybenzo[c]phenanthrene

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

| | 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** | **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 39. 1-Hydroxybenzo[c]phenanthrene (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 99-00 | * | **< LOD** | **10.1** (7.69-13.3) | **22.8** (15.7-30.0) | **36.1** (23.5-62.3) | 2200 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **41.3** (21.0-70.8) | 2732 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **< LOD** | **9.73** (7.29-17.7) | **22.7** (10.7-39.6) | **32.8** (20.5-80.5) | 297 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **28.3** (7.00-114) | 385 |
| 12-19 years | 99-00 | * | **< LOD** | **7.69** (5.73-10.2) | **16.3** (11.5-22.0) | **24.3** (16.3-34.0) | 665 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **21.5** (15.0-46.7) | 728 |
| 20 years and older | 99-00 | * | **< LOD** | **10.5** (7.88-13.8) | **23.5** (15.4-33.3) | **37.4** (23.5-80.7) | 1238 |
| | 01-02 | * | **< LOD** | **< LOD** | **12.4** (8.50-20.7) | **45.9** (20.7-76.5) | 1619 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **8.61** (6.67-11.1) | **18.6** (12.7-26.7) | **28.8** (22.8-37.1) | 1054 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **18.7** (12.2-37.2) | 1340 |
| Females | 99-00 | * | **< LOD** | **11.8** (8.24-17.5) | **25.1** (15.4-41.1) | **40.4** (21.1-93.3) | 1146 |
| | 01-02 | * | **< LOD** | **< LOD** | **19.3** (9.55-45.5) | **69.6** (33.3-103) | 1392 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **12.3** (9.47-17.0) | **26.7** (19.0-36.3) | **37.1** (27.1-50.0) | 716 |
| | 01-02 | * | **< LOD** | **< LOD** | **16.2** (5.12-54.5) | **42.0** (12.4-106) | 659 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **5.75** (4.32-7.86) | **11.8** (7.80-20.5) | **21.1** (11.4-40.5) | 497 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **14.0** (5.38-78.5) | 687 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **10.4** (7.84-14.3) | **23.9** (15.4-36.4) | **37.4** (22.8-86.9) | 806 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **45.7** (19.1-87.5) | 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 mean (95% conf. interval) | Selected percentiles (95% confidence interval) 50th | 75th | 90th | 95th | 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 A for LODs.
* Not calculated. Proportion of results below limit of detection was too high to provide a valid result.

## Table 41. 2-Hydroxybenzo[c]phenanthrene (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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 | * | **< LOD** | **< LOD** | **15.5** (11.7-20.8) | **22.9** (16.6-25.0) | 686 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **23.3** (14.0-53.7) | 665 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **7.38** (5.57-11.7) | **16.7** (11.7-22.3) | **23.3** (18.0-33.0) | 495 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **13.2** (10.9-18.4) | 692 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **20.8** (16.1-25.3) | **28.6** (25.3-32.0) | 810 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **21.9** (16.7-28.2) | 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 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)

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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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** (10.7-18.4) | 692 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 807 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **15.9** (14.3-16.7) | 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.

# 1-Hydroxychrysene, 2-Hydroxychrysene 3-Hydroxychrysene, 4-Hydroxychrysene, and 6-Hydroxychrysene

*Metabolites of Chrysene, CAS No. 218-01-9*

### Interpreting Levels of Urinary Chrysene Metabolites Reported in the Tables

Urinary levels of 1-hydroxychrysene, 2-hydroxychrysene 3-hydroxychrysene, 4-hydroxychrysene, and 6-hydroxychrysene were measured in a subsample of NHANES 2001-2002 participants aged 6 years and older. Similar levels of 6-hydroxychrysene have been reported in preschool children (Wilson et al., 2003). A sampling of 24 adults and 24 children from low income households in North Carolina found higher levels of urinary 6-hydroxychrysene, exceeding five- to ten-fold the concentrations measured in the NHANES 1999-2002 subsamples (Chuang et al., 1999).

## Table 44. 1-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, 2001-2002.

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | * | **< LOD** | **13.0** (<LOD-27.0) | **64.0** (46.0-78.0) | **105** (85.0-138) | 2748 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | * | **< LOD** | **< LOD** | **35.0** (19.0-52.0) | **69.0** (37.0-83.0) | 387 |
| 12-19 years | 01-02 | * | **< LOD** | **8.00** (<LOD-23.0) | **46.0** (31.0-62.0) | **71.0** (50.0-119) | 735 |
| 20 years and older | 01-02 | * | **< LOD** | **17.0** (<LOD-30.0) | **71.0** (53.0-87.0) | **116** (92.0-147) | 1626 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | **< LOD** | **23.0** (<LOD-38.0) | **73.0** (55.0-89.0) | **107** (87.0-152) | 1349 |
| Females | 01-02 | * | **< LOD** | **5.00** (<LOD-20.0) | **49.0** (31.0-71.0) | **92.0** (74.0-134) | 1399 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | **< LOD** | **< LOD** | **62.0** (31.0-102) | **104** (74.0-206) | 665 |
| Non-Hispanic blacks | 01-02 | * | **< LOD** | **19.0** (<LOD-47.0) | **78.0** (53.0-103) | **135** (81.0-190) | 692 |
| Non-Hispanic whites | 01-02 | * | **< LOD** | **12.0** (<LOD-28.0) | **60.0** (42.0-79.0) | **105** (75.0-143) | 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 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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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

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, 2001-2002.

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | * | **< LOD** | **< LOD** | **11.0** (<LOD-26.0) | **31.0** (14.0-45.0) | 2748 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | * | **< LOD** | **< LOD** | **22.0** (<LOD-43.0) | **39.0** (13.0-49.0) | 387 |
| 12-19 years | 01-02 | * | **< LOD** | **< LOD** | **9.00** (<LOD-32.0) | **32.0** (<LOD-49.0) | 735 |
| 20 years and older | 01-02 | * | **< LOD** | **< LOD** | **10.0** (<LOD-23.0) | **32.0** (12.0-46.0) | 1626 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | **< LOD** | **< LOD** | **12.0** (<LOD-28.0) | **34.0** (13.0-50.0) | 1349 |
| Females | 01-02 | * | **< LOD** | **< LOD** | **9.00** (<LOD-22.0) | **31.0** (12.0-43.0) | 1399 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **15.0** (<LOD-39.0) | 665 |
| Non-Hispanic blacks | 01-02 | * | **< LOD** | **< LOD** | **20.0** (<LOD-43.0) | **43.0** (17.0-65.0) | 692 |
| Non-Hispanic whites | 01-02 | * | **< LOD** | **< LOD** | **9.00** (<LOD-24.0) | **27.0** (11.0-45.0) | 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 47. 2-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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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** | **19.5** (7.50-32.4) | **30.8** (18.4-45.5) | 692 |
| Non-Hispanic whites | 01-02 | * | **< LOD** | **< LOD** | **17.3** (11.7-25.0) | **27.1** (20.3-35.0) | 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 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 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** | 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 49. 3-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** | **< LOD** | **< LOD** | 2233 |
| | 01-02 | * | **< LOD** | **< LOD** | **35.0** (27.1-41.5) | **56.8** (47.4-62.5) | 2748 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **26.9** (17.5-46.2) | 300 |
| | 01-02 | * | **< LOD** | **< LOD** | **36.8** (23.8-62.5) | **67.3** (36.7-89.9) | 387 |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **17.3** (13.7-21.9) | 674 |
| | 01-02 | * | **< LOD** | **< LOD** | **28.2** (20.0-40.7) | **43.8** (33.8-57.0) | 735 |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1259 |
| | 01-02 | * | **< LOD** | **< LOD** | **35.8** (26.7-44.6) | **57.8** (50.0-63.6) | 1626 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **20.6** (17.5-29.2) | 1067 |
| | 01-02 | * | **< LOD** | **< LOD** | **28.2** (24.1-35.0) | **47.6** (40.9-57.0) | 1349 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1166 |
| | 01-02 | * | **< LOD** | **< LOD** | **40.9** (30.2-50.0) | **65.0** (51.6-83.0) | 1399 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **33.3** (21.9-37.1) | 722 |
| | 01-02 | * | **< LOD** | **< LOD** | **28.4** (24.4-35.8) | **42.0** (30.0-54.0) | 665 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 515 |
| | 01-02 | * | **< LOD** | **< LOD** | **22.8** (15.1-30.5) | **35.0** (23.0-62.5) | 692 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 807 |
| | 01-02 | * | **< LOD** | **16.3** (13.9-18.4) | **40.6** (31.8-47.4) | **61.8** (51.5-70.2) | 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 50. 4-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, 2001-2002.

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 2748 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **5.00** (<LOD-11.0) | 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** | **13.0** (4.00-18.0) | 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 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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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 52. 6-Hydroxychrysene

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

| | 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** | **4.50** (<LOD-5.30) | **6.00** (5.30-6.80) | 2279 |
| | 01-02 | * | **< LOD** | **7.00** (<LOD-13.0) | **43.0** (32.0-55.0) | **77.0** (57.0-101) | 2736 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **< LOD** | **< LOD** | **5.00** (<LOD-5.90) | **6.10** (5.70-7.60) | 298 |
| | 01-02 | * | **< LOD** | **10.0** (<LOD-20.0) | **32.0** (25.0-52.0) | **68.0** (34.0-115) | 386 |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **5.70** (4.30-7.50) | **7.70** (5.00-11.2) | 689 |
| | 01-02 | * | **< LOD** | **10.0** (6.00-16.0) | **46.0** (29.0-59.0) | **79.0** (59.0-105) | 728 |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **4.40** (<LOD-5.10) | **5.80** (4.90-6.60) | 1292 |
| | 01-02 | * | **< LOD** | **7.00** (<LOD-13.0) | **44.0** (32.0-60.0) | **77.0** (57.0-103) | 1622 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **4.80** (<LOD-5.70) | **6.40** (5.40-7.70) | 1091 |
| | 01-02 | * | **< LOD** | **13.0** (7.00-18.0) | **55.0** (41.0-67.0) | **101** (67.0-123) | 1341 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **4.20** (<LOD-5.10) | **5.80** (4.50-7.30) | 1188 |
| | 01-02 | * | **< LOD** | **< LOD** | **33.0** (22.0-46.0) | **59.0** (44.0-78.0) | 1395 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **4.70** (3.70-5.10) | **6.00** (4.90-8.10) | 749 |
| | 01-02 | * | **< LOD** | **16.0** (7.00-20.0) | **48.0** (38.0-63.0) | **84.0** (63.0-117) | 664 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **4.90** (<LOD-6.60) | **6.80** (4.70-9.50) | 515 |
| | 01-02 | * | **< LOD** | **9.00** (<LOD-14.0) | **61.0** (40.0-88.0) | **112** (77.0-134) | 683 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **4.50** (<LOD-5.50) | **5.90** (5.50-6.60) | 827 |
| | 01-02 | * | **< LOD** | **9.00** (<LOD-15.0) | **42.0** (29.0-58.0) | **73.0** (52.0-107) | 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.

## 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

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

| | 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 | **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) | 675 |
| 20 years and older | 99-00 | **13.2** (9.39-18.6) | **17.3** (8.20-24.5) | **31.1** (26.8-38.5) | **58.2** (48.9-74.0) | **90.7** (71.7-151) | 1253 |
| **Gender** | | | | | | | |
| Males | 99-00 | **13.5** (9.55-19.0) | **17.4** (8.80-25.1) | **32.6** (27.1-42.1) | **58.2** (47.6-74.0) | **98.8** (64.7-190) | 1074 |
| Females | 99-00 | **13.3** (9.26-19.1) | **17.5** (6.80-26.1) | **31.8** (26.9-39.1) | **58.7** (48.9-77.2) | **88.4** (68.4-146) | 1162 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **14.0** (8.96-21.9) | **17.1** (6.90-26.8) | **30.4** (22.7-44.4) | **52.1** (42.9-73.8) | **96.6** (60.8-312) | 715 |
| Non-Hispanic blacks | 99-00 | **13.9** (8.32-23.2) | **17.7** (<LOD-29.3) | **38.2** (25.0-57.6) | **89.3** (56.8-174) | **185** (95.5-291) | 527 |
| Non-Hispanic whites | 99-00 | **13.2** (8.64-20.2) | **17.3** (6.50-28.1) | **32.0** (25.8-41.6) | **56.7** (43.6-74.0) | **87.3** (64.7-127) | 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 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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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.

# 2-Hydroxyfluorene, 3-Hydroxyfluorene, and 9-Hydroxyfluorene

*Metabolites of Fluorene, CAS No. 86-73-7*

### Interpreting Levels of Urinary Fluorene Metabolites Reported in the Tables

Urinary levels of 2-hydroxyfluorene, 3-hydroxyfluorene, 9-hydroxyfluorene were measured in a subsample of NHANES 2001-2002 participants aged 6 years and older. Levels of 2-hydroxyfluorene have been shown to be higher in smokers than non-smokers (Toriba et al., 2003).

### Comparing Adjusted Geometric Means

Geometric mean levels of urinary fluorene metabolites for the demographic groups were compared after adjusting for the covariates of race/ethnicity, age, gender, creatinine, and log serum cotinine (data not shown). In NHANES 2001-2002, adjusted geometric mean levels of 2- and 3-fluorene were higher for the group aged 6-11 years than either of the groups aged 12-19 years or 20 years and older.

For adjusted geometric mean levels of 9-fluorene in NHANES 2001-2002, the group aged 12-19 years had lower levels than either of the groups aged 6-11 years or 20 years and older.

It is unknown whether these differences associated with age represent differences in exposure, pharmacokinetics, or the relationship of dose per body weight.

## Table 56. 2-Hydroxyfluorene

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

| | 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 | **441** (287-678) | **422** (237-826) | **1350** (895-2290) | **3710** (2620-5250) | **6450** (4630-9470) | 2315 |
| | 01-02 | **318** (277-366) | **293** (252-328) | **619** (515-779) | **1700** (1330-2090) | **2820** (2340-3450) | 2745 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **294** (181-477) | **262** (157-563) | **780** (447-1360) | **1800** (1140-2000) | **2010** (1810-3260) | 306 |
| | 01-02 | **246** (219-277) | **262** (212-298) | **417** (357-492) | **679** (530-926) | **979** (773-1180) | 387 |
| 12-19 years | 99-00 | **469** (301-729) | **421** (243-933) | **1410** (932-2190) | **2810** (2180-4130) | **4980** (3540-6610) | 694 |
| | 01-02 | **295** (244-357) | **267** (237-319) | **548** (427-652) | **1190** (712-2090) | **2190** (1290-3250) | 733 |
| 20 years and older | 99-00 | **461** (300-709) | **456** (251-857) | **1510** (973-2620) | **4280** (2750-6090) | **7270** (4720-10300) | 1315 |
| | 01-02 | **333** (287-385) | **300** (254-343) | **716** (546-893) | **1950** (1520-2310) | **3140** (2540-3660) | 1625 |
| **Gender** | | | | | | | |
| Males | 99-00 | **474** (294-765) | **468** (223-923) | **1450** (875-2460) | **3780** (2440-6350) | **6920** (4160-12500) | 1106 |
| | 01-02 | **377** (324-439) | **329** (287-377) | **773** (579-1010) | **2060** (1480-2690) | **3210** (2340-3930) | 1346 |
| Females | 99-00 | **412** (276-616) | **385** (246-755) | **1330** (866-2150) | **3600** (2700-4660) | **5790** (4350-9470) | 1209 |
| | 01-02 | **272** (232-317) | **250** (211-296) | **512** (425-614) | **1270** (1120-1700) | **2310** (1990-2920) | 1399 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **296** (217-404) | **268** (164-454) | **807** (485-1290) | **1870** (1230-2530) | **2930** (1900-5400) | 750 |
| | 01-02 | **267** (212-337) | **270** (200-344) | **491** (368-620) | **951** (652-1190) | **1350** (1080-2130) | 662 |
| Non-Hispanic blacks | 99-00 | **646** (337-1240) | **680** (258-1520) | **2140** (983-4570) | **5790** (2680-11800) | **10800** (4830-19300) | 534 |
| | 01-02 | **459** (401-526) | **433** (377-474) | **1020** (725-1400) | **2200** (1760-3110) | **3480** (2520-4770) | 692 |
| Non-Hispanic whites | 99-00 | **418** (249-704) | **402** (211-860) | **1320** (825-2550) | **3990** (2590-5150) | **6450** (4600-9470) | 842 |
| | 01-02 | **310** (259-372) | **282** (234-332) | **599** (477-817) | **1710** (1210-2260) | **2920** (2260-3640) | 1207 |

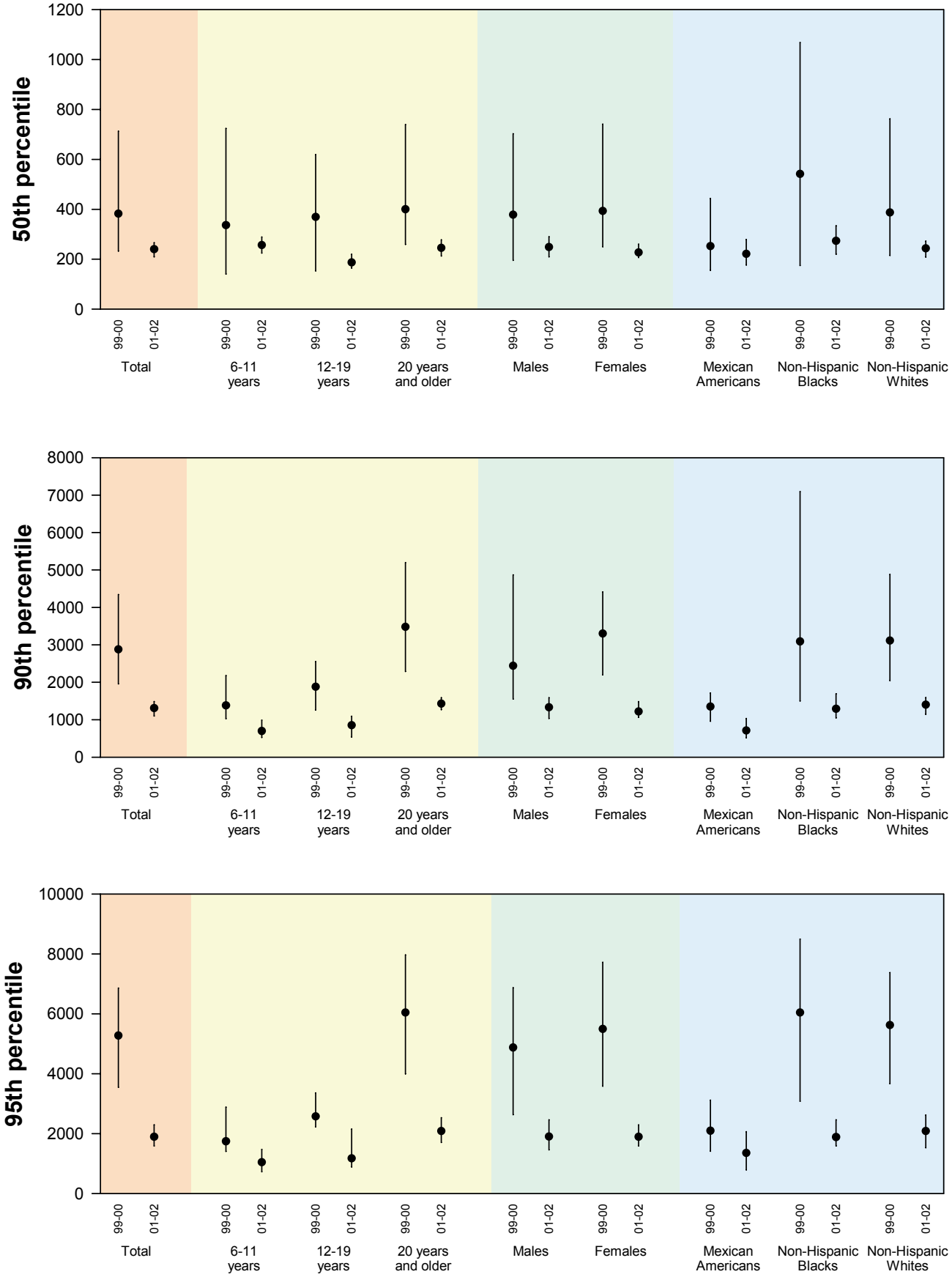
## Table 57. 2-Hydroxyfluorene (creatinine corrected)

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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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** (176-279) | **375** (306-501) | **711** (517-1040) | **1350** (787-2060) | 662 |
| Non-Hispanic blacks | 99-00 | **425** (219-823) | **541** (174-1070) | **1190** (679-2650) | **3090** (1500-7100) | **6040** (3080-8500) | 534 |
| | 01-02 | **323** (281-373) | **273** (220-334) | **660** (496-856) | **1290** (1050-1700) | **1880** (1590-2460) | 692 |
| Non-Hispanic whites | 99-00 | **414** (241-711) | **387** (215-762) | **1240** (756-1910) | **3110** (2050-4880) | **5620** (3670-7370) | 842 |
| | 01-02 | **306** (260-360) | **243** (208-273) | **546** (435-741) | **1400** (1140-1590) | **2080** (1530-2620) | 1207 |

## Figure 14. 2-Hydroxyfluorene (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 58. 3-Hydroxyfluorene

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

| | 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 | **170** (114-254) | **151** (86.3-280) | **572** (341-956) | **1840** (1260-2530) | **3390** (2290-4680) | 2312 |
| | 01-02 | **134** (115-155) | **111** (96.0-125) | **253** (207-349) | **959** (666-1300) | **1620** (1390-1900) | 2745 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **105** (70.3-157) | **92.8** (57.2-166) | **247** (137-439) | **615** (328-851) | **851** (647-1290) | 306 |
| | 01-02 | **106** (94.8-119) | **106** (90.0-124) | **174** (145-200) | **287** (235-358) | **377** (306-455) | 387 |
| 12-19 years | 99-00 | **192** (126-293) | **198** (119-295) | **621** (358-903) | **1330** (978-1910) | **2110** (1550-2400) | 692 |
| | 01-02 | **129** (103-161) | **113** (97.0-137) | **221** (177-266) | **542** (325-1070) | **1210** (680-2130) | 733 |
| 20 years and older | 99-00 | **178** (117-269) | **156** (89.1-306) | **639** (375-1160) | **2080** (1450-3350) | **4060** (2600-5020) | 1314 |
| | 01-02 | **138** (119-161) | **110** (94.0-128) | **311** (228-429) | **1130** (823-1400) | **1840** (1470-2080) | 1625 |
| **Gender** | | | | | | | |
| Males | 99-00 | **189** (119-299) | **167** (85.4-319) | **689** (341-1230) | **2060** (1320-3160) | **3520** (2090-6060) | 1105 |
| | 01-02 | **163** (137-194) | **134** (114-154) | **352** (242-481) | **1100** (721-1500) | **1810** (1390-2190) | 1346 |
| Females | 99-00 | **154** (106-224) | **141** (85.2-250) | **478** (333-742) | **1710** (986-2490) | **3010** (1900-4610) | 1207 |
| | 01-02 | **111** (95.0-130) | **93.0** (83.0-108) | **203** (167-248) | **796** (498-1040) | **1390** (1230-1660) | 1399 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **105** (75.6-145) | **96.7** (53.8-167) | **313** (203-432) | **862** (493-1370) | **1490** (941-1650) | 748 |
| | 01-02 | **108** (87.1-134) | **98.0** (80.0-118) | **190** (144-255) | **476** (302-641) | **668** (476-1140) | 662 |
| Non-Hispanic blacks | 99-00 | **266** (145-489) | **257** (116-572) | **954** (441-1750) | **2800** (1320-5800) | **5290** (2390-8600) | 534 |
| | 01-02 | **203** (169-244) | **161** (135-188) | **444** (308-830) | **1420** (1130-1780) | **2350** (1520-3000) | 692 |
| Non-Hispanic whites | 99-00 | **161** (99.9-259) | **137** (72.9-298) | **552** (318-964) | **1910** (1160-2720) | **3590** (2290-4730) | 842 |
| | 01-02 | **130** (108-157) | **108** (93.0-127) | **246** (202-352) | **948** (621-1320) | **1610** (1320-1990) | 1207 |

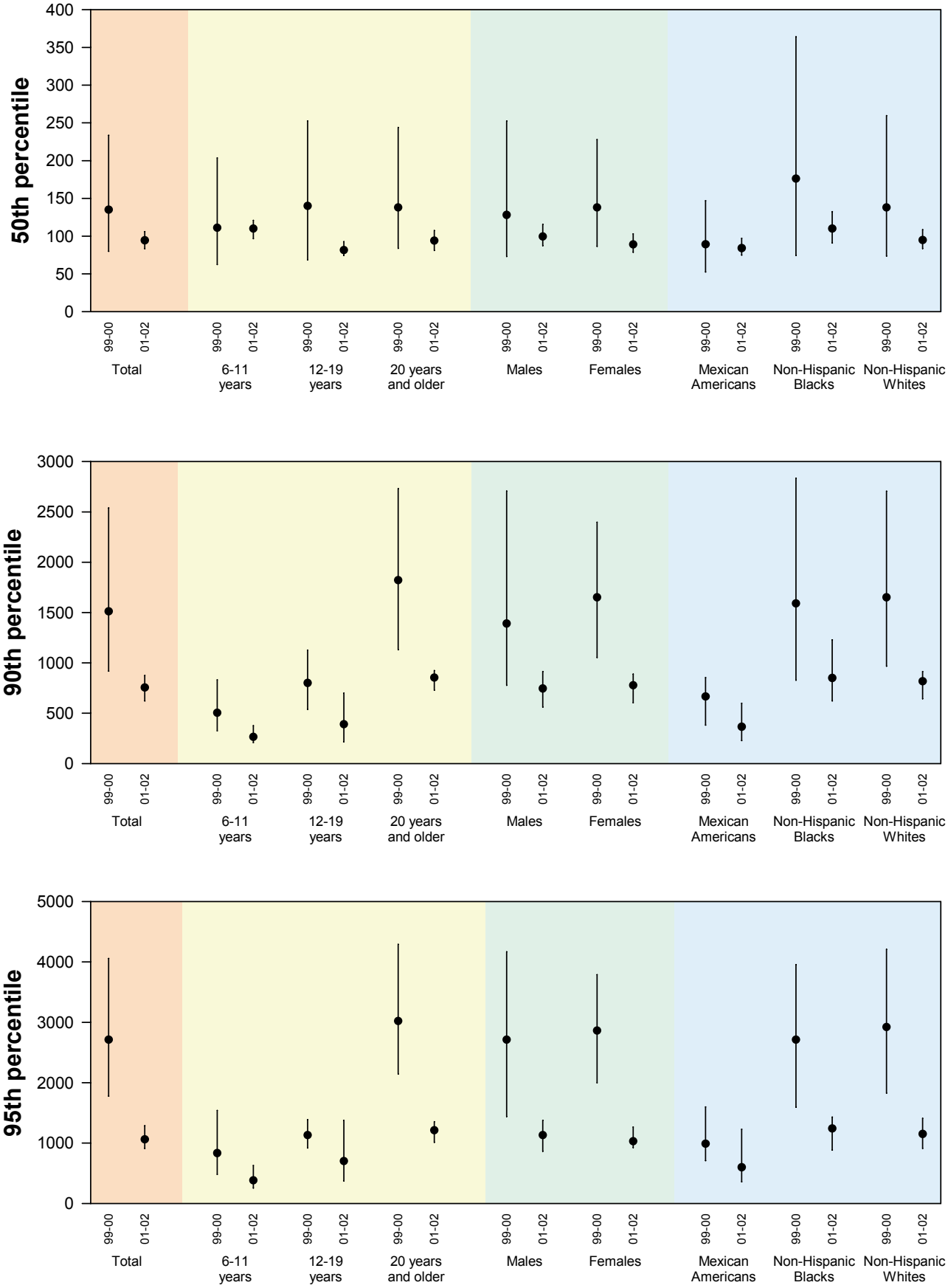
## Table 59. 3-Hydroxyfluorene (creatinine corrected)

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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 99-00 | **157** (102-241) | **135** (79.9-234) | **482** (306-766) | **1510** (918-2540) | **2710** (1780-4060) | 2312 |
| | 01-02 | **125** (108-144) | **94.4** (83.3-106) | **219** (174-303) | **754** (622-873) | **1060** (909-1290) | 2745 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **110** (69.8-173) | **111** (62.4-204) | **268** (175-418) | **504** (324-832) | **832** (480-1540) | 306 |
| | 01-02 | **119** (103-137) | **110** (96.7-121) | **153** (135-197) | **264** (206-377) | **382** (254-631) | 387 |
| 12-19 years | 99-00 | **129** (79.4-209) | **140** (68.7-253) | **374** (228-496) | **799** (536-1120) | **1130** (917-1390) | 692 |
| | 01-02 | **99.3** (81.6-121) | **81.5** (74.2-92.6) | **144** (109-197) | **390** (214-700) | **700** (372-1380) | 733 |
| 20 years and older | 99-00 | **170** (111-262) | **138** (83.9-244) | **613** (329-978) | **1820** (1130-2730) | **3020** (2140-4290) | 1314 |
| | 01-02 | **131** (113-151) | **94.0** (81.0-108) | **279** (195-367) | **853** (727-923) | **1210** (1010-1350) | 1625 |
| **Gender** | | | | | | | |
| Males | 99-00 | **150** (90.9-246) | **128** (72.9-253) | **496** (270-807) | **1390** (777-2710) | **2710** (1440-4170) | 1105 |
| | 01-02 | **132** (111-156) | **99.4** (87.3-116) | **260** (194-361) | **745** (560-914) | **1130** (862-1380) | 1346 |
| Females | 99-00 | **164** (111-243) | **138** (86.6-228) | **477** (311-792) | **1650** (1050-2400) | **2860** (2000-3790) | 1207 |
| | 01-02 | **119** (104-136) | **88.9** (78.6-103) | **179** (156-227) | **777** (604-888) | **1030** (923-1270) | 1399 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **97.5** (65.6-145) | **89.2** (52.4-147) | **220** (146-338) | **665** (380-854) | **987** (709-1600) | 748 |
| | 01-02 | **101** (84.2-121) | **84.0** (74.8-97.2) | **158** (124-214) | **364** (227-598) | **598** (357-1230) | 662 |
| Non-Hispanic blacks | 99-00 | **175** (94.1-325) | **176** (74.3-364) | **550** (313-1060) | **1590** (828-2830) | **2710** (1590-3950) | 534 |
| | 01-02 | **143** (118-173) | **110** (90.7-133) | **316** (186-525) | **849** (622-1230) | **1240** (882-1430) | 692 |
| Non-Hispanic whites | 99-00 | **159** (96.6-262) | **138** (73.4-260) | **505** (314-832) | **1650** (967-2700) | **2920** (1830-4210) | 842 |
| | 01-02 | **128** (108-152) | **94.7** (83.4-109) | **223** (171-323) | **816** (642-914) | **1150** (910-1410) | 1207 |

## Figure 15. 3-Hydroxyfluorene (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 60. 9-Hydroxyfluorene

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

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | **219** (191-251) | **219** (186-258) | **429** (363-510) | **779** (690-897) | **1090** (950-1300) | 2745 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | **169** (142-201) | **168** (144-202) | **295** (255-369) | **487** (415-683) | **720** (546-994) | 387 |
| 12-19 years | 01-02 | **197** (161-242) | **200** (153-266) | **370** (319-445) | **666** (527-784) | **883** (679-1270) | 733 |
| 20 years and older | 01-02 | **230** (199-265) | **231** (201-270) | **452** (376-568) | **839** (726-965) | **1150** (995-1360) | 1625 |
| **Gender** | | | | | | | |
| Males | 01-02 | **251** (217-292) | **249** (207-296) | **475** (396-578) | **858** (698-1080) | **1240** (990-1520) | 1346 |
| Females | 01-02 | **192** (164-225) | **194** (164-238) | **387** (328-462) | **701** (617-881) | **1020** (913-1100) | 1399 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | **199** (147-269) | **202** (155-273) | **347** (277-506) | **701** (451-1080) | **1080** (603-1690) | 662 |
| Non-Hispanic blacks | 01-02 | **327** (287-373) | **324** (289-348) | **609** (538-708) | **1060** (884-1430) | **1570** (1130-2350) | 692 |
| Non-Hispanic whites | 01-02 | **213** (182-250) | **214** (176-260) | **414** (347-508) | **772** (676-868) | **1060** (884-1300) | 1207 |

## Table 61. 9-Hydroxyfluorene (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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 |
| Females | 01-02 | **206** (182-234) | **213** (183-245) | **361** (306-395) | **541** (488-697) | **894** (702-1160) | 1399 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | **186** (143-243) | **182** (142-250) | **302** (233-416) | **515** (375-724) | **724** (515-1380) | 662 |
| Non-Hispanic blacks | 01-02 | **231** (201-265) | **224** (199-240) | **359** (324-388) | **605** (453-929) | **1190** (674-1680) | 692 |
| Non-Hispanic whites | 01-02 | **211** (186-239) | **211** (178-245) | **367** (324-411) | **605** (521-719) | **896** (747-1160) | 1207 |

# 1-Hydroxyphenanthrene, 2-Hydroxyphenanthrene, 3-Hydroxyphenanthrene, 4-Hydroxyphenanthrene, and 9-Hydroxyphenanthrene

*Metabolites of Phenanthrene, CAS No. 85-01-8*

### Interpreting Levels of Urinary Phenanthrene Metabolites Reported in the Tables

Urinary levels of 1-hydroxyphenanthrene, 2-hydroxyphenanthrene, 3-hydroxyphenanthrene, 4-hydroxyphenanthrene, and 9-hydroxyphenanthrene were measured in a subsample of NHANES 2001-2002 participants aged 6 years and older. Residents of homes with PAH contaminated parquet flooring had higher mean urinary 1-, 2-, 3- and 4-hydroxy-phenanthrene levels than were found in this NHANES 1999-2002 subsample (Heudorf and Angerer, 2001*a*). Workers manufacturing fireproof stone had urinary levels of 1-, 2-, 3- and 4-hydroxy-phenanthrene levels that were about ten times higher than the levels that were found in this NHANES 1999-2002 subsample (Gundel et al., 2000). Tobacco smoking increased levels of 2-, 3- and 4-hydroxyphenanthrene levels (Heudorf and Angerer, 2001*b*).

### Comparing Adjusted Geometric Means

Geometric means levels of urinary phenanthrene metabolites 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 1-hydroxyphenanthrene were higher in females than males, higher in non-Hispanic whites than non-Hispanic blacks, and higher in the group aged 6-11 years than either of the groups aged 12-19 years or 20 years and older.

## Table 62. 1-Hydroxyphenanthrene

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

| | 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 | **154** (115-206) | **160** (105-236) | **367** (280-483) | **698** (609-836) | **1070** (851-1390) | 2246 |
| | 01-02 | **140** (125-158) | **140** (128-152) | **266** (229-312) | **476** (426-539) | **684** (581-763) | 2741 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **121** (85.4-172) | **102** (74.2-204) | **257** (184-389) | **513** (360-666) | **666** (535-1080) | 294 |
| | 01-02 | **119** (104-137) | **121** (98.0-142) | **228** (182-249) | **357** (265-501) | **493** (367-661) | 387 |
| 12-19 years | 99-00 | **167** (128-218) | **175** (137-229) | **353** (266-443) | **688** (580-865) | **1080** (721-1560) | 680 |
| | 01-02 | **133** (110-162) | **130** (109-152) | **238** (198-303) | **429** (376-546) | **579** (439-820) | 733 |
| 20 years and older | 99-00 | **157** (116-212) | **163** (105-247) | **400** (295-523) | **739** (623-899) | **1100** (859-1530) | 1272 |
| | 01-02 | **145** (127-164) | **145** (132-163) | **273** (237-326) | **498** (440-565) | **712** (582-789) | 1621 |
| **Gender** | | | | | | | |
| Males | 99-00 | **153** (112-209) | **147** (99.8-236) | **351** (262-498) | **680** (588-836) | **1020** (735-1590) | 1072 |
| | 01-02 | **150** (133-169) | **145** (132-164) | **284** (235-348) | **499** (424-593) | **713** (575-845) | 1344 |
| Females | 99-00 | **156** (118-205) | **172** (119-236) | **372** (290-480) | **753** (610-946) | **1100** (855-1530) | 1174 |
| | 01-02 | **132** (115-152) | **136** (120-151) | **254** (221-297) | **462** (390-520) | **654** (538-769) | 1397 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **113** (94.9-134) | **113** (98.9-137) | **230** (180-314) | **447** (328-557) | **618** (459-745) | 727 |
| | 01-02 | **117** (90.8-152) | **115** (88.0-147) | **214** (157-294) | **364** (254-583) | **514** (342-847) | 664 |
| Non-Hispanic blacks | 99-00 | **162** (100-262) | **170** (82.7-303) | **441** (252-680) | **821** (574-1300) | **1210** (790-2290) | 516 |
| | 01-02 | **150** (127-179) | **145** (126-170) | **287** (243-327) | **493** (423-629) | **713** (568-975) | 690 |
| Non-Hispanic whites | 99-00 | **154** (109-218) | **156** (102-248) | **378** (267-533) | **704** (604-891) | **1060** (867-1450) | 815 |
| | 01-02 | **144** (125-166) | **143** (130-160) | **276** (241-330) | **489** (436-552) | **649** (550-793) | 1204 |

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.

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.

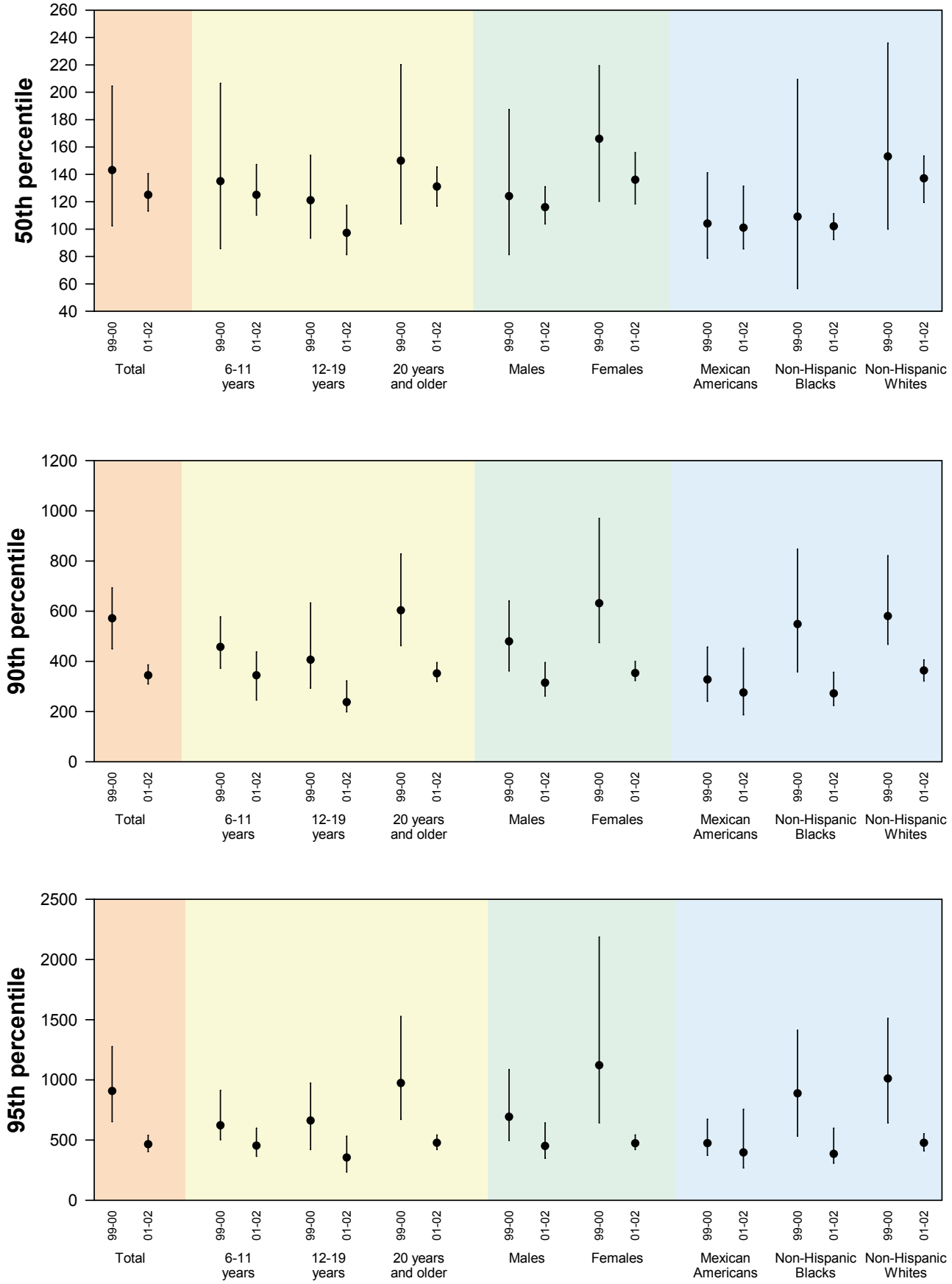
### Table 63. 1-Hydroxyphenanthrene (creatinine corrected)

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 | **142** (103-195) | **143** (102-204) | **299** (240-379) | **571** (450-693) | **907** (652-1270) | 2246 |
| | 01-02 | **132** (118-147) | **125** (113-141) | **210** (191-231) | **344** (310-385) | **464** (404-539) | 2741 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **127** (86.4-187) | **135** (85.8-206) | **265** (185-372) | **457** (372-577) | **622** (503-913) | 294 |
| | 01-02 | **133** (116-153) | **125** (110-147) | **188** (165-225) | **344** (245-437) | **452** (364-598) | 387 |
| 12-19 years | 99-00 | **112** (79.9-156) | **121** (93.5-154) | **207** (164-283) | **406** (293-632) | **661** (421-972) | 680 |
| | 01-02 | **103** (87.9-121) | **97.2** (81.4-117) | **158** (131-192) | **237** (198-322) | **354** (235-531) | 733 |
| 20 years and older | 99-00 | **150** (109-207) | **150** (104-220) | **321** (254-397) | **603** (462-828) | **973** (671-1530) | 1272 |
| | 01-02 | **137** (122-153) | **131** (117-145) | **223** (200-243) | **351** (319-395) | **476** (421-541) | 1621 |
| **Gender** | | | | | | | |
| Males | 99-00 | **120** (85.0-170) | **124** (81.4-187) | **260** (195-328) | **479** (362-641) | **692** (497-1090) | 1072 |
| | 01-02 | **122** (108-137) | **116** (104-131) | **194** (173-218) | **314** (262-395) | **450** (348-642) | 1344 |
| Females | 99-00 | **166** (122-225) | **166** (120-219) | **351** (276-418) | **631** (474-969) | **1120** (643-2180) | 1174 |
| | 01-02 | **142** (125-160) | **136** (118-156) | **226** (199-256) | **353** (323-399) | **473** (421-541) | 1397 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **104** (81.4-133) | **104** (78.8-141) | **192** (154-234) | **327** (241-456) | **474** (372-672) | 727 |
| | 01-02 | **110** (88.6-136) | **101** (85.5-131) | **162** (138-203) | **275** (187-452) | **396** (268-755) | 664 |
| Non-Hispanic blacks | 99-00 | **107** (65.5-174) | **109** (56.6-209) | **269** (173-395) | **548** (358-847) | **887** (534-1410) | 516 |
| | 01-02 | **106** (88.7-127) | **102** (92.4-111) | **172** (141-203) | **272** (224-356) | **384** (308-598) | 690 |
| Non-Hispanic whites | 99-00 | **151** (104-220) | **153** (99.9-236) | **323** (249-395) | **580** (468-820) | **1010** (643-1510) | 815 |
| | 01-02 | **142** (126-161) | **137** (119-153) | **226** (206-247) | **363** (321-406) | **476** (411-552) | 1204 |

## 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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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 |

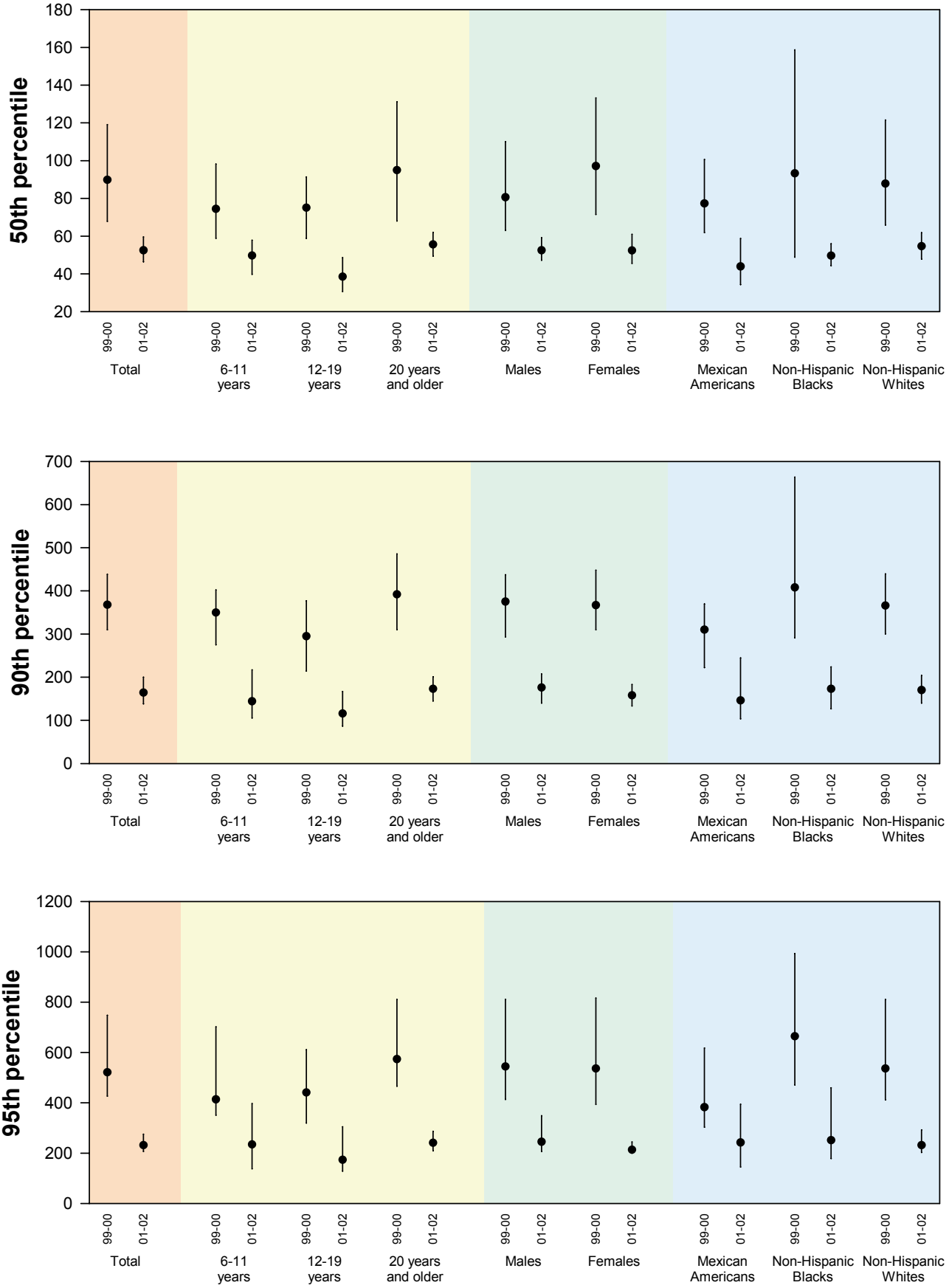
## Table 65. 2-Hydroxyphenanthrene (creatinine corrected)

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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 99-00 | **90.3** (69.3-118) | **89.8** (67.8-119) | **188** (147-255) | **368** (310-439) | **521** (426-748) | 2179 |
| | 01-02 | **50.6** (43.3-59.2) | **52.5** (46.4-59.6) | **91.4** (78.7-108) | **164** (138-200) | **231** (206-275) | 2742 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **83.8** (59.6-118) | **74.4** (58.8-98.3) | **173** (98.3-289) | **350** (275-402) | **413** (350-702) | 291 |
| | 01-02 | **45.3** (38.8-52.8) | **49.7** (39.8-57.8) | **85.9** (69.6-100) | **144** (105-217) | **234** (138-397) | 387 |
| 12-19 years | 99-00 | **74.0** (57.7-94.8) | **75.0** (58.8-91.4) | **133** (105-196) | **295** (214-377) | **441** (319-611) | 650 |
| | 01-02 | **38.4** (29.6-49.7) | **38.5** (30.6-48.7) | **64.9** (52.4-84.0) | **116** (86.7-167) | **173** (128-305) | 733 |
| 20 years and older | 99-00 | **94.3** (71.8-124) | **94.9** (68.0-131) | **197** (157-263) | **392** (310-486) | **573** (466-810) | 1238 |
| | 01-02 | **53.7** (46.2-62.4) | **55.6** (49.4-62.0) | **94.2** (84.1-112) | **173** (145-201) | **241** (209-287) | 1622 |
| **Gender** | | | | | | | |
| Males | 99-00 | **85.2** (64.7-112) | **80.6** (63.0-110) | **175** (135-231) | **375** (293-438) | **544** (413-810) | 1048 |
| | 01-02 | **50.4** (43.3-58.5) | **52.5** (47.2-59.2) | **91.4** (78.6-103) | **176** (140-208) | **245** (206-349) | 1345 |
| Females | 99-00 | **95.5** (72.5-126) | **97.1** (71.5-133) | **207** (163-262) | **367** (310-448) | **536** (393-816) | 1131 |
| | 01-02 | **50.9** (42.7-60.7) | **52.4** (45.5-61.0) | **91.6** (75.0-115) | **158** (133-183) | **213** (200-245) | 1397 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **78.8** (62.0-100) | **77.3** (61.9-101) | **155** (113-202) | **310** (222-370) | **382** (303-618) | 698 |
| | 01-02 | **43.7** (31.9-59.8) | **43.9** (34.3-58.8) | **80.5** (59.8-115) | **146** (103-245) | **242** (144-394) | 665 |
| Non-Hispanic blacks | 99-00 | **86.9** (55.8-135) | **93.3** (48.8-159) | **207** (131-318) | **408** (291-664) | **664** (470-993) | 509 |
| | 01-02 | **50.2** (40.5-62.2) | **49.6** (44.3-56.0) | **87.6** (72.5-103) | **173** (127-224) | **251** (178-459) | 690 |
| Non-Hispanic whites | 99-00 | **89.4** (64.9-123) | **87.8** (65.8-122) | **188** (141-261) | **366** (300-439) | **536** (411-810) | 792 |
| | 01-02 | **52.5** (43.8-62.9) | **54.7** (47.7-61.9) | **92.5** (80.5-113) | **170** (140-204) | **231** (202-293) | 1204 |

## 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

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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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** | | | | | | | |
| 6-11 years | 99-00 | **136** (102-181) | **140** (102-197) | **247** (185-334) | **383** (280-632) | **622** (336-794) | 302 |
| | 01-02 | **105** (91.1-122) | **108** (81.0-136) | **193** (160-231) | **298** (245-346) | **412** (319-545) | 387 |
| 12-19 years | 99-00 | **147** (126-173) | **163** (137-196) | **281** (240-322) | **417** (363-536) | **611** (457-725) | 700 |
| | 01-02 | **104** (87.3-125) | **106** (90.0-122) | **201** (165-231) | **329** (255-444) | **447** (331-631) | 733 |
| 20 years and older | 99-00 | **122** (102-146) | **133** (108-155) | **254** (223-295) | **477** (410-554) | **671** (594-760) | 1297 |
| | 01-02 | **105** (91.7-119) | **105** (89.0-118) | **200** (178-228) | **433** (366-515) | **683** (597-806) | 1621 |
| **Gender** | | | | | | | |
| Males | 99-00 | **141** (114-174) | **149** (119-185) | **287** (225-357) | **495** (409-626) | **658** (552-802) | 1100 |
| | 01-02 | **122** (107-138) | **117** (105-131) | **224** (187-277) | **474** (372-597) | **734** (597-1010) | 1344 |
| Females | 99-00 | **114** (96.2-135) | **130** (102-152) | **242** (215-270) | **399** (346-506) | **624** (554-718) | 1199 |
| | 01-02 | **90.8** (77.7-106) | **92.0** (80.0-106) | **184** (155-207) | **328** (287-386) | **518** (429-649) | 1397 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **113** (103-123) | **120** (99.7-139) | **231** (193-244) | **353** (296-438) | **495** (369-635) | 763 |
| | 01-02 | **83.5** (64.1-109) | **83.0** (63.0-111) | **144** (116-193) | **259** (189-421) | **454** (253-1140) | 664 |
| Non-Hispanic blacks | 99-00 | **174** (124-245) | **182** (116-292) | **390** (289-470) | **671** (477-1060) | **1110** (775-2750) | 522 |
| | 01-02 | **145** (122-172) | **135** (120-163) | **281** (228-346) | **507** (407-684) | **957** (609-1410) | 690 |
| Non-Hispanic whites | 99-00 | **120** (95.3-151) | **135** (107-167) | **248** (217-292) | **448** (356-554) | **632** (515-721) | 821 |
| | 01-02 | **104** (90.8-120) | **105** (91.0-119) | **199** (177-224) | **401** (331-495) | **649** (518-747) | 1204 |

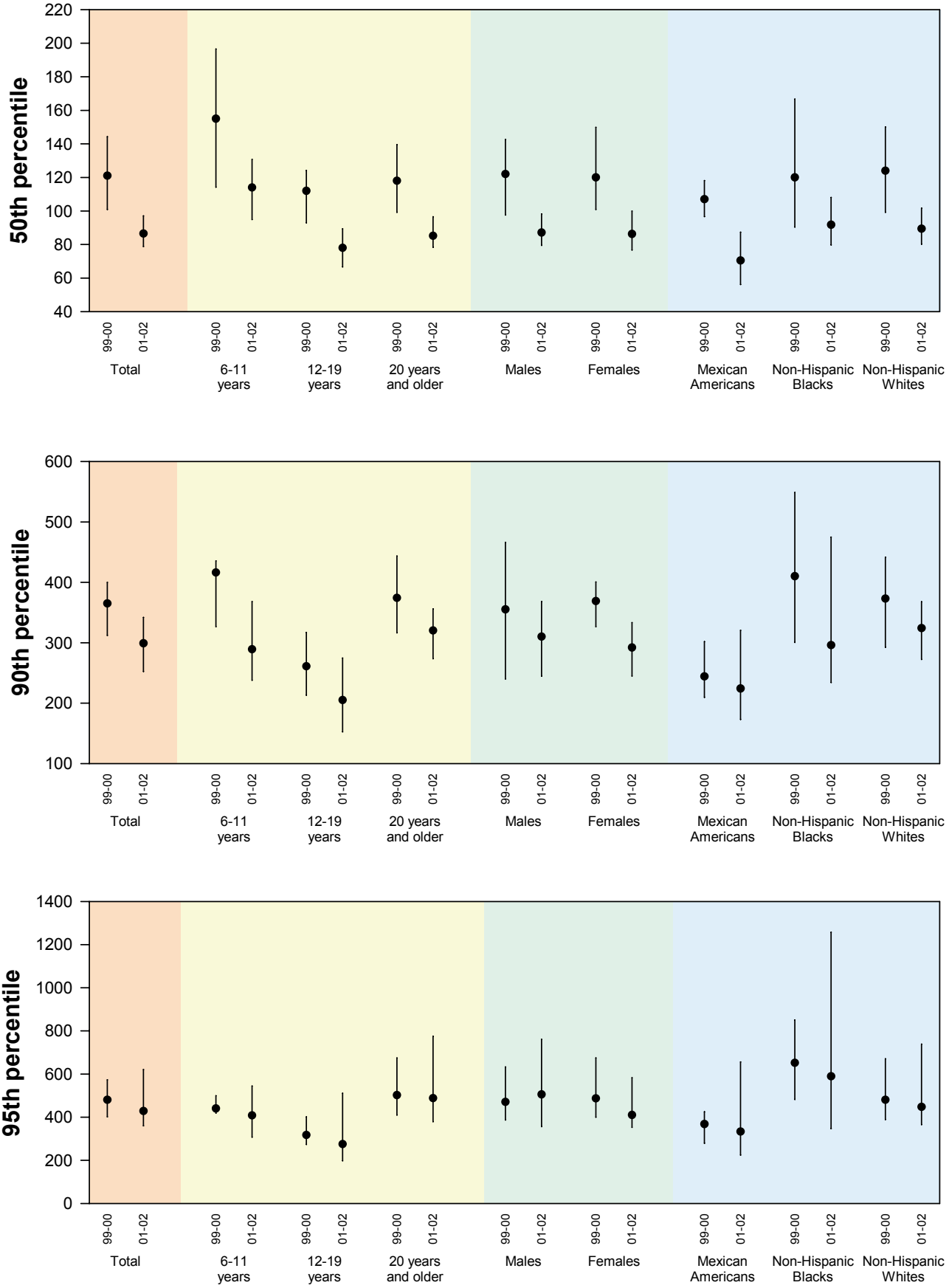
## Table 67. 3-Hydroxyphenanthrene (creatinine corrected)

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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 99-00 | **116** (94.5-143) | **121** (101-144) | **198** (171-235) | **365** (312-400) | **480** (402-574) | 2299 |
| | 01-02 | **98.0** (87.4-110) | **86.5** (78.8-97.1) | **158** (142-174) | **299** (252-342) | **428** (360-621) | 2741 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **143** (106-192) | **155** (114-197) | **226** (183-331) | **416** (326-436) | **440** (418-499) | 302 |
| | 01-02 | **118** (103-135) | **114** (94.9-131) | **173** (150-201) | **289** (238-368) | **408** (308-544) | 387 |
| 12-19 years | 99-00 | **99.3** (78.5-126) | **112** (92.9-124) | **173** (134-213) | **261** (213-317) | **317** (273-402) | 700 |
| | 01-02 | **81.1** (70.1-93.8) | **78.0** (66.7-89.4) | **116** (96.5-144) | **205** (153-275) | **275** (198-511) | 733 |
| 20 years and older | 99-00 | **116** (94.9-143) | **118** (99.2-140) | **201** (167-241) | **374** (316-444) | **502** (410-675) | 1297 |
| | 01-02 | **98.9** (88.3-111) | **85.2** (78.3-96.6) | **164** (147-183) | **320** (273-356) | **488** (379-774) | 1621 |
| **Gender** | | | | | | | |
| Males | 99-00 | **111** (86.9-143) | **122** (97.6-143) | **189** (157-240) | **355** (240-466) | **470** (387-633) | 1100 |
| | 01-02 | **98.6** (87.7-111) | **87.1** (79.5-98.2) | **159** (138-188) | **310** (245-368) | **505** (356-761) | 1344 |
| Females | 99-00 | **121** (99.8-147) | **120** (101-150) | **214** (168-265) | **369** (326-401) | **487** (400-675) | 1199 |
| | 01-02 | **97.5** (84.9-112) | **86.3** (76.7-100) | **157** (139-178) | **292** (245-333) | **410** (352-583) | 1397 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **105** (93.2-118) | **107** (96.6-118) | **161** (147-174) | **244** (209-302) | **368** (279-425) | 763 |
| | 01-02 | **78.2** (62.4-98.0) | **70.5** (56.2-87.4) | **130** (92.9-171) | **224** (173-321) | **333** (224-656) | 664 |
| Non-Hispanic blacks | 99-00 | **115** (80.8-163) | **120** (90.4-167) | **213** (162-300) | **410** (300-549) | **652** (482-850) | 522 |
| | 01-02 | **102** (85.8-122) | **91.8** (79.8-108) | **160** (133-202) | **296** (234-475) | **589** (347-1260) | 690 |
| Non-Hispanic whites | 99-00 | **117** (91.4-151) | **124** (99.2-150) | **203** (173-253) | **373** (292-442) | **480** (389-671) | 821 |
| | 01-02 | **103** (91.5-117) | **89.4** (80.2-102) | **167** (148-193) | **324** (272-368) | **447** (365-738) | 1204 |

## Figure 18. 3-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 68. 4-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, 2001-2002.

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | **41.9** (31.3-56.0) | **67.0** (46.0-92.0) | **141** (119-170) | **225** (196-254) | **280** (250-339) | 2741 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | **34.5** (24.3-48.9) | **51.0** (30.0-77.0) | **118** (87.0-155) | **201** (155-256) | **250** (184-284) | 387 |
| 12-19 years | 01-02 | **38.8** (28.9-52.1) | **66.0** (38.0-85.0) | **131** (112-156) | **223** (188-261) | **306** (257-358) | 733 |
| 20 years and older | 01-02 | **43.4** (32.0-58.9) | **70.0** (46.0-96.0) | **146** (124-173) | **228** (196-264) | **292** (249-346) | 1621 |
| **Gender** | | | | | | | |
| Males | 01-02 | **45.3** (33.6-61.0) | **73.0** (46.0-99.0) | **142** (117-176) | **226** (192-250) | **287** (247-346) | 1344 |
| Females | 01-02 | **38.9** (28.8-52.5) | **64.0** (43.0-88.0) | **141** (118-165) | **222** (190-265) | **278** (249-350) | 1397 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | **42.8** (23.7-77.4) | **72.0** (25.0-120) | **144** (92.0-215) | **227** (183-268) | **289** (243-398) | 664 |
| Non-Hispanic blacks | 01-02 | **48.6** (33.8-69.9) | **78.0** (51.0-113) | **159** (129-186) | **233** (194-276) | **277** (240-335) | 690 |
| Non-Hispanic whites | 01-02 | **41.1** (29.6-57.0) | **66.0** (41.0-96.0) | **140** (116-171) | **225** (186-266) | **287** (247-356) | 1204 |

## Table 69. 4-Hydroxyphenanthrene (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | **39.2** (29.6-52.0) | **56.5** (39.3-76.3) | **121** (97.3-147) | **236** (196-273) | **347** (293-411) | 2741 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | **38.5** (26.4-56.2) | **56.7** (25.5-91.0) | **123** (92.6-168) | **239** (169-278) | **314** (243-371) | 387 |
| 12-19 years | 01-02 | **30.1** (22.5-40.4) | **47.8** (29.1-61.4) | **89.6** (73.9-112) | **165** (132-194) | **236** (164-540) | 733 |
| 20 years and older | 01-02 | **41.0** (30.7-54.9) | **58.8** (41.1-79.5) | **127** (105-154) | **245** (200-292) | **371** (300-447) | 1621 |
| **Gender** | | | | | | | |
| Males | 01-02 | **36.7** (27.6-48.8) | **54.5** (34.4-71.6) | **109** (88.0-130) | **189** (161-224) | **282** (252-307) | 1344 |
| Females | 01-02 | **41.8** (31.0-56.2) | **60.4** (42.4-80.4) | **135** (106-170) | **268** (227-332) | **418** (346-488) | 1397 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | **40.1** (22.8-70.4) | **60.7** (26.2-100) | **134** (97.5-173) | **236** (176-314) | **323** (242-408) | 664 |
| Non-Hispanic blacks | 01-02 | **34.3** (24.7-47.7) | **56.8** (36.8-71.4) | **98.8** (84.1-123) | **157** (138-176) | **230** (193-256) | 690 |
| Non-Hispanic whites | 01-02 | **40.6** (29.8-55.4) | **58.1** (37.8-81.4) | **126** (100-157) | **252** (198-297) | **387** (293-470) | 1204 |

## Table 70. 9-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, 2001-2002.

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | **33.9** (29.7-38.6) | **41.0** (36.0-46.0) | **87.0** (75.0-103) | **205** (169-254) | **343** (291-396) | 2741 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | **24.7** (21.0-29.1) | **32.0** (28.0-39.0) | **59.0** (50.0-68.0) | **95.0** (70.0-125) | **124** (90.0-225) | 387 |
| 12-19 years | 01-02 | **30.2** (25.1-36.4) | **34.0** (31.0-40.0) | **70.0** (60.0-86.0) | **151** (101-204) | **250** (161-312) | 733 |
| 20 years and older | 01-02 | **35.9** (30.9-41.6) | **44.0** (38.0-49.0) | **100** (81.0-117) | **244** (183-292) | **392** (314-476) | 1621 |
| **Gender** | | | | | | | |
| Males | 01-02 | **39.4** (33.8-46.0) | **47.0** (42.0-53.0) | **93.0** (76.0-123) | **236** (170-290) | **381** (269-487) | 1344 |
| Females | 01-02 | **29.4** (25.1-34.5) | **36.0** (32.0-42.0) | **78.0** (69.0-97.0) | **179** (151-244) | **337** (247-392) | 1397 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | **26.7** (21.2-33.7) | **34.0** (26.0-43.0) | **62.0** (49.0-78.0) | **132** (86.0-202) | **202** (124-396) | 664 |
| Non-Hispanic blacks | 01-02 | **34.7** (28.5-42.4) | **41.0** (36.0-47.0) | **104** (81.0-127) | **269** (170-391) | **399** (285-550) | 690 |
| Non-Hispanic whites | 01-02 | **34.6** (30.2-39.7) | **43.0** (37.0-48.0) | **91.0** (78.0-108) | **207** (160-269) | **344** (281-421) | 1204 |

## Table 71. 9-Hydroxyphenanthrene (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | **31.7** (28.1-35.8) | **36.3** (32.3-40.4) | **72.1** (63.2-85.9) | **156** (139-179) | **240** (213-290) | 2741 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | **27.6** (23.7-32.2) | **35.0** (30.3-40.2) | **56.4** (46.3-66.7) | **89.5** (72.0-101) | **120** (88.9-152) | 387 |
| 12-19 years | 01-02 | **23.5** (19.9-27.7) | **26.7** (22.8-30.6) | **44.8** (38.5-55.9) | **101** (77.8-118) | **158** (107-270) | 733 |
| 20 years and older | 01-02 | **33.9** (29.7-38.7) | **38.8** (34.1-42.9) | **80.5** (69.4-102) | **175** (148-212) | **268** (216-321) | 1621 |
| **Gender** | | | | | | | |
| Males | 01-02 | **31.9** (27.7-36.8) | **36.0** (32.0-40.4) | **71.0** (58.6-91.6) | **163** (131-187) | **218** (182-290) | 1344 |
| Females | 01-02 | **31.6** (27.3-36.5) | **36.7** (31.7-41.5) | **73.1** (63.6-86.6) | **151** (133-187) | **271** (216-308) | 1397 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | **25.0** (20.7-30.3) | **28.2** (24.8-31.8) | **52.7** (42.7-68.9) | **110** (74.8-160) | **166** (107-346) | 664 |
| Non-Hispanic blacks | 01-02 | **24.5** (20.0-30.1) | **29.4** (25.8-32.7) | **63.4** (44.2-84.9) | **143** (96.9-209) | **233** (153-313) | 690 |
| Non-Hispanic whites | 01-02 | **34.3** (30.6-38.4) | **39.1** (34.0-43.3) | **78.7** (65.2-96.4) | **167** (144-199) | **268** (216-313) | 1204 |

# 1-Hydroxypyrene

*Metabolite of Pyrene, CAS No. 129-00-0*

### Interpreting Levels of Urinary 1-Hydroxypyrene Reported in the Tables

Pyrene is commonly found in PAH mixtures, and its urinary metabolite has been used as an indicator of exposure to PAH chemicals. Urinary 1-hydroxypyrene levels were measured in a subsample of NHANES 2001-2002 participants aged 6 years and older. The geometric mean levels of 1-hydroxypyrene in the NHANES 2001-2002 subsample is similar to that of other general populations residing in an urban setting (Goen et al., 1995; Chuang et al., 1999, Heudorf and Angerer, 2001*b*; Roggi et al., 1997; Yang et al., 2003). Higher levels have been noted for residents of industrialized urban areas compared with rural or suburban settings (Adonis et al., 2003; Kanoh et al., 1993; Kuo et al., 2004).

Many-fold higher levels can be found in workers from certain occupations (Jacob and Seidel, 2002) including aluminum smelting (Alexandrie et al., 2000); diesel engine mechanics (Adonis et al., 2003, Kuusimaki et al., 2004); taxi, bus, and truck drivers (Chuang et al., 2003, Hansen et al., 2004; Kuusimaki et al., 2004); painters (Lee et al., 2003), boilermakers (Mukherjee et al., 2004); toll booth operators (Tsai et al., 2004); traffic police (Merlo et al., 1998) and coke oven plant workers (Lu et al., 2002; Serdar et al., 2003a; Siwinska et al., 2004). Tobacco smoking leads to higher levels in smokers (Chuang et al., 2003; Adonis et al., 2003, Heudorf and Angerer, 2001*b*) as well as the non-smoking children of smokers (Tsai et al., 2003). Coal stove exposure or consumption of broiled, fried or grilled meat contribute to higher levels of 1-hydroxypyrene (Siwinska et al., 1999; Scheepers et al., 2002, Yang et al., 2003).

### Table 72. 1-Hydroxypyrene

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

| | 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 | **79.8** (66.9-95.1) | **78.0** (67.9-92.6) | **187** (164-229) | **434** (372-506) | **730** (571-926) | 2312 |
| | 01-02 | **49.6** (43.4-56.7) | **47.0** (42.0-56.0) | **103** (90.0-116) | **214** (184-245) | **349** (290-400) | 2747 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **90.8** (71.4-115) | **94.1** (77.9-120) | **170** (136-201) | **300** (197-413) | **419** (257-757) | 310 |
| | 01-02 | **59.7** (52.8-67.5) | **59.0** (48.0-66.0) | **109** (86.0-150) | **212** (164-257) | **272** (224-453) | 387 |
| 12-19 years | 99-00 | **105** (87.8-125) | **108** (83.0-130) | **226** (188-264) | **473** (336-596) | **642** (468-1170) | 693 |
| | 01-02 | **57.8** (47.4-70.6) | **60.0** (44.0-71.0) | **111** (89.0-148) | **230** (179-273) | **329** (267-489) | 735 |
| 20 years and older | 99-00 | **74.8** (61.5-91.1) | **70.1** (61.5-86.1) | **187** (155-235) | **446** (379-547) | **795** (596-940) | 1309 |
| | 01-02 | **47.3** (41.1-54.6) | **45.0** (40.0-53.0) | **100** (88.0-115) | **216** (182-246) | **361** (290-416) | 1625 |
| **Gender** | | | | | | | |
| Males | 99-00 | **90.1** (73.2-111) | **85.2** (70.5-105) | **227** (178-287) | **496** (413-577) | **747** (577-1020) | 1106 |
| | 01-02 | **57.8** (49.8-67.1) | **55.0** (46.0-64.0) | **120** (97.0-149) | **246** (203-312) | **416** (299-528) | 1348 |
| Females | 99-00 | **71.2** (59.4-85.3) | **70.9** (63.1-87.3) | **163** (152-188) | **361** (300-412) | **669** (387-940) | 1206 |
| | 01-02 | **43.0** (36.7-50.4) | **43.0** (35.0-52.0) | **92.0** (76.0-107) | **178** (150-199) | **278** (219-349) | 1399 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **74.2** (67.1-82.0) | **68.1** (62.7-76.8) | **161** (143-179) | **344** (284-460) | **545** (372-714) | 766 |
| | 01-02 | **51.0** (38.0-68.4) | **51.0** (40.0-68.0) | **99.0** (69.0-133) | **163** (125-269) | **269** (154-666) | 665 |
| Non-Hispanic blacks | 99-00 | **108** (83.9-140) | **99.7** (72.2-159) | **245** (202-352) | **586** (428-778) | **839** (496-1480) | 528 |
| | 01-02 | **66.2** (56.9-77.0) | **63.0** (49.0-82.0) | **134** (112-171) | **305** (236-386) | **442** (337-561) | 692 |
| Non-Hispanic whites | 99-00 | **73.7** (58.5-92.9) | **72.9** (63.3-86.1) | **178** (155-213) | **399** (333-506) | **747** (477-977) | 832 |
| | 01-02 | **46.9** (40.0-55.1) | **45.0** (38.0-56.0) | **98.0** (87.0-115) | **214** (179-249) | **343** (271-431) | 1207 |

### Comparing Adjusted Geometric Means

Geometric mean levels of urinary 1-hydroxypyrene 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, children aged 6-11 years had higher adjusted geometric mean levels of 1-hydroxypyrene than the two other age groups. This age-related difference also has been found by other investigators (Heudorf and Angerer, 2001*b*; Chuang et al., 1999). In addition, the levels for children in this *Report* are similar to levels measured in other studies (van Wijnen et al., 1996; Chuang et al., 1999; Heudorf and Angerer, 2001*a*; Kanoh et al., 1993; Tsai et al., 2003). No differences were observed for race/ethnicity or gender, and several previous studies have also not found differences. It is unknown whether these differences associated with age represent differences in exposure, pharmacokinetics, or the relationship of dose per body weight.

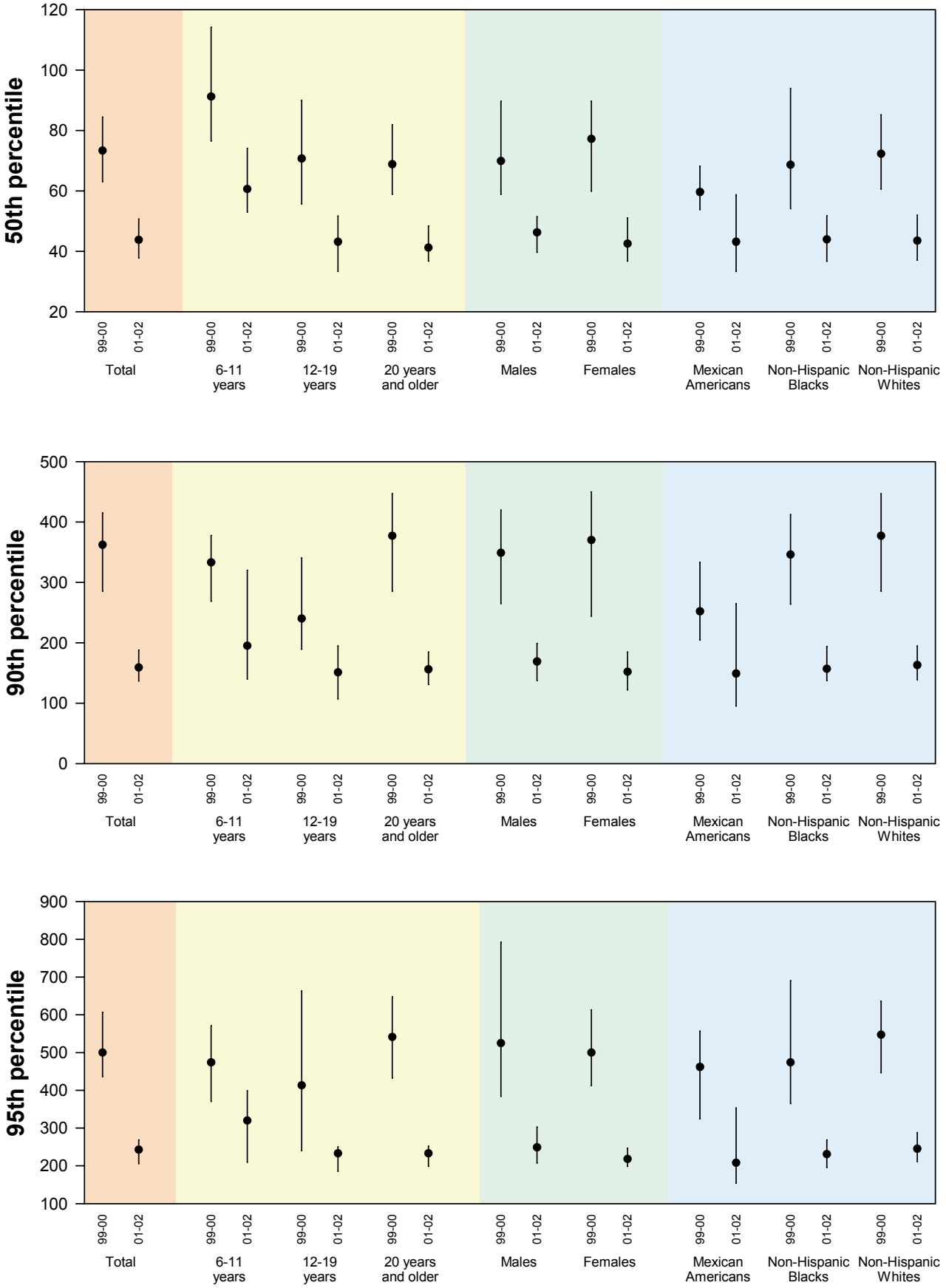
## Table 73. 1-Hydroxypyrene (creatinine corrected)

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 | **74.2** (61.6-89.3) | **73.3** (63.1-84.4) | **158** (139-178) | **362** (286-415) | **500** (436-607) | 2312 |
| | 01-02 | **46.4** (40.9-52.8) | **43.8** (37.8-50.7) | **80.8** (72.9-90.1) | **159** (137-188) | **243** (206-269) | 2747 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **94.1** (75.3-118) | **91.2** (76.5-114) | **168** (126-234) | **333** (269-378) | **474** (371-571) | 310 |
| | 01-02 | **66.8** (57.5-77.7) | **60.6** (52.9-74.1) | **105** (83.3-137) | **195** (140-320) | **320** (209-399) | 387 |
| 12-19 years | 99-00 | **71.5** (59.0-86.5) | **70.7** (55.6-90.0) | **137** (120-170) | **240** (189-341) | **413** (240-663) | 693 |
| | 01-02 | **44.7** (37.8-52.9) | **43.1** (33.3-51.7) | **71.4** (59.0-87.9) | **151** (107-195) | **233** (186-250) | 735 |
| 20 years and older | 99-00 | **72.3** (58.8-88.8) | **68.8** (58.9-81.9) | **159** (131-188) | **377** (286-447) | **541** (433-648) | 1309 |
| | 01-02 | **44.7** (39.4-50.7) | **41.2** (36.7-48.4) | **79.5** (72.2-87.5) | **156** (131-185) | **233** (199-252) | 1625 |
| **Gender** | | | | | | | |
| Males | 99-00 | **72.1** (56.8-91.6) | **69.9** (58.9-89.7) | **167** (130-189) | **349** (265-420) | **525** (384-793) | 1106 |
| | 01-02 | **46.8** (40.8-53.7) | **46.2** (39.6-51.4) | **83.8** (74.1-96.4) | **169** (138-199) | **249** (207-303) | 1348 |
| Females | 99-00 | **76.1** (63.1-91.9) | **77.2** (59.9-89.7) | **148** (127-183) | **370** (244-450) | **500** (413-613) | 1206 |
| | 01-02 | **46.1** (40.0-53.1) | **42.5** (36.7-51.0) | **77.3** (68.5-89.5) | **152** (122-185) | **218** (199-247) | 1399 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **68.2** (61.8-75.3) | **59.6** (53.8-68.1) | **124** (110-141) | **252** (204-333) | **462** (325-557) | 766 |
| | 01-02 | **47.6** (36.9-61.5) | **43.1** (33.3-58.7) | **76.6** (58.7-106) | **149** (95.2-265) | **208** (155-353) | 665 |
| Non-Hispanic blacks | 99-00 | **70.5** (55.6-89.4) | **68.6** (54.1-93.9) | **156** (121-177) | **346** (264-412) | **474** (365-691) | 528 |
| | 01-02 | **46.6** (40.1-54.2) | **43.9** (36.7-51.8) | **87.1** (75.0-108) | **157** (138-194) | **231** (196-269) | 692 |
| Non-Hispanic whites | 99-00 | **73.2** (58.1-92.2) | **72.3** (60.6-85.2) | **163** (133-184) | **377** (286-447) | **547** (447-636) | 832 |
| | 01-02 | **46.4** (40.1-53.6) | **43.5** (37.0-51.9) | **82.7** (73.7-91.2) | **163** (139-195) | **245** (211-288) | 1207 |

## 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, National Health and Nutrition Examination Survey, 1999-2002.



# 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 the NTP and U.S. EPA. 3-hydroxybenzo[a]pyrene is a metabolite of benzo[a]pyrene and urinary levels were measured in a subsample of NHANES 2001-2002 participants aged 6 years and older. Similar levels of 3-hydroxybenzo[a] pyrene have been reported in a small sample of pre-school children (Wilson et al., 2003) and in workers manufacturing fireproof stone (Gundel et al., 2000).

## Table 74. 3-Hydroxybenzo[a]pyrene

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, 2001-2002.

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | * | **< LOD** | **33.0** (28.0-39.0) | **95.0** (73.0-121) | **179** (137-251) | 2748 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | * | **< LOD** | **26.0** (18.0-41.0) | **73.0** (44.0-126) | **139** (79.0-273) | 387 |
| 12-19 years | 01-02 | * | **< LOD** | **28.0** (20.0-37.0) | **77.0** (46.0-129) | **139** (82.0-284) | 735 |
| 20 years and older | 01-02 | * | **< LOD** | **36.0** (30.0-41.0) | **97.0** (72.0-126) | **206** (135-285) | 1626 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | **< LOD** | **34.0** (29.0-41.0) | **98.0** (72.0-126) | **167** (133-273) | 1349 |
| Females | 01-02 | * | **< LOD** | **31.0** (26.0-37.0) | **86.0** (67.0-117) | **206** (134-251) | 1399 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | **13.0** (<LOD-16.0) | **41.0** (30.0-55.0) | **125** (80.0-199) | **253** (165-648) | 665 |
| Non-Hispanic blacks | 01-02 | * | **11.0** (<LOD-16.0) | **29.0** (25.0-37.0) | **68.0** (53.0-106) | **136** (76.0-240) | 692 |
| Non-Hispanic whites | 01-02 | * | **< LOD** | **32.0** (26.0-40.0) | **96.0** (69.0-126) | **167** (124-251) | 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 75. 3-Hydroxybenzo[a]pyrene (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | * | **< LOD** | **32.3** (27.3-38.9) | **84.7** (69.2-120) | **184** (147-248) | 2748 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | * | **< LOD** | **28.8** (22.7-45.5) | **91.4** (59.0-171) | **207** (91.3-348) | 387 |
| 12-19 years | 01-02 | * | **< LOD** | **24.0** (16.7-35.8) | **69.8** (43.4-86.7) | **103** (77.0-201) | 735 |
| 20 years and older | 01-02 | * | **< LOD** | **34.3** (28.4-42.0) | **91.7** (69.0-134) | **186** (148-263) | 1626 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | **< LOD** | **28.9** (23.8-37.8) | **72.9** (62.1-99.1) | **167** (110-226) | 1349 |
| Females | 01-02 | * | **< LOD** | **35.3** (29.6-43.9) | **99.0** (75.0-135) | **198** (148-285) | 1399 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | **15.3** (12.9-18.3) | **41.6** (30.0-58.3) | **135** (74.9-188) | **225** (157-345) | 665 |
| Non-Hispanic blacks | 01-02 | * | **9.86** (8.47-11.1) | **21.7** (18.3-26.5) | **49.4** (36.2-91.1) | **116** (58.6-190) | 692 |
| Non-Hispanic whites | 01-02 | * | **< LOD** | **34.1** (27.3-41.4) | **85.7** (68.0-127) | **190** (147-263) | 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.

# 1-Hydroxynaphthalene and 2-Hydroxynaphthalene

*Metabolite of Naphthalene, CAS No. 91-20-3*

### Interpreting Levels of Urinary 1-Hydroxynaphthalene and 2-Hydroxynaphthalene Reported in the Tables

Urinary levels of 1-hydroxynaphthalene and 2-hydroxynaphthalene were measured in a subsample of NHANES 2001-2002 participants aged 6 years and older. Similar levels have been reported in pre-school chidlren (Wilson et al., 2003), middle school students living in major cities (Kang et al., 2002) and adults (Kim et al.,2003, Kuusimaki et al., 2004, Serdar et al., 2003*b*). Bus mechanics and truck drivers (Kuusimaki et al., 2004), coke oven workers (Nan et al., 2001; Serdar et al., 2003*a*), air force personnel exposed to jet fuel (Serdar 2003*b*), and tobacco smokers (Serdar et al., 2003*a*; Nan et al., 2001) had higher levels.

### Comparing Adjusted Geometric Means

Geometric means levels of urinary 1-hydroxynaphthalene and 2-hydroxynaphthalene for demographic groups were compared after adjusting for the covariates of race/ethnicity, age, gender, log serum cotinine, and urinary creatinine (data not shown). For adjusted geometric mean levels of urinary 1-hydroxynaphthalene in NHANES 2001-2002, non-Hispanic whites had higher levels than Mexican-Americans, while the group aged 12-19 years had lower levels than either of the groups 6-11 years or 20 years and older.

For adjusted geometric mean levels of urinary 2-hydroxynaphthalene in NHANES 2001-2002 , females had higher levels than males, Mexican Americans had higher levels than either non-Hispanic whites or blacks, and the group aged 12-19 years had lower levels than the group aged 20 years and older. 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.

Note: 1-hydroxynaphthalene is sometimes called 1-naphthol and 2-hydroxynapthalene is also referred to as 2-naphthol.

### Table 76. 1-Hydroxynaphthalene

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, 2001-2002.

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | **2050** (1790-2340) | **1720** (1490-2030) | **4760** (3890-5930) | **12500** (10600-15900) | **22300** (18000-26600) | 2748 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | **1430** (1170-1730) | **1190** (1010-1560) | **2740** (1770-3630) | **6670** (4340-11300) | **12400** (9410-16500) | 387 |
| 12-19 years | 01-02 | **1750** (1440-2130) | **1380** (1210-1690) | **3560** (2840-4570) | **9270** (6760-17200) | **21400** (10400-28500) | 735 |
| 20 years and older | 01-02 | **2190** (1900-2530) | **1890** (1580-2280) | **5280** (4250-6520) | **13600** (11100-18000) | **23300** (18100-28600) | 1626 |
| **Gender** | | | | | | | |
| Males | 01-02 | **2270** (1940-2650) | **1980** (1640-2440) | **5580** (4000-6950) | **12200** (9650-16700) | **21500** (15100-28500) | 1349 |
| Females | 01-02 | **1860** (1600-2160) | **1560** (1320-1760) | **4120** (3380-5030) | **13300** (11100-16300) | **22300** (19400-25500) | 1399 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | **1590** (1300-1960) | **1440** (1180-1860) | **3010** (2240-4080) | **6750** (4990-9270) | **11900** (7670-20600) | 665 |
| Non-Hispanic blacks | 01-02 | **2700** (2160-3370) | **2190** (1630-2930) | **7170** (4400-10900) | **14900** (11900-22100) | **24700** (17000-44100) | 692 |
| Non-Hispanic whites | 01-02 | **2030** (1720-2390) | **1740** (1470-2150) | **4680** (3630-5990) | **12300** (10200-16300) | **22300** (16600-27200) | 1207 |

## Table 77. 1-Hydroxynaphthalene (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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** (2140-3840) | **5280** (4450-9720) | **12900** (7960-26400) | 387 |
| 12-19 years | 01-02 | **1350** (1140-1600) | **1130** (973-1360) | **2520** (2090-3160) | **6920** (3790-11000) | **11200** (8240-16100) | 735 |
| 20 years and older | 01-02 | **2070** (1830-2350) | **1720** (1480-2000) | **4980** (3930-6120) | **11600** (9370-14200) | **18600** (15000-22000) | 1626 |
| **Gender** | | | | | | | |
| Males | 01-02 | **1830** (1580-2120) | **1550** (1300-1880) | **4050** (3380-5360) | **9440** (7550-11400) | **14200** (12200-16500) | 1349 |
| Females | 01-02 | **1990** (1760-2250) | **1620** (1360-1900) | **4190** (3560-5190) | **12400** (9810-15000) | **20500** (17100-26700) | 1399 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | **1490** (1240-1780) | **1310** (1070-1630) | **2590** (2140-3370) | **5710** (4280-7530) | **10300** (6120-18300) | 665 |
| Non-Hispanic blacks | 01-02 | **1900** (1500-2410) | **1640** (1340-1980) | **4400** (2830-6450) | **10100** (6560-15900) | **18900** (11700-32700) | 692 |
| Non-Hispanic whites | 01-02 | **2000** (1740-2300) | **1660** (1410-1940) | **4410** (3660-5790) | **10900** (8640-13400) | **17300** (13400-19600) | 1207 |

## Table 78. 2-Hydroxynaphthalene

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, 2001-2002.

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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) | **33000** (25900-38700) | 692 |
| Non-Hispanic whites | 01-02 | **2190** (1760-2720) | **1910** (1610-2420) | **4880** (3710-6780) | **14100** (10700-20200) | **25900** (20700-30000) | 1207 |

## Table 79. 2-Hydroxynaphthalene (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | **2310** (1980-2680) | **1940** (1670-2300) | **4730** (3820-5860) | **11500** (9980-13100) | **16700** (14100-19200) | 2748 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | **1890** (1740-2070) | **1830** (1720-1940) | **3110** (2510-3470) | **5040** (4380-5540) | **6490** (5270-12400) | 387 |
| 12-19 years | 01-02 | **1720** (1350-2190) | **1510** (1340-1830) | **2750** (2080-4070) | **7060** (4070-10900) | **10900** (7860-17400) | 735 |
| 20 years and older | 01-02 | **2480** (2130-2880) | **2080** (1680-2600) | **5630** (4460-6940) | **12400** (10900-13900 | **17700** (15200-20600) | 1626 |
| **Gender** | | | | | | | |
| Males | 01-02 | **2230** (1900-2610) | **1850** (1630-2100) | **4750** (3510-6120) | **11400** (8950-14300) | **15800** (13100-19200) | 1349 |
| Females | 01-02 | **2380** (2050-2770) | **1970** (1660-2560) | **4730** (3790-6000) | **11500** (10300-1280 | **17400** (13700-21500) | 1399 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | **2520** (2230-2850) | **2350** (2010-2950) | **4650** (3970-5210) | **7120** (6050-8090) | **12000** (7820-15300) | 665 |
| Non-Hispanic blacks | 01-02 | **2790** (2390-3270) | **2390** (2040-2770) | **5980** (4840-6980) | **11600** (9090-15300) | **17400** (12200-23400) | 692 |
| Non-Hispanic whites | 01-02 | **2160** (1780-2620) | **1740** (1440-2180) | **4340** (3320-6090) | **11900** (9930-14300) | **16900** (13800-20600) | 1207 |

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

# 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 mills; and the chemical syntheses of trichlorophenoxyacetic acid, hexachlorophene, vinyl chloride, trichlorophenol, and pentachlorophenol. Synthesis and heat-related degradation of polychlorinated biphenyls (PCBs) will produce furan byproducts. As a result of man-made environmental release and contamination, most soil and water samples reveal trace amounts of polychlorinated dibenzo-*p*-dioxins and dibenzofurans when advanced analytical techniques are applied. Releases from industrial sources have decreased approximately 80% since the 1980s. Today, the largest release of these chemicals occurs as a result of the open burning of household trash and municipal trash, landfill fires, and agricultural and forest fires.

The coplanar and mono-ortho-substituted polychlorinated biphenyls belong to the class of chlorinated aromatic hydrocarbon chemicals that once were used as electrical insulating and heat-exchange fluids. Production of PCBs peaked in the early 1970s and was banned in the United States after 1979. Together with the polychlorinated dioxins and furans, these two classes of PCBs are often referred to as “dioxin-like” chemicals because they act through a similar mechanism. In the environment, these dioxin-like chemicals are persistent and usually occur as a mixture of congeners (i.e., compounds that differ by numbers and positions of chlorine atoms attached to the dibenzo-*p*-dioxin, dibenzofuran, or biphenyl structures). Structural nomenclature is available at http://www.epa.gov/toxteam/pcbid/consistent.htm.

People in the general population are exposed primarily through ingestion of foods that are contaminated with polychlorinated dibenzo-*p*-dioxins and dibenzofurans as a result of the accumulation of these substances in the food chain including high-fat foods, such as dairy products, eggs, and animal fats, and some fish and wildlife. Breast feeding is a substantial source for infants (Beck et al., 1994). People have also been exposed as a result of industrial accidents (e.g., after an explosion in a factory in Seveso, Italy), the use of accidentally contaminated cooking oils (e.g., as occurred in Yusho in Japan and Yucheng in Taiwan), the spraying of herbicides contaminated with 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD, as Agent Orange in Vietnam), and the burning of PCBs contaminated with polychlorinated dibenzofurans, such as in old electrical transformers. Workplace exposures are rare today, and generally recognized standards for external exposure have not been established.

Because exposure to these chemicals is from a mixture of varying congeners, the effects due to specific individual congeners are difficult to determine (Masuda et al., 1998; Masuda 2001). However, these four groups of chemicals (polychlorinated dibenzo-*p*-dioxins, polychlorinated dibenzofurans, and the coplanar and mono-ortho-substituted polychlorinated biphenyls) are considered to act through a similar mechanism to produce toxic effects. These dioxin-like effects are thought to be mediated through an interaction with the aryl hydrocarbon receptor (AhR), particularly the induction of gene expression for cytochromes P450, CYP1A1 and CYP1A2. Dioxins and furans require four lateral chlorine atoms on the dibenzo-*p*-dioxin or dibenzofuran backbone to bind this receptor. The rank order of interaction with the AhR receptor by degree and position of chlorination is similar for both the dioxin and furan series, with greater effect exhibited with four or five chlorine atoms and with substitution at all four lateral positions. The coplanar polychlorinated biphenyls (unsubstituted at ortho positions) and the mono-ortho-substituted polychlorinated biphenyls (which contain a chlorine atom at one of the ortho positions) can achieve a planar configuration and also interact with the AhR receptor.

The variation in the effect on AhR among the dioxin-like chemicals is 10,000-fold, with TCDD and 1,2,3,7,8-pentachlorodibenzo-*p*-dioxin being the most potent. To compare potency, each of these congeners has been assigned a potency value relative to TCDD (toxic equivalency factor [TEF]). When a TEF is multiplied by the concentration of the congener, a toxic equivalency (TEQ) value is obtained. Thus, the dioxin-like toxicity contributed by each of the polychlorinated dibenzo-*p*-dioxins, dibenzofurans, and coplanar PCBs can then be compared. The sum of all congener TEQs in a specimen (total TEQ) can be used to compare dioxin-like activity among specimens. Many co-planar PCBs have lesser potency, but their concentrations are often much higher than concentrations of TCDD (Kang et al., 1997; Patterson et al., 1994), so their relative contribution to the total TEQ is potentially sizable.

Health effects of exposure to dioxins and furans in people have been observed as a result of industrial or accidental exposures involving large quantities of these chemicals. Chloracne, biochemical liver test abnormalities, elevated blood lipids, fetal injury, and porphyria cutanea tarda have been reported in many of the studies. In some of these exposures, endocrine, reproductive, and immunologic effects have also been suggested although with varying consistency (Baccarelli et al., 2002; Fierens et al., 2003; Kogevinas, 2001; Halperin et al., 1998; Michalek et al., 1999; Jung et al., 1998; Matsuura et al., 2001; Schnorr et al., 2001; Institute of Medicine, 2003). Congenital anomalies and intrauterine growth retardation were observed in offspring of Yucheng mothers exposed to cooking oil contaminated with electrical oil containing PCBs and dibenzofurans. Background levels of PCBs, and possibly dioxins, have been associated with impaired neurological development in newborns and children (Koopman-Esseboom et al., 1997; Jacobsen and Jacobsen, 1996; Longnecker et al., 2003). A possible dioxin-induced neuropathy may occur in highly exposed adults (Michalek et al., 2001). Many organochlorine-type chemicals, including the dioxins, furans, and PCBs, are also considered to interact with estrogen receptors. Although human studies have yielded inconsistent findings for associations between dioxin exposure and disorders such as endometriosis (Eskenazi et al., 2002; Fierens et al., 2003; Johnson et al., 2001), animal studies have suggested a relationship (Rier and Foster, 2003). The mono-ortho-substituted PCBs (see Table 81) may also interact with estrogen-receptors in addition to their dioxin-like effects, and have been demonstrated to elevate liver enzymes in experimental animals (Parkinson et al., 1983).

Carcinogenic, genetic, reproductive, and developmental effects have been observed in many animal studies although species differ dramatically in sensitivity to these

**Table 80. Polychlorinated Dibenzo-p-dioxins, Polychlorinated Dibenzofurans, and Coplanar and Mono-ortho-substituted Polychlorinated Biphenyls**

| Polychlorinated dibenzo-*p*-dioxins | CAS number |
|---|---|
| 1,2,3,4,6,7,8,9-Octachlorodibenzo-*p*-dioxin (OCDD) | 3268-87-9 |
| 1,2,3,4,6,7,8-Heptachlorodibenzo-*p*-dioxin (HpCDD) | 35822-46-9 |
| 1,2,3,4,7,8-Hexachlorodibenzo-*p*-dioxin (HxCDD) | 39227-28-6 |
| 1,2,3,6,7,8-Hexachlorodibenzo-*p*-dioxin (HxCDD) | 57653-85-7 |
| 1,2,3,7,8,9-Hexachlorodibenzo-*p*-dioxin (HxCDD) | 19408-74-3 |
| 1,2,3,7,8-Pentachlorodibenzo-p-dioxin (PeCDD) | 40321-76-4 |
| 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD) | 1746-01-6 |
| **Polychlorinated dibenzofurans** | **CAS number** |
| 1,2,3,4,6,7,8,9-Octachlorodibenzofuran (OCDF) | 39001-02-0 |
| 1,2,3,4,6,7,8-Heptachlorodibenzofuran (HpCDF) | 67562-39-4 |
| 1,2,3,4,7,8,9-Heptachlorodibenzofuran (HpCDF) | 55673-89-7 |
| 1,2,3,4,7,8-Hexachlorodibenzofuran (HxCDF) | 70648-26-9 |
| 1,2,3,6,7,8-Hexachlorodibenzofuran (HxCDF) | 57117-44-9 |
| 1,2,3,7,8,9-Hexachlorodibenzofuran (HxCDF) | 72918-21-9 |
| 1,2,3,7,8-Pentachlorodibenzofuran (PeCDF) | 57117-41-6 |
| 2,3,4,6,7,8-Hexchlorodibenzofuran (HxCDF) | 60851-34-5 |
| 2,3,4,7,8-Pentachlorodibenzofuran (PeCDF) | 57117-31-4 |
| 2,3,7,8-Tetrachlorodibenzofuran (TCDF) | 51207-31-9 |
| **Coplanar polychlorinated biphenyls (IUPAC number)** | **CAS number** |
| 3,3',4,4',5,5'-Hexachlorobiphenyl (PCB 169) | 32774-16-6 |
| 3,3',4,4',5-Pentachlorobiphenyl (PCB 126) | 57465-28-8 |
| 3,4,4',5-Tetrachlorobiphenyl (PCB 81) | 70362-50-4 |
| **Mono-ortho-substituted polychlorinated biphenyls (IUPAC number)** | **CAS number** |
| 2,4,4'-Trichlorobiphenyl (PCB 28) | 7012-37-5 |
| 2,3',4,4'-Tetrachlorobiphenyl (PCB 66) | 32598-10-0 |
| 2,4,4',5-Tetrachlorobiphenyl (PCB 74) | 32690-93-0 |
| 2,3,3',4,4'-Pentachlorobiphenyl (PCB 105) | 32598-14-4 |
| 2,3',4,4',5-Pentachlorobiphenyl (PCB 118) | 31508-00-6 |
| 2,3,3',4,4',5-Hexachlorobiphenyl (PCB 156) | 38380-08-4 |
| 2,3,3',4,4',5'-Hexachlorobiphenyl (PCB 157) | 69782-90-7 |
| 2,3',4,4',5,5'-Hexachlorobiphenyl (PCB 167) | 52663-72-6 |
| 2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB 189) | 39635-31-9 |

chemicals. The Institute of Medicine (2003) has determined that human epidemologic evidence is sufficient for causally linking exposure from herbicides contaminated with TCDD to an increased risk for non-Hodgkin's lymphoma, Hodgkin's lymphoma, chronic lymphocytic leukemia, and soft tissue sarcoma. Generally, the increased risk for these cancers occurs in association with large exposures encountered in contaminated occupational settings or massive unintentional releases. Because of its exceptional potency and because it is the most studied dioxin or furan, TCDD is separately classified by the IARC as a known human carcinogen (Group 1) and by NTP as a known human carcinogen. Other polychlorinated dibenzo-*p*-dioxins and dibenzofurans have not been studied sufficiently for IARC to determine their carcinogenicity. Information about environmental levels and health effects is available online from ATSDR's Toxicological Profiles at http://www.atsdr.cdc.gov/toxprofiles. The U.S. EPA provides updated exposure and health assessments online at http://www.epa.gov/ncea/pdfs/dioxin.

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

Lipid-adjusted serum measurements and whole weight-based measurements of polychlorinated dibenzo-*p*-dioxins, dibenzofurans, and coplanar PCBs were measured in a subsample of NHANES 2001-2002 participants aged 20 years and older. Participants were selected within the specified age range to be a representative sample of the U.S. population. (Note: The NHANES 1999-2000 subsample included people aged 12-19 years and people aged 20 years and older. The NHANES 2001-2002 subsample does not include the 12-19 year-old age group). The generally low values reported here support the observation that human serum levels of polychlorinated dibenzo-*p*-dioxins, dibenzofurans, and PCBs have decreased by more than 80% since the 1980s (Aylward and Hays, 2002; Lorber, 2002).

Only the following polychlorinated dibenzo-*p*-dioxins, dibenzofurans, coplanar and mono-ortho-substituted polychlorinated biphenyls (IUPAC nomenclature) had demonstrable 90$^{th}$ percentile levels in the NHANES 2001-2002 subsample, and those in bold letters had sufficient data for calculating geometric means:

- **1,2,3,4,6,7,8,9-octachlorodibenzo-*p*-dioxin**
- **1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin**
- 1,2,3,4,7,8-hexachlorodibenzo-*p*-dioxin
- **1,2,3,6,7,8-hexachlorodibenzo-*p*-dioxin***
- 1,2,3,7,8,9-hexachlorodibenzo-*p*-dioxin
- 1,2,3,7,8-pentachlorodibenzo-*p*-dioxin*
- **1,2,3,4,6,7,8-heptachlorodibenzofuran**
- 1,2,3,4,7,8-hexachlorodibenzofuran
- 1,2,3,6,7,8-hexachlorodibenzofuran
- 2,3,4,7,8-pentachlorodibenzofuran*
- **coplanar polychlorinated biphenyls 126* and 169**
- mono-ortho substituted PCBs 74, 118* and 156*

About 80%-90% of the total TEQ can be estimated from six of the congeners (indicated by asterisks) listed above, plus an estimate of the TCDD level. Though the mono-ortho-substituted PCBs are less potent (i.e., lower TEFs), their contribution to the total TEQ is substantial since they are present in much higher concentrations than are the coplanar PCBs, dioxins, and furans. In keeping with results from reports from Germany (Papke et al., 1998), New Zealand (Bates et al., 2004*b*) and elsewhere, the NHANES 1999-2000 and 2001-2002 data show that the highly chlorinated and laterally substituted congeners are frequently detected. The presence of many of these congeners in human sera is probably due to their greater solubility in body fat and slower elimination (Geyer et al., 2002), but can also be due to their greater presence in the food chain. For example, people consuming fish from the Great Lakes had mean concentrations of dioxins and furans that are several times background values in the population (Falk et al., 1999; Anderson et al., 1998; Hanrahan et al., 1999).

Of the dioxins and furans, octachlorodibenzo-*p*-dioxin typically is present in the highest concentration but contributes little to the TEQ, with the other commonly detected dioxin and furan congeners being more than eight-fold lower in concentration. Similar levels of octachlorodibenzo-*p*-dioxin are seen in a representative pooled sampling of New Zealanders aged 15 years and older who were studied during 1997-1998. The weighted mean octachlorodibenzo-*p*-dioxin level in the New Zealand study was 361 picograms per gram (pg/g) lipid (Bates et al., 2004*b*) compared with the NHANES 2001-2002 median level of 349 pg/g lipid for non-Hispanic whites aged 20 years and older. On the other hand, 1,2,3,7,8-pentachlorodibenzo-*p*-dioxin concentrations in this *Report* are about 60-fold lower than octachlorodibenzo-*p*-dioxin levels (at the comparable percentiles), but because of a 10,000-fold greater TEF (equal to that of TCDD), the contribution of 1,2,3,7,8-pentachlorodibenzo-*p*-dioxin to the TEQ is about 160 times greater than the octachlorodibenzo-*p*-dioxin. In 1996, a small convenience sample of German residents aged 18-71 years showed that levels of 1,2,3,7,8-pentachlorodibenzo-*p*-dioxin at the 95$^{th}$ percentile were

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*-dioxin, but men had higher levels for PCBs 169, 156, and 189 (Arisawa et al., 2003). In NHANES 2001-2002, Mexican Americans had lower adjusted geometric mean levels than non-Hispanic blacks

and whites for 1,2,3,4,6,7,8-heptachlorodibenzofuran, 1,2,3,6,7,8-hexachlorodibenzo-*p*-dioxin, and 3,3,4,4,5,-hexachlorobiphenyl (PCB 126). Also, non-Hispanic whites had lower levels than non-Hispanic blacks for 1,2,3,4,6,7,8-heptachlorodibenzofuran.

Differences in levels of specific polychlorinated dibenzo-*p*-dioxins, dibenzofurans, coplanar and mono-ortho-substituted polychlorinated biphenyls are due in part to exposure but also result from differences in absorption, tissue distribution, metabolism, and elimination. Half-lives for all the dioxins and furans vary from 3 years to 19 years, with the half-life of TCDD estimated at around 7 years (Geyer et al., 2002). Current levels may be influenced by both past (stored in body fat) and recent exposures. Several studies have shown that levels of dioxins and furans in serum or fat increase with the age of the individual (Falk et al., 1999; Kang et al., 1997; Luotamo et al., 1991; Patterson et al., 1986). Most of the dioxins, furans and PCBs measured in the previously mentioned New Zealand representative sample showed an increasing trend with age (Bates et al., 2004*b*). In part, this age trend was noticeable at the higher percentiles for the more highly chlorinated congeners in the NHANES 1999-2000 subsample which included both the groups aged 12-19 years and 20 and older.

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

Notes: 1) As seen in other recent population studies, pooling of approximately 50 or more specimens is sometimes required to have adequate amounts of specimen to to properly estimate a TEQ of dioxin-like compounds in the general population. Because of limited availability of serum volumes and the low levels detected in the NHANES 1999-2002 population, TEQ values are not estimated from this analysis of individual samples. Future plans include an analysis of pooled specimens to improve the LOD for these compounds and allow calculation of TEQ values. 2) PCB analyses by GC-high resolution mass spectrometry are usually specific for the stated PCB congener. However, in some cases, multiple congeners of the same molecular weight could potentially contribute to the analytical result for a stated congener. Such potentially contributing congeners are not present in significant proportions in the environment or in the body and are unlikely to affect the stated results. Known situations would include: PCBs 158, 160, 163, and 164 contributing to the result for PCB 138; PCB 132 contributing to the result for PCB 153; PCB 190 contributing to the result for PCB 170; and PCB 203 contributing to the result for PCB 196.

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

Geometric mean and selected percentiles of serum concentrations (in pg/g of lipid or parts per trillion on a lipid-weight basis) 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** | **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 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 99-00 | * | **< LOD** | **331** (<LOD-378) | **541** (453-639) | **710** (572-873) | 575 |
| | 01-02 | * | **< LOD** | **438** (346-579) | **745** (593-968) | **1030** (837-1240) | 517 |
| Females | 99-00 | * | **< LOD** | **525** (475-608) | **846** (689-982) | **1050** (948-1290) | 679 |
| | 01-02 | **410** (356-472) | **405** (333-498) | **643** (574-731) | **1020** (858-1360) | **1450** (1060-1780) | 654 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **471** (374-572) | **703** (608-916) | **940** (746-1190) | 333 |
| | 01-02 | * | **< LOD** | **432** (394-545) | **754** (578-1220) | **1150** (696-1640) | 250 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **493** (405-566) | **820** (727-1070) | **1170** (820-1680) | 226 |
| | 01-02 | **421** (352-503) | **420** (339-509) | **669** (537-907) | **1110** (956-1520) | **1640** (1130-1900) | 210 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **427** (369-484) | **671** (581-800) | **913** (731-1080) | 578 |
| | 01-02 | **349** (<LOD-409) | **333** (<LOD-421) | **574** (493-670) | **945** (764-1170) | **1290** (971-1650) | 632 |

< 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 82. 1,2,3,4,6,7,8,9-Octachlorodibenzo-*p*-dioxin (OCDD) (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** | **2800** (2480-3110) | **4570** (4100-5020) | **6200** (5340-7300) | 1254 |
| | 01-02 | **2230** (1970-2540) | **2170** (1870-2550) | **3860** (3180-4520) | **6460** (5140-8290) | **9110** (6940-11400) | 1171 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **1910** (1600-2340) | 667 |
| | 01-02 | † | † | † | † | † | † |
| 20 years and older | 99-00 | * | **< LOD** | **2800** (2480-3110) | **4570** (4100-5020) | **6200** (5340-7300) | 1254 |
| | 01-02 | **2230** (1970-2540) | **2170** (1870-2550) | **3860** (3180-4520) | **6460** (5140-8290) | **9110** (6940-11400) | 1171 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 99-00 | * | **< LOD** | **2210** (1860-2480) | **3270** (2880-3900) | **4620** (3630-6870) | 575 |
| | 01-02 | * | **< LOD** | **3100** (2410-4070) | **5270** (4070-7140) | **7410** (6020-9760) | 517 |
| Females | 99-00 | * | **< LOD** | **3370** (2990-3830) | **5270** (4780-6050) | **7070** (6150-9280) | 679 |
| | 01-02 | **2590** (2250-2980) | **2620** (2160-3000) | **4340** (3880-4860) | **6990** (5870-9040) | **9460** (7070-12300) | 654 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **2880** (2400-3390) | **4450** (3870-6010) | **6690** (5340-7990) | 333 |
| | 01-02 | * | **< LOD** | **3410** (2760-3860) | **5810** (4250-7670) | **8050** (5760-11800) | 250 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **2780** (2480-3660) | **5080** (4310-6550) | **7550** (4900-11600) | 226 |
| | 01-02 | **2480** (2050-3000) | **2460** (2060-2970) | **4170** (3160-5560) | **7140** (5470-9920) | **9460** (7990-12000) | 210 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **2800** (2400-3150) | **4270** (3790-4980) | **5960** (4930-7390) | 578 |
| | 01-02 | **2270** (1930-2660) | **2200** (1840-2770) | **3860** (3090-4720) | **6460** (4890-8860) | **9120** (6630-12300) | 632 |

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

Geometric mean and selected percentiles of serum concentrations (in pg/g of lipid or parts per trillion on a lipid-weight basis) 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** | **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** (126-177) | 1220 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 99-00 | * | **< LOD** | **56.2** (<LOD-63.6) | **75.5** (69.9-85.2) | **95.0** (84.0-103) | 572 |
| | 01-02 | **36.6** (31.7-42.3) | **38.7** (33.3-42.6) | **61.6** (49.7-75.0) | **101** (75.6-131) | **138** (103-169) | 553 |
| Females | 99-00 | * | **< LOD** | **67.1** (59.7-73.6) | **105** (94.8-122) | **137** (120-169) | 665 |
| | 01-02 | **41.2** (34.9-48.7) | **43.6** (35.3-52.4) | **76.0** (59.5-90.1) | **123** (92.6-143) | **157** (130-191) | 667 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **66.8** (60.7-74.1) | **102** (83.6-115) | **135** (108-169) | 330 |
| | 01-02 | **39.6** (35.7-43.9) | **39.7** (33.6-47.4) | **64.0** (55.8-74.7) | **107** (82.4-128) | **148** (111-171) | 262 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **62.2** (<LOD-75.1) | **101** (81.8-114) | **137** (106-187) | 224 |
| | 01-02 | **43.7** (35.4-54.0) | **42.0** (32.2-59.8) | **80.6** (60.9-106) | **134** (101-166) | **166** (130-230) | 218 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **62.2** (<LOD-67.1) | **88.7** (74.0-102) | **116** (97.0-134) | 567 |
| | 01-02 | **39.3** (33.0-46.8) | **40.5** (34.0-50.1) | **70.9** (56.3-87.5) | **117** (85.9-145) | **147** (125-186) | 657 |

< 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 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. 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 | **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 |

< 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 85. 1,2,3,4,7,8-Hexachlorodibenzo-*p*-dioxin (HxCDD) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (in pg/g of lipid or parts per trillion on a lipid-weight basis) for the U.S. population aged 20 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 20 and older** | 01-02 | * | **< LOD** | **< LOD** | **10.7** (<LOD-13.8) | **14.9** (11.7-20.0) | 1239 |
| **Age group** | | | | | | | |
| 12-19 years | 01-02 | † | † | † | † | † | † |
| 20 years and older | 01-02 | * | **< LOD** | **< LOD** | **10.7** (<LOD-13.8) | **14.9** (11.7-20.0) | 1239 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 01-02 | * | **< LOD** | **< LOD** | **10.9** (<LOD-14.3) | **14.7** (11.4-16.5) | 566 |
| Females | 01-02 | * | **< LOD** | **< LOD** | **10.6** (<LOD-14.1) | **14.9** (11.1-23.0) | 673 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| Mexican Americans | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **9.20** (<LOD-11.7) | 263 |
| Non-Hispanic blacks | 01-02 | * | **< LOD** | **< LOD** | **13.9** (<LOD-17.6) | **18.3** (13.9-23.0) | 220 |
| Non-Hispanic whites | 01-02 | * | **< LOD** | **< LOD** | **11.2** (<LOD-14.4) | **15.1** (12.0-20.5) | 672 |

< 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 86. 1,2,3,4,7,8-Hexachlorodibenzo-*p*-dioxin (HxCDD) (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 mean (95% conf. interval) | Selected percentiles (95% confidence interval) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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 |
| Non-Hispanic blacks | 01-02 | * | **< LOD** | **< LOD** | **82.1** (53.3-130) | **125** (75.7-184) | 220 |
| Non-Hispanic whites | 01-02 | * | **< LOD** | **< LOD** | **77.5** (53.2-97.1) | **105** (78.8-143) | 672 |

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

Geometric mean and selected percentiles of serum concentrations (in pg/g of lipid or parts per trillion on a lipid-weight basis) 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 | **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** (99.4-153) | 1234 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | **26.7** (20.2-29.6) | 648 |
| | 01-02 | † | † | † | † | † | † |
| 20 years 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** (99.4-153) | 1234 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 99-00 | * | < LOD | **34.4** (27.2-40.5) | **59.2** (47.1-68.5) | **73.0** (64.4-81.9) | 569 |
| | 01-02 | **34.1** (28.3-41.1) | **38.8** (31.5-44.6) | **61.3** (50.0-79.5) | **94.7** (70.8-131) | **128** (88.5-181) | 564 |
| Females | 99-00 | * | < LOD | **37.9** (32.5-41.6) | **65.6** (55.1-70.5) | **82.8** (69.3-98.9) | 668 |
| | 01-02 | **35.1** (29.9-41.2) | **40.1** (32.4-46.3) | **59.8** (49.8-72.3) | **97.0** (77.1-114) | **126** (108-142) | 670 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | **24.2** (<LOD-32.4) | **46.8** (38.1-56.1) | **59.5** (52.7-67.9) | 332 |
| | 01-02 | **18.3** (15.6-21.4) | **21.2** (19.4-25.0) | **31.9** (27.0-40.3) | **51.5** (40.3-69.9) | **67.9** (48.0-111) | 260 |
| Non-Hispanic blacks | 99-00 | * | < LOD | **35.1** (28.4-44.9) | **62.8** (48.0-79.2) | **84.9** (72.2-98.1) | 223 |
| | 01-02 | **38.9** (33.6-45.0) | **40.2** (33.5-47.3) | **63.2** (54.6-76.9) | **93.9** (78.5-132) | **133** (92.6-185) | 219 |
| Non-Hispanic whites | 99-00 | * | < LOD | **38.2** (34.4-42.0) | **64.4** (54.3-69.3) | **77.7** (69.9-84.9) | 567 |
| | 01-02 | **37.8** (31.5-45.4) | **42.6** (33.9-51.1) | **65.0** (52.3-82.2) | **99.6** (78.4-130) | **130** (103-165) | 671 |

< 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 88. 1,2,3,6,7,8-Hexachlorodibenzo-*p*-dioxin (HxCDD) (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 | **232** (196-268) | **403** (349-458) | **520** (458-607) | 1237 |
| | 01-02 | **224** (192-261) | **246** (219-287) | **410** (347-498) | **663** (549-785) | **870** (696-1100) | 1234 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | **122** (93.2-155) | 648 |
| | 01-02 | † | † | † | † | † | † |
| 20 years and older | 99-00 | * | < LOD | **232** (196-268) | **403** (349-458) | **520** (458-607) | 1237 |
| | 01-02 | **224** (192-261) | **246** (219-287) | **410** (347-498) | **663** (549-785) | **870** (696-1100) | 1234 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 99-00 | * | < LOD | **211** (170-255) | **380** (297-440) | **460** (398-571) | 569 |
| | 01-02 | **226** (190-270) | **262** (223-301) | **425** (347-540) | **677** (547-794) | **883** (666-1180) | 564 |
| Females | 99-00 | * | < LOD | **246** (196-298) | **424** (350-521) | **579** (492-672) | 668 |
| | 01-02 | **222** (190-260) | **237** (207-281) | **397** (338-474) | **643** (526-771) | **863** (720-1060) | 670 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | **154** (102-213) | **307** (272-359) | **392** (357-445) | 332 |
| | 01-02 | **117** (99.4-139) | **128** (107-157) | **233** (198-270) | **401** (278-524) | **524** (384-731) | 260 |
| Non-Hispanic blacks | 99-00 | * | < LOD | **212** (167-275) | **389** (302-477) | **522** (399-627) | 223 |
| | 01-02 | **229** (199-264) | **226** (190-284) | **371** (333-477) | **643** (480-799) | **799** (596-1260) | 219 |
| Non-Hispanic whites | 99-00 | * | < LOD | **251** (207-293) | **421** (353-481) | **526** (472-617) | 567 |
| | 01-02 | **246** (206-293) | **272** (233-325) | **440** (365-552) | **679** (549-870) | **897** (718-1150) | 671 |

< 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 89. 1,2,3,7,8,9-Hexachlorodibenzo-*p*-dioxin (HxCDD) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (in pg/g of lipid or parts per trillion on a lipid-weight basis) 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** | 1228 |
| | 01-02 | * | **< LOD** | **< LOD** | **12.4** (10.4-15.1) | **16.9** (14.3-20.0) | 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** | **12.4** (10.4-15.1) | **16.9** (14.3-20.0) | 1238 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 565 |
| | 01-02 | * | **< LOD** | **< LOD** | **12.0** (<LOD-14.5) | **14.8** (12.9-18.0) | 567 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 663 |
| | 01-02 | * | **< LOD** | **< LOD** | **12.9** (10.7-16.7) | **18.3** (15.3-20.9) | 671 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 328 |
| | 01-02 | * | **< LOD** | **< LOD** | **9.40** (<LOD-11.2) | **12.1** (<LOD-20.0) | 262 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 223 |
| | 01-02 | * | **< LOD** | **< LOD** | **14.4** (11.2-20.0) | **19.9** (14.6-23.9) | 220 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 562 |
| | 01-02 | * | **< LOD** | **< LOD** | **12.6** (9.90-15.9) | **17.2** (14.7-20.6) | 672 |

< 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 90. 1,2,3,7,8,9-Hexachlorodibenzo-*p*-dioxin (HxCDD) (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** | 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 |

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

Geometric mean and selected percentiles of serum concentrations (in pg/g of lipid or parts per trillion on a lipid-weight basis) 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** | 1256 |
| | 01-02 | * | **< LOD** | **< LOD** | **11.2** (9.30-13.3) | **15.8** (13.3-19.8) | 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** | **11.2** (9.30-13.3) | **15.8** (13.3-19.8) | 1236 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 578 |
| | 01-02 | * | **< LOD** | **< LOD** | **10.5** (9.10-13.3) | **14.3** (11.7-19.4) | 564 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 678 |
| | 01-02 | * | **< LOD** | **6.10** (<LOD-7.80) | **11.6** (9.30-13.9) | **16.4** (13.7-20.8) | 672 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 338 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **8.70** (<LOD-12.7) | 262 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 225 |
| | 01-02 | * | **< LOD** | **7.70** (<LOD-9.30) | **13.8** (9.60-18.4) | **18.4** (14.2-24.0) | 218 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 576 |
| | 01-02 | * | **< LOD** | **< LOD** | **11.6** (9.40-14.1) | **16.7** (13.6-20.2) | 672 |

< 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 92. 1,2,3,7,8-Pentachlorodibenzo-*p*-dioxin (PeCDD) (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** | 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 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 93. 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin (TCDD) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (in pg/g of lipid or parts per trillion on a lipid-weight basis) 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** | **6.40** (<LOD-9.10) | 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** | **7.40** (<LOD-10.0) | 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 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 95. 1,2,3,4,6,7,8,9-Octachlorodibenzofuran (OCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (in pg/g of lipid or parts per trillion on a lipid-weight basis) 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 | 1232 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1202 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 652 |
| | 01-02 | † | † | † | † | † | † |
| 20 years and older | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1232 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1202 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 569 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 541 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 663 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 661 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 329 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 257 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 224 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 212 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 568 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 653 |

< 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)

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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 20 and older** | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1232 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1202 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 652 |
| | 01-02 | † | † | † | † | † | † |
| 20 years and older | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1232 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1202 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 569 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 541 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 663 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 661 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 329 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 257 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 224 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 212 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 568 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 653 |

< 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 97. 1,2,3,4,6,7,8-Heptachlorodibenzofuran (HpCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (in pg/g of lipid or parts per trillion on a lipid-weight basis) 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** | **14.2** (<LOD-17.5) | **18.4** (15.0-23.8) | 1109 |
| | 01-02 | **9.64** (8.53-10.9) | **10.3** (8.80-11.7) | **14.5** (12.7-16.6) | **21.3** (18.0-25.5) | **27.1** (22.5-32.0) | 1219 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **17.7** (16.2-20.9) | **24.0** (20.9-28.1) | 600 |
| | 01-02 | † | † | † | † | † | † |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **14.2** (<LOD-17.5) | **18.4** (15.0-23.8) | 1109 |
| | 01-02 | **9.64** (8.53-10.9) | **10.3** (8.80-11.7) | **14.5** (12.7-16.6) | **21.3** (18.0-25.5) | **27.1** (22.5-32.0) | 1219 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **15.9** (<LOD-20.0) | **19.9** (16.4-26.9) | 508 |
| | 01-02 | **10.1** (8.74-11.6) | **10.9** (9.00-12.5) | **15.2** (12.9-17.2) | **20.8** (17.2-27.8) | **28.9** (22.0-34.8) | 557 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **17.0** (14.0-25.2) | 601 |
| | 01-02 | **9.28** (8.20-10.5) | **9.30** (8.10-11.0) | **14.1** (12.3-15.9) | **21.0** (17.4-25.5) | **26.5** (22.3-31.9) | 662 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **17.3** (<LOD-23.1) | 299 |
| | 01-02 | **7.73** (7.19-8.31) | **8.20** (7.80-8.60) | **11.1** (10.6-12.5) | **16.5** (14.5-19.6) | **20.2** (17.2-26.8) | 260 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **22.4** (14.0-28.3) | **28.2** (25.3-29.8) | 202 |
| | 01-02 | **12.3** (10.6-14.4) | **12.8** (10.9-15.2) | **17.2** (15.4-21.0) | **25.5** (22.4-31.2) | **32.1** (25.7-37.6) | 214 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **16.8** (14.2-18.5) | 503 |
| | 01-02 | **9.50** (8.30-10.9) | **10.0** (8.20-11.8) | **14.4** (12.6-16.2) | **20.5** (16.9-25.3) | **25.5** (20.5-31.7) | 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 98. 1,2,3,4,6,7,8-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 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 | **85.7** (74.7-97.7) | **108** (93.6-127) | 1109 |
| | 01-02 | **62.2** (55.4-69.9) | **64.4** (58.0-71.6) | **94.1** (82.3-110) | **134** (119-165) | **181** (147-206) | 1219 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | < LOD | < LOD | **79.3** (69.5-84.2) | **99.0** (83.4-120) | 600 |
| | 01-02 | † | † | † | † | † | † |
| 20 years and older | 99-00 | * | < LOD | < LOD | **85.7** (74.7-97.7) | **108** (93.6-127) | 1109 |
| | 01-02 | **62.2** (55.4-69.9) | **64.4** (58.0-71.6) | **94.1** (82.3-110) | **134** (119-165) | **181** (147-206) | 1219 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | **89.0** (74.7-111) | **111** (93.6-138) | 508 |
| | 01-02 | **66.3** (58.2-75.6) | **70.0** (59.8-81.8) | **99.3** (85.5-120) | **143** (120-181) | **181** (146-237) | 557 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | **101** (85.7-149) | 601 |
| | 01-02 | **58.8** (52.0-66.4) | **60.2** (53.5-67.6) | **89.1** (74.7-107) | **130** (108-164) | **169** (131-225) | 662 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | **112** (81.1-121) | 299 |
| | 01-02 | **49.5** (46.0-53.4) | **50.2** (45.7-57.2) | **76.5** (67.1-82.1) | **97.2** (90.9-124) | **133** (94.8-202) | 260 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | **124** (92.0-153) | **157** (114-214) | 202 |
| | 01-02 | **72.6** (61.9-85.2) | **70.5** (62.4-85.2) | **107** (91.5-128) | **146** (131-177) | **192** (154-259) | 214 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | **97.8** (89.3-105) | 503 |
| | 01-02 | **61.8** (54.3-70.4) | **64.5** (57.4-72.2) | **94.3** (78.1-112) | **133** (114-166) | **180** (137-222) | 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 99. 1,2,3,4,7,8,9-Heptachlorodibenzofuran (HpCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (in pg/g of lipid or parts per trillion on a lipid-weight basis) for the U.S. population aged 20 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 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 |

< 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 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 mean (95% conf. interval) | Selected percentiles (95% confidence interval) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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 |

< 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 101. 1,2,3,4,7,8-Hexachlorodibenzofuran (HxCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (in pg/g of lipid or parts per trillion on a lipid-weight basis) 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** | 1233 |
| | 01-02 | * | **< LOD** | **8.00** (6.90-9.30) | **12.1** (9.40-14.9) | **15.4** (12.9-18.6) | 1223 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 657 |
| | 01-02 | † | † | † | † | † | † |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1233 |
| | 01-02 | * | **< LOD** | **8.00** (6.90-9.30) | **12.1** (9.40-14.9) | **15.4** (12.9-18.6) | 1223 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 567 |
| | 01-02 | * | **< LOD** | **8.20** (7.10-9.70) | **12.6** (9.50-15.9) | **15.9** (12.2-20.9) | 562 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **13.0** (<LOD-17.1) | 666 |
| | 01-02 | * | **< LOD** | **7.90** (6.60-9.00) | **11.7** (9.40-13.8) | **14.1** (12.1-18.6) | 661 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 333 |
| | 01-02 | * | **< LOD** | **< LOD** | **7.20** (<LOD-8.00) | **8.00** (6.90-10.7) | 261 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **14.5** (<LOD-18.1) | 221 |
| | 01-02 | * | **< LOD** | **8.90** (7.70-10.1) | **13.6** (11.1-17.1) | **18.6** (14.6-22.6) | 214 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 563 |
| | 01-02 | * | **< LOD** | **8.20** (7.10-10.2) | **12.5** (9.90-15.5) | **15.9** (13.1-19.0) | 664 |

< 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 102. 1,2,3,4,7,8-Hexachlorodibenzofuran (HxCDF) (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** | 1233 |
| | 01-02 | * | **< LOD** | **54.0** (46.5-63.6) | **82.3** (65.5-104) | **108** (88.0-138) | 1223 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 657 |
| | 01-02 | † | † | † | † | † | † |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1233 |
| | 01-02 | * | **< LOD** | **54.0** (46.5-63.6) | **82.3** (65.5-104) | **108** (88.0-138) | 1223 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 567 |
| | 01-02 | * | **< LOD** | **56.9** (48.6-71.4) | **90.1** (71.1-108) | **108** (87.4-144) | 562 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **86.1** (72.5-105) | 666 |
| | 01-02 | * | **< LOD** | **51.6** (43.7-59.6) | **76.1** (62.6-97.0) | **104** (80.1-139) | 661 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 333 |
| | 01-02 | * | **< LOD** | **< LOD** | **48.4** (42.2-56.3) | **65.3** (48.6-79.4) | 261 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **96.5** (75.9-120) | 221 |
| | 01-02 | * | **< LOD** | **52.7** (45.0-62.7) | **85.2** (63.7-108) | **122** (85.2-147) | 214 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 563 |
| | 01-02 | * | **< LOD** | **56.0** (48.5-66.1) | **84.2** (64.5-115) | **112** (88.6-142) | 664 |

< 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 103. 1,2,3,6,7,8-Hexachlorodibenzofuran (HxCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (in pg/g of lipid or parts per trillion on a lipid-weight basis) 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** | 1242 |
| | 01-02 | * | **< LOD** | **7.10** (<LOD-8.20) | **10.3** (9.00-13.1) | **14.0** (11.0-17.1) | 1236 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 656 |
| | 01-02 | † | † | † | † | † | † |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1242 |
| | 01-02 | * | **< LOD** | **7.10** (<LOD-8.20) | **10.3** (9.00-13.1) | **14.0** (11.0-17.1) | 1236 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 573 |
| | 01-02 | * | **< LOD** | **7.10** (<LOD-8.50) | **11.3** (8.50-13.8) | **14.8** (11.3-18.7) | 566 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 669 |
| | 01-02 | * | **< LOD** | **7.00** (6.10-7.90) | **9.90** (9.20-11.2) | **13.1** (10.5-15.6) | 670 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 332 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **6.80** (<LOD-11.1) | 262 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 225 |
| | 01-02 | * | **< LOD** | **7.60** (6.10-9.10) | **11.9** (10.0-14.1) | **15.6** (12.3-21.0) | 219 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 569 |
| | 01-02 | * | **< LOD** | **7.30** (6.20-9.00) | **10.7** (9.00-14.0) | **14.8** (11.6-17.2) | 670 |

< 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 104. 1,2,3,6,7,8-Hexachlorodibenzofuran (HxCDF) (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** | 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 | † | † | † | † | † | † |
| 20 years 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 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 573 |
| | 01-02 | * | **< LOD** | **47.6** (38.3-60.5) | **72.3** (57.5-105) | **104** (73.5-133) | 566 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 669 |
| | 01-02 | * | **< LOD** | **45.0** (37.0-54.3) | **66.2** (58.3-79.1) | **90.2** (71.9-115) | 670 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 332 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **52.7** (41.2-65.9) | 262 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 225 |
| | 01-02 | * | **< LOD** | **44.4** (37.2-57.3) | **71.5** (59.8-90.9) | **107** (70.7-142) | 219 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 569 |
| | 01-02 | * | **< LOD** | **49.6** (41.9-57.9) | **72.8** (58.4-102) | **103** (82.6-121) | 670 |

< 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 105. 1,2,3,7,8,9-Hexachlorodibenzofuran (HxCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (in pg/g of lipid or parts per trillion on a lipid-weight basis) 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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 332 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 261 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 221 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 216 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 560 |
| | 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 106. 1,2,3,7,8,9-Hexachlorodibenzofuran (HxCDF) (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 | 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** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 332 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 261 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 221 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 216 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 560 |
| | 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 107. 1,2,3,7,8-Pentachlorodibenzofuran (PeCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (in pg/g of lipid or parts per trillion on a lipid-weight basis) 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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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) | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 339 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 263 |
| 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 | 576 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 670 |

< 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 108. 1,2,3,7,8-Pentachlorodibenzofuran (PeCDF) (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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) | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 339 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 263 |
| 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 | 576 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 670 |

< 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 109. 2,3,4,6,7,8-Hexachlorodibenzofuran (HxCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (in pg/g of lipid or parts per trillion on a lipid-weight basis) 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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 20 and older** | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1232 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1230 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 652 |
| | 01-02 | † | † | † | † | † | † |
| 20 years and older | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1232 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1230 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 566 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 565 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 666 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 665 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 326 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 260 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 225 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 218 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 564 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 671 |

< 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 110. 2,3,4,6,7,8-Hexachlorodibenzofuran (HxCDF) (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 20 and older** | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1232 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1230 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 652 |
| | 01-02 | † | † | † | † | † | † |
| 20 years and older | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1232 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1230 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 566 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 565 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 666 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 665 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 326 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 260 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 225 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 218 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 564 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 671 |

< 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 111. 2,3,4,7,8-Pentachlorodibenzofuran (PeCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (in pg/g of lipid or parts per trillion on a lipid-weight basis) 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** | **16.1** (13.9-17.2) | 1239 |
| | 01-02 | * | **< LOD** | **9.10** (7.40-11.0) | **14.3** (12.3-16.2) | **18.0** (16.1-21.1) | 1230 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 656 |
| | 01-02 | † | † | † | † | † | † |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **16.1** (13.9-17.2) | 1239 |
| | 01-02 | * | **< LOD** | **9.10** (7.40-11.0) | **14.3** (12.3-16.2) | **18.0** (16.1-21.1) | 1230 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **14.1** (12.9-15.7) | 569 |
| | 01-02 | * | **< LOD** | **9.30** (7.30-11.6) | **14.1** (11.6-16.7) | **16.7** (13.9-21.4) | 560 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **13.7** (<LOD-16.1) | **17.1** (15.5-19.3) | 670 |
| | 01-02 | * | **< LOD** | **9.10** (7.50-10.7) | **14.3** (13.0-16.1) | **18.5** (16.4-21.2) | 670 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| **Mexican Americans** | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 339 |
| | 01-02 | * | **< LOD** | **< LOD** | **7.80** (6.00-9.60) | **9.80** (7.80-12.5) | 264 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **12.9** (<LOD-15.0) | **16.6** (13.7-21.0) | 220 |
| | 01-02 | * | **< LOD** | **8.30** (6.80-9.30) | **13.9** (11.7-16.4) | **18.9** (15.1-23.0) | 216 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **12.8** (<LOD-14.1) | **16.1** (14.1-17.5) | 564 |
| | 01-02 | * | **5.80** (<LOD-6.80) | **10.3** (8.10-11.9) | **15.5** (13.0-17.6) | **18.4** (16.5-22.2) | 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 112. 2,3,4,7,8-Pentachlorodibenzofuran (PeCDF) (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** | **107** (98.3-125) | 1239 |
| | 01-02 | * | **< LOD** | **60.8** (51.3-70.5) | **98.5** (83.4-114) | **134** (113-152) | 1230 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 656 |
| | 01-02 | † | † | † | † | † | † |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **107** (98.3-125) | 1239 |
| | 01-02 | * | **< LOD** | **60.8** (51.3-70.5) | **98.5** (83.4-114) | **134** (113-152) | 1230 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **98.2** (80.7-109) | 569 |
| | 01-02 | * | **< LOD** | **61.7** (49.3-76.6) | **98.4** (76.6-134) | **135** (105-160) | 560 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **93.5** (79.1-104) | **115** (103-129) | 670 |
| | 01-02 | * | **< LOD** | **59.7** (52.0-67.6) | **99.6** (90.5-105) | **126** (107-146) | 670 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 339 |
| | 01-02 | * | **< LOD** | **< LOD** | **55.8** (48.7-69.7) | **76.3** (61.9-92.4) | 264 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **79.4** (68.3-95.6) | **107** (86.9-143) | 220 |
| | 01-02 | * | **< LOD** | **50.0** (41.3-60.4) | **89.5** (72.3-107) | **121** (92.0-154) | 216 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **88.8** (78.2-97.2) | **109** (98.2-128) | 564 |
| | 01-02 | * | **37.3** (30.1-44.1) | **65.4** (52.9-78.2) | **104** (90.7-118) | **135** (118-154) | 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 113. 2,3,7,8-Tetrachlorodibenzofuran (TCDF) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (in pg/g of lipid or parts per trillion on a lipid-weight basis) 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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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 | 564 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 667 |

< 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 114. 2,3,7,8-Tetrachlorodibenzofuran (TCDF) (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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 | 564 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 667 |

< 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 115. 2,4,4'-Trichlorobiphenyl (PCB 28) (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, 1999-2000.

| | 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** | 1849 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 647 |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1202 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 886 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 963 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 618 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 392 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 687 |

< 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 116. 2,4,4'-Trichlorobiphenyl (PCB 28) (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, 1999-2000.

| | 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 | 1849 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 647 |
| 20 years and older | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1202 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 886 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 963 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 618 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 392 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 687 |

< 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 117. 2,3',4,4'-Tetrachlorobiphenyl (PCB 66) (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 | 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 | < LOD | 1260 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1526 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 919 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1047 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1012 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1203 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 636 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 548 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 414 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 495 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 723 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1047 |

< 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 118. 2,3',4,4'-Tetrachlorobiphenyl (PCB 66) (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 | 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 | < LOD | 1260 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1526 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 919 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1047 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1012 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1203 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 636 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 548 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 414 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 495 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 723 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1047 |

< 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 119. 2,4,4',5-Tetrachlorobiphenyl (PCB 74) (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** | **20.7** (17.8-23.4) | **29.0** (24.5-32.3) | 1924 |
| | 01-02 | * | **< LOD** | **13.1** (11.0-15.7) | **23.3** (20.1-27.4) | **32.6** (26.9-38.7) | 2307 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 671 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 758 |
| 20 years and older | 99-00 | * | **< LOD** | **12.6** (<LOD-14.4) | **22.3** (19.5-25.6) | **30.0** (26.2-35.8) | 1253 |
| | 01-02 | * | **< LOD** | **14.6** (12.4-17.1) | **25.2** (21.4-28.9) | **34.8** (28.5-41.1) | 1549 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **15.3** (12.9-17.5) | **21.5** (18.3-24.4) | 915 |
| | 01-02 | * | **< LOD** | **10.5** (<LOD-12.1) | **20.2** (15.1-24.9) | **28.5** (20.8-38.2) | 1075 |
| Females | 99-00 | * | **< LOD** | **13.9** (<LOD-16.3) | **24.5** (21.9-28.5) | **31.6** (28.8-40.3) | 1009 |
| | 01-02 | * | **< LOD** | **15.7** (13.5-18.6) | **26.1** (23.1-29.3) | **35.9** (31.4-41.4) | 1232 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **15.8** (12.8-18.2) | 636 |
| | 01-02 | * | **< LOD** | **< LOD** | **13.0** (<LOD-18.1) | **19.6** (16.2-23.0) | 567 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **29.0** (18.6-38.4) | **43.5** (35.4-64.0) | 411 |
| | 01-02 | * | **< LOD** | **12.0** (<LOD-14.2) | **21.7** (16.4-26.9) | **31.5** (24.5-41.0) | 515 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **21.6** (18.9-24.0) | **29.0** (24.1-32.0) | 719 |
| | 01-02 | * | **< LOD** | **14.6** (12.2-17.3) | **25.7** (21.3-30.1) | **35.5** (29.0-42.5) | 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 120. 2,4,4',5-Tetrachlorobiphenyl (PCB 74) (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** | **.139** (.120-.151) | **.183** (.162-.218) | 1924 |
| | 01-02 | * | **< LOD** | **.084** (.073-.099) | **.150** (.134-.174) | **.212** (.181-.263) | 2307 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 671 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 758 |
| 20 years and older | 99-00 | * | **< LOD** | **.084** (.072-.096) | **.148** (.137-.158) | **.203** (.174-.232) | 1253 |
| | 01-02 | * | **< LOD** | **.094** (.081-.110) | **.166** (.140-.192) | **.226** (.196-.279) | 1549 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **.098** (.088-.118) | **.151** (.128-.168) | 915 |
| | 01-02 | * | **< LOD** | **.069** (.057-.078) | **.131** (.101-.171) | **.189** (.138-.241) | 1075 |
| Females | 99-00 | * | **< LOD** | **.096** (.077-.109) | **.158** (.143-.184) | **.223** (.186-.254) | 1009 |
| | 01-02 | * | **< LOD** | **.101** (.088-.112) | **.168** (.149-.190) | **.236** (.205-.285) | 1232 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.111** (.083-.126) | 636 |
| | 01-02 | * | **< LOD** | **< LOD** | **.087** (.067-.123) | **.144** (.107-.157) | 567 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **.169** (.109-.246) | **.277** (.218-.418) | 411 |
| | 01-02 | * | **< LOD** | **.070** (.058-.083) | **.131** (.104-.166) | **.192** (.152-.251) | 515 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **.145** (.126-.157) | **.185** (.163-.212) | 719 |
| | 01-02 | * | **< LOD** | **.096** (.078-.111) | **.167** (.139-.196) | **.229** (.194-.282) | 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 121. 3,4,4',5-Tetrachlorobiphenyl (PCB 81) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (in pg/g of lipid or parts per trillion on a lipid-weight basis) 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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 20 and older** | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1232 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1215 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 651 |
| | 01-02 | † | † | † | † | † | † |
| 20 years and older | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1232 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1215 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 566 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 554 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 666 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 661 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 333 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 259 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 225 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 218 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 557 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 657 |

< 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 122. 3,4,4',5-Tetrachlorobiphenyl (PCB 81) (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 | 1232 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1215 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 651 |
| | 01-02 | † | † | † | † | † | † |
| 20 years and older | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1232 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1215 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 566 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 554 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 666 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 661 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 333 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 259 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 225 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 218 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 557 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 657 |

< 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 123. 2,3,3',4,4'-Pentachlorobiphenyl (PCB 105) (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** | 1915 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 2307 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 665 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 758 |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1250 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1549 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 913 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1075 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1002 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1232 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 635 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 567 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **12.8** (<LOD-18.0) | 409 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 515 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 714 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 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 124. 2,3,3',4,4'-Pentachlorobiphenyl (PCB 105) (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** | 1915 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 2307 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 665 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 758 |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1250 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1549 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 913 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1075 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1002 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1232 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 635 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 567 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.076** (.058-.112) | 409 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 515 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 714 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 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 125. 2,3',4,4',5-Pentachlorobiphenyl (PCB 118) (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** | **13.1** (<LOD-15.1) | **27.0** (22.1-30.3) | **40.3** (32.8-47.4) | 1926 |
| | 01-02 | * | **< LOD** | **15.1** (13.0-17.5) | **29.0** (26.1-33.7) | **44.6** (39.6-48.9) | 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** | **14.7** (12.8-17.4) | **28.0** (24.4-33.5) | **43.6** (35.6-52.3) | 1259 |
| | 01-02 | * | **< LOD** | **16.9** (15.1-18.8) | **32.4** (28.3-37.3) | **46.4** (41.1-51.0) | 1549 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **19.6** (16.6-24.4) | **28.0** (24.4-38.1) | 919 |
| | 01-02 | * | **< LOD** | **11.9** (<LOD-14.6) | **22.0** (17.6-27.1) | **32.7** (25.4-47.5) | 1075 |
| Females | 99-00 | * | **< LOD** | **16.7** (13.5-19.5) | **32.0** (27.0-40.3) | **46.8** (41.0-57.0) | 1007 |
| | 01-02 | * | **< LOD** | **18.7** (16.3-20.5) | **35.9** (31.6-40.9) | **48.7** (44.5-54.3) | 1232 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **17.0** (14.1-18.3) | **23.7** (20.9-27.1) | 636 |
| | 01-02 | * | **< LOD** | **< LOD** | **16.8** (12.5-21.7) | **26.4** (19.3-33.2) | 567 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **18.9** (12.9-21.7) | **38.6** (28.4-54.4) | **59.7** (45.7-80.8) | 413 |
| | 01-02 | * | **< LOD** | **15.6** (12.6-19.9) | **37.3** (26.1-46.4) | **54.9** (40.0-66.6) | 515 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **13.1** (<LOD-15.6) | **25.6** (20.7-32.0) | **40.3** (30.4-46.8) | 720 |
| | 01-02 | * | **< LOD** | **15.8** (13.6-18.1) | **31.1** (27.1-35.7) | **45.3** (38.7-50.1) | 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 126. 2,3',4,4',5-Pentachlorobiphenyl (PCB 118) (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** | **.085** (.077-.097) | **.179** (.151-.196) | **.259** (.217-.322) | 1926 |
| | 01-02 | * | **< LOD** | **.095** (.084-.111) | **.192** (.163-.224) | **.293** (.267-.322) | 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** | **.099** (.087-.111) | **.189** (.168-.220) | **.281** (.230-.360) | 1259 |
| | 01-02 | * | **< LOD** | **.109** (.095-.124) | **.212** (.183-.245) | **.310** (.282-.367) | 1549 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **.128** (.114-.142) | **.188** (.159-.217) | 919 |
| | 01-02 | * | **< LOD** | **.080** (.065-.095) | **.139** (.116-.167) | **.208** (.162-.289) | 1075 |
| Females | 99-00 | * | **< LOD** | **.110** (.088-.133) | **.210** (.181-.259) | **.321** (.261-.408) | 1007 |
| | 01-02 | * | **< LOD** | **.125** (.102-.141) | **.237** (.213-.262) | **.356** (.302-.384) | 1232 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **.112** (.093-.128) | **.143** (.129-.183) | 636 |
| | 01-02 | * | **< LOD** | **< LOD** | **.120** (.082-.155) | **.180** (.128-.224) | 567 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **.111** (.079-.146) | **.223** (.182-.322) | **.399** (.259-.503) | 413 |
| | 01-02 | * | **< LOD** | **.094** (.073-.121) | **.213** (.165-.271) | **.322** (.231-.457) | 515 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **.086** (.077-.102) | **.176** (.145-.199) | **.250** (.202-.331) | 720 |
| | 01-02 | * | **< LOD** | **.101** (.089-.119) | **.205** (.172-.239) | **.301** (.269-.364) | 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 127. 3,3',4,4',5-Pentachlorobiphenyl (PCB 126) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (in pg/g of lipid or parts per trillion on a lipid-weight basis) 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** | **30.8** (27.2-36.3) | **57.1** (50.5-65.8) | **89.5** (66.1-110) | 1238 |
| | 01-02 | **22.7** (20.9-24.7) | **24.5** (22.0-26.5) | **40.8** (36.1-47.5) | **69.3** (61.6-80.8) | **108** (92.7-116) | 1226 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **23.8** (<LOD-27.5) | **30.6** (26.2-36.0) | 658 |
| | 01-02 | † | † | † | † | † | † |
| 20 years and older | 99-00 | * | **< LOD** | **30.8** (27.2-36.3) | **57.1** (50.5-65.8) | **89.5** (66.1-110) | 1238 |
| | 01-02 | **22.7** (20.9-24.7) | **24.5** (22.0-26.5) | **40.8** (36.1-47.5) | **69.3** (61.6-80.8) | **108** (92.7-116) | 1226 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 99-00 | * | **< LOD** | **27.1** (<LOD-30.6) | **44.6** (38.0-50.5) | **65.0** (50.5-82.8) | 572 |
| | 01-02 | **20.3** (18.5-22.3) | **23.0** (20.8-25.4) | **36.5** (32.8-39.4) | **52.6** (46.2-61.6) | **81.9** (61.0-101) | 561 |
| Females | 99-00 | * | **< LOD** | **36.6** (30.4-44.4) | **67.8** (55.7-83.8) | **99.1** (75.9-122) | 666 |
| | 01-02 | **25.1** (22.9-27.4) | **26.0** (22.8-28.8) | **48.6** (41.4-54.4) | **82.7** (71.1-96.8) | **116** (98.6-128) | 665 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **27.5** (<LOD-34.3) | **49.0** (38.7-59.9) | **70.0** (57.2-82.4) | 337 |
| | 01-02 | **17.8** (15.5-20.4) | **19.6** (17.8-20.9) | **28.4** (26.2-33.9) | **47.9** (39.7-54.9) | **69.2** (49.3-103) | 262 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **38.4** (29.4-46.0) | **75.1** (50.2-136) | **136** (71.4-279) | 223 |
| | 01-02 | **22.2** (18.2-27.0) | **22.1** (19.4-25.3) | **44.3** (37.9-51.5) | **76.5** (59.0-111) | **115** (96.1-153) | 217 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **29.6** (24.2-35.6) | **53.0** (43.2-61.2) | **75.0** (59.1-98.6) | 562 |
| | 01-02 | **23.1** (20.9-25.4) | **24.7** (22.0-27.6) | **42.0** (35.4-49.6) | **72.3** (63.9-82.9) | **114** (88.3-124) | 663 |

< 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 128. 3,3',4,4',5-Pentachlorobiphenyl (PCB 126) (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 | **204** (173-232) | **381** (319-451) | **591** (479-709) | 1238 |
| | 01-02 | **147** (135-160) | **158** (143-175) | **270** (249-298) | **482** (436-541) | **730** (625-840) | 1226 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | < LOD | < LOD | **108** (94.0-126) | **144** (116-196) | 658 |
| | 01-02 | † | † | † | † | † | † |
| 20 years and older | 99-00 | * | < LOD | **204** (173-232) | **381** (319-451) | **591** (479-709) | 1238 |
| | 01-02 | **147** (135-160) | **158** (143-175) | **270** (249-298) | **482** (436-541) | **730** (625-840) | 1226 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 99-00 | * | < LOD | **173** (147-194) | **271** (250-319) | **422** (319-560) | 572 |
| | 01-02 | **134** (121-149) | **152** (130-169) | **249** (233-267) | **399** (346-467) | **566** (467-693) | 561 |
| Females | 99-00 | * | < LOD | **237** (182-297) | **470** (402-586) | **684** (586-804) | 666 |
| | 01-02 | **159** (146-172) | **160** (149-184) | **298** (270-348) | **548** (483-637) | **818** (658-958) | 665 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | **184** (123-242) | **327** (271-381) | **512** (364-576) | 337 |
| | 01-02 | **114** (97.8-133) | **125** (106-150) | **214** (175-257) | **335** (272-460) | **585** (354-784) | 262 |
| Non-Hispanic blacks | 99-00 | * | < LOD | **236** (162-308) | **547** (356-779) | **941** (517-1600) | 223 |
| | 01-02 | **131** (106-161) | **128** (110-158) | **266** (214-304) | **532** (361-662) | **779** (585-1060) | 217 |
| Non-Hispanic whites | 99-00 | * | < LOD | **188** (157-237) | **329** (285-424) | **554** (424-666) | 562 |
| | 01-02 | **150** (136-164) | **160** (146-179) | **276** (249-301) | **486** (431-553) | **746** (600-937) | 663 |

< 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 129. 2,3,3',4,4',5-Hexachlorobiphenyl (PCB 156) (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** | **12.5** (<LOD-13.8) | **16.5** (15.5-18.0) | 1907 |
| | 01-02 | * | **< LOD** | **< LOD** | **14.2** (12.1-15.8) | **18.2** (15.6-20.9) | 2296 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 665 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 756 |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **13.5** (<LOD-14.7) | **17.5** (16.0-19.7) | 1242 |
| | 01-02 | * | **< LOD** | **< LOD** | **14.9** (13.2-16.6) | **19.7** (17.0-22.1) | 1540 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **12.6** (<LOD-14.0) | **16.0** (14.6-18.0) | 912 |
| | 01-02 | * | **< LOD** | **< LOD** | **13.6** (11.2-16.4) | **18.2** (14.3-22.1) | 1069 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **12.8** (<LOD-14.7) | **16.3** (14.7-20.1) | 995 |
| | 01-02 | * | **< LOD** | **< LOD** | **14.7** (13.2-15.5) | **18.1** (16.2-21.0) | 1227 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 631 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 566 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **14.6** (<LOD-20.5) | **21.6** (17.2-32.1) | 412 |
| | 01-02 | * | **< LOD** | **< LOD** | **15.5** (12.6-20.0) | **23.5** (16.4-29.4) | 511 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **13.6** (<LOD-15.2) | **17.4** (16.0-18.9) | 711 |
| | 01-02 | * | **< LOD** | **< LOD** | **15.0** (13.0-17.1) | **19.3** (16.2-22.1) | 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 130. 2,3,3',4,4',5-Hexachlorobiphenyl (PCB 156) (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** | **.085** (.075-.092) | **.109** (.098-.129) | 1907 |
| | 01-02 | * | **< LOD** | **< LOD** | **.094** (.082-.107) | **.126** (.110-.140) | 2296 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 665 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 756 |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **.090** (.081-.099) | **.116** (.104-.139) | 1242 |
| | 01-02 | * | **< LOD** | **< LOD** | **.104** (.089-.114) | **.132** (.118-.144) | 1540 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **.085** (.072-.098) | **.109** (.094-.130) | 912 |
| | 01-02 | * | **< LOD** | **< LOD** | **.092** (.078-.113) | **.123** (.105-.151) | 1069 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **.085** (.075-.093) | **.108** (.092-.141) | 995 |
| | 01-02 | * | **< LOD** | **< LOD** | **.096** (.086-.104) | **.134** (.111-.140) | 1227 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 631 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 566 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **.094** (.071-.124) | **.151** (.113-.188) | 412 |
| | 01-02 | * | **< LOD** | **< LOD** | **.096** (.079-.131) | **.144** (.104-.179) | 511 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **.089** (.081-.098) | **.111** (.101-.129) | 711 |
| | 01-02 | * | **< LOD** | **< LOD** | **.104** (.089-.115) | **.131** (.117-.140) | 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 131. 2,3,3',4,4',5'-Hexachlorobiphenyl (PCB 157) (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 | 1897 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 2294 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 654 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 755 |
| 20 years and older | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1243 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1539 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 901 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1068 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 996 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1226 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 622 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 566 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 405 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 510 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 716 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1055 |

< 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 132. 2,3,3',4,4',5'-Hexachlorobiphenyl (PCB 157) (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 | 1897 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 2294 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 654 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 755 |
| 20 years and older | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1243 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1539 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 901 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1068 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 996 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1226 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 622 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 566 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 405 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 510 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 716 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1055 |

< 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 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 134. 2,3',4,4',5,5'-Hexachlorobiphenyl (PCB 167) (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 | 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) 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** | **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 |

< 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 136. 3,3',4,4',5,5'-Hexachlorobiphenyl (PCB 169) (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 | **240** (227-261) | **303** (281-339) | 1240 |
| | 01-02 | **115** (103-129) | **125** (108-146) | **217** (189-253) | **343** (299-374) | **416** (379-490) | 1223 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 648 |
| | 01-02 | † | † | † | † | † | † |
| 20 years and older | 99-00 | * | < LOD | < LOD | **240** (227-261) | **303** (281-339) | 1240 |
| | 01-02 | **115** (103-129) | **125** (108-146) | **217** (189-253) | **343** (299-374) | **416** (379-490) | 1223 |
| **Gender** (20 years and older) | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | **245** (223-276) | **298** (274-341) | 572 |
| | 01-02 | **133** (117-152) | **151** (130-168) | **244** (198-293) | **363** (309-409) | **446** (372-529) | 559 |
| Females | 99-00 | * | < LOD | < LOD | **240** (214-264) | **310** (273-347) | 668 |
| | 01-02 | **102** (90.0-115) | **107** (91.0-123) | **194** (170-234) | **318** (282-368) | **391** (373-462) | 664 |
| **Race/ethnicity** (20 years and older) | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | **235** (190-295) | 335 |
| | 01-02 | * | < LOD | **97.6** (79.3-138) | **184** (143-250) | **262** (179-341) | 260 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | **262** (192-334) | **334** (265-505) | 224 |
| | 01-02 | **101** (91.2-113) | **103** (88.0-118) | **190** (147-234) | **295** (261-328) | **361** (309-423) | 217 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | **244** (226-273) | **298** (276-347) | 568 |
| | 01-02 | **127** (112-144) | **145** (124-157) | **229** (195-275) | **368** (317-388) | **438** (388-515) | 662 |

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

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) | | | | 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** | 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.

## 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) | | | | 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** | 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

# Non-dioxin-like Polychlorinated Biphenyls

*(The coplanar and mono-ortho-substituted PCBs are reported and specifically discussed in the section titled "Polychlorinated Dibenzo-*p*-dioxins, Polychlorinated Dibenzofurans, and Coplanar and Mono-ortho-substituted Polychlorinated Biphenyls.")*

## General Information

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

Food is the main source of exposure for the general population. PCBs enter the food chain by a variety of routes, including migration into food from packaging materials, contamination of animal feeds, and accumulation in the fatty tissues of animals. PCBs are found at higher concentrations in fatty foods. Diets that contain PCB-contaminated fats (e.g., milk and dairy products; fish, including whales) will increase exposure to PCBs. The transfer of PCBs from mother to infants via breast milk is another source of exposure.
Other sources for the general population include the release of these chemicals from PCB-containing waste sites and fires involving transformers and capacitors. Additionally, the heat from fires can result in the production of furans (and to a much lesser extent dioxins) from PCBs. In certain occupational settings workers can be exposed to PCBs, including when repairing or manufacturing transformers, capacitors, and hydraulic systems, and when remediating hazardous-waste sites. Both U.S. FDA and OSHA have developed criteria on the allowable levels of these chemicals in foods and the workplace. The U.S. EPA has also set criteria for water and for storing and removing waste that contains PCBs. The Stockholm Treaty, signed in May 2001, will put into effect the most stringent guidelines to date regarding elimination, restriction and unintentional production of PCBs and selected pesticides (Porta and Zumeta, 2002).
Exposure to these chemicals nearly always occurs from mixtures rather than from individual PCBs. The different types of PCB chemicals are known as congeners, compounds that are distinguished by the number of

**Table 139. Non-dioxin-like Polychlorinated Biphenyls (PCBs) and their classification**

| Non-dioxin-like polychlorinated biphenyls (IUPAC number) | CAS number |
|---|---|
| Polychlorinated biphenyls (general class) | 1336-36-3 |
| 2,2',5,5'-Tetrachlorobiphenyl (PCB 52) | 35693-99-3 |
| 2,2',3,4,5'-Pentachlorobiphenyl (PCB 87) | 38380-02-8 |
| 2,2',4,4',5-Pentachlorobiphenyl (PCB 99) | 38380-01-7 |
| 2,2',4,5,5'-Pentachlorobiphenyl (PCB 101) | 37680-73-2 |
| 2,3,3',4',6-Pentachlorobiphenyl (PCB 110) | 38380-03-9 |
| 2,2',3,3',4,4'-Hexachlorobiphenyl (PCB 128) | 38380-07-3 |
| 2,2',3,4,4',5'-Hexachlorobiphenyl (PCB 138) | 35065-28-2 |
| 2,3,3',4,4',6-Hexachlorobiphenyl (PCB 158) | 74472-42-7 |
| 2,2',3,4',5,5'-Hexachlorobiphenyl (PCB 146) | 51908-16-8 |
| 2,2',3,4',5',6-Hexachlorobiphenyl (PCB 149) | 38380-04-0 |
| 2,2',3,5,5',6-Hexachlorobiphenyl (PCB 151) | 52663-63-5 |
| 2,2',4,4',5,5'-Hexachlorobiphenyl (PCB 153) | 35065-27-1 |
| 2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB 170) | 35065-30-6 |
| 2,2',3,3',4,5,5'-Heptachlorobiphenyl (PCB 172) | 52663-74-8 |
| 2,2',3,3',4,5',6'-Heptachlorobiphenyl (PCB 177) | 52663-70-4 |
| 2,2',3,3',5,5',6-Heptachlorobiphenyl (PCB 178) | 52663-67-9 |
| 2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB 180) | 35065-29-3 |
| 2,2',3,4,4',5',6-Heptachlorobiphenyl (PCB 183) | 52663-69-1 |
| 2,2',3,4',5,5',6-Heptachlorobiphenyl (PCB 187) | 52663-68-0 |
| 2,2',3,3',4,4',5,5'-Octachlorobiphenyl (PCB 194) | 35694-08-7 |
| 2,2',3,3',4,4',5,6-Octachlorobiphenyl (PCB 195) | 52663-78-2 |
| 2,2',3,3',4,4',5,6'-Octachlorobiphenyl (PCB 196) | 42740-50-1 |
| 2,2',3,3',4,5,5',6'-Octachlorobiphenyl (PCB 199) | 52663-75-9 |
| 2,2',3,4,4',5,5',6-Octachlorobiphenyl (PCB 203) | 52663-76-0 |
| 2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl (PCB 206) | 40186-72-9 |

chlorine atoms and their location on the biphenyl structure. PCB congeners can be divided into the coplanar, the mono-ortho-substituted PCBs, and other PCBs. The significance of this designation is that the coplanar and the mono-ortho-substituted PCBs have dioxin-like toxicologic effects. The coplanar and mono-ortho-substituted PCBs are discussed in the section titled "Polychlorinated Dibenzo-p-dioxins, Polychlorinated Dibenzofurans, and the Coplanar and Mono-ortho-substituted Polychlorinated Biphenyls." Table 138 gives the nomenclature for the PCBs in this section.

The human health effects observed after exposure to PCBs include liver disorders (elevated hepatic enzymes), elevated blood lipids, and gastrointestinal cancers. A firm association between exposure to PCBs and breast cancer has not been established. (Negri et al., 2003; Pavuk, et al., 2003; Charles et al., 2001; Lucena et al., 2001; Charlier et al., 2003; Warner et al., 2002). Reproductive and developmental effects demonstrated in animals may also be of concern. Background levels of PCBs from transplacental transfer after environmental exposure are associated with impaired neurological development in newborns and children (Koopman-Esseboom et al., 1997; Jacobsen and Jacobsen, 1996; Longnecker et al., 2003; Sala et al., 2001). PCBs are classified as probable human carcinogens by IARC and are classified by NTP as reasonably anticipated to be carcinogens. 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 Non-dioxin-like PCBs Reported in the Tables

Lipid-adjusted serum levels of PCBs were measured in a subsample of NHANES participants aged 12 years and older. Participants were randomly selected within the specified age range to be a representative sample of the U.S. population. Measurement of serum PCBs can reflect either recent or past exposure to PCBs. Some PCBs can persist in the body for years after exposure. The contribution of individual PCB congeners to the sum of PCB measurements in the body may vary by exposure source and differences in pharmacokinetics. Some of the PCBs measured may represent exposure to the breakdown of other PCBs in a person's environment. The most frequently detected di-ortho-chlorine-substituted PCBs in general populations are 138, 153, and 180 (Patterson et al., 1994; Heudorf et al., 2002). These congeners also were found to contribute a substantial portion of the total PCB concentration observed in pooled specimens representative of a New Zealand population (Bates et al., 2004*b*) and in a smaller population of Swedish men (Glynn et al., 2000). Because of its predominance, PCB 153 has been used as a marker of exposure for the other PCBs. In 1994, levels of PCBs 138, 153, and 180 in pooled, banked serum were generally three to four times lower than levels reported in 1988 (Longnecker et al., 2000; Patterson et al., 1994). The concentrations of the di-ortho-substituted PCBs are generally higher than the mono-ortho-substituted PCBs, which in turn are higher than the coplanar PCBs (Glynn et al., 2000; Longnecker et al., 2000; Patterson et al., 1994). In a convenience sample of 624 urban Germans aged 0-65 years conducted during 1998 (Heudorf et al., 2002), 95$^{th}$ percentile levels for PCBs 138, 153, and 180 were similar or up to two-fold higher than 95$^{th}$ percentile levels in this *Report*. A representative pooled sampling of New Zealanders showed slightly lower levels than those in this *Report* (Bates et al., 2004*b*). Heavy fish consumption is considered to contribute to about a two-fold increase in the concentration of these PCB congeners (Patterson et al., 1994).

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

### 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, serum cotinine, and lipid level (data not shown). Due to improved limits of detection in NHANES 2001-2002, PCB 138 & 158, PCB 153, and PCB 180 had sufficient detection rates to allow comparison of adjusted geometric means of the demographic groups, which were not possible in the 1999-2000 subssample. For PCB 138 & 158, no differences between the demographic groups were found. For PCB 153, males had slightly higher levels than females, and Mexican Americans had two-fold lower levels than either non-Hispanic blacks or non-Hispanic whites. For PCB 180, males had slightly higher adjusted geometric mean levels than females. It is unknown whether these differences associated with gender or race/ethnicity represent differences in exposure, 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)

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** | 1912 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **16.2** (14.3-17.2) | 1537 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 664 |
| | 01-02 | * | **< LOD** | **< LOD** | **16.2** (<LOD-23.8) | **22.9** (16.9-32.3) | 291 |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1248 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **16.0** (13.5-16.9) | 1246 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 908 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **16.0** (<LOD-17.5) | 716 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1004 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **16.5** (14.0-18.2) | 821 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 631 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **16.9** (<LOD-20.6) | 366 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 408 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **16.1** (<LOD-20.9) | 282 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 716 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **16.5** (14.3-17.5) | 773 |

< 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 141. 2,2',5,5'-Tetrachlorobiphenyl (PCB 52) (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** | 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** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 631 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.083** (.051-.102) | 366 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 408 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.092** (.068-.112) | 282 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 716 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.088** (.081-.099) | 773 |

< 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 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 143. 2,2',3,4,5'-Pentachlorobiphenyl (PCB 87) (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) | | | | 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)

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** | **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 | * | **< LOD** | **< LOD** | **12.5** (<LOD-14.5) | **18.1** (14.3-20.8) | 715 |
| | 01-02 | * | **< LOD** | **< LOD** | **18.5** (15.3-22.3) | **28.5** (22.1-32.4) | 1046 |

< 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 145. 2,2',4,4',5-Pentachlorobiphenyl (PCB 99) (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** | **.085** (.075-.098) | **.114** (.102-.145) | 1897 |
| | 01-02 | * | **< LOD** | **< LOD** | **.117** (.100-.139) | **.183** (.149-.208) | 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** | **.093** (.082-.104) | **.126** (.106-.151) | 1243 |
| | 01-02 | * | **< LOD** | **.070** (.063-.079) | **.131** (.109-.157) | **.193** (.161-.212) | 1523 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.107** (.086-.127) | 905 |
| | 01-02 | * | **< LOD** | **< LOD** | **.107** (.090-.137) | **.161** (.120-.197) | 1061 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **.098** (.078-.108) | **.133** (.102-.165) | 992 |
| | 01-02 | * | **< LOD** | **< LOD** | **.129** (.106-.157) | **.200** (.159-.212) | 1220 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 624 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.100** (.068-.120) | 562 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **.135** (.106-.175) | **.213** (.151-.395) | 400 |
| | 01-02 | * | **< LOD** | **.071** (.063-.084) | **.129** (.106-.151) | **.187** (.139-.232) | 510 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **.085** (.070-.098) | **.111** (.094-.145) | 715 |
| | 01-02 | * | **< LOD** | **< LOD** | **.124** (.098-.159) | **.187** (.156-.211) | 1046 |

< 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 146. 2,2',4,5,5'-Pentachlorobiphenyl (PCB 101) (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 | 1929 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 2307 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 669 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 758 |
| 20 years and older | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1260 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1549 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 918 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1075 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1011 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1232 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 634 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 567 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 413 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 515 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 724 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 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 147. 2,2',4,5,5'-Pentachlorobiphenyl (PCB 101) (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 | 1929 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 2307 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 669 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 758 |
| 20 years and older | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1260 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1549 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 918 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1075 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1011 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1232 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 634 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 567 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 413 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 515 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 724 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 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 148. 2,3,3',4',6-Pentachlorobiphenyl (PCB 110) (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 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) | | | | 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 150. 2,2',3,3',4,4'-Hexachlorobiphenyl (PCB 128) (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 | 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 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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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 152. 2,2',3,4,4',5' and 2,3,3',4,4',6-Hexachlorobiphenyl (PCB 138 & 158) (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** | **49.2** (42.9-55.8) | **70.8** (59.8-82.7) | 1930 |
| | 01-02 | **19.9** (18.0-22.0) | **20.0** (18.0-22.8) | **40.4** (35.3-44.9) | **70.1** (61.8-78.8) | **94.6** (82.5-107) | 2293 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 669 |
| | 01-02 | * | **< LOD** | **< LOD** | **17.0** (13.7-20.2) | **23.1** (17.7-41.2) | 748 |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **54.7** (47.4-60.8) | **72.8** (66.0-88.9) | 1261 |
| | 01-02 | **23.3** (21.1-25.8) | **23.9** (21.4-26.8) | **44.6** (40.4-49.2) | **73.8** (66.2-83.0) | **99.5** (88.7-109) | 1545 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **47.2** (<LOD-55.7) | **68.2** (55.7-83.8) | 918 |
| | 01-02 | **20.1** (17.9-22.6) | **20.4** (17.5-23.5) | **39.2** (32.2-46.0) | **68.6** (58.1-82.5) | **94.5** (77.8-109) | 1066 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **52.8** (44.7-61.2) | **72.0** (61.1-88.4) | 1012 |
| | 01-02 | **19.7** (17.8-21.7) | **20.2** (18.2-23.1) | **41.8** (37.5-45.9) | **69.6** (63.4-78.5) | **93.9** (80.2-109) | 1227 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 636 |
| | 01-02 | * | **< LOD** | **18.6** (13.6-23.4) | **33.3** (26.5-44.2) | **51.6** (42.3-57.6) | 559 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **72.1** (61.7-89.4) | **122** (86.5-185) | 412 |
| | 01-02 | **22.3** (19.3-25.6) | **21.8** (18.4-27.1) | **46.5** (38.0-55.6) | **91.5** (70.1-112) | **122** (91.5-169) | 513 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **49.3** (41.4-55.8) | **70.1** (55.7-85.2) | 727 |
| | 01-02 | **21.5** (19.2-24.0) | **21.9** (19.4-24.8) | **43.0** (37.7-48.0) | **70.6** (62.3-79.7) | **96.1** (79.1-110) | 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 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)

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** | **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)

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** | **.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** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 915 |
| | 01-02 | * | **< LOD** | **< LOD** | **.071** (.061-.083) | **.102** (.090-.123) | 1069 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.085** (.074-.114) | 1008 |
| | 01-02 | * | **< LOD** | **< LOD** | **.073** (.066-.083) | **.112** (.089-.121) | 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** | **.101** (.082-.129) | **.175** (.117-.274) | 412 |
| | 01-02 | * | **< LOD** | **< LOD** | **.103** (.079-.133) | **.148** (.114-.195) | 515 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 723 |
| | 01-02 | * | **< LOD** | **< LOD** | **.071** (.066-.081) | **.100** (.087-.115) | 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 156. 2,2',3,4',5',6-Hexachlorobiphenyl (PCB 149) (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** | 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 |

< 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 158. 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 | 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 | 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 |

< 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 159. 2,2',3,5,5',6-Hexachlorobiphenyl (PCB 151) (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 | 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 |

< 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 160. 2,2',3,5,5',6-Hexachlorobiphenyl (PCB 151) (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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 |

< 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 161. 2,2',4,4',5,5'-Hexachlorobiphenyl (PCB 153) (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** | **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** (10.8-14.4) | **10.9** (<LOD-13.0) | **24.2** (18.2-33.9) | **47.4** (35.7-58.1) | **66.7** (55.2-72.3) | 567 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **59.1** (<LOD-82.0) | **121** (90.3-159) | **176** (130-287) | 412 |
| | 01-02 | **30.0** (26.2-34.4) | **31.0** (25.8-36.4) | **64.5** (54.2-82.7) | **126** (97.1-152) | **170** (126-246) | 515 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **76.4** (69.3-83.9) | **102** (87.7-125) | 725 |
| | 01-02 | **29.9** (26.8-33.4) | **32.9** (28.7-36.8) | **61.2** (55.8-66.7) | **96.3** (86.5-109) | **126** (104-142) | 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 162. 2,2',4,4',5,5'-Hexachlorobiphenyl (PCB 153) (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** | **.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 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **.368** (.273-.514) | **.749** (.619-.894) | **1.27** (.816-1.64) | 412 |
| | 01-02 | **.169** (.146-.195) | **.179** (.144-.202) | **.392** (.331-.486) | **.776** (.578-.954) | **1.04** (.831-1.43) | 515 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **.519** (.480-.563) | **.702** (.583-.846) | 725 |
| | 01-02 | **.185** (.165-.207) | **.207** (.182-.231) | **.393** (.367-.425) | **.637** (.563-.720) | **.838** (.738-.987) | 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 163. 2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB 170) (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** | **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 | * | **< LOD** | **< LOD** | **23.8** (22.0-26.3) | **32.6** (28.1-37.0) | 863 |
| | 01-02 | * | **10.7** (<LOD-11.9) | **18.4** (16.3-20.9) | **27.9** (24.7-31.9) | **36.1** (32.1-38.3) | 1073 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **22.4** (20.7-25.4) | **29.7** (25.8-36.3) | 935 |
| | 01-02 | * | **< LOD** | **16.4** (15.0-17.9) | **25.9** (24.0-28.4) | **34.0** (30.4-38.1) | 1228 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **23.2** (20.3-26.5) | 606 |
| | 01-02 | * | **< LOD** | **< LOD** | **15.4** (11.1-18.6) | **21.1** (17.1-25.1) | 565 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **30.9** (23.1-36.3) | **39.6** (33.7-59.1) | 382 |
| | 01-02 | * | **< LOD** | **18.7** (14.8-23.1) | **32.4** (25.5-43.9) | **44.1** (32.5-61.7) | 514 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **24.0** (22.0-25.8) | **31.0** (26.8-37.3) | 658 |
| | 01-02 | * | **10.9** (<LOD-11.8) | **18.4** (16.8-20.4) | **27.7** (25.4-30.2) | **35.0** (32.3-38.1) | 1059 |

< 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 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 mean (95% conf. interval) | Selected percentiles (95% confidence interval) 50th | 75th | 90th | 95th | 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 |

< 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 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) | | | | 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 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)

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** | 1873 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 2287 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 653 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 756 |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1220 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1531 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 887 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1065 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 986 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1222 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 622 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 562 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 399 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **10.6** (<LOD-12.3) | 515 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 698 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1048 |

< 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 168. 2,2',3,3',4,5',6'-Heptachlorobiphenyl (PCB 177) (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** | 1873 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 2287 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 653 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 756 |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1220 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1531 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 887 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1065 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 986 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1222 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 622 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 562 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 399 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.064** (.042-.099) | 515 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 698 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1048 |

< 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 169. 2,2',3,3',5,5',6-Heptachlorobiphenyl (PCB 178) (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 | 1932 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 2299 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 669 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 758 |
| 20 years and older | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1263 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1541 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 919 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1069 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1013 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1230 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 635 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 567 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 415 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 515 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 724 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 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 170. 2,2',3,3',5,5',6-Heptachlorobiphenyl (PCB 178) (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** | 1932 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 2299 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 669 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 758 |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1263 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1541 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 919 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1069 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1013 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1230 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 635 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 567 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 415 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 515 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 724 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 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 171. 2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB 180) (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** | **37.4** (32.7-41.8) | **62.0** (56.6-66.6) | **79.0** (72.1-89.2) | 1924 |
| | 01-02 | **19.2** (17.4-21.1) | **21.8** (19.0-24.6) | **42.2** (38.3-47.5) | **69.7** (63.7-75.9) | **87.0** (83.3-93.0) | 2302 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 667 |
| | 01-02 | * | **< LOD** | **< LOD** | **12.2** (<LOD-14.8) | **21.3** (14.2-26.0) | 755 |
| 20 years and older | 99-00 | * | **< LOD** | **41.0** (37.6-45.2) | **65.5** (60.6-69.4) | **83.8** (75.6-96.1) | 1257 |
| | 01-02 | **23.0** (20.8-25.5) | **26.4** (22.7-28.5) | **46.7** (41.4-51.1) | **74.0** (66.7-79.8) | **90.7** (85.0-99.5) | 1547 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **40.5** (34.5-45.0) | **65.1** (58.6-71.4) | **83.8** (75.8-96.3) | 919 |
| | 01-02 | **21.1** (18.8-23.7) | **25.1** (21.2-30.0) | **46.7** (39.8-51.8) | **73.8** (63.2-79.8) | **86.9** (78.0-99.4) | 1073 |
| Females | 99-00 | * | **< LOD** | **34.4** (29.8-39.3) | **56.7** (52.2-62.6) | **74.6** (66.6-90.5) | 1005 |
| | 01-02 | **17.5** (15.9-19.3) | **18.3** (16.0-21.6) | **39.6** (34.8-43.9) | **64.0** (57.9-72.0) | **87.9** (79.1-98.1) | 1229 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **41.7** (33.2-50.5) | **56.6** (49.7-63.8) | 633 |
| | 01-02 | * | **< LOD** | **18.0** (11.4-22.2) | **36.9** (28.2-45.7) | **54.2** (42.2-60.0) | 566 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **39.1** (32.2-48.4) | **78.4** (64.3-93.7) | **117** (89.6-144) | 414 |
| | 01-02 | **19.5** (16.5-23.1) | **20.7** (16.9-23.8) | **48.4** (36.7-57.9) | **89.6** (73.7-101) | **116** (96.1-167) | 514 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **39.9** (34.5-45.3) | **62.0** (56.5-68.6) | **79.0** (71.3-91.4) | 719 |
| | 01-02 | **21.4** (19.1-23.9) | **24.8** (21.4-27.9) | **45.6** (40.2-51.0) | **72.3** (63.8-78.0) | **87.9** (83.8-94.3) | 1059 |

< 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 172 2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB 180) (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** | **.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 | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 667 |
| | 01-02 | * | **< LOD** | **< LOD** | **.061** (.053-.075) | **.092** (.068-.135) | 755 |
| 20 years and older | 99-00 | * | **< LOD** | **.266** (.244-.296) | **.441** (.407-.482) | **.558** (.503-.617) | 1257 |
| | 01-02 | **.146** (.131-.162) | **.168** (.150-.188) | **.302** (.275-.337) | **.490** (.429-.555) | **.637** (.572-.738) | 1547 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **.257** (.224-.300) | **.459** (.365-.506) | **.568** (.501-.648) | 919 |
| | 01-02 | **.131** (.117-.147) | **.165** (.137-.197) | **.296** (.258-.339) | **.479** (.405-.554) | **.616** (.526-.716) | 1073 |
| Females | 99-00 | * | **< LOD** | **.231** (.195-.266) | **.377** (.344-.413) | **.510** (.430-.557) | 1005 |
| | 01-02 | **.106** (.096-.117) | **.113** (.100-.135) | **.261** (.228-.281) | **.415** (.375-.470) | **.604** (.519-.701) | 1229 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **.275** (.198-.324) | **.390** (.316-.452) | 633 |
| | 01-02 | * | **< LOD** | **.110** (.079-.157) | **.259** (.198-.307) | **.353** (.279-.419) | 566 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **.245** (.188-.298) | **.497** (.349-.656) | **.727** (.534-1.04) | 414 |
| | 01-02 | **.110** (.092-.131) | **.119** (.091-.142) | **.287** (.215-.345) | **.560** (.436-.651) | **.719** (.523-1.01) | 514 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **.263** (.234-.299) | **.430** (.377-.470) | **.537** (.483-.604) | 719 |
| | 01-02 | **.132** (.118-.148) | **.160** (.142-.180) | **.292** (.262-.327) | **.471** (.405-.532) | **.617** (.526-.730) | 1059 |

< 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 173. 2,2',3,4,4',5',6-Heptachlorobiphenyl (PCB 183) (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** | 1928 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 2306 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 668 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 757 |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1260 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1549 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 919 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1074 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1009 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1232 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 635 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 567 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 413 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **12.7** (<LOD-14.9) | 514 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 722 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 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 174. 2,2',3,4,4',5',6-Heptachlorobiphenyl (PCB 183) (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** | 1928 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 2306 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 668 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 757 |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1260 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1549 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 919 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1074 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1009 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1232 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 635 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 567 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 413 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.082** (.057-.105) | 514 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 722 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 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 175. 2,2',3,4',5,5',6-Heptachlorobiphenyl (PCB 187) (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** | **17.7** (15.6-20.0) | **24.6** (22.0-27.6) | 1930 |
| | 01-02 | * | **< LOD** | **12.1** (10.5-13.7) | **21.7** (19.6-23.7) | **27.9** (26.8-29.7) | 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** | **19.2** (16.8-21.8) | **25.9** (24.1-29.0) | 1263 |
| | 01-02 | * | **< LOD** | **13.3** (12.0-15.2) | **23.0** (20.9-24.7) | **29.2** (27.3-32.0) | 1549 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **17.7** (15.7-19.6) | **25.9** (21.6-29.0) | 917 |
| | 01-02 | * | **< LOD** | **12.7** (<LOD-15.8) | **22.3** (19.4-24.1) | **27.7** (25.1-30.1) | 1075 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **17.7** (15.1-21.7) | **24.2** (21.6-27.0) | 1013 |
| | 01-02 | * | **< LOD** | **11.9** (<LOD-13.0) | **21.3** (18.5-23.5) | **28.5** (26.2-31.3) | 1232 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **17.3** (15.1-19.1) | 636 |
| | 01-02 | * | **< LOD** | **< LOD** | **10.5** (<LOD-13.4) | **15.7** (12.5-18.0) | 567 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **15.3** (<LOD-21.1) | **31.1** (26.0-39.0) | **47.1** (36.6-72.1) | 412 |
| | 01-02 | * | **< LOD** | **16.3** (12.3-21.0) | **30.0** (22.9-40.6) | **43.5** (30.3-61.9) | 515 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **16.8** (14.9-18.6) | **22.0** (19.1-25.2) | 727 |
| | 01-02 | * | **< LOD** | **12.5** (10.7-14.5) | **21.7** (18.9-23.7) | **27.4** (25.2-29.2) | 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 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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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 177. 2,2',3,3',4,4',5,5'-Octachlorobiphenyl (PCB 194) (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** | **11.1** (<LOD-11.9) | **18.1** (16.5-19.5) | **23.7** (20.9-27.0) | 2279 |
| **Age group** | | | | | | | |
| 12-19 years | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 746 |
| 20 years and older | 01-02 | * | **< LOD** | **11.9** (11.0-13.2) | **18.9** (17.7-20.5) | **25.3** (22.7-28.0) | 1533 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | **< LOD** | **12.2** (10.6-13.9) | **19.1** (17.1-21.1) | **25.2** (21.2-28.3) | 1059 |
| Females | 01-02 | * | **< LOD** | **< LOD** | **17.0** (14.7-18.8) | **21.7** (19.3-26.2) | 1220 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **13.9** (10.5-17.6) | 561 |
| Non-Hispanic blacks | 01-02 | * | **< LOD** | **12.2** (<LOD-15.3) | **22.6** (18.0-27.5) | **29.8** (23.7-41.1) | 508 |
| Non-Hispanic whites | 01-02 | * | **< LOD** | **11.9** (10.9-13.1) | **18.7** (17.1-20.2) | **24.1** (20.9-28.0) | 1048 |

< 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)

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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 12 and older** | 01-02 | * | **< LOD** | **.070** (.064-.078) | **.123** (.104-.139) | **.162** (.146-.187) | 2279 |
| **Age group** | | | | | | | |
| 12-19 years | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 746 |
| 20 years and older | 01-02 | * | **< LOD** | **.079** (.070-.086) | **.132** (.109-.147) | **.174** (.149-.197) | 1533 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | **< LOD** | **.078** (.069-.087) | **.132** (.106-.152) | **.169** (.147-.206) | 1059 |
| Females | 01-02 | * | **< LOD** | **< LOD** | **.109** (.094-.132) | **.147** (.133-.176) | 1220 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.099** (.080-.114) | 561 |
| Non-Hispanic blacks | 01-02 | * | **< LOD** | **.079** (.059-.089) | **.138** (.101-.175) | **.195** (.138-.253) | 508 |
| Non-Hispanic whites | 01-02 | * | **< LOD** | **.076** (.069-.085) | **.129** (.109-.146) | **.165** (.146-.193) | 1048 |

< 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 179. 2,2',3,3',4,4',5,6-Octachlorobiphenyl (PCB 195) (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** | 2230 |
| **Age group** | | | | | | | |
| 12-19 years | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 716 |
| 20 years and older | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1514 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1035 |
| Females | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1195 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 544 |
| Non-Hispanic blacks | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 490 |
| Non-Hispanic whites | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1037 |

< 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 180. 2,2',3,3',4,4',5,6-Octachlorobiphenyl (PCB 195) (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 12 and older** | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 2230 |
| **Age group** | | | | | | | |
| 12-19 years | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 716 |
| 20 years and older | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1514 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1035 |
| Females | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1195 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 544 |
| Non-Hispanic blacks | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 490 |
| Non-Hispanic whites | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1037 |

< 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 181. 2,2',3,3',4,4',5,6' and 2,2',3,4,4',5,5',6-Octachlorobiphenyl (PCB 196 & 203) (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** | **14.1** (13.0-15.7) | **19.2** (17.4-20.9) | 2299 |
| **Age group** | | | | | | | |
| 12-19 years | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 755 |
| 20 years and older | 01-02 | * | **< LOD** | **< LOD** | **15.0** (13.7-16.9) | **19.9** (18.2-21.4) | 1544 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | **< LOD** | **< LOD** | **14.6** (13.3-16.5) | **19.4** (16.3-21.2) | 1071 |
| Females | 01-02 | * | **< LOD** | **< LOD** | **13.8** (11.9-15.9) | **19.0** (17.0-21.3) | 1228 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **11.1** (<LOD-12.5) | 565 |
| Non-Hispanic blacks | 01-02 | * | **< LOD** | **< LOD** | **17.5** (14.0-21.0) | **22.8** (19.6-30.2) | 513 |
| Non-Hispanic whites | 01-02 | * | **< LOD** | **< LOD** | **14.6** (13.5-16.2) | **19.5** (18.1-21.3) | 1058 |

< 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 182. 2,2',3,3',4,4',5,6' and 2,2',3,4,4',5,5',6-Octachlorobiphenyl (PCB 196 & 203) (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 12 and older** | 01-02 | * | **< LOD** | **< LOD** | **.095** (.086-.105) | **.127** (.113-.140) | 2299 |
| **Age group** | | | | | | | |
| 12-19 years | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 755 |
| 20 years and older | 01-02 | * | **< LOD** | **< LOD** | **.103** (.092-.111) | **.133** (.114-.150) | 1544 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | **< LOD** | **< LOD** | **.100** (.086-.115) | **.126** (.110-.150) | 1071 |
| Females | 01-02 | * | **< LOD** | **< LOD** | **.092** (.078-.101) | **.126** (.110-.138) | 1228 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.071** (.060-.089) | 565 |
| Non-Hispanic blacks | 01-02 | * | **< LOD** | **< LOD** | **.108** (.086-.135) | **.148** (.108-.208) | 513 |
| Non-Hispanic whites | 01-02 | * | **< LOD** | **< LOD** | **.099** (.090-.110) | **.131** (.112-.143) | 1058 |

< 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 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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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)

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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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.

# Results by Chemical Group

## 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, food packaging, 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 or through food that is in contact with packaging that contains 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

**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) | DiNP | Mono-isononyl phthalate | MiNP |

periods and in the amounts of putative metabolites generated in animals versus humans, as well as the large doses given to test animals, make it difficult to translate the effects observed in animals to health effects in people. For instance, blood levels of phthalate monoesters can be higher in rodents than in non-human primates that are given equivalent doses due to the greater absorption in rodents or possibly greater hydrolysis to the monoester metabolite (Kessler et al., 2004; Lake et al., 1977). In addition, phthalates cause peroxisomal proliferation, which may be a pathway to the development of liver cancers in animals. However, peroxisomal proliferation may be a less relevant pathway in people (Melnick, 2001).

The Center for the Evaluation of Risks to Human Reproduction of the NTP has reviewed the reproductive effects for many of the phthalates (see http://cerhr.niehs.nih.gov/news/phthalates/monographs.html). Information about external exposure (i.e., environmental levels) and health effects is also available for some phthalates 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 Phthalate Metabolites Reported in the Tables

Urinary levels of phthalate metabolites were measured in a subsample of NHANES participants aged 6 years and older. Participants were randomly selected within the specified age range to be a representative sample of the U.S. population. The concentrations for the monoester phthalate metabolites in the NHANES 2001-2002 subsample appear roughly similar to concentrations to those seen in an earlier survey of U.S. residents (Blount et al., 2000), pregnant women in New York City (Adibi et al., 2003), and in men from a Boston infertility clinic (Duty et al., 2004). In a small sample of Germans aged 7-64 years, median levels of mono-2-ethylhexyl phthalate (MEHP), mono-2-ethyl-5-hydroxyhexyl phthalate (MEHHP), mono-2-ethyl-5-oxohexyl phthalate (MEOHP) and mono-benzyl phthalate (MBzP) were about two-fold higher than median levels in the NHANES 2001-2002 subsample; the median level of mono-butyl phthalate (MBP) was about six-fold higher; and the median level of mono-ethyl phthalate (MEP) was slightly lower than the median levels of these metabolites in the NHANES 1999-2002 subsamples (Koch et al., 2003).

With the exception of MEP, the NHANES 1999-2000 and 2001-2002 subsamples showed that children aged 6-11 years excreted higher concentrations of metabolites than did older age groups, a finding that has been noted in other studies of German adults and children for DEHP metabolites (Koch et al., 2004; Becker et al., 2004). The 1999-2000 and 2001-2002 NHANES subsamples also showed other differences in concentrations of specific phthalate metabolites by age, gender, and race/ethnicity (see data on individual phthalates). It is known that there is variation from person to person in the proportions or amounts of the metabolite excreted after people received similar doses (Anderson et al., 2001) as well as variation in the same person during repetitive monitoring (Hauser et al., 2004; Hoppin et al., 2002). The proportions of each metabolite for a given phthalate may vary also by differing routes of exposure (Liss et al., 1985; Peck and Albro, 1982).

Differences among the levels of various phthalate metabolites within a person may be due to differences in either exposure or pharmacokinetics for each of those phthalates. For instance, DEHP has been one of the more widely used phthalates, yet levels of MEHP are found in lower concentrations than MEP, MBP, or MBzP. It is now known that a greater proportion of the dose is accounted by other DEHP urinary metabolites (e.g., MEOHP and MEHHP), which demonstrate higher urinary concentrations than MEHP (Barr et al., 2003; Koch et al., 2003). Likewise, the low detection rates for some of the monoester metabolites of the long alkyl chain phthalates (di-isononyl and dioctyl) may be due to lower exposure to these compounds, to less of the parent compound being metabolized to the measured monoester metabolite, or, as seen with DEHP, to further oxidation to other unmeasured metabolites.

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

# Mono-methyl Phthalate

CAS No. 4376-18-5

*Metabolite of Dimethyl Phthalate, CAS No.131-11-3*

## General Information

Dimethyl phthalate (DMP) is used to manufacture solid rocket propellant and some consumer products such as insect repellants and plastics. People exposed to DMP will excrete mono-methyl phthalate (MMP) in their urine. The amount of MMP is an indicator of how much contact with DMP has occurred. Workplace air standards for external exposure to dimethyl phthalate have been established by NIOSH and ACGIH. DMP has not been completely classified with respect to carcinogenicity by IARC and NTP.

## Comparing Adjusted Geometric Means

MMP was not measured in NHANES 1999-2000. For NHANES 2001-2002, geometric mean levels of urinary MMP for the demographic groups were compared after adjusting for the covariates of race/ethnicity, age, gender, and urinary creatinine (data not shown). Adjusted geometric mean levels of urinary MMP were found to be higher in children aged 6-11 years than in either of the groups aged 12-19 years and 20 years and older and levels in the group aged 12-19 years were higher than in the group aged 20 years and older. Females had higher levels than males. It is unknown whether these differences associated with age and gender represent differences in exposure, pharmacokinetics, or the relationship of dose per body weight.

### Table 188. Mono-methyl phthalate

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

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | **1.15** (.985-1.34) | **1.50** (1.30-1.70) | **3.30** (2.80-3.70) | **6.00** (5.10-7.40) | **9.80** (8.00-12.5) | 2782 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | **1.45** (1.13-1.87) | **1.80** (1.40-2.60) | **4.00** (3.30-4.70) | **6.90** (6.00-8.00) | **11.6** (7.60-20.8) | 393 |
| 12-19 years | 01-02 | **1.59** (1.28-1.96) | **2.10** (1.80-2.50) | **3.80** (3.30-4.70) | **8.50** (5.30-10.5) | **12.7** (9.60-17.8) | 742 |
| 20 years and older | 01-02 | **1.06** (.904-1.25) | **1.40** (1.10-1.60) | **3.10** (2.40-3.50) | **5.60** (4.60-6.90) | **9.10** (7.10-11.8) | 1647 |
| **Gender** | | | | | | | |
| Males | 01-02 | **1.17** (.962-1.43) | **1.50** (1.20-1.80) | **3.30** (2.80-3.80) | **5.90** (4.80-7.90) | **9.10** (7.10-12.7) | 1371 |
| Females | 01-02 | **1.13** (.973-1.31) | **1.30** (1.10-1.60) | **3.30** (2.80-3.70) | **6.40** (4.90-7.80) | **10.3** (8.00-15.2) | 1411 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | **1.21** (1.02-1.45) | **1.50** (1.30-1.70) | **3.30** (2.70-3.90) | **5.50** (4.70-7.30) | **8.30** (6.40-15.2) | 677 |
| Non-Hispanic blacks | 01-02 | **1.64** (1.37-1.98) | **2.00** (1.70-2.50) | **4.40** (3.50-5.10) | **8.30** (6.20-10.1) | **10.8** (9.50-13.4) | 703 |
| Non-Hispanic whites | 01-02 | **1.08** (.906-1.29) | **1.40** (1.10-1.60) | **3.10** (2.50-3.60) | **5.60** (4.60-6.60) | **9.70** (7.10-14.0) | 1216 |

## Table 189. Mono-methyl phthalate (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, 2001-2002.

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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** (2.14-2.65) | **4.49** (3.49-5.88) | **7.72** (5.54-11.7) | 1638 |
| **Gender** | | | | | | | |
| Males | 01-02 | **.953** (.792-1.15) | **1.17** (1.01-1.40) | **2.38** (2.03-2.78) | **4.12** (3.45-5.64) | **6.42** (4.94-9.32) | 1367 |
| Females | 01-02 | **1.21** (1.06-1.38) | **1.45** (1.24-1.82) | **2.86** (2.60-3.04) | **5.45** (4.55-7.07) | **10.0** (7.20-15.3) | 1405 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | **1.14** (.969-1.34) | **1.47** (1.29-1.63) | **2.48** (2.19-2.94) | **4.19** (3.75-5.79) | **7.53** (4.76-15.2) | 674 |
| Non-Hispanic blacks | 01-02 | **1.15** (.945-1.40) | **1.39** (1.28-1.67) | **2.69** (2.35-2.93) | **4.86** (4.20-5.88) | **8.02** (5.85-10.9) | 702 |
| Non-Hispanic whites | 01-02 | **1.07** (.913-1.25) | **1.30** (1.05-1.58) | **2.60** (2.32-2.97) | **5.23** (3.72-6.82) | **8.29** (6.08-12.6) | 1211 |

# 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

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 | **179** (156-204) | **164** (136-201) | **450** (370-538) | **1260** (1010-1480) | **2840** (2150-3770) | 2536 |
| | 01-02 | **178** (159-199) | **169** (141-194) | **465** (415-527) | **1230** (1040-1440) | **2500** (1860-3220) | 2782 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **91.3** (74.8-111) | **74.7** (62.1-93.7) | **197** (129-249) | **378** (290-730) | **756** (379-1070) | 328 |
| | 01-02 | **85.1** (71.2-102) | **71.9** (61.9-92.5) | **181** (142-217) | **444** (315-636) | **808** (572-1090) | 393 |
| 12-19 years | 99-00 | **211** (160-278) | **193** (141-256) | **558** (419-818) | **1510** (1050-2150) | **3260** (1550-4420) | 752 |
| | 01-02 | **197** (159-243) | **184** (148-227) | **479** (387-651) | **1260** (983-1480) | **2060** (1470-3050) | 742 |
| 20 years and older | 99-00 | **190** (164-219) | **180** (140-220) | **482** (390-590) | **1340** (1010-1660) | **3480** (2230-4640) | 1456 |
| | 01-02 | **191** (171-214) | **181** (152-212) | **498** (441-567) | **1350** (1060-1660) | **2720** (2160-3670) | 1647 |
| **Gender** | | | | | | | |
| Males | 99-00 | **179** (149-215) | **154** (119-197) | **523** (372-650) | **1430** (1020-2280) | **3480** (2130-4560) | 1214 |
| | 01-02 | **182** (157-211) | **171** (139-199) | **502** (419-603) | **1450** (1060-2110) | **3050** (2110-4390) | 1371 |
| Females | 99-00 | **178** (154-206) | **174** (138-210) | **425** (350-508) | **977** (880-1230) | **2230** (1370-3880) | 1322 |
| | 01-02 | **174** (153-198) | **167** (139-194) | **427** (387-498) | **1050** (879-1310) | **1840** (1490-2500) | 1411 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **181** (157-209) | **174** (146-210) | **441** (390-541) | **1250** (851-1510) | **1720** (1460-2130) | 813 |
| | 01-02 | **226** (195-262) | **220** (190-264) | **530** (444-660) | **1490** (1050-2110) | **2590** (1540-4460) | 677 |
| Non-Hispanic blacks | 99-00 | **322** (275-377) | **306** (256-350) | **789** (635-949) | **1880** (1410-2270) | **3600** (2130-4640) | 603 |
| | 01-02 | **352** (324-384) | **357** (290-407) | **839** (709-1090) | **2160** (1620-2470) | **3540** (2810-5070) | 703 |
| Non-Hispanic whites | 99-00 | **152** (133-175) | **133** (108-157) | **366** (287-482) | **977** (798-1340) | **2470** (1590-3880) | 908 |
| | 01-02 | **158** (141-178) | **147** (119-177) | **413** (366-451) | **1020** (905-1230) | **2310** (1560-2720) | 1216 |

### 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.

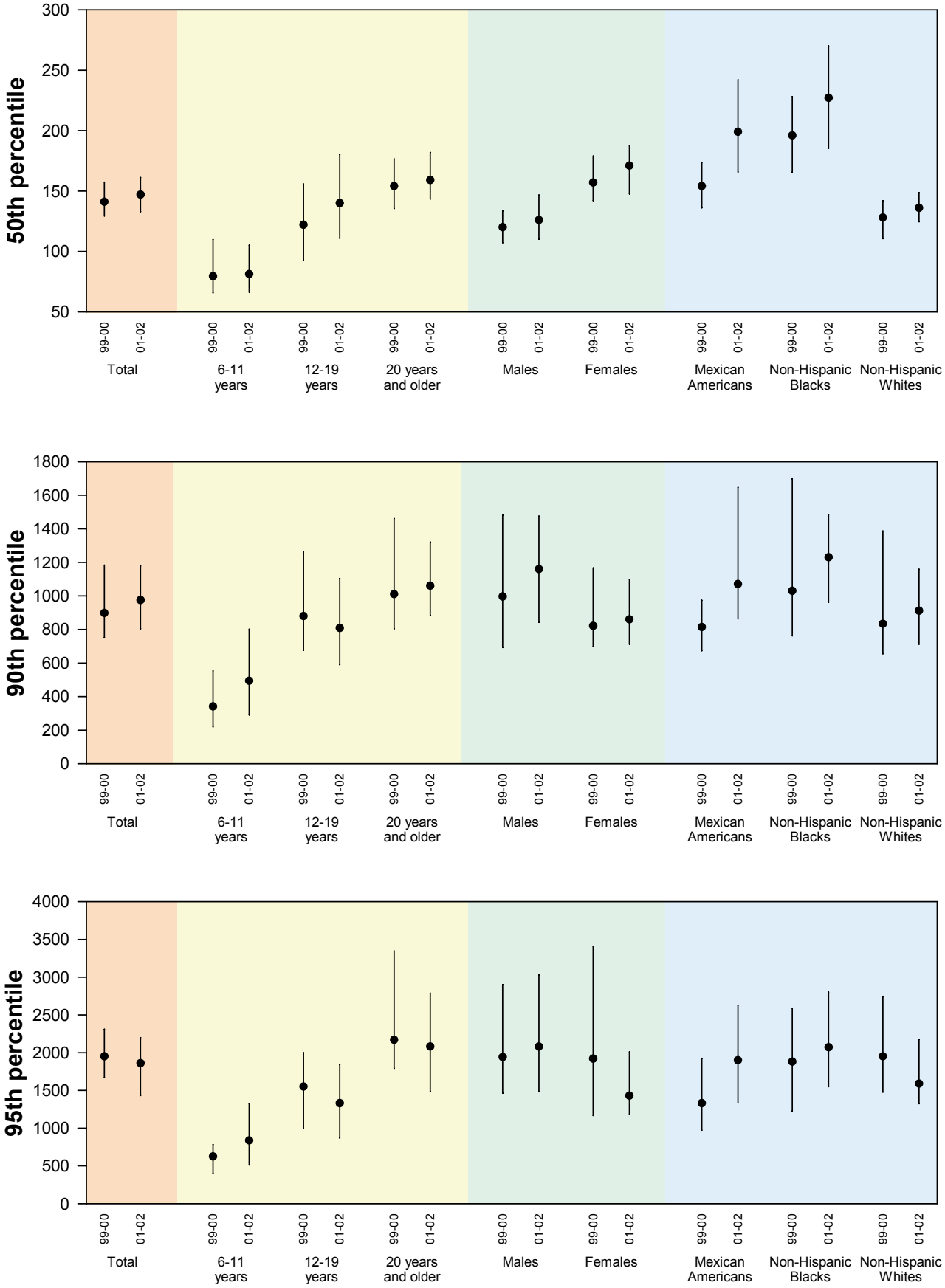
## Table 191. Mono-ethyl phthalate (creatinine corrected)

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 | **163** (149-178) | **141** (129-157) | **360** (307-422) | **898** (753-1180) | **1950** (1670-2310) | 2536 |
| | 01-02 | **167** (150-185) | **147** (133-161) | **388** (333-435) | **975** (804-1180) | **1860** (1430-2200) | 2772 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **92.6** (77.9-110) | **79.4** (65.7-110) | **165** (127-208) | **341** (219-554) | **625** (400-784) | 328 |
| | 01-02 | **96.9** (82.4-114) | **81.2** (66.3-105) | **171** (135-224) | **494** (290-802) | **837** (512-1320) | 392 |
| 12-19 years | 99-00 | **142** (119-169) | **122** (93.0-156) | **361** (275-495) | **879** (676-1260) | **1550** (1000-2000) | 752 |
| | 01-02 | **152** (126-184) | **140** (111-180) | **325** (249-409) | **808** (590-1100) | **1330** (868-1840) | 742 |
| 20 years and older | 99-00 | **179** (161-199) | **154** (136-177) | **390** (336-452) | **1010** (803-1460) | **2170** (1790-3350) | 1456 |
| | 01-02 | **181** (164-200) | **159** (143-182) | **419** (363-486) | **1060** (883-1320) | **2080** (1490-2790) | 1638 |
| **Gender** | | | | | | | |
| Males | 99-00 | **141** (124-159) | **120** (107-134) | **324** (249-415) | **996** (693-1480) | **1940** (1460-2900) | 1214 |
| | 01-02 | **147** (129-168) | **126** (110-147) | **347** (279-418) | **1160** (843-1480) | **2080** (1490-3030) | 1367 |
| Females | 99-00 | **187** (165-211) | **157** (142-179) | **377** (307-495) | **821** (697-1170) | **1920** (1170-3410) | 1322 |
| | 01-02 | **187** (166-210) | **171** (148-187) | **410** (356-476) | **860** (712-1100) | **1430** (1190-2010) | 1405 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **164** (142-190) | **154** (136-174) | **382** (314-472) | **814** (673-974) | **1330** (974-1920) | 813 |
| | 01-02 | **214** (183-250) | **199** (166-242) | **472** (396-572) | **1070** (862-1650) | **1900** (1330-2630) | 674 |
| Non-Hispanic blacks | 99-00 | **208** (183-236) | **196** (166-228) | **443** (390-505) | **1030** (762-1700) | **1880** (1230-2590) | 603 |
| | 01-02 | **247** (225-271) | **227** (185-270) | **557** (478-618) | **1230** (961-1480) | **2070** (1550-2800) | 702 |
| Non-Hispanic whites | 99-00 | **149** (135-165) | **128** (111-142) | **313** (239-387) | **834** (655-1390) | **1950** (1480-2740) | 908 |
| | 01-02 | **156** (141-173) | **136** (124-149) | **337** (288-402) | **911** (712-1160) | **1590** (1320-2170) | 1211 |

## Figure 20. Mono-ethyl phthalate (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.



# 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

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 | **24.6** (22.1-27.4) | **26.0** (23.6-29.2) | **51.6** (44.4-59.8) | **98.6** (90.2-114) | **149** (121-169) | 2541 |
| | 01-02 | **18.9** (17.4-20.6) | **20.4** (19.1-21.7) | **40.4** (36.5-44.2) | **73.6** (65.3-85.4) | **108** (94.1-122) | 2782 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **41.4** (35.6-48.0) | **40.0** (36.2-49.2) | **75.5** (59.1-92.8) | **124** (98.4-159) | **163** (127-279) | 328 |
| | 01-02 | **31.1** (26.6-36.5) | **32.4** (25.5-36.4) | **62.1** (51.3-76.9) | **107** (84.3-136) | **157** (110-290) | 393 |
| 12-19 years | 99-00 | **36.0** (30.8-42.1) | **36.1** (30.6-44.9) | **67.7** (55.9-79.7) | **119** (90.2-159) | **165** (121-227) | 752 |
| | 01-02 | **25.1** (21.6-29.2) | **26.4** (22.0-32.6) | **52.2** (48.1-60.4) | **92.4** (72.3-119) | **147** (105-183) | 742 |
| 20 years and older | 99-00 | **21.6** (19.0-24.5) | **23.0** (19.7-26.0) | **46.1** (36.6-53.5) | **95.0** (78.7-111) | **142** (117-161) | 1461 |
| | 01-02 | **17.0** (15.4-18.8) | **19.1** (17.1-20.4) | **35.1** (31.6-40.2) | **64.8** (57.3-79.7) | **95.4** (84.6-113) | 1647 |
| **Gender** | | | | | | | |
| Males | 99-00 | **22.0** (20.1-24.1) | **23.1** (20.3-26.1) | **43.1** (36.6-49.5) | **83.9** (71.3-96.2) | **115** (97.8-132) | 1215 |
| | 01-02 | **17.7** (16.0-19.6) | **19.3** (17.0-20.6) | **34.4** (30.3-40.6) | **62.1** (54.1-75.5) | **95.2** (75.5-117) | 1371 |
| Females | 99-00 | **27.3** (23.6-31.5) | **30.0** (25.9-33.3) | **59.5** (51.6-69.6) | **119** (98.3-145) | **167** (143-223) | 1326 |
| | 01-02 | **20.2** (18.2-22.4) | **21.6** (19.7-24.3) | **46.7** (43.1-51.1) | **85.0** (72.7-92.5) | **120** (106-136) | 1411 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **23.4** (21.8-25.1) | **26.3** (23.9-28.1) | **48.1** (41.2-56.7) | **92.2** (78.9-101) | **116** (104-131) | 814 |
| | 01-02 | **20.1** (16.6-24.5) | **23.0** (17.9-26.3) | **41.9** (34.0-51.2) | **76.9** (62.9-92.5) | **112** (84.6-143) | 677 |
| Non-Hispanic blacks | 99-00 | **37.0** (31.9-42.9) | **38.7** (33.4-44.5) | **78.2** (58.7-91.8) | **117** (107-143) | **167** (143-197) | 603 |
| | 01-02 | **29.6** (26.6-33.1) | **31.5** (28.7-34.1) | **58.0** (49.3-62.5) | **91.7** (79.5-121) | **138** (110-184) | 703 |
| Non-Hispanic whites | 99-00 | **21.8** (19.3-24.6) | **23.1** (19.5-27.5) | **45.9** (37.5-53.3) | **90.2** (74.7-106) | **138** (111-161) | 912 |
| | 01-02 | **17.6** (16.0-19.3) | **19.1** (17.0-20.9) | **36.5** (32.4-42.6) | **69.2** (59.2-87.6) | **107** (89.8-123) | 1216 |

Note: In 99-00, concentrations of mono-isobutyl phthalate and mono-n-butyl phthalate were measured together and expressed as a combined value.
For 01-02, mono-n-butyl phthalate levels were measured separately, and only mono-n-butyl phthalate levels are given in this table.

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 1999-2002 are six-fold lower than levels reported in German residents (Koch et al., 2003) and slightly lower than levels found in a small sample of pregnant women in New York City (Adibi et al.,2003).

### Comparing Adjusted Geometric Means

Geometric mean levels of urinary monobutyl phthalates 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 MnBP 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 were higher in females than in males.

In NHANES 2001-2002, adjusted geometric mean levels of urinary MiBP were higher in children aged 6-11 years than in people aged 12-19 years and 20 years. Levels were higher in females than in males. Non-Hispanic whites had lower levels than non-Hispanic blacks or Mexican Americans. 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 193. Mono-n-butyl phthalate (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 | **22.4** (20.6-24.4) | **21.9** (19.8-24.3) | **38.9** (35.0-41.8) | **68.3** (60.3-78.3) | **97.5** (81.4-131) | 2541 |
| | 01-02 | **17.8** (16.7-18.9) | **17.4** (16.3-18.3) | **30.4** (28.2-32.4) | **52.4** (47.3-61.1) | **81.3** (71.0-92.5) | 2772 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **41.9** (37.4-47.1) | **38.9** (34.3-49.0) | **65.7** (56.7-80.0) | **107** (71.2-179) | **159** (102-263) | 328 |
| | 01-02 | **35.5** (31.7-39.6) | **35.1** (29.3-38.9) | **55.4** (50.1-62.3) | **84.0** (69.0-113) | **146** (93.8-235) | 392 |
| 12-19 years | 99-00 | **24.3** (21.2-27.8) | **23.6** (20.6-27.4) | **37.6** (31.6-43.8) | **62.3** (52.4-76.4) | **88.1** (61.4-142) | 752 |
| | 01-02 | **19.4** (17.3-21.7) | **20.3** (17.5-22.3) | **34.9** (30.5-37.9) | **53.4** (45.2-73.9) | **88.6** (60.3-106) | 742 |
| 20 years and older | 99-00 | **20.4** (18.6-22.4) | **19.5** (18.1-21.4) | **34.9** (30.3-40.0) | **62.4** (53.4-72.1) | **91.0** (70.3-135) | 1461 |
| | 01-02 | **16.1** (15.0-17.3) | **15.4** (14.2-16.5) | **26.3** (24.2-28.6) | **44.3** (38.7-51.1) | **71.6** (61.2-85.6) | 1638 |
| **Gender** | | | | | | | |
| Males | 99-00 | **17.3** (16.1-18.6) | **17.0** (15.5-18.8) | **28.6** (25.8-32.1) | **49.1** (42.6-53.5) | **63.6** (57.3-71.5) | 1215 |
| | 01-02 | **14.4** (13.5-15.4) | **13.7** (13.0-14.9) | **22.9** (20.8-24.9) | **39.9** (35.6-44.0) | **60.0** (50.5-78.0) | 1367 |
| Females | 99-00 | **28.6** (25.3-32.3) | **28.6** (25.5-30.5) | **50.6** (41.9-56.3) | **84.3** (69.2-106) | **131** (93.6-155) | 1326 |
| | 01-02 | **21.7** (19.6-23.9) | **21.5** (19.7-23.6) | **35.9** (33.0-39.2) | **64.9** (58.9-70.2) | **91.5** (81.4-103) | 1405 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **21.2** (19.3-23.3) | **20.0** (18.2-22.9) | **40.1** (32.6-44.3) | **63.6** (57.5-70.1) | **81.6** (73.9-100) | 814 |
| | 01-02 | **19.0** (16.2-22.2) | **19.2** (16.3-21.4) | **33.3** (28.3-39.6) | **61.0** (43.9-84.0) | **86.7** (60.6-128) | 674 |
| Non-Hispanic blacks | 99-00 | **23.9** (21.3-26.8) | **25.0** (20.7-28.0) | **42.2** (35.9-49.6) | **69.6** (61.1-83.9) | **94.4** (83.9-105) | 603 |
| | 01-02 | **20.8** (18.7-23.0) | **20.2** (19.2-22.8) | **34.5** (30.8-36.6) | **61.9** (50.0-73.9) | **85.6** (71.6-99.0) | 702 |
| Non-Hispanic whites | 99-00 | **21.3** (19.1-23.8) | **20.5** (18.6-23.2) | **36.4** (31.5-41.0) | **67.1** (56.7-78.4) | **97.6** (73.5-142) | 912 |
| | 01-02 | **17.4** (16.3-18.6) | **16.5** (15.3-17.8) | **29.0** (26.6-32.2) | **50.7** (45.5-59.0) | **81.4** (68.5-103) | 1211 |

Note: In 99-00, concentrations of mono-isobutyl phthalate and mono-n-butyl phthalate were measured together and expressed as a combined value.
For 01-02, mono-n-butyl phthalate levels were measured separately, and only mono-n-butyl phthalate levels are given in this table.

## Table 194. Mono-isobutyl phthalate

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

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | **2.71** (2.49-2.94) | **2.60** (2.40-2.90) | **5.70** (5.30-6.00) | **11.9** (11.3-12.6) | **17.9** (16.3-19.8) | 2782 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | **4.22** (3.28-5.43) | **4.40** (3.10-6.10) | **10.7** (7.30-13.4) | **18.6** (14.2-22.0) | **23.4** (20.4-27.8) | 393 |
| 12-19 years | 01-02 | **3.48** (2.90-4.17) | **3.80** (2.90-4.40) | **7.30** (6.00-9.00) | **14.5** (11.7-18.6) | **22.2** (16.2-33.4) | 742 |
| 20 years and older | 01-02 | **2.46** (2.30-2.63) | **2.40** (2.10-2.50) | **5.00** (4.70-5.30) | **10.4** (9.40-12.0) | **16.3** (13.6-18.5) | 1647 |
| **Gender** | | | | | | | |
| Males | 01-02 | **2.73** (2.50-2.97) | **2.70** (2.40-3.10) | **5.60** (5.00-6.10) | **11.6** (10.1-12.6) | **16.6** (13.6-20.1) | 1371 |
| Females | 01-02 | **2.68** (2.44-2.96) | **2.50** (2.20-2.90) | **5.70** (5.20-6.20) | **12.6** (11.0-14.7) | **18.7** (16.3-24.0) | 1411 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | **3.26** (2.72-3.91) | **3.40** (2.60-4.10) | **7.10** (6.10-9.00) | **12.1** (11.1-14.5) | **18.3** (14.1-25.6) | 677 |
| Non-Hispanic blacks | 01-02 | **4.90** (4.46-5.37) | **5.30** (4.50-6.00) | **10.6** (9.20-12.0) | **18.3** (15.7-18.9) | **25.4** (20.5-30.8) | 703 |
| Non-Hispanic whites | 01-02 | **2.33** (2.10-2.59) | **2.20** (1.90-2.60) | **4.90** (4.40-5.30) | **9.60** (8.30-11.4) | **15.6** (13.0-18.6) | 1216 |

Note: In 99-00, concentrations of mono-isobutyl phthalate and mono-n-butyl phthalate were measured together and expressed as a combined value.
For 01-02, mono-isobutyl phthalate levels were measured separately, and only mono-isobutyl phthalate levels are given in this table.

## Table 195. Mono-isobutyl phthalate (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, 2001-2002.

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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** | | | | | | | |
| 6-11 years | 01-02 | **4.80** (3.89-5.93) | **5.17** (4.13-6.32) | **9.17** (7.03-11.6) | **15.0** (11.1-24.3) | **24.3** (13.8-40.3) | 392 |
| 12-19 years | 01-02 | **2.68** (2.29-3.15) | **2.83** (2.39-3.33) | **4.79** (4.04-5.51) | **7.60** (6.18-10.2) | **12.8** (8.76-15.6) | 742 |
| 20 years and older | 01-02 | **2.31** (2.18-2.45) | **2.24** (2.06-2.43) | **3.79** (3.64-4.22) | **7.13** (6.88-7.63) | **10.6** (9.46-11.3) | 1638 |
| **Gender** | | | | | | | |
| Males | 01-02 | **2.21** (2.08-2.35) | **2.16** (1.97-2.35) | **3.71** (3.58-4.04) | **7.18** (6.44-7.95) | **10.9** (10.0-12.5) | 1367 |
| Females | 01-02 | **2.87** (2.59-3.17) | **2.83** (2.51-3.18) | **5.10** (4.61-5.83) | **8.66** (8.02-10.1) | **13.5** (11.1-15.0) | 1405 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | **3.05** (2.55-3.66) | **2.98** (2.50-3.79) | **5.73** (4.86-6.99) | **10.5** (8.04-13.3) | **16.0** (12.2-19.4) | 674 |
| Non-Hispanic blacks | 01-02 | **3.43** (3.20-3.68) | **3.52** (2.95-3.81) | **6.10** (5.03-7.04) | **10.5** (8.80-12.6) | **15.6** (12.6-19.7) | 702 |
| Non-Hispanic whites | 01-02 | **2.29** (2.09-2.51) | **2.20** (1.99-2.43) | **3.77** (3.50-4.34) | **7.13** (6.67-7.78) | **10.7** (9.62-12.6) | 1211 |

Note: In 99-00, concentrations of mono-isobutyl phthalate and mono-n-butyl phthalate were measured together and expressed as a combined value.
For 01-02, mono-isobutyl phthalate levels were measured separately, and only mono-isobutyl phthalate levels are given in this table.

# 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).

### Table 196. Mono-benzyl phthalate

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

| | 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 | **15.3** (13.7-17.1) | **17.0** (15.3-18.9) | **35.3** (32.6-39.6) | **67.1** (55.3-82.0) | **103** (94.6-116) | 2541 |
| | 01-02 | **15.1** (13.9-16.3) | **15.7** (14.8-17.4) | **38.0** (34.5-41.2) | **80.8** (71.3-88.2) | **122** (102-142) | 2782 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **39.4** (32.9-47.2) | **40.3** (33.8-48.6) | **82.0** (55.8-98.1) | **128** (98.1-214) | **214** (108-399) | 328 |
| | 01-02 | **33.4** (29.1-38.4) | **37.0** (26.6-43.4) | **68.5** (61.6-92.8) | **166** (116-191) | **226** (183-330) | 393 |
| 12-19 years | 99-00 | **25.6** (21.9-30.0) | **28.3** (22.2-34.8) | **51.1** (43.7-58.5) | **87.9** (67.2-115) | **125** (93.7-170) | 752 |
| | 01-02 | **23.2** (19.9-27.2) | **24.7** (21.2-31.0) | **55.5** (47.4-62.9) | **113** (91.8-133) | **169** (134-198) | 742 |
| 20 years and older | 99-00 | **12.4** (10.9-14.2) | **13.8** (12.1-15.6) | **28.9** (25.2-33.1) | **52.0** (43.9-62.5) | **86.3** (54.7-119) | 1461 |
| | 01-02 | **12.7** (11.7-13.9) | **13.8** (12.8-14.9) | **31.8** (28.5-33.5) | **65.4** (53.8-76.3) | **99.7** (82.8-121) | 1647 |
| **Gender** | | | | | | | |
| Males | 99-00 | **16.2** (14.1-18.6) | **17.7** (15.0-19.9) | **35.4** (31.5-40.3) | **69.4** (59.9-87.2) | **108** (96.3-130) | 1215 |
| | 01-02 | **15.6** (13.6-17.9) | **16.0** (14.2-18.3) | **37.0** (33.1-43.0) | **78.4** (63.5-97.4) | **122** (88.1-178) | 1371 |
| Females | 99-00 | **14.6** (12.7-16.6) | **16.0** (14.2-19.2) | **35.8** (30.8-41.4) | **63.7** (53.7-82.4) | **103** (84.2-116) | 1326 |
| | 01-02 | **14.6** (13.1-16.3) | **15.4** (13.7-17.9) | **38.1** (32.2-42.9) | **81.4** (68.3-91.6) | **122** (102-143) | 1411 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **13.9** (12.1-16.1) | **15.7** (13.4-16.8) | **33.0** (27.5-36.1) | **67.5** (55.5-84.0) | **98.3** (80.6-150) | 814 |
| | 01-02 | **13.2** (10.8-16.2) | **14.7** (10.8-18.5) | **29.5** (25.5-38.0) | **70.3** (53.0-85.4) | **91.6** (70.3-161) | 677 |
| Non-Hispanic blacks | 99-00 | **23.0** (20.7-25.5) | **23.0** (20.5-25.6) | **49.3** (43.4-55.6) | **94.0** (80.0-130) | **138** (106-241) | 603 |
| | 01-02 | **23.8** (21.0-26.9) | **24.2** (19.9-28.0) | **50.6** (41.5-62.9) | **101** (86.4-127) | **139** (127-179) | 703 |
| Non-Hispanic whites | 99-00 | **14.3** (12.7-16.1) | **16.1** (14.2-18.5) | **33.9** (30.6-38.4) | **58.7** (51.3-74.1) | **103** (74.1-116) | 912 |
| | 01-02 | **14.0** (12.7-15.4) | **14.6** (13.3-15.5) | **35.3** (32.2-39.5) | **76.6** (66.1-90.3) | **121** (93.2-155) | 1216 |

### Comparing Adjusted Geometric Means

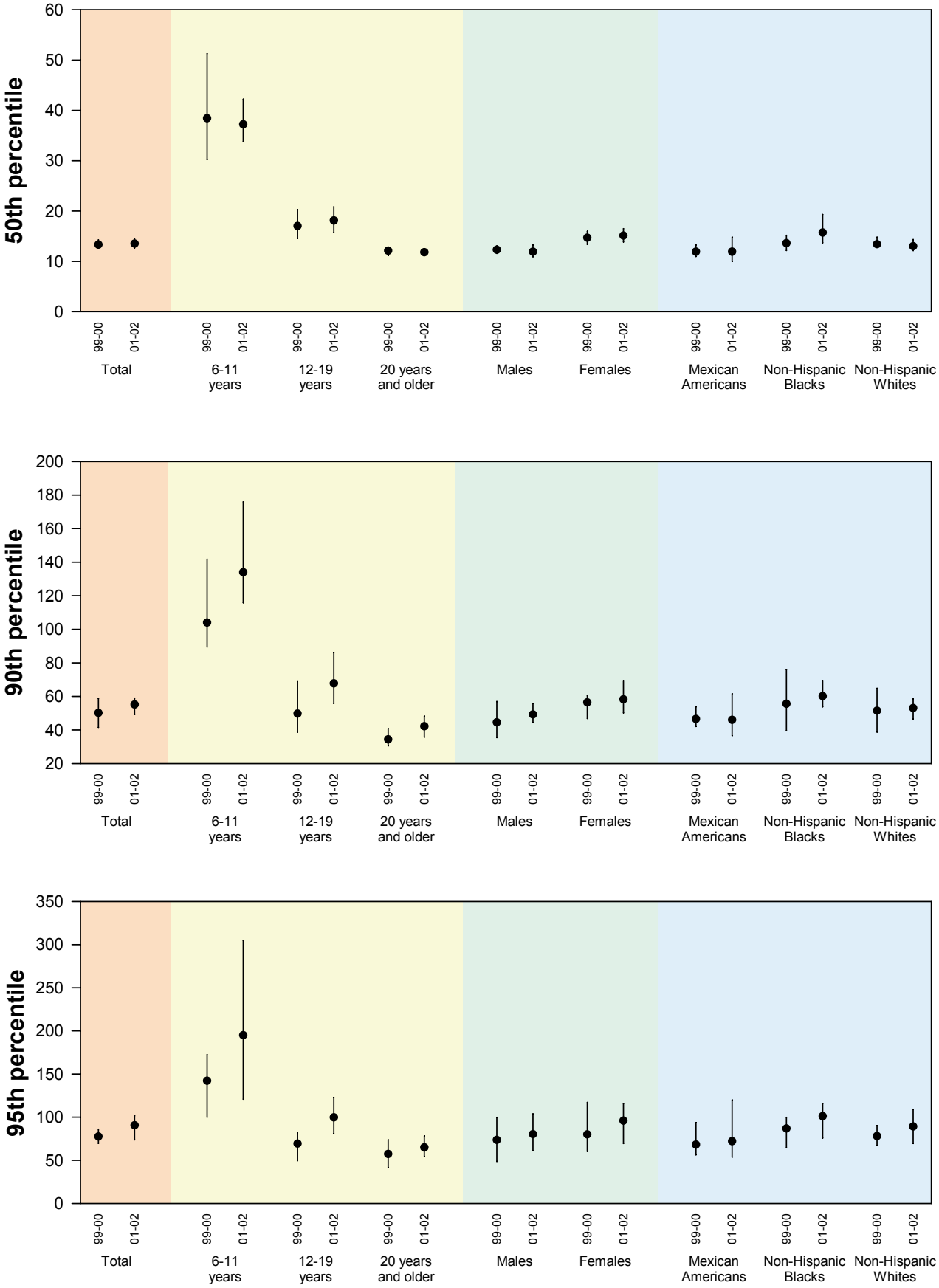
Geometric mean levels of urinary mono-benzyl phthalate for the demographic groups were compared after adjusting for the covariates of race/ethnicity, age, gender, and urinary creatinine (data not shown). In NHANES 2001-2002, adjusted geometric mean levels of urinary mono-benzyl phthalate were higher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

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 | **14.0** (13.0-15.0) | **13.3** (12.8-14.3) | **25.1** (23.4-27.2) | **50.1** (41.5-58.8) | **77.4** (69.6-86.3) | 2541 |
| | 01-02 | **14.1** (13.2-15.1) | **13.5** (12.7-14.4) | **26.6** (24.9-29.3) | **55.1** (49.2-59.0) | **90.4** (73.6-102) | 2772 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **40.0** (33.6-47.6) | **38.4** (30.2-51.3) | **73.2** (56.6-99.1) | **104** (89.4-142) | **142** (99.8-173) | 328 |
| | 01-02 | **38.1** (34.5-42.1) | **37.2** (33.8-42.2) | **67.9** (55.8-80.4) | **134** (116-176) | **195** (121-305) | 392 |
| 12-19 years | 99-00 | **17.3** (15.4-19.4) | **17.0** (14.6-20.3) | **28.3** (24.3-34.8) | **49.7** (38.8-69.2) | **69.3** (49.6-81.9) | 752 |
| | 01-02 | **17.9** (15.7-20.5) | **18.1** (15.7-20.8) | **33.9** (29.3-38.6) | **67.7** (55.8-85.9) | **99.7** (80.7-123) | 742 |
| 20 years and older | 99-00 | **11.8** (10.7-12.9) | **12.1** (11.1-12.9) | **20.1** (18.4-23.3) | **34.3** (30.5-40.8) | **57.2** (41.3-73.9) | 1461 |
| | 01-02 | **12.0** (11.2-12.9) | **11.8** (11.2-12.5) | **21.6** (19.9-23.7) | **42.2** (35.7-48.3) | **64.9** (54.5-78.3) | 1638 |
| **Gender** | | | | | | | |
| Males | 99-00 | **12.7** (11.8-13.6) | **12.3** (11.6-13.0) | **23.7** (21.5-26.1) | **44.5** (35.5-57.0) | **73.5** (48.5-99.8) | 1215 |
| | 01-02 | **12.7** (11.4-14.2) | **11.9** (10.9-13.2) | **24.0** (21.2-26.4) | **49.2** (44.3-55.9) | **80.3** (60.9-104) | 1367 |
| Females | 99-00 | **15.3** (13.8-16.8) | **14.7** (13.3-16.0) | **25.9** (24.1-29.3) | **56.4** (46.8-60.6) | **80.0** (60.1-117) | 1326 |
| | 01-02 | **15.7** (14.2-17.3) | **15.1** (13.8-16.5) | **29.5** (25.9-34.3) | **58.2** (50.2-69.4) | **95.8** (69.4-116) | 1405 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **12.6** (11.4-14.0) | **11.9** (10.9-13.2) | **24.1** (21.5-26.5) | **46.5** (42.0-53.8) | **68.1** (56.4-93.8) | 814 |
| | 01-02 | **12.4** (10.7-14.4) | **11.9** (9.97-14.8) | **23.7** (19.7-29.3) | **46.0** (36.5-61.6) | **72.0** (53.5-120) | 674 |
| Non-Hispanic blacks | 99-00 | **14.8** (13.5-16.3) | **13.6** (12.2-15.2) | **26.9** (22.5-31.8) | **55.5** (39.5-76.0) | **86.8** (64.4-99.8) | 603 |
| | 01-02 | **16.7** (14.7-19.0) | **15.7** (13.7-19.3) | **33.4** (26.5-38.0) | **60.1** (53.7-69.4) | **101** (75.6-116) | 702 |
| Non-Hispanic whites | 99-00 | **14.0** (12.7-15.3) | **13.4** (12.8-14.8) | **25.2** (23.1-27.4) | **51.5** (38.8-64.8) | **77.9** (67.4-90.3) | 912 |
| | 01-02 | **13.9** (12.9-15.0) | **13.0** (12.1-14.3) | **25.7** (24.0-28.1) | **53.0** (46.5-58.5) | **89.2** (69.4-109) | 1211 |

**Figure 21. Mono-benzyl phthalate (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.



# 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 90th and 95th percentiles.

## Table 198. Mono-cyclohexyl phthalate

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

| | 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** | **1.00** (<LOD-1.60) | 2541 |
| | 01-02 | * | **< LOD** | **< LOD** | **.400** (<LOD-.400) | **.400** (.400-.500) | 2782 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **< LOD** | **< LOD** | **1.00** (<LOD-1.10) | **1.70** (1.00-3.80) | 328 |
| | 01-02 | * | **< LOD** | **< LOD** | **.300** (.300-.500) | **.600** (.500-.700) | 393 |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **1.00** (<LOD-1.50) | **1.70** (1.00-2.40) | 752 |
| | 01-02 | * | **< LOD** | **< LOD** | **.400** (<LOD-.400) | **.500** (.400-.600) | 742 |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1461 |
| | 01-02 | * | **< LOD** | **< LOD** | **.400** (<LOD-.400) | **.500** (.400-.500) | 1647 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **1.00** (<LOD-2.00) | 1215 |
| | 01-02 | * | **< LOD** | **< LOD** | **.400** (<LOD-.400) | **.500** (.400-.500) | 1371 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **1.00** (<LOD-1.70) | 1326 |
| | 01-02 | * | **< LOD** | **< LOD** | **.400** (<LOD-.400) | **.500** (.400-.500) | 1411 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 814 |
| | 01-02 | * | **< LOD** | **< LOD** | **.400** (<LOD-.400) | **.500** (.300-.600) | 677 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **1.00** (.900-1.20) | 603 |
| | 01-02 | * | **< LOD** | **< LOD** | **.300** (<LOD-.400) | **.400** (.400-.600) | 703 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.900** (<LOD-1.30) | 912 |
| | 01-02 | * | **< LOD** | **< LOD** | **.400** (<LOD-.400) | **.500** (.400-.500) | 1216 |

< 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 199. Mono-cyclohexyl phthalate (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 | * | **< LOD** | **< LOD** | **< LOD** | **3.00** (2.60-3.33) | 2541 |
| | 01-02 | * | **< LOD** | **< LOD** | **.588** (.513-.667) | **.854** (.769-.952) | 2772 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **< LOD** | **< LOD** | **1.50** (1.20-1.94) | **2.82** (1.54-6.44) | 328 |
| | 01-02 | * | **< LOD** | **< LOD** | **.667** (.513-.741) | **.909** (.690-1.17) | 392 |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **1.22** (.952-1.46) | **1.67** (1.36-1.82) | 752 |
| | 01-02 | * | **< LOD** | **< LOD** | **.465** (.385-.659) | **.769** (.526-1.02) | 742 |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1461 |
| | 01-02 | * | **< LOD** | **< LOD** | **.606** (.513-.669) | **.870** (.755-.952) | 1638 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **2.14** (1.62-3.16) | 1215 |
| | 01-02 | * | **< LOD** | **< LOD** | **.500** (.417-.625) | **.800** (.667-1.00) | 1367 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **3.28** (2.86-3.51) | 1326 |
| | 01-02 | * | **< LOD** | **< LOD** | **.667** (.588-.755) | **.870** (.769-.952) | 1405 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 814 |
| | 01-02 | * | **< LOD** | **< LOD** | **.556** (.476-.669) | **.882** (.690-1.04) | 674 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **1.43** (1.09-1.71) | 603 |
| | 01-02 | * | **< LOD** | **< LOD** | **.408** (.357-.465) | **.588** (.500-.723) | 702 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **3.00** (2.60-3.53) | 912 |
| | 01-02 | * | **< LOD** | **< LOD** | **.606** (.492-.690) | **.870** (.690-.952) | 1211 |

< 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.

# 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, food containers, 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.

DEHP is metabolized into various metabolites (Albro et al., 1982; Dirven et al., 1993; Kato et al., 2004; Barr et al., 2003; Koch et al., 2003). Three of these metabolites, measured for this *Report* are mono-(2-ethyl-5-hexyl) phthalate (MEHP), mono-(2-ethyl-5-oxohexyl) phthalate (MEOHP), mono-(2-ethyl-5-hydroxyhexyl) phthalate (MEHHP).

MEHP is primarily formed by the hydrolysis of DEHP in

### Table 200. Mono-2-ethylhexyl phthalate

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

| | 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 | **3.43** (3.19-3.69) | **3.20** (2.90-3.50) | **7.60** (6.80-8.20) | **14.8** (13.5-17.4) | **23.8** (19.2-28.6) | 2541 |
| | 01-02 | **4.27** (3.80-4.79) | **4.10** (3.60-4.90) | **9.80** (8.40-11.6) | **22.8** (18.9-27.4) | **38.9** (31.8-50.0) | 2782 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **5.12** (4.42-5.92) | **4.90** (3.30-5.80) | **11.1** (8.30-13.6) | **19.0** (13.8-36.1) | **34.5** (15.6-130) | 328 |
| | 01-02 | **4.41** (3.90-5.00) | **4.40** (4.10-5.30) | **9.20** (7.80-11.7) | **19.3** (14.6-25.9) | **29.9** (20.7-47.4) | 393 |
| 12-19 years | 99-00 | **3.75** (3.24-4.35) | **3.70** (2.80-4.60) | **8.10** (6.40-9.40) | **15.0** (11.4-20.5) | **22.8** (19.1-29.2) | 752 |
| | 01-02 | **4.57** (3.96-5.27) | **4.50** (3.70-5.10) | **11.0** (9.50-13.5) | **23.0** (17.6-31.7) | **42.5** (25.9-57.5) | 742 |
| 20 years and older | 99-00 | **3.21** (2.94-3.51) | **3.00** (2.70-3.30) | **7.20** (6.40-8.00) | **14.2** (12.1-16.8) | **22.4** (17.5-27.0) | 1461 |
| | 01-02 | **4.20** (3.63-4.86) | **4.10** (3.40-4.80) | **9.40** (8.10-11.9) | **23.5** (18.0-29.8) | **39.5** (30.3-57.1) | 1647 |
| **Gender** | | | | | | | |
| Males | 99-00 | **3.68** (3.31-4.10) | **3.40** (2.90-3.90) | **8.00** (7.30-8.80) | **16.0** (14.0-19.0) | **25.3** (19.5-36.7) | 1215 |
| | 01-02 | **4.31** (3.84-4.83) | **4.30** (3.70-5.10) | **9.60** (8.20-11.1) | **23.0** (16.9-29.8) | **37.9** (29.9-48.4) | 1371 |
| Females | 99-00 | **3.21** (2.91-3.54) | **3.00** (2.80-3.40) | **7.00** (5.70-8.20) | **13.5** (11.4-15.3) | **21.6** (15.6-28.5) | 1326 |
| | 01-02 | **4.23** (3.67-4.86) | **4.10** (3.40-4.80) | **9.70** (8.40-12.2) | **23.0** (19.4-28.4) | **42.5** (31.4-53.7) | 1411 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **3.49** (3.16-3.85) | **3.50** (2.90-3.80) | **7.00** (5.70-8.60) | **13.3** (10.7-18.7) | **23.9** (17.4-27.3) | 814 |
| | 01-02 | **4.32** (3.75-4.98) | **4.70** (3.80-5.70) | **10.1** (8.30-11.0) | **19.4** (16.6-23.0) | **28.4** (24.2-39.9) | 677 |
| Non-Hispanic blacks | 99-00 | **4.82** (3.92-5.93) | **5.10** (4.10-5.80) | **9.40** (7.60-11.4) | **19.5** (12.9-26.5) | **29.2** (18.6-60.3) | 603 |
| | 01-02 | **6.60** (5.57-7.82) | **6.70** (5.40-8.10) | **15.4** (13.0-18.7) | **32.7** (26.5-41.4) | **52.1** (41.0-84.0) | 703 |
| Non-Hispanic whites | 99-00 | **3.16** (2.89-3.46) | **2.80** (2.50-3.10) | **7.30** (6.30-8.20) | **14.4** (12.2-17.0) | **22.4** (16.9-28.5) | 912 |
| | 01-02 | **3.85** (3.37-4.40) | **3.60** (3.10-4.30) | **8.60** (7.70-9.90) | **20.9** (17.3-25.9) | **37.9** (29.9-49.5) | 1216 |

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 Human Reproduction, 2003). DEHP has also been observed to suppress estradiol production in female rats (Lovecamp-Swan and Davis, 2003). Recently, the U.S. Food and Drug Administration (U.S. FDA) considered the amounts of DEHP or MEHP received from intravenous delivery systems or blood transfusions (MEHP is formed in situ in blood from DEHP) to be below thresholds likely to cause injury in adults. However, in lifesaving instances during which neonates would receive exchange blood transfusions, relatively higher exposures might occur (http://www.fda.gov/cdrh/ost/dehp-pvc.pdf; Calafat et al., 2004).

Workplace air standards for external exposure to DEHP are generally established by OSHA and ACGIH. It is classified as a probable human carcinogen by the U.S. EPA, reasonably anticipated to be a human carcinogen by NTP, but considered not classifiable by IARC.

### Interpreting Levels of Urinary Di-2-ethylhexyl Phthalate Metabolites in the Tables

The levels of MEHP in the NHANES 2001-2002 subsample appear roughly comparable to those reported previously for U.S. residents (Blount et al., 2000) and in a small sample of pregnant women in New York City (Adibi et al., 2003), and in men from an infertility clinic (Duty et al., 2004). Levels of MEHP, MEOHP, and MHHP were similar or up to two-fold higher in a sample of German residents (Koch et al., 2003) and German children (Koch et al., 2004; Becker et al., 2004).

## Table 201. Mono-2-ethylhexyl phthalate (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 | **3.12** (2.95-3.31) | **3.08** (2.82-3.27) | **5.88** (5.38-6.25) | **10.8** (9.62-12.5) | **18.5** (15.0-21.8) | 2541 |
| | 01-02 | **3.99** (3.57-4.46) | **3.89** (3.42-4.44) | **7.94** (7.14-9.02) | **18.2** (15.4-21.6) | **32.8** (25.2-42.9) | 2772 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **5.19** (4.55-5.93) | **5.37** (4.52-5.95) | **9.11** (8.06-11.4) | **21.6** (11.5-41.9) | **41.9** (13.5-86.2) | 328 |
| | 01-02 | **5.02** (4.47-5.64) | **5.38** (4.51-6.21) | **9.82** (7.87-11.0) | **20.9** (13.7-28.8) | **31.2** (24.3-40.7) | 392 |
| 12-19 years | 99-00 | **2.53** (2.14-2.99) | **2.31** (2.05-2.76) | **5.83** (4.38-6.29) | **9.63** (7.41-11.5) | **12.1** (10.5-17.3) | 752 |
| | 01-02 | **3.53** (3.09-4.03) | **3.62** (2.89-4.48) | **7.45** (6.51-8.67) | **15.2** (11.7-21.9) | **25.2** (17.7-32.8) | 742 |
| 20 years and older | 99-00 | **3.03** (2.83-3.25) | **2.98** (2.73-3.23) | **5.55** (4.90-6.06) | **10.0** (8.60-12.9) | **17.5** (13.8-22.1) | 1461 |
| | 01-02 | **3.96** (3.48-4.50) | **3.81** (3.24-4.37) | **7.77** (6.88-9.00) | **18.4** (15.3-22.1) | **33.3** (23.1-47.9) | 1638 |
| **Gender** | | | | | | | |
| Males | 99-00 | **2.89** (2.60-3.22) | **2.76** (2.52-2.96) | **5.58** (4.71-6.08) | **10.3** (9.35-12.4) | **21.6** (14.1-27.7) | 1215 |
| | 01-02 | **3.49** (3.06-3.98) | **3.32** (2.76-3.90) | **7.00** (6.46-7.77) | **16.2** (12.9-20.9) | **31.2** (20.1-49.9) | 1367 |
| Females | 99-00 | **3.36** (3.11-3.63) | **3.33** (2.90-3.80) | **6.15** (5.55-6.77) | **11.1** (9.02-14.0) | **16.3** (12.4-24.6) | 1326 |
| | 01-02 | **4.53** (4.01-5.11) | **4.43** (3.79-5.13) | **9.17** (7.93-10.3) | **20.4** (16.6-24.8) | **35.1** (27.7-42.0) | 1405 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **3.16** (2.72-3.68) | **3.15** (2.52-3.81) | **5.88** (4.86-7.24) | **11.6** (9.63-13.1) | **15.7** (12.6-23.1) | 814 |
| | 01-02 | **4.05** (3.57-4.61) | **4.16** (3.75-4.89) | **7.76** (6.47-9.60) | **16.4** (13.5-18.9) | **24.5** (19.8-28.7) | 674 |
| Non-Hispanic blacks | 99-00 | **3.11** (2.59-3.73) | **3.13** (2.50-3.61) | **5.84** (4.43-7.32) | **10.2** (8.05-15.6) | **18.4** (11.6-35.2) | 603 |
| | 01-02 | **4.63** (3.95-5.42) | **4.59** (3.97-5.02) | **9.89** (7.95-12.5) | **21.2** (16.0-33.2) | **39.8** (27.1-48.1) | 702 |
| Non-Hispanic whites | 99-00 | **3.09** (2.84-3.36) | **3.08** (2.73-3.47) | **5.87** (5.11-6.67) | **10.6** (8.95-13.5) | **20.0** (13.7-23.9) | 912 |
| | 01-02 | **3.80** (3.33-4.33) | **3.63** (3.11-4.32) | **7.71** (6.63-9.17) | **17.0** (13.8-21.8) | **32.8** (21.5-46.9) | 1211 |

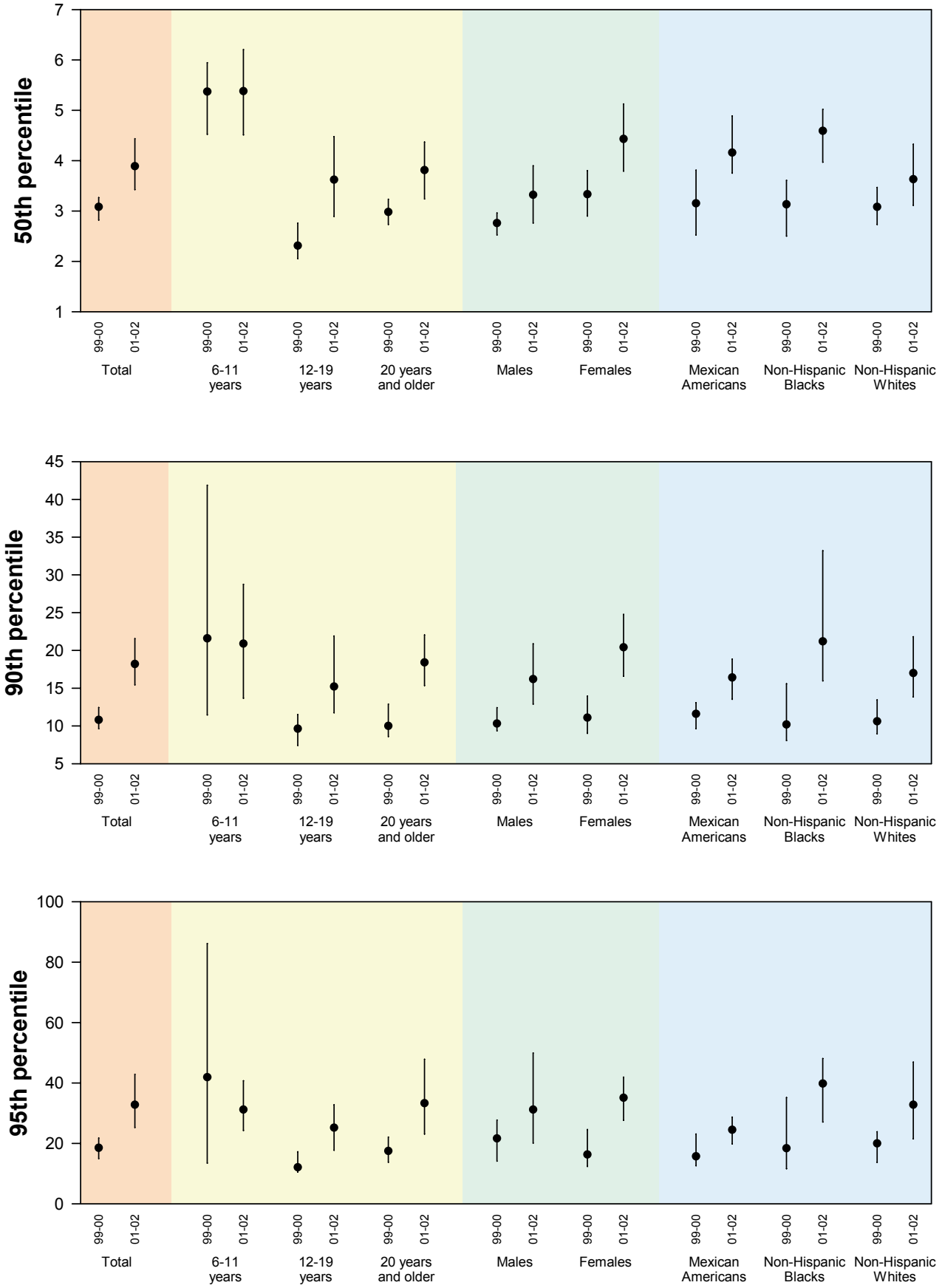
### Comparing Adjusted Geometric Means

Geometric mean levels of urinary MEHP 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 MEHP were higher in children aged 6-11 years than in people aged 12-19 years and 20 years. Females had slightly higher levels than in males. Adjusted geometric mean levels in non-Hispanic blacks were higher than levels in non-Hispanic whites.

Geometric mean levels of urinary MEOHP and MEHHP for the demographic groups were compared after adjusting for the covariates of race/ethnicity, age, gender, and urinary creatinine. In the NHANES 2001-2002 subsample (not measured in NHANES 1999-2000), levels of MEOHP and MEHHP were found to be higher in children aged 6-11 years than in people aged 12-19 years and 20 years and older. For MEOHP, females had slightly higher levels than males. 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. Koch et al. (2004) showed that levels of MEHP, MEOHP, and MEHHP were higher in nursery school children (aged 2-6 years) than in their teachers or parents. In another study of children (Becker et al., 2004), boys showed higher levels of all three DEHP metabolites than girls, and lower concentrations of MEHHP and MEOHP were seen in children aged 13-14 years compared with younger children.

## Figure 22. Mono-2-ethylhexyl phthalate (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 202. Mono-(2-ethyl-5-hydroxyhexyl) phthalate

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

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | **20.0** (17.8-22.5) | **20.1** (17.8-22.4) | **43.6** (38.0-49.7) | **91.3** (77.0-108) | **192** (131-256) | 2782 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | **33.6** (29.7-37.9) | **32.9** (26.9-39.1) | **66.9** (49.7-74.0) | **126** (103-148) | **210** (137-280) | 393 |
| 12-19 years | 01-02 | **24.9** (21.3-29.1) | **25.2** (22.9-31.3) | **50.6** (40.7-64.5) | **107** (78.5-148) | **202** (114-280) | 742 |
| 20 years and older | 01-02 | **18.1** (15.7-20.9) | **17.7** (14.7-20.7) | **39.8** (32.5-47.8) | **86.2** (65.7-107) | **175** (110-279) | 1647 |
| **Gender** | | | | | | | |
| Males | 01-02 | **22.0** (19.5-24.7) | **21.2** (19.4-23.9) | **47.8** (40.9-54.3) | **94.2** (80.8-110) | **212** (130-256) | 1371 |
| Females | 01-02 | **18.3** (15.7-21.4) | **18.2** (14.9-22.1) | **39.8** (34.2-46.0) | **86.0** (69.4-115) | **170** (119-273) | 1411 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | **18.5** (16.2-21.1) | **19.0** (16.2-21.6) | **36.3** (31.6-44.0) | **79.9** (66.4-93.9) | **123** (100-161) | 677 |
| Non-Hispanic blacks | 01-02 | **29.8** (26.1-34.1) | **30.9** (27.2-34.3) | **61.9** (52.6-68.3) | **126** (108-157) | **276** (157-339) | 703 |
| Non-Hispanic whites | 01-02 | **19.1** (16.7-21.9) | **19.2** (16.8-21.3) | **41.7** (35.3-50.7) | **91.1** (75.6-110) | **212** (130-275) | 1216 |

## Table 203. Mono-(2-ethyl-5-hydroxyhexyl) phthalate (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, 2001-2002.

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | **18.8** (17.0-20.8) | **16.6** (14.9-18.6) | **32.3** (27.8-37.2) | **70.8** (58.4-88.3) | **147** (101-200) | 2772 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | **38.3** (34.3-42.6) | **34.2** (29.9-38.9) | **60.4** (51.9-76.4) | **107** (96.3-147) | **211** (122-313) | 392 |
| 12-19 years | 01-02 | **19.2** (17.0-21.8) | **17.7** (15.6-20.0) | **34.9** (29.2-42.6) | **73.4** (58.4-80.7) | **102** (86.6-160) | 742 |
| 20 years and older | 01-02 | **17.2** (15.2-19.4) | **15.0** (13.3-16.7) | **27.7** (23.2-34.7) | **63.2** (48.3-88.3) | **134** (84.7-207) | 1638 |
| **Gender** | | | | | | | |
| Males | 01-02 | **17.9** (16.2-19.7) | **15.4** (13.8-17.8) | **32.4** (28.0-37.2) | **73.4** (55.3-91.8) | **136** (97.7-224) | 1367 |
| Females | 01-02 | **19.7** (17.3-22.5) | **17.6** (15.4-19.5) | **32.3** (26.8-38.9) | **69.3** (57.6-93.7) | **160** (93.7-201) | 1405 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | **17.5** (15.9-19.2) | **15.7** (14.6-17.6) | **30.7** (26.1-35.7) | **65.3** (50.6-83.9) | **106** (76.3-130) | 674 |
| Non-Hispanic blacks | 01-02 | **21.0** (18.8-23.3) | **19.7** (17.5-21.8) | **38.3** (32.1-46.0) | **93.5** (69.2-124) | **161** (130-183) | 702 |
| Non-Hispanic whites | 01-02 | **19.0** (17.1-21.1) | **16.3** (14.8-18.4) | **32.4** (27.6-37.3) | **71.5** (57.8-94.3) | **178** (99.3-242) | 1211 |

## Table 204. Mono-(2-ethyl-5-oxohexyl) phthalate

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

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | **13.5** (12.0-15.0) | **14.0** (12.5-15.1) | **29.6** (25.2-34.0) | **59.9** (50.4-70.9) | **120** (87.2-156) | 2782 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | **23.3** (20.9-26.1) | **22.6** (18.5-28.1) | **46.5** (38.1-52.0) | **80.5** (64.7-109) | **142** (93.9-178) | 393 |
| 12-19 years | 01-02 | **17.5** (15.1-20.3) | **18.5** (16.0-20.7) | **35.0** (27.6-42.1) | **69.9** (52.2-104) | **118** (74.0-174) | 742 |
| 20 years and older | 01-02 | **12.0** (10.5-13.9) | **12.2** (10.4-14.1) | **25.9** (21.3-32.1) | **52.3** (41.8-68.3) | **115** (74.9-160) | 1647 |
| **Gender** | | | | | | | |
| Males | 01-02 | **14.5** (13.0-16.2) | **14.6** (13.0-16.1) | **31.6** (25.6-34.7) | **60.4** (52.3-71.4) | **129** (84.4-167) | 1371 |
| Females | 01-02 | **12.5** (10.8-14.6) | **13.0** (10.9-14.9) | **28.1** (23.7-33.5) | **57.5** (45.8-72.7) | **115** (81.8-147) | 1411 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | **13.1** (11.6-14.9) | **13.2** (11.6-15.0) | **25.3** (21.6-30.8) | **56.6** (40.6-70.3) | **76.5** (70.5-101) | 677 |
| Non-Hispanic blacks | 01-02 | **19.6** (17.1-22.5) | **20.0** (17.9-22.4) | **39.0** (34.8-44.2) | **80.5** (71.4-97.4) | **148** (102-228) | 703 |
| Non-Hispanic whites | 01-02 | **12.8** (11.2-14.6) | **13.1** (11.6-14.6) | **28.5** (23.6-34.0) | **58.6** (48.8-70.9) | **126** (83.7-172) | 1216 |

## Table 205. Mono-(2-ethyl-5-oxohexyl) phthalate (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, 2001-2002.

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | **12.6** (11.5-13.9) | **11.2** (10.2-12.3) | **21.3** (18.3-23.9) | **45.1** (37.1-58.1) | **87.5** (69.0-124) | 2772 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | **26.6** (24.0-29.4) | **22.8** (20.3-25.0) | **43.3** (33.6-48.2) | **74.4** (69.0-91.9) | **130** (83.0-187) | 392 |
| 12-19 years | 01-02 | **13.5** (12.0-15.2) | **12.0** (10.8-14.3) | **23.4** (19.9-28.5) | **48.4** (39.2-54.9) | **70.5** (55.0-97.2) | 742 |
| 20 years and older | 01-02 | **11.4** (10.2-12.8) | **10.1** (8.90-11.4) | **17.5** (15.2-21.9) | **39.0** (30.3-53.9) | **84.3** (53.1-134) | 1638 |
| **Gender** | | | | | | | |
| Males | 01-02 | **11.8** (10.7-13.0) | **10.2** (8.93-11.7) | **21.0** (18.5-23.0) | **46.1** (34.9-58.7) | **83.1** (69.7-104) | 1367 |
| Females | 01-02 | **13.5** (11.9-15.3) | **12.0** (10.8-13.7) | **21.5** (18.0-25.9) | **44.8** (36.8-61.9) | **92.3** (59.3-139) | 1405 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | **12.4** (11.4-13.5) | **10.8** (10.5-12.4) | **20.8** (18.5-24.4) | **46.4** (33.4-56.5) | **65.8** (53.1-83.1) | 674 |
| Non-Hispanic blacks | 01-02 | **13.8** (12.3-15.4) | **13.0** (12.0-14.1) | **23.9** (20.0-29.2) | **58.3** (45.3-77.7) | **101** (81.3-124) | 702 |
| Non-Hispanic whites | 01-02 | **12.7** (11.4-14.1) | **11.2** (9.91-12.3) | **21.0** (18.0-24.0) | **45.8** (36.2-66.0) | **96.0** (68.5-161) | 1211 |

# Mono-3-carboxypropyl Phthalate

# Mono-n-octyl Phthalate

CAS No. 5393-19-1

*Metabolites of di-n-octyl phthalate, CAS No. 117-84-0*

### General Information

Di-n-octylphthalate (DOP) is used primarily to produce flexible plastics. People exposed to DOP will excrete primarily mono-3-carboxypropyl phthalate (MCPP) and smaller amounts of mono-n-octyl phthalate (MOP) in their urine. Workplace air standards for external exposure are established for DOP by OSHA. Like other phthalates, DOP has low acute toxicity. It has not been classified with respect to carcinogenicity by IARC and NTP.

### Interpreting Levels of Urinary Mono-3-carboxypropyl and Mono-n-octyl Phthalates in the Tables

In both the NHANES 1999-2000 and 2001-2002 subsamples, MOP was only detectable at the 90th and 95th percentiles. A low detection rate was also reported in a small sample of German residents (Koch et al., 2003). MCPP levels were measured only in the 2001-2002 subsample and were higher in children aged 6-11 years than in people aged 12-19 years and 20 years and older; the group aged 12-19 years had higher levels than in the group aged 20 years and older. Females had slightly higher levels than males. Additionally, levels of MCPP were lower in non-Hispanic blacks than in either non-Hispanic whites or Mexican Americans. 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 206. Mono-3-carboxypropyl phthalate

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

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | **2.75** (2.49-3.04) | **3.00** (2.80-3.30) | **5.70** (5.00-6.30) | **10.0** (8.80-11.2) | **14.6** (12.7-17.5) | 2782 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | **6.11** (5.46-6.84) | **6.60** (5.40-7.50) | **11.8** (10.2-13.2) | **20.1** (17.8-23.1) | **24.7** (22.2-31.6) | 393 |
| 12-19 years | 01-02 | **3.71** (3.18-4.33) | **4.00** (3.40-4.70) | **7.00** (6.10-8.10) | **11.5** (9.50-12.7) | **13.9** (11.8-19.0) | 742 |
| 20 years and older | 01-02 | **2.37** (2.11-2.66) | **2.60** (2.20-3.00) | **4.80** (4.20-5.30) | **8.10** (7.10-9.20) | **12.0** (10.0-14.2) | 1647 |
| **Gender** | | | | | | | |
| Males | 01-02 | **2.89** (2.64-3.17) | **3.10** (2.80-3.30) | **5.60** (4.90-6.70) | **9.80** (8.70-12.0) | **14.2** (12.4-18.0) | 1371 |
| Females | 01-02 | **2.62** (2.29-2.99) | **3.00** (2.40-3.30) | **5.60** (4.90-6.30) | **10.0** (8.30-11.2) | **14.7** (11.2-20.3) | 1411 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | **2.67** (2.26-3.16) | **3.00** (2.30-3.40) | **5.30** (4.40-5.90) | **9.10** (7.30-12.4) | **13.6** (10.4-18.7) | 677 |
| Non-Hispanic blacks | 01-02 | **3.09** (2.81-3.40) | **3.20** (2.90-3.50) | **6.30** (5.50-6.50) | **10.8** (9.10-13.0) | **14.9** (13.5-22.4) | 703 |
| Non-Hispanic whites | 01-02 | **2.72** (2.40-3.08) | **2.90** (2.50-3.30) | **5.70** (4.80-6.70) | **10.3** (8.90-11.9) | **15.8** (12.6-19.5) | 1216 |

## Table 207. Mono-3-carboxypropyl phthalate (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, 2001-2002.

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | **2.57** (2.34-2.82) | **2.45** (2.23-2.76) | **4.07** (3.85-4.46) | **7.25** (6.59-8.01) | **11.4** (10.1-12.6) | 2772 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | **6.96** (6.29-7.71) | **7.07** (5.77-7.87) | **11.3** (9.27-14.0) | **20.7** (15.5-22.3) | **26.4** (20.7-27.0) | 392 |
| 12-19 years | 01-02 | **2.86** (2.52-3.25) | **2.93** (2.50-3.36) | **4.57** (4.03-5.23) | **6.69** (6.30-7.25) | **9.44** (8.03-10.7) | 742 |
| 20 years and older | 01-02 | **2.24** (2.03-2.47) | **2.19** (1.99-2.39) | **3.49** (3.10-3.93) | **5.32** (4.79-6.18) | **7.71** (6.71-9.28) | 1638 |
| **Gender** | | | | | | | |
| Males | 01-02 | **2.35** (2.16-2.56) | **2.20** (2.01-2.42) | **3.76** (3.45-4.20) | **7.16** (6.03-7.98) | **11.6** (9.28-15.4) | 1367 |
| Females | 01-02 | **2.80** (2.47-3.18) | **2.75** (2.44-3.01) | **4.37** (3.97-4.86) | **7.65** (6.17-8.69) | **11.1** (8.66-15.9) | 1405 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | **2.51** (2.20-2.87) | **2.36** (2.05-2.73) | **4.24** (3.65-5.00) | **7.42** (5.58-10.3) | **11.2** (8.18-14.5) | 674 |
| Non-Hispanic blacks | 01-02 | **2.17** (2.02-2.33) | **2.07** (1.88-2.28) | **3.64** (3.24-4.07) | **6.73** (5.46-7.70) | **10.0** (8.27-13.1) | 702 |
| Non-Hispanic whites | 01-02 | **2.69** (2.41-3.00) | **2.56** (2.23-2.92) | **4.16** (3.87-4.76) | **7.66** (6.59-8.47) | **11.8** (10.0-14.7) | 1211 |

## Table 208. Mono-n-octyl phthalate

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

| | 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** | **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) | **2.80** (2.00-3.40) | 1215 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1371 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **1.40** (1.10-2.00) | **3.10** (2.20-3.70) | 1326 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1411 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **1.00** (<LOD-1.40) | **1.50** (1.40-2.60) | 814 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 677 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **1.80** (<LOD-3.00) | **3.00** (2.20-3.70) | 603 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 703 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **1.50** (1.20-2.10) | **3.00** (2.30-3.50) | 912 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1216 |

< 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 209. Mono-n-octyl phthalate (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 | * | **< LOD** | **< LOD** | **2.40** (2.07-2.61) | **3.51** (2.86-4.29) | 2541 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 2772 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **< LOD** | **< LOD** | **2.22** (1.60-3.75) | **3.75** (1.97-10.3) | 328 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 392 |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **1.49** (1.29-1.71) | **1.82** (1.54-3.33) | 752 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 742 |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **2.56** (2.07-2.91) | **3.47** (2.86-4.29) | 1461 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1638 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **1.82** (1.54-2.05) | **2.52** (1.94-3.45) | 1215 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1367 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **2.95** (2.50-3.55) | **4.00** (3.33-5.56) | 1326 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1405 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **1.82** (1.43-2.61) | **3.16** (2.60-4.00) | 814 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 674 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **1.36** (1.03-1.94) | **2.18** (1.50-3.27) | 603 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 702 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **2.60** (2.07-3.00) | **3.60** (3.00-4.62) | 912 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1211 |

< 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.

# Mono-isononyl Phthalate

*Metabolite of Di-isononyl Phthalate, CAS No. 28553-12-0*

## General Information

Di-isononyl phthalate (DiNP) is actually a mixture of phthalates with branched alkyl side chains of varying length (C8, C9, and C10). DINP is primarily used to produce flexible plastics and has been used to replace di-2-ethylhexyl phthalate (DEHP) in some plastics. DiNP is now widely used in such products as children's toys, flooring, gloves, food-packaging material, drinking straws, and garden hoses. People exposed to DiNP will excrete small amounts of mono-isononyl phthalate (MiNP) in their urine. As with DEHP, other oxidative metabolites of DiNP are probably the most abundant urinary metabolites (McKee et al., 2002). Because DiNP is a complex mixture, MiNP may not reflect total exposure to all DiNP components.

Workplace air standards for external exposure have not been established for DiNP, which although considered an animal carcinogen, has not been completely classified as to human carcinogenicity (IARC, NTP).

In both the NHANES 1999-2000 and 2001-2002 subsamples, MiNP was detectable only at the 95th percentiles.

## Table 210. Mono-isononyl phthalate

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

| | 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** | **3.50** (<LOD-13.8) | 2541 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 2782 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **5.70** (<LOD-22.5) | 328 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 393 |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **2.30** (<LOD-20.3) | 752 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 742 |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **3.10** (<LOD-13.2) | 1461 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1647 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **4.90** (<LOD-18.9) | 1215 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1371 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **2.50** (<LOD-6.80) | 1326 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1411 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **1.40** (<LOD-2.70) | 814 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **1.00** (<LOD-1.20) | 677 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **2.30** (<LOD-13.8) | **6.80** (<LOD-30.2) | 603 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **1.00** (<LOD-1.70) | 703 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **3.50** (<LOD-16.0) | 912 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1216 |

< 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 211. Mono-isononyl phthalate (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 | * | **< LOD** | **< LOD** | **< LOD** | **4.29** (2.86-7.88) | 2541 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 2772 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **6.00** (2.77-14.2) | 328 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 392 |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **1.94** (1.30-7.65) | 752 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 742 |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **4.62** (3.16-7.93) | 1461 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1638 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **4.24** (1.94-10.2) | 1215 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1367 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **4.29** (3.33-5.79) | 1326 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1405 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **3.51** (2.86-5.00) | 814 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **2.31** (1.76-2.73) | 674 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **2.03** (.759-5.31) | **4.26** (1.43-14.3) | 603 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **1.62** (1.25-1.88) | 702 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **5.00** (3.00-10.0) | 912 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1211 |

< 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.

# Results by Chemical Group

## 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).

Studies of the effects of dietary phytoestrogens or soy protein on the incidence of breast and prostate cancer vary in outcome but suggest a protective effect (Knowles et al., 2000; den Tonkelaar et al., 2001; Stattin et al., 2002; Ingram et al., 1997; Murkies et al., 2000; Howe et al., 1990; Lee et al., 1991). In such studies, many unmeasured non-phytoestrogen flavonoid chemicals, vitamins, and other nutrients that also are present in plant foods may also contribute to observed health outcomes. *In vitro* experiments have shown both anti-cancer and stimulatory effects on cell growth of target cells. Many of the different phytoestrogens have been tested for mutagenic activity *in vitro* and do not appear to be mutagenic, but studies assessing the carcinogenicity of phytoestrogens have not been conducted. Cornwell et al. (2004) have summarized the potential anti-cancer benefits of phytoestrogens.

Comparisons of Western diets with Asian diets, which include higher intakes of soy-based foods, suggest that the higher isoflavone intake in Asian diets may account for the lower incidence of menopausal symptoms such as hot flashes and osteoporosis. The ingestion of isoflavones by pre- and post-menopausal women produces varying effects on the menstrual cycle, sex-hormone protein binding, pituitary responses, and bone density, depending on dose, the type of phytoestrogen used, the hormonal state of the subjects, and the design of the studies (see, for example, Teede et al., 2001; Murkies et al., 2000; Xu et al., 2000; Hodgert et al., 2000; Safe et al., 2001; Nicholls et al., 2002; Kotsopoulos et al., 2000; Cassidy et al., 1994; Adlercreutz et al., 1995*a*; Kim et al., 2002; Kreijkamp-Kaspers et al., 2004).

Adverse reproductive effects have been observed in animals that graze on clover. Although the results of these studies are conflicting, results of some chronic feeding studies suggest that high doses of phytoestrogens alter the fetal hormonal environment when consumed during gestation (Cornwell et al., 2004). Results of studies of children who had been fed soy-based formula as infants and who were followed up through adolescence (Klein, 1998) and young adulthood (Strom et al., 2001) found no adverse reproductive or endocrine effects.

### Interpreting Levels of Urinary Phytoestrogens Reported in the Tables

Urinary levels of phytoestrogens 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 general, the concentrations observed in the NHANES 1999-2000 and 2000-2001 subsamples reflect a diet lower in isoflavones than lignans, consistent with consumption of a Western diet in which whole grains and cereals rather than soybean products contribute the bulk of phytoestrogens. Enterolactone levels were highest followed by daidzein, genistein, enterodiol, equol, and O-desmethylangolensin. Isoflavone levels at the higher percentiles may reflect dietary supplementation with soy products. The relationship between the dose and urinary excretion is linear for many phytoestrogens, except for equol (Karr et al., 1997; Slavin et al 1998; Lampe et al., 1999). Because excretory half-lives are reported to be in the range of 3-10 hours (Lu et al., 1995, Setchell et al., 2001), urinary concentrations reflect recent consumption.

Levels of lignans (enterolactone, enterodiol) in the 1999-2000 and 2001-2002 subsamples appeared broadly similar to levels found in studies of postmenopausal women in the United Kingdom (Grace et al., 2004); men and women in the United States (Valentin-Blasini et al., 2003); men and women in Minnesota (Lampe et al., 1999); postmenopausal Dutch women (den Tonkelaar et al., 2001); young African-American, Latina; and Japanese women in the San Francisco Bay Area (Horn-Ross et al., 1997); Japanese men and women (Adlercreutz et al.,1991; Uehara et al., 2000*a*); premenopausal omnivorous women in Boston (Adlercreutz et al., 1986); and healthy postmenopausal Finnish omnivore and vegetarians (Uehara et al., 2000*a,b*). Vegetarian women in Boston and Helsinki (Adlercreutz et al., 1986); men and women consuming an experimental cruciferous diet (Kirkman et al.,1995); and Boston women consuming a macrobiotic diet excrete significantly higher levels of these lignans (Hutchins, 1995*a*).

Levels of isoflavones (daidzein, genistein, equol, and O-desmethylangolensin) in the NHANES 1999-2000 and 2001-2002 subsamples appear broadly similar to those seen in young Caucasian, African-American, Latina, and Japanese women in the San Francisco Bay Area (Horn-Ross et al., 1997); men and women in the United States (Valentin-Blasini et al., 2003, Lampe et al., 1999); Caucasian and Filipino women living in Hawaii (Maskarinec et al.,1998); postmenopausal women from Holland (den Tonkelaar et al., 2001) and the United Kingdom (Grace et al., 2004); omnivorous and vegetarian Helsinki women (Uehara et al., 2000 *a,b*); and premenopausal omnivorous Boston women (Hutchins, 1995 *a,b*).

Isoflavone levels seen in the NHANES 1999-2000 and 2001-2002 subsamples were 4 to 50 times lower than

levels observed in Japanese men and women (Adlercreutz et al.,1991; Uehara et al., 2000*a*); Japanese women (Arai et al., 2000); postmenopausal Chinese 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 than levels reported in people consuming a carotenoid diet but lower than levels found in people consuming a cruciferous diet, and O-desmethylangolensin levels were seven times lower (Kirkman et al., 1995). Levels of genistein, daidzein, and O-desmethylangolensin for people consuming a soy diet were 6 to 100 times higher than levels in either NHANES subsample. Supplementing an omnivorous American diet over a three month period with 60 grams of soy powder for female subjects increased isoflavone levels by more than 13-fold. (Albertazzi et al.,1999).

**Comparing Adjusted Geometric Means**

Geometric means of urinary phytoestrogen levels 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, both urinary enterodiol and enterolactone levels were higher in the group aged 6-11 years than in the group aged 12-19 years. Levels of the lignans previously have been reported to differ by race (Horn-Ross et al., 1997), and in an NHANES III statistical analysis, to differ by income, gender, and age (Valentin-Blasini et al., 2003).

In NHANES 2001-2002, both urinary genistein and daizein levels were higher in the group aged 6-11 years than in either of the groups aged 12-19 years or 20 years and older, and females had higher levels than males. One study found that levels were higher in males for all phytoestrogens except equol (Lampe et al., 1999).

In NHANES 2001-2002, adjusted geometric mean levels of urinary equol were higher for non-Hispanic whites than for Mexican Americans or non-Hispanic blacks. Adjusted geometric mean levels of urinary equol were higher in the group aged 6-11 years than in either of the other two age groups.

In NHANES 2001-2002, adjusted geometric mean levels of urinary O-desmethylangolensin were higher in non-Hispanic whites than in Mexican Americans. The group aged 20 years and older had lower adjusted geometric mean levels of urinary O-desmethylangolensin than either of the other two age groups.

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.

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

## Table 213. Daidzein

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

| | 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 | **75.1** (61.9-91.1) | **69.7** (57.8-82.6) | **229** (184-298) | **538** (471-702) | **1310** (990-1540) | 2553 |
| | 01-02 | **51.7** (46.6-57.5) | **52.3** (48.9-57.4) | **192** (151-226) | **577** (447-725) | **1250** (863-1640) | 2794 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **90.5** (75.1-109) | **101** (70.3-138) | **257** (172-430) | **505** (437-840) | **1130** (657-1740) | 330 |
| | 01-02 | **84.9** (71.6-101) | **72.7** (56.3-97.0) | **257** (155-385) | **571** (437-989) | **1030** (628-1470) | 396 |
| 12-19 years | 99-00 | **123** (91.4-166) | **123** (85.6-168) | **325** (227-454) | **833** (445-1490) | **1460** (861-2410) | 753 |
| | 01-02 | **69.3** (52.6-91.3) | **70.2** (52.5-87.5) | **251** (185-344) | **769** (573-984) | **1360** (922-1950) | 744 |
| 20 years and older | 99-00 | **67.6** (55.4-82.4) | **60.9** (49.3-74.1) | **215** (167-239) | **518** (459-573) | **1320** (978-1540) | 1470 |
| | 01-02 | **46.4** (41.4-52.0) | **49.1** (40.8-53.4) | **176** (133-216) | **520** (396-703) | **1210** (771-1900) | 1654 |
| **Gender** | | | | | | | |
| Males | 99-00 | **88.9** (71.4-111) | **80.6** (66.6-112) | **261** (198-355) | **573** (501-989) | **1540** (989-2080) | 1220 |
| | 01-02 | **49.8** (42.8-57.9) | **50.7** (46.0-55.0) | **189** (137-237) | **498** (386-694) | **906** (717-1380) | 1375 |
| Females | 99-00 | **64.1** (52.9-77.6) | **57.8** (45.0-73.2) | **199** (150-244) | **476** (389-722) | **1220** (566-1700) | 1333 |
| | 01-02 | **53.6** (48.1-59.8) | **55.7** (49.8-62.7) | **197** (148-231) | **642** (511-816) | **1470** (1170-1980) | 1419 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **78.9** (59.8-104) | **66.2** (48.4-87.1) | **254** (170-402) | **800** (534-1020) | **1360** (968-2780) | 816 |
| | 01-02 | **39.2** (28.5-54.0) | **39.9** (28.8-59.9) | **168** (100-287) | **515** (388-669) | **896** (613-1480) | 679 |
| Non-Hispanic blacks | 99-00 | **91.9** (71.9-118) | **102** (81.6-133) | **286** (243-377) | **553** (459-824) | **1190** (640-1900) | 607 |
| | 01-02 | **66.1** (48.2-90.7) | **72.2** (52.8-97.3) | **255** (176-393) | **757** (448-1400) | **1400** (757-2480) | 706 |
| Non-Hispanic whites | 99-00 | **74.4** (61.5-89.9) | **66.9** (56.2-78.2) | **216** (157-298) | **512** (438-745) | **1360** (989-1710) | 917 |
| | 01-02 | **48.6** (43.8-54.0) | **49.5** (42.7-54.1) | **171** (137-204) | **504** (389-658) | **1140** (774-1620) | 1222 |

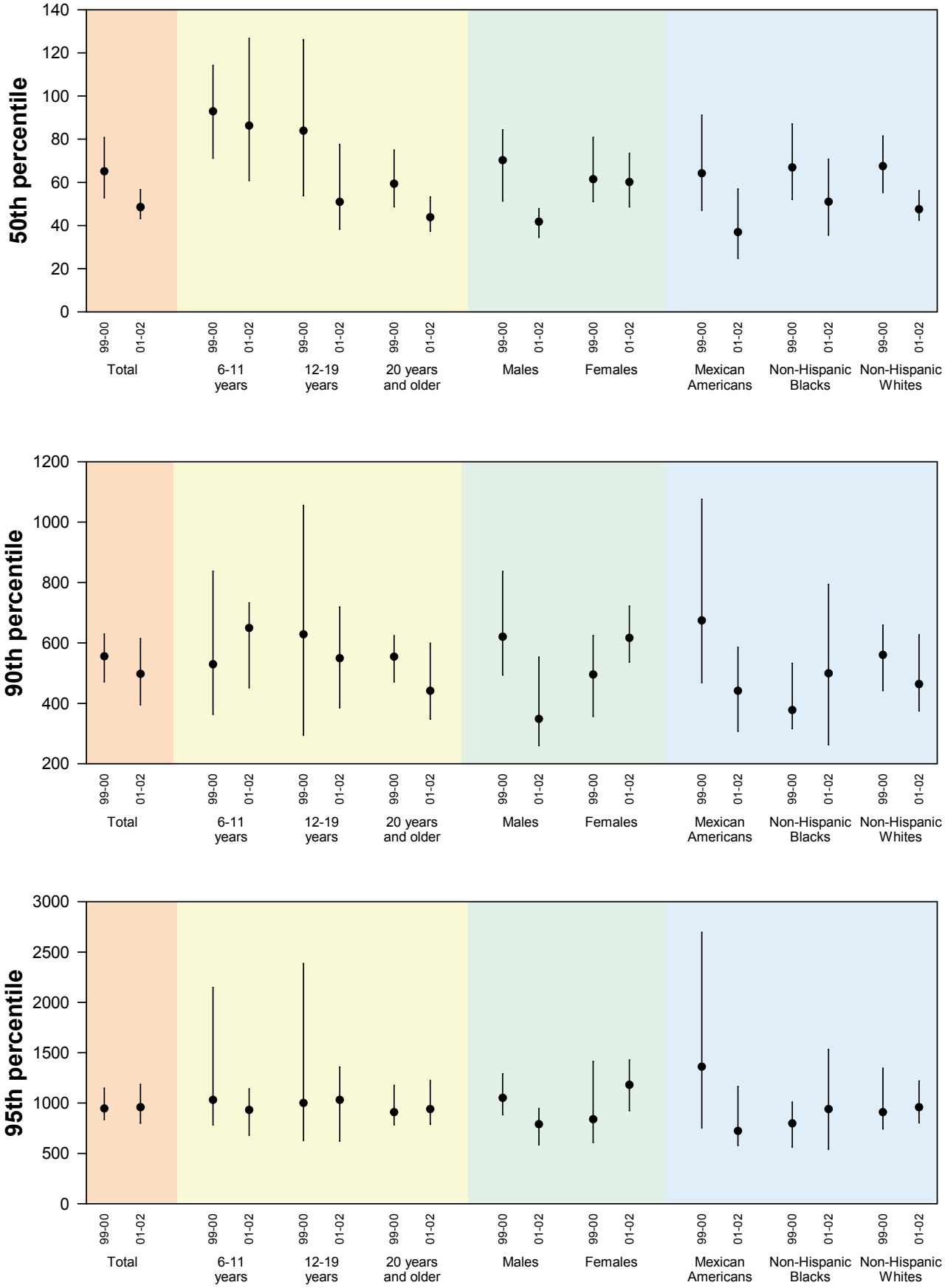
## Table 214. Daidzein (creatinine corrected)

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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 99-00 | **68.5** (55.9-83.9) | **65.1** (52.8-80.8) | **204** (156-249) | **555** (471-629) | **944** (836-1150) | 2553 |
| | 01-02 | **48.6** (43.7-54.0) | **48.5** (43.3-56.6) | **166** (140-196) | **497** (395-614) | **957** (801-1180) | 2784 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **92.6** (76.3-112) | **92.9** (71.2-114) | **251** (157-324) | **529** (363-838) | **1030** (781-2150) | 330 |
| | 01-02 | **96.6** (79.2-118) | **86.3** (60.8-127) | **275** (159-395) | **649** (452-733) | **930** (679-1140) | 395 |
| 12-19 years | 99-00 | **83.1** (58.4-118) | **83.9** (53.8-126) | **207** (138-386) | **628** (295-1060) | **1000** (628-2380) | 753 |
| | 01-02 | **53.4** (40.8-70.0) | **50.9** (38.3-77.6) | **181** (142-248) | **549** (385-718) | **1030** (622-1360) | 744 |
| 20 years and older | 99-00 | **63.8** (51.5-79.1) | **59.3** (48.7-75.0) | **194** (151-234) | **554** (471-624) | **908** (783-1180) | 1470 |
| | 01-02 | **43.9** (39.4-48.9) | **43.8** (37.4-53.3) | **153** (127-188) | **441** (348-599) | **939** (788-1220) | 1645 |
| **Gender** | | | | | | | |
| Males | 99-00 | **69.7** (54.7-88.8) | **70.2** (51.3-84.3) | **197** (147-276) | **620** (494-836) | **1050** (884-1290) | 1220 |
| | 01-02 | **40.5** (34.8-47.1) | **41.7** (34.5-47.9) | **140** (108-179) | **348** (260-553) | **788** (585-946) | 1371 |
| Females | 99-00 | **67.4** (54.8-82.9) | **61.4** (51.1-80.9) | **207** (152-250) | **495** (356-624) | **838** (610-1410) | 1333 |
| | 01-02 | **57.7** (50.8-65.5) | **60.1** (48.6-73.4) | **191** (159-228) | **616** (536-722) | **1180** (924-1430) | 1413 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **72.5** (59.1-88.9) | **64.2** (47.1-91.1) | **243** (176-310) | **674** (468-1080) | **1360** (753-2690) | 816 |
| | 01-02 | **36.8** (27.7-48.9) | **36.9** (24.8-56.9) | **148** (101-225) | **441** (307-585) | **722** (578-1160) | 676 |
| Non-Hispanic blacks | 99-00 | **59.1** (46.5-75.1) | **66.9** (52.1-87.1) | **171** (134-207) | **377** (316-533) | **797** (562-1010) | 607 |
| | 01-02 | **46.4** (33.7-63.8) | **51.0** (35.5-70.8) | **167** (105-249) | **499** (263-794) | **939** (542-1530) | 705 |
| Non-Hispanic whites | 99-00 | **72.8** (60.3-88.0) | **67.5** (55.3-81.5) | **207** (160-249) | **560** (442-659) | **908** (742-1350) | 917 |
| | 01-02 | **48.1** (43.4-53.4) | **47.5** (42.4-56.1) | **163** (138-191) | **463** (375-627) | **957** (805-1220) | 1217 |

## Figure 23. Daidzein (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 215. Enterodiol

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

| | 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 | **26.6** (21.9-32.3) | **34.0** (29.4-38.7) | **78.7** (62.6-95.5) | **165** (135-215) | **266** (215-335) | 2527 |
| | 01-02 | **35.7** (32.5-39.3) | **39.4** (36.3-43.4) | **89.0** (80.7-96.9) | **180** (162-205) | **252** (223-295) | 2794 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **26.5** (17.1-41.0) | **29.4** (21.2-44.2) | **77.6** (44.2-109) | **193** (91.1-279) | **276** (131-458) | 327 |
| | 01-02 | **33.6** (29.8-37.8) | **35.4** (29.4-43.7) | **78.1** (63.8-87.0) | **150** (113-171) | **201** (167-327) | 396 |
| 12-19 years | 99-00 | **29.8** (23.8-37.2) | **33.9** (27.4-42.0) | **83.9** (59.1-101) | **166** (112-234) | **247** (182-337) | 744 |
| | 01-02 | **35.3** (30.5-40.9) | **37.7** (34.8-43.4) | **84.2** (72.1-96.9) | **162** (128-206) | **238** (169-343) | 744 |
| 20 years and older | 99-00 | **26.1** (21.8-31.3) | **34.3** (29.8-38.7) | **78.2** (63.5-94.8) | **160** (132-196) | **261** (189-335) | 1456 |
| | 01-02 | **36.1** (31.8-41.0) | **40.4** (36.0-45.7) | **91.2** (79.3-105) | **190** (161-220) | **254** (224-311) | 1654 |
| **Gender** | | | | | | | |
| Males | 99-00 | **25.3** (19.5-32.7) | **33.0** (28.0-38.0) | **72.6** (54.7-94.3) | **149** (109-219) | **258** (167-280) | 1206 |
| | 01-02 | **35.2** (31.8-39.1) | **40.5** (36.8-44.8) | **90.6** (82.3-103) | **182** (158-198) | **263** (223-338) | 1375 |
| Females | 99-00 | **27.9** (23.4-33.3) | **36.0** (29.9-40.3) | **84.4** (71.8-97.9) | **174** (146-219) | **279** (219-375) | 1321 |
| | 01-02 | **36.2** (32.2-40.7) | **38.3** (35.3-43.4) | **87.0** (75.6-98.5) | **174** (152-212) | **245** (220-283) | 1419 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **21.7** (19.5-24.1) | **28.0** (24.7-34.7) | **70.4** (60.8-78.8) | **143** (117-169) | **213** (169-256) | 791 |
| | 01-02 | **30.5** (25.7-36.3) | **34.0** (29.0-39.2) | **75.2** (58.8-89.7) | **159** (119-202) | **244** (192-298) | 679 |
| Non-Hispanic blacks | 99-00 | **25.8** (21.7-30.7) | **31.2** (24.4-35.9) | **66.0** (50.2-86.7) | **157** (122-193) | **260** (185-336) | 608 |
| | 01-02 | **35.0** (28.9-42.3) | **38.7** (33.2-49.0) | **83.6** (70.0-103) | **168** (132-186) | **218** (175-339) | 706 |
| Non-Hispanic whites | 99-00 | **29.2** (24.0-35.4) | **37.5** (31.3-43.8) | **85.8** (68.3-99.4) | **171** (138-228) | **270** (187-375) | 915 |
| | 01-02 | **35.6** (31.8-40.0) | **40.4** (36.0-44.4) | **89.6** (78.4-101) | **174** (153-198) | **254** (214-337) | 1222 |

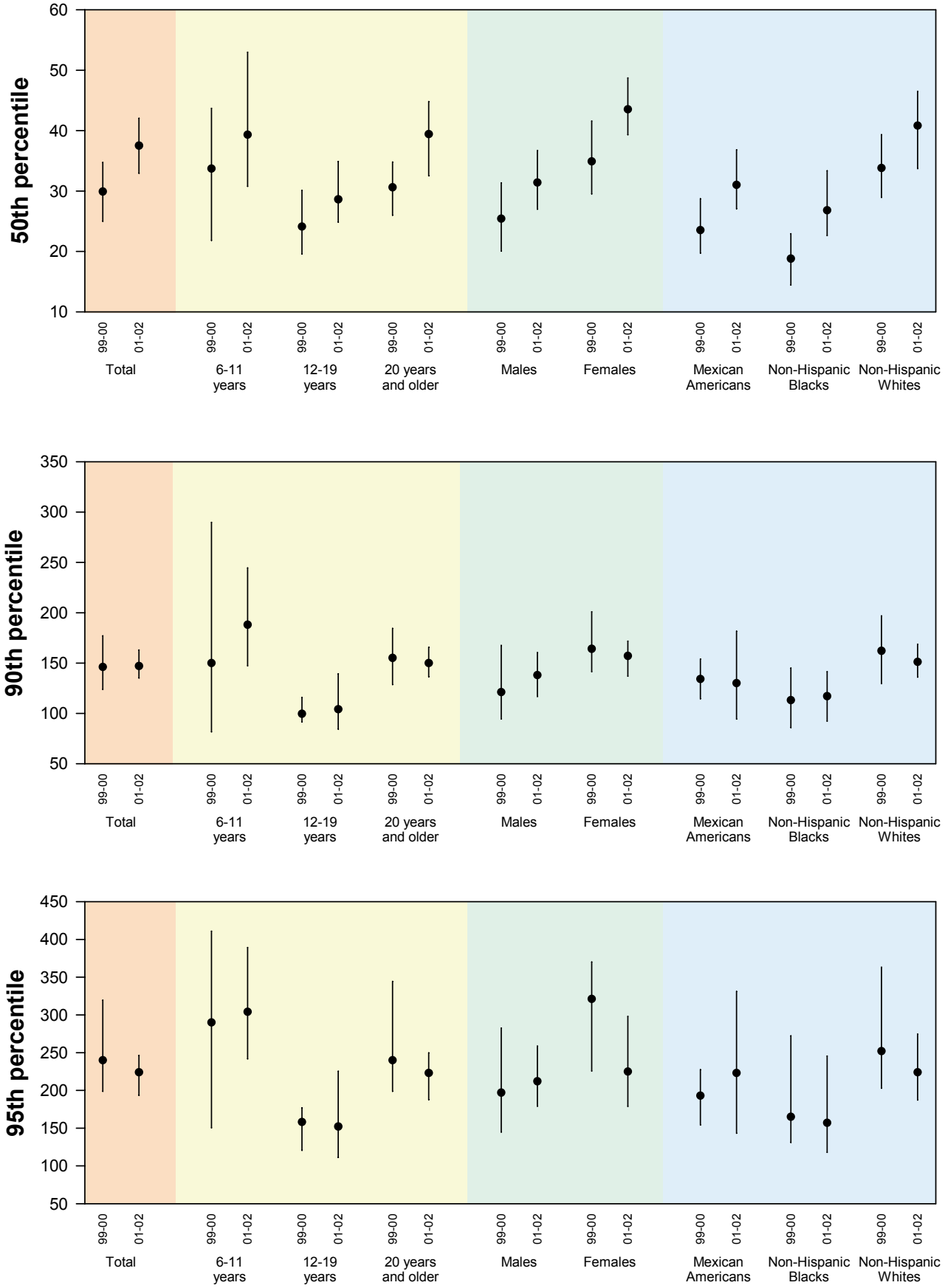
## Table 216. Enterodiol (creatinine corrected)

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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 99-00 | **24.2** (20.3-28.9) | **29.9** (25.0-34.7) | **70.5** (59.6-82.1) | **146** (124-177) | **240** (199-320) | 2527 |
| | 01-02 | **33.4** (30.6-36.6) | **37.5** (33.0-42.0) | **78.3** (71.8-87.0) | **147** (135-163) | **224** (193-246) | 2784 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **27.0** (18.6-39.3) | **33.7** (21.8-43.7) | **62.7** (43.0-108) | **150** (81.6-290) | **290** (150-411) | 327 |
| | 01-02 | **38.1** (32.5-44.7) | **39.3** (30.8-53.0) | **78.3** (66.6-101) | **188** (147-244) | **304** (242-389) | 395 |
| 12-19 years | 99-00 | **20.1** (16.7-24.2) | **24.1** (19.6-30.1) | **55.0** (42.6-71.7) | **99.5** (91.5-116) | **158** (121-177) | 744 |
| | 01-02 | **27.2** (23.3-31.8) | **28.6** (24.9-34.9) | **62.7** (54.9-71.0) | **104** (84.2-139) | **152** (111-225) | 744 |
| 20 years and older | 99-00 | **24.7** (20.6-29.5) | **30.6** (26.0-34.8) | **72.7** (62.5-84.5) | **155** (129-184) | **240** (199-344) | 1456 |
| | 01-02 | **34.0** (30.2-38.3) | **39.4** (32.5-44.8) | **83.3** (74.0-92.5) | **150** (136-166) | **223** (188-250) | 1645 |
| **Gender** | | | | | | | |
| Males | 99-00 | **19.8** (15.4-25.4) | **25.4** (20.0-31.4) | **55.1** (46.4-64.2) | **121** (94.6-168) | **197** (145-282) | 1206 |
| | 01-02 | **28.7** (26.0-31.7) | **31.4** (27.0-36.7) | **71.2** (64.2-78.0) | **138** (117-160) | **212** (179-259) | 1371 |
| Females | 99-00 | **29.3** (25.0-34.4) | **34.9** (29.5-41.6) | **85.2** (74.5-92.3) | **164** (141-201) | **321** (226-370) | 1321 |
| | 01-02 | **38.6** (34.6-43.1) | **43.5** (39.3-48.7) | **88.3** (74.7-102) | **157** (137-172) | **225** (179-298) | 1413 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **19.6** (17.3-22.2) | **23.5** (19.7-28.7) | **59.6** (49.8-77.7) | **134** (114-154) | **193** (154-227) | 791 |
| | 01-02 | **28.7** (24.5-33.6) | **31.0** (27.0-36.8) | **64.1** (55.0-77.5) | **130** (94.4-182) | **223** (143-331) | 676 |
| Non-Hispanic blacks | 99-00 | **16.6** (13.9-19.7) | **18.8** (14.4-22.9) | **47.3** (37.7-55.8) | **113** (85.9-145) | **165** (131-272) | 608 |
| | 01-02 | **24.5** (19.7-30.6) | **26.8** (22.6-33.3) | **57.5** (48.1-73.2) | **117** (92.2-141) | **157** (118-246) | 705 |
| Non-Hispanic whites | 99-00 | **28.6** (24.3-33.6) | **33.8** (28.9-39.3) | **75.8** (65.3-87.2) | **162** (130-197) | **252** (203-363) | 915 |
| | 01-02 | **35.1** (31.5-39.2) | **40.8** (33.7-46.5) | **82.7** (74.3-90.3) | **151** (136-169) | **224** (187-275) | 1217 |

## Figure 24. Enterodiol (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 217. Enterolactone

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

| | 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 | **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** | | | | | | | |
| Mexican Americans | 99-00 | **212** (169-265) | **281** (230-335) | **631** (539-732) | **1650** (950-2210) | **2690** (2380-3350) | 813 |
| | 01-02 | **275** (221-342) | **347** (312-395) | **777** (671-913) | **1520** (1090-1920) | **2280** (1610-2990) | 679 |
| Non-Hispanic blacks | 99-00 | **262** (196-349) | **360** (293-440) | **759** (629-925) | **1710** (1000-2420) | **2500** (1870-3280) | 605 |
| | 01-02 | **278** (226-342) | **417** (341-479) | **769** (686-853) | **1450** (1110-1710) | **1960** (1540-2420) | 706 |
| Non-Hispanic whites | 99-00 | **247** (196-311) | **317** (240-403) | **751** (616-955) | **2040** (1600-2450) | **2950** (2460-3880) | 917 |
| | 01-02 | **267** (235-303) | **354** (307-397) | **834** (750-923) | **1630** (1420-1890) | **2780** (1820-3740) | 1222 |

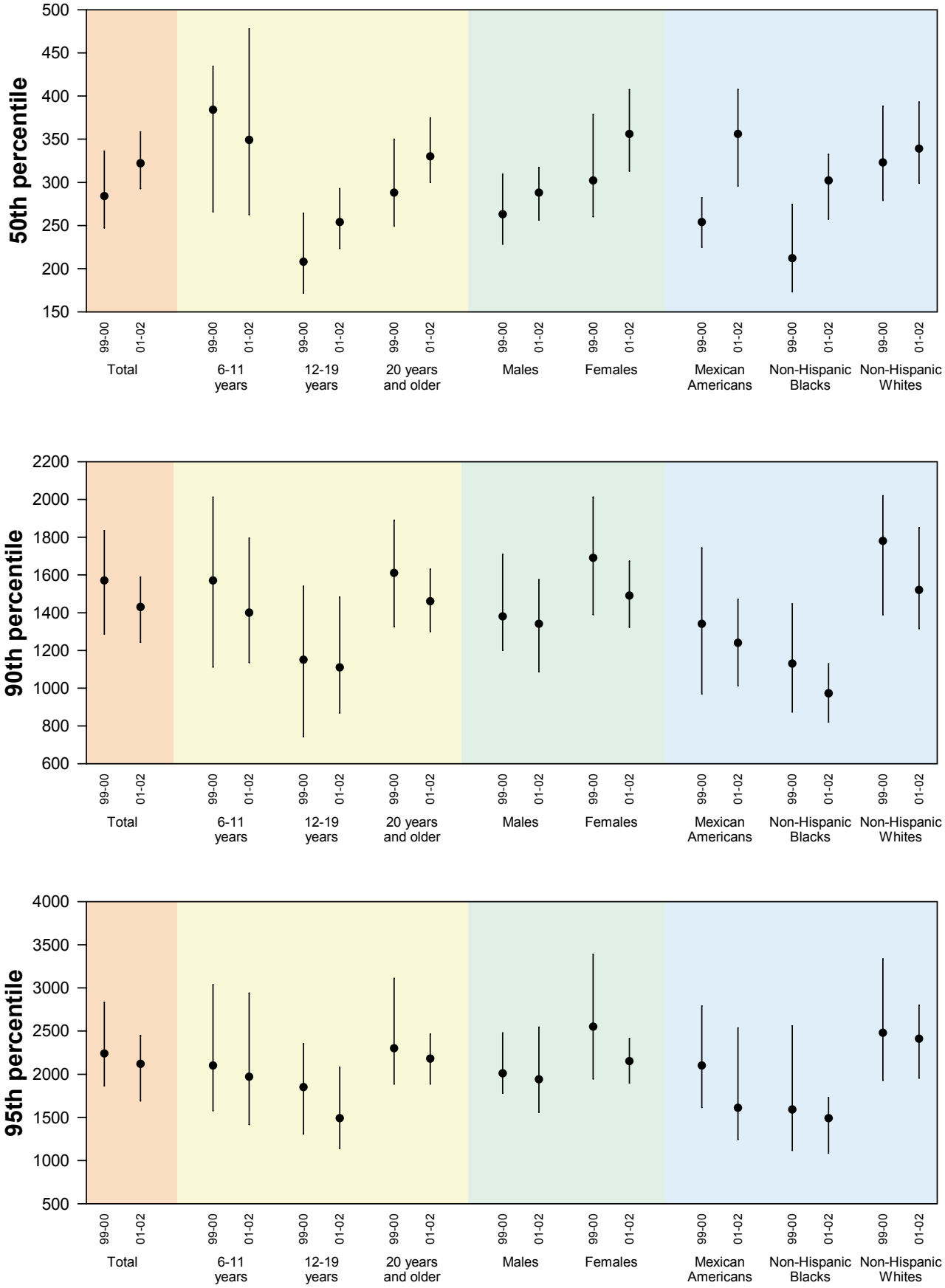
## Table 218. Enterolactone (creatinine corrected)

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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 99-00 | **218** (184-260) | **284** (247-336) | **733** (613-869) | **1570** (1290-1830) | **2240** (1860-2830) | 2548 |
| | 01-02 | **242** (219-267) | **322** (293-358) | **755** (668-857) | **1430** (1240-1590) | **2120** (1690-2450) | 2784 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **315** (238-416) | **384** (266-435) | **703** (495-1110) | **1570** (1110-2010) | **2100** (1580-3040) | 331 |
| | 01-02 | **327** (273-391) | **349** (262-478) | **725** (603-994) | **1400** (1140-1800) | **1970** (1420-2940) | 395 |
| 12-19 years | 99-00 | **169** (133-214) | **208** (172-264) | **484** (371-615) | **1150** (742-1540) | **1850** (1310-2350) | 746 |
| | 01-02 | **206** (178-239) | **254** (223-293) | **619** (466-753) | **1110** (869-1480) | **1490** (1140-2080) | 744 |
| 20 years and older | 99-00 | **217** (181-261) | **288** (249-350) | **785** (653-923) | **1610** (1330-1890) | **2300** (1890-3110) | 1471 |
| | 01-02 | **240** (212-270) | **330** (300-375) | **784** (672-915) | **1460** (1300-1630) | **2180** (1890-2470) | 1645 |
| **Gender** | | | | | | | |
| Males | 99-00 | **199** (170-234) | **263** (228-309) | **664** (490-828) | **1380** (1200-1710) | **2010** (1780-2480) | 1219 |
| | 01-02 | **213** (191-238) | **288** (256-317) | **682** (602-764) | **1340** (1090-1580) | **1940** (1560-2550) | 1371 |
| Females | 99-00 | **238** (191-297) | **302** (260-379) | **819** (662-954) | **1690** (1390-2010) | **2550** (1940-3390) | 1329 |
| | 01-02 | **273** (240-311) | **356** (313-407) | **824** (698-1010) | **1490** (1320-1670) | **2150** (1900-2410) | 1413 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **194** (165-228) | **254** (225-282) | **605** (519-695) | **1340** (969-1740) | **2100** (1620-2790) | 813 |
| | 01-02 | **258** (213-313) | **356** (296-408) | **725** (590-905) | **1240** (1010-1470) | **1610** (1240-2540) | 676 |
| Non-Hispanic blacks | 99-00 | **168** (125-226) | **212** (173-274) | **539** (411-732) | **1130** (874-1450) | **1590** (1120-2560) | 605 |
| | 01-02 | **195** (155-245) | **302** (257-332) | **561** (477-629) | **972** (821-1130) | **1490** (1080-1730) | 705 |
| Non-Hispanic whites | 99-00 | **241** (194-300) | **323** (279-388) | **828** (674-997) | **1780** (1390-2020) | **2480** (1930-3340) | 917 |
| | 01-02 | **264** (231-301) | **339** (299-393) | **828** (716-944) | **1520** (1320-1850) | **2410** (1950-2800) | 1217 |

## 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

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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 99-00 | **8.37** (7.21-9.72) | **8.02** (6.27-9.90) | **17.2** (15.2-19.8) | **35.0** (28.9-41.6) | **53.5** (40.1-74.2) | 2182 |
| | 01-02 | **9.17** (7.76-10.8) | **9.00** (7.40-10.5) | **19.6** (16.6-23.5) | **42.1** (34.3-51.5) | **72.2** (53.6-89.2) | 2794 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **10.5** (7.65-14.3) | **11.2** (5.43-18.6) | **24.9** (17.5-29.5) | **34.4** (29.5-53.3) | **54.8** (30.1-149) | 272 |
| | 01-02 | **12.2** (10.2-14.6) | **13.6** (11.1-16.0) | **26.2** (17.9-36.3) | **50.0** (35.0-84.3) | **85.4** (50.4-159) | 396 |
| 12-19 years | 99-00 | **10.9** (8.64-13.8) | **10.7** (8.52-13.4) | **22.0** (16.0-34.9) | **42.9** (34.1-71.3) | **71.6** (48.1-210) | 657 |
| | 01-02 | **10.2** (8.50-12.1) | **10.4** (8.20-12.5) | **20.4** (16.8-24.8) | **43.1** (30.1-56.1) | **64.4** (46.3-99.2) | 744 |
| 20 years and older | 99-00 | **7.79** (6.79-8.94) | **7.43** (5.71-8.85) | **16.0** (13.6-18.1) | **33.1** (24.4-39.7) | **52.2** (36.3-93.9) | 1253 |
| | 01-02 | **8.70** (7.29-10.4) | **8.00** (6.20-10.1) | **18.6** (15.0-22.3) | **41.2** (34.1-47.4) | **73.5** (53.9-89.0) | 1654 |
| **Gender** | | | | | | | |
| Males | 99-00 | **9.15** (7.37-11.4) | **8.44** (6.36-11.2) | **19.0** (15.9-24.0) | **35.6** (29.2-54.8) | **71.3** (39.7-166) | 1042 |
| | 01-02 | **9.41** (7.99-11.1) | **9.10** (7.60-10.7) | **20.1** (16.7-26.1) | **43.1** (32.4-53.1) | **61.7** (51.8-81.5) | 1375 |
| Females | 99-00 | **7.70** (6.79-8.75) | **7.57** (5.79-9.04) | **15.6** (12.7-18.9) | **33.5** (26.7-37.7) | **48.2** (37.1-62.9) | 1140 |
| | 01-02 | **8.94** (7.38-10.8) | **8.50** (6.70-10.7) | **19.0** (15.6-22.9) | **41.5** (33.3-51.5) | **79.8** (56.6-122) | 1419 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **5.24** (4.77-5.76) | **4.49** (3.65-5.18) | **9.44** (7.96-10.3) | **18.5** (14.5-22.6) | **30.9** (21.6-48.4) | 726 |
| | 01-02 | **7.22** (6.04-8.62) | **6.40** (4.40-9.00) | **14.2** (11.3-20.1) | **31.2** (21.1-41.0) | **42.4** (37.2-49.2) | 679 |
| Non-Hispanic blacks | 99-00 | **6.73** (5.20-8.71) | **6.24** (3.86-10.0) | **15.1** (12.7-17.6) | **27.6** (19.4-35.6) | **36.4** (28.9-49.4) | 514 |
| | 01-02 | **7.15** (6.06-8.43) | **6.00** (4.60-7.60) | **14.7** (11.8-18.7) | **30.9** (22.8-41.9) | **45.7** (36.1-90.5) | 706 |
| Non-Hispanic whites | 99-00 | **9.26** (7.80-11.0) | **8.95** (6.73-11.9) | **19.0** (16.1-22.7) | **36.1** (30.1-45.4) | **56.1** (42.1-89.4) | 758 |
| | 01-02 | **9.91** (7.95-12.4) | **9.90** (7.30-12.6) | **22.0** (17.4-27.4) | **44.4** (35.1-57.5) | **74.4** (55.1-107) | 1222 |

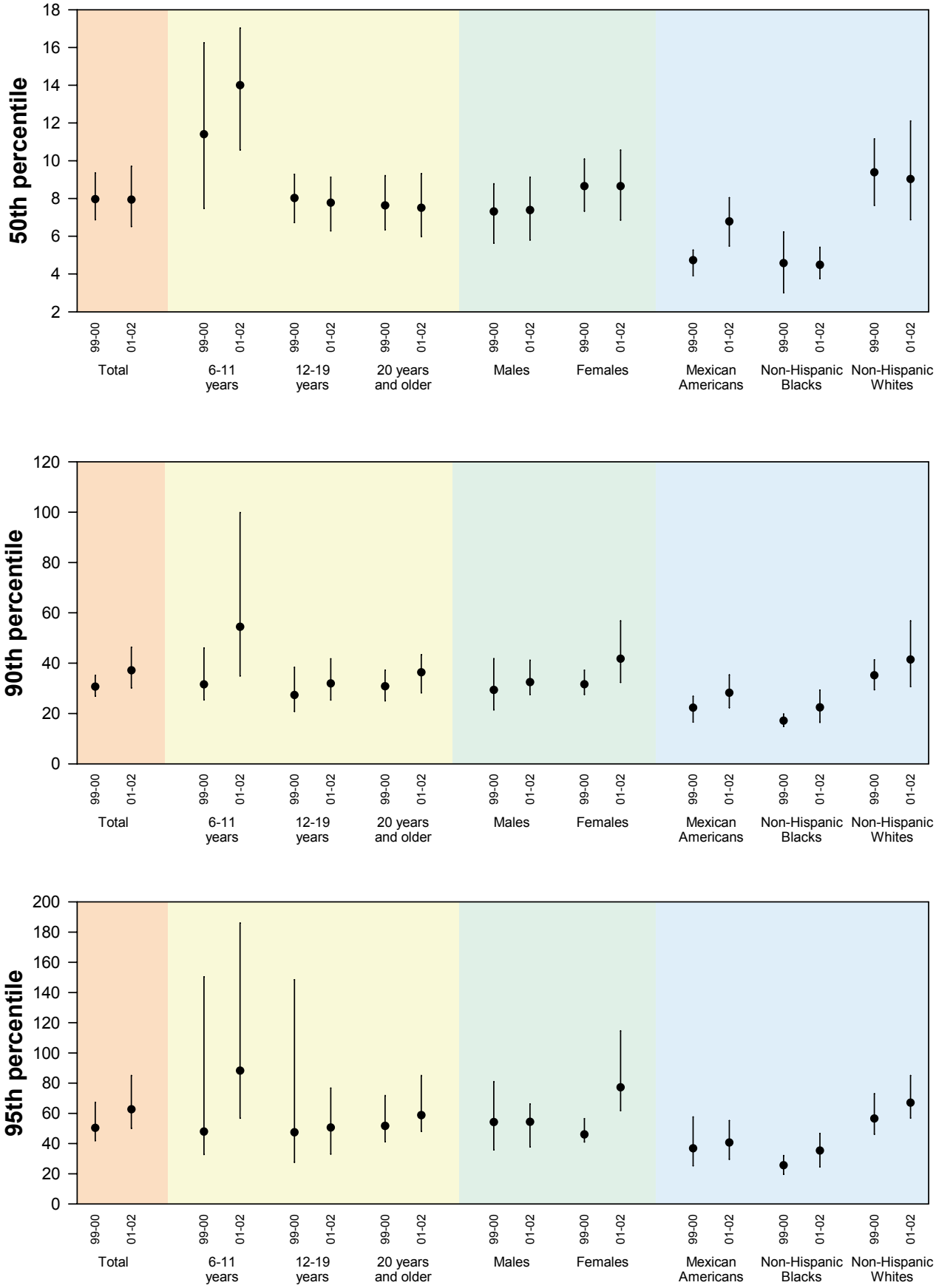
## Table 220. Equol (creatinine corrected)

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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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) | **30.6** (26.9-35.1) | **50.3** (41.8-67.3) | 2182 |
| | 01-02 | **8.55** (7.22-10.1) | **7.94** (6.52-9.71) | **17.4** (14.6-21.5) | **37.1** (30.1-46.3) | **62.6** (50.0-85.0) | 2784 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **10.3** (7.83-13.5) | **11.4** (7.46-16.3) | **22.6** (14.7-27.2) | **31.5** (25.5-46.0) | **47.8** (32.7-150) | 272 |
| | 01-02 | **13.8** (11.2-17.2) | **14.0** (10.6-17.0) | **28.7** (19.6-39.8) | **54.4** (34.9-99.8) | **88.2** (56.8-186) | 395 |
| 12-19 years | 99-00 | **7.61** (6.17-9.39) | **8.02** (6.72-9.29) | **13.9** (11.4-20.4) | **27.3** (20.8-38.3) | **47.4** (27.5-149) | 657 |
| | 01-02 | **7.83** (6.68-9.17) | **7.77** (6.29-9.13) | **17.3** (14.9-19.2) | **31.9** (25.3-41.7) | **50.6** (33.0-76.7) | 744 |
| 20 years and older | 99-00 | **7.45** (6.60-8.41) | **7.63** (6.34-9.22) | **15.3** (12.7-17.7) | **30.8** (25.0-37.2) | **51.6** (41.2-71.8) | 1253 |
| | 01-02 | **8.17** (6.88-9.72) | **7.50** (5.97-9.32) | **16.3** (13.7-20.2) | **36.3** (28.2-43.3) | **58.7** (47.9-85.0) | 1645 |
| **Gender** | | | | | | | |
| Males | 99-00 | **7.01** (5.93-8.29) | **7.31** (5.63-8.78) | **13.8** (11.7-17.6) | **29.3** (21.4-41.8) | **54.1** (35.8-81.0) | 1042 |
| | 01-02 | **7.62** (6.35-9.14) | **7.38** (5.80-9.13) | **16.0** (13.9-19.2) | **32.4** (27.5-41.2) | **54.3** (37.7-66.2) | 1371 |
| Females | 99-00 | **8.41** (7.33-9.66) | **8.65** (7.33-10.1) | **17.4** (15.1-19.9) | **31.6** (27.5-37.2) | **46.0** (41.0-56.5) | 1140 |
| | 01-02 | **9.55** (7.95-11.5) | **8.65** (6.85-10.6) | **19.0** (15.7-23.3) | **41.7** (32.3-56.8) | **77.1** (61.7-115) | 1413 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **4.89** (4.36-5.47) | **4.73** (3.90-5.27) | **8.83** (8.18-9.91) | **22.3** (16.5-26.8) | **36.8** (25.3-57.6) | 726 |
| | 01-02 | **6.73** (5.71-7.92) | **6.78** (5.47-8.04) | **14.9** (11.6-17.8) | **28.2** (22.3-35.3) | **40.6** (29.5-55.2) | 676 |
| Non-Hispanic blacks | 99-00 | **4.36** (3.41-5.57) | **4.57** (2.94-6.23) | **10.2** (7.96-12.0) | **17.1** (14.8-19.8) | **25.6** (19.6-32.0) | 514 |
| | 01-02 | **5.00** (4.25-5.89) | **4.48** (3.76-5.42) | **10.9** (8.74-13.0) | **22.4** (16.5-29.3) | **35.3** (24.5-46.7) | 705 |
| Non-Hispanic whites | 99-00 | **9.13** (7.85-10.6) | **9.38** (7.63-11.2) | **18.0** (15.2-21.6) | **35.1** (29.5-41.3) | **56.5** (46.0-73.0) | 758 |
| | 01-02 | **9.76** (7.89-12.1) | **9.03** (6.87-12.1) | **19.5** (15.3-25.4) | **41.4** (30.6-56.8) | **67.0** (56.8-85.0) | 1217 |

## 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

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 | **24.4** (19.7-30.3) | **27.0** (22.5-32.8) | **93.6** (75.8-118) | **284** (244-331) | **562** (413-709) | 2557 |
| | 01-02 | **33.0** (30.1-36.2) | **28.9** (26.8-31.7) | **92.5** (77.9-109) | **306** (240-372) | **613** (523-719) | 2794 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **27.6** (21.1-36.1) | **31.9** (18.1-42.6) | **104** (67.6-151) | **218** (151-315) | **376** (272-725) | 331 |
| | 01-02 | **39.2** (33.4-46.0) | **31.5** (25.8-39.6) | **94.1** (61.8-158) | **258** (188-399) | **502** (258-830) | 396 |
| 12-19 years | 99-00 | **43.7** (34.2-55.7) | **45.4** (34.3-60.5) | **137** (93.7-179) | **319** (245-464) | **547** (321-777) | 754 |
| | 01-02 | **34.1** (27.2-42.8) | **28.9** (25.7-32.8) | **90.1** (69.2-110) | **278** (216-363) | **467** (360-687) | 744 |
| 20 years and older | 99-00 | **21.9** (17.6-27.2) | **24.0** (21.7-28.4) | **86.2** (67.5-108) | **284** (235-343) | **566** (412-744) | 1472 |
| | 01-02 | **32.1** (28.8-35.8) | **28.8** (25.4-33.4) | **93.4** (77.3-110) | **312** (235-389) | **627** (530-788) | 1654 |
| **Gender** | | | | | | | |
| Males | 99-00 | **29.8** (22.2-40.0) | **31.8** (26.3-37.2) | **108** (79.1-151) | **335** (257-440) | **709** (437-981) | 1222 |
| | 01-02 | **32.2** (27.9-37.2) | **29.5** (25.4-33.7) | **90.7** (73.4-103) | **239** (190-331) | **470** (335-719) | 1375 |
| Females | 99-00 | **20.3** (17.0-24.2) | **23.1** (20.1-26.3) | **84.7** (59.6-105) | **235** (203-288) | **427** (339-619) | 1335 |
| | 01-02 | **33.7** (30.9-36.8) | **28.7** (26.0-32.3) | **97.0** (79.9-118) | **385** (253-500) | **666** (598-807) | 1419 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **31.1** (25.1-38.5) | **30.0** (25.1-37.3) | **117** (83.9-179) | **328** (248-479) | **570** (419-1180) | 819 |
| | 01-02 | **28.3** (22.0-36.4) | **25.6** (19.2-32.4) | **74.5** (48.8-111) | **225** (174-314) | **424** (323-523) | 679 |
| Non-Hispanic blacks | 99-00 | **26.7** (19.2-37.0) | **32.8** (24.4-41.5) | **103** (84.8-137) | **252** (209-364) | **495** (329-926) | 608 |
| | 01-02 | **37.6** (27.4-51.6) | **35.2** (23.6-49.5) | **95.5** (71.1-142) | **375** (188-523) | **596** (375-1120) | 706 |
| Non-Hispanic whites | 99-00 | **23.6** (19.1-29.3) | **25.3** (21.7-32.0) | **91.4** (68.0-122) | **284** (227-353) | **566** (395-734) | 917 |
| | 01-02 | **30.9** (27.8-34.4) | **27.6** (24.6-30.8) | **89.7** (70.7-105) | **276** (226-365) | **626** (485-755) | 1222 |

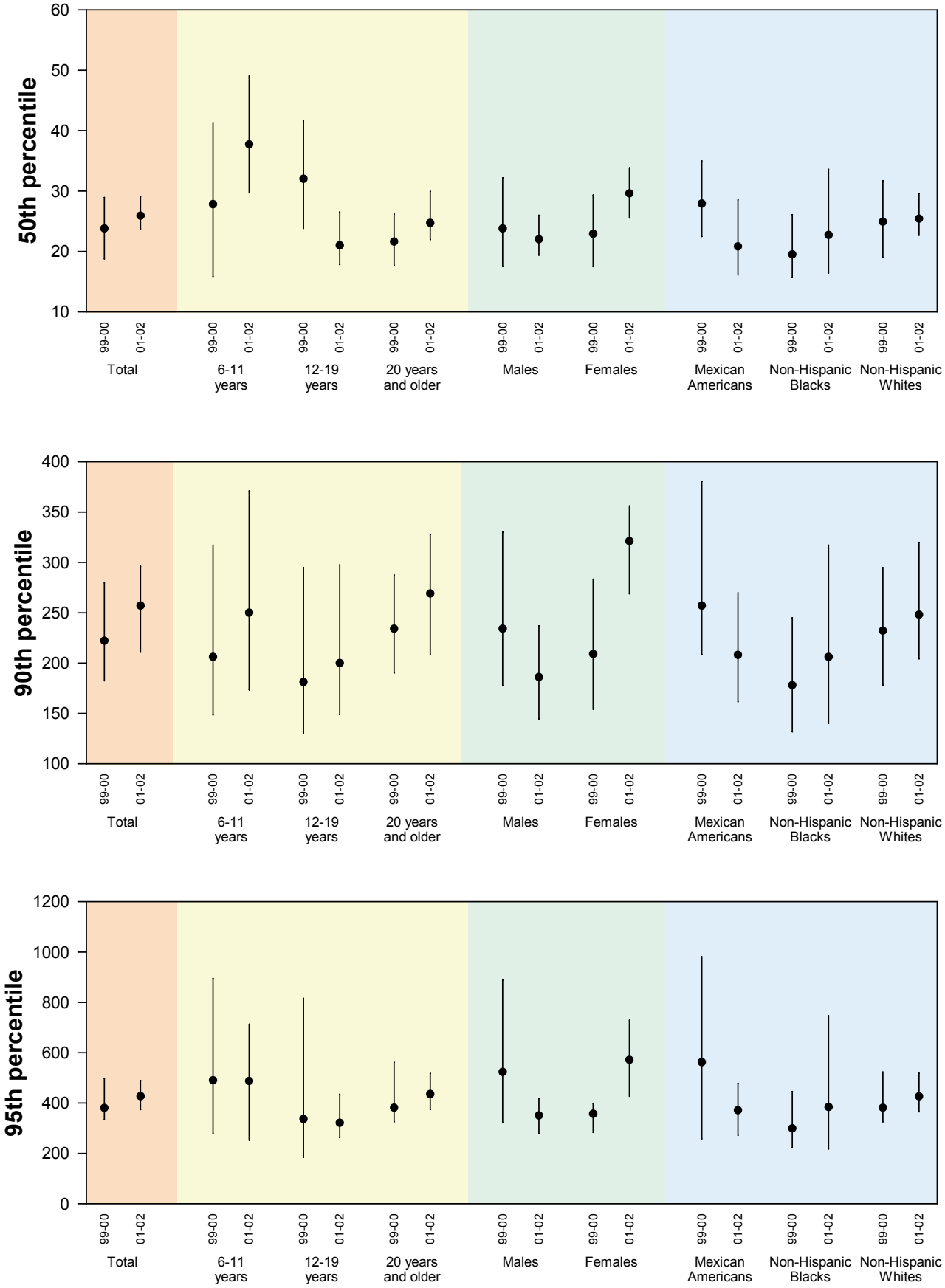
## Table 222. Genistein (creatinine corrected)

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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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)

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 223. O-Desmethylangolensin

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

| | 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 | **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** (177-332) | 1087 |
| | 01-02 | **3.81** (3.08-4.71) | **3.20** (2.50-4.00) | **17.4** (13.2-24.6) | **82.2** (58.4-116) | **194** (123-324) | 1375 |
| Females | 99-00 | **3.92** (2.97-5.16) | **4.21** (3.18-5.51) | **19.4** (14.1-26.1) | **83.8** (61.1-114) | **192** (123-250) | 1184 |
| | 01-02 | **4.36** (3.64-5.23) | **3.40** (2.50-4.50) | **21.2** (16.8-29.2) | **106** (70.6-199) | **394** (230-746) | 1419 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **2.41** (1.55-3.73) | **2.14** (1.31-3.37) | **21.0** (10.6-30.5) | **96.6** (59.7-140) | **191** (122-320) | 721 |
| | 01-02 | **2.44** (1.51-3.94) | **1.40** (.500-3.40) | **12.6** (5.80-27.6) | **65.2** (33.5-102) | **152** (75.8-265) | 679 |
| Non-Hispanic blacks | 99-00 | **5.74** (4.55-7.24) | **8.43** (5.82-10.9) | **33.5** (22.1-52.4) | **106** (78.3-156) | **192** (149-255) | 538 |
| | 01-02 | **5.35** (4.00-7.14) | **5.30** (2.80-7.20) | **32.7** (21.8-52.4) | **119** (75.9-216) | **303** (150-436) | 706 |
| Non-Hispanic whites | 99-00 | **4.50** (3.26-6.22) | **4.99** (3.43-7.10) | **22.5** (17.1-34.4) | **100** (72.0-152) | **228** (177-259) | 826 |
| | 01-02 | **4.13** (3.43-4.96) | **3.40** (2.60-4.20) | **17.9** (15.5-23.8) | **98.7** (67.4-153) | **260** (148-493) | 1222 |

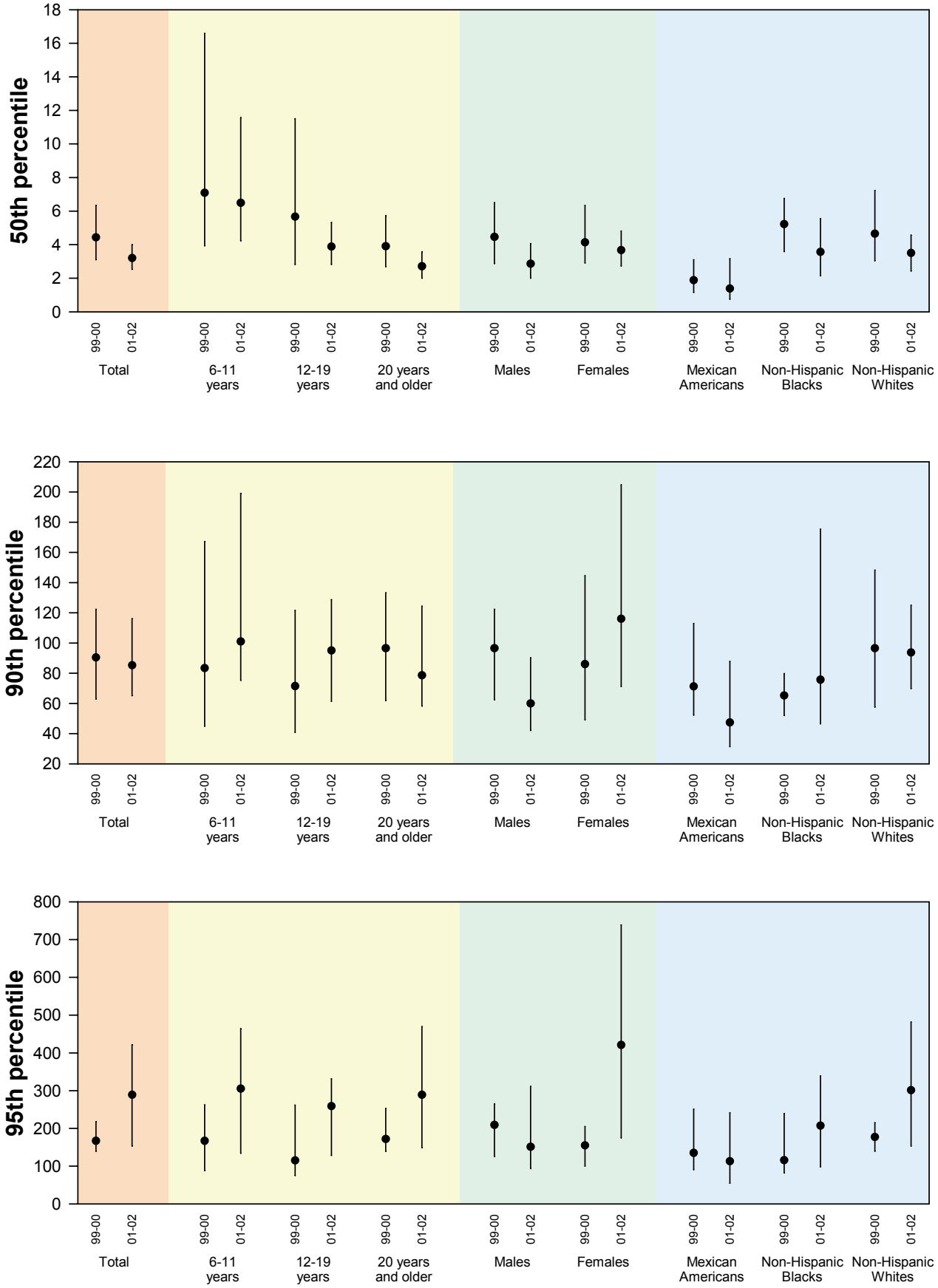
## Table 224. O-Desmethylangolensin (creatinine corrected)

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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 99-00 | **4.03** (2.97-5.45) | **4.43** (3.10-6.34) | **21.8** (15.3-31.6) | **90.4** (62.9-122) | **167** (140-218) | 2271 |
| | 01-02 | **3.81** (3.31-4.39) | **3.20** (2.53-4.00) | **18.8** (16.1-22.9) | **85.2** (65.1-116) | **289** (153-421) | 2784 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **6.00** (4.04-8.91) | **7.09** (3.94-16.6) | **28.8** (14.3-45.0) | **83.3** (45.0-167) | **167** (88.2-262) | 287 |
| | 01-02 | **7.03** (5.05-9.78) | **6.49** (4.24-11.6) | **29.9** (16.3-54.1) | **101** (75.3-199) | **305** (134-464) | 395 |
| 12-19 years | 99-00 | **4.13** (2.33-7.35) | **5.67** (2.82-11.5) | **26.0** (14.7-44.4) | **71.4** (40.8-122) | **115** (75.2-262) | 667 |
| | 01-02 | **4.57** (3.44-6.07) | **3.88** (2.82-5.32) | **26.0** (18.0-35.9) | **95.0** (61.4-129) | **259** (129-331) | 744 |
| 20 years and older | 99-00 | **3.82** (2.84-5.13) | **3.90** (2.69-5.73) | **20.2** (12.9-29.2) | **96.5** (61.8-133) | **172** (140-252) | 1317 |
| | 01-02 | **3.43** (2.94-4.00) | **2.71** (2.00-3.57) | **16.4** (13.5-19.6) | **78.5** (58.2-124) | **289** (149-470) | 1645 |
| **Gender** | | | | | | | |
| Males | 99-00 | **3.95** (2.79-5.58) | **4.46** (2.88-6.50) | **24.5** (13.8-40.5) | **96.5** (62.4-122) | **209** (125-265) | 1087 |
| | 01-02 | **3.09** (2.48-3.86) | **2.86** (2.00-4.07) | **15.1** (10.4-19.9) | **60.0** (42.1-90.2) | **151** (93.6-311) | 1371 |
| Females | 99-00 | **4.10** (3.00-5.61) | **4.14** (2.91-6.34) | **20.4** (14.4-27.2) | **86.0** (49.1-145) | **155** (100-205) | 1184 |
| | 01-02 | **4.64** (3.83-5.63) | **3.67** (2.73-4.81) | **25.8** (18.1-34.0) | **116** (71.3-205) | **421** (175-739) | 1413 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **2.19** (1.49-3.24) | **1.88** (1.15-3.10) | **14.7** (11.3-25.8) | **71.2** (52.3-113) | **135** (90.5-251) | 721 |
| | 01-02 | **2.29** (1.47-3.57) | **1.38** (.748-3.17) | **11.8** (4.91-23.6) | **47.4** (31.4-87.8) | **113** (54.7-242) | 676 |
| Non-Hispanic blacks | 99-00 | **3.65** (2.90-4.60) | **5.22** (3.58-6.75) | **23.8** (17.6-32.1) | **65.2** (52.1-79.7) | **116** (81.9-239) | 538 |
| | 01-02 | **3.75** (2.76-5.10) | **3.56** (2.14-5.56) | **22.8** (15.3-30.4) | **75.6** (46.5-175) | **207** (98.5-339) | 705 |
| Non-Hispanic whites | 99-00 | **4.42** (3.12-6.27) | **4.65** (3.05-7.23) | **22.3** (15.3-37.9) | **96.5** (57.6-148) | **177** (140-215) | 826 |
| | 01-02 | **4.05** (3.39-4.84) | **3.50** (2.43-4.57) | **20.2** (16.1-25.9) | **93.7** (69.8-125) | **301** (153-482) | 1217 |

## Figure 28. O-Desmethylangolensin (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.



# 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 from direct application and runoff, disposal of contaminated wastes into landfills, emissions from waste incinerators, and releases from manufacturing plants that produce these chemicals. Some organochlorine pesticides are volatile or can adhere to soil or particles in the air. In aquatic systems, organochlorine pesticides are adsorbed onto sediments in water that can then bioaccumulate in fish and other marine mammals. Because these chemicals are soluble in fat, they are found at higher concentrations in fatty foods. In the general population, the diet is the main source of exposure to organochlorine pesticides, primarily through the ingestion of fatty foods (such as milk, dairy products, and fish). Minor sources of exposure for the general population include contaminated drinking water and air. Infants can be exposed to these chemicals through breast milk and the fetus can be exposed in utero via the placenta. Workers can be exposed to organochlorine chemicals in the manufacture, formulation, or application of these chemicals. The U.S. FDA, U.S. EPA, and OSHA have developed criteria on the allowable levels of certain organochlorine chemicals in foods, the environment, and the workplace.

Organochlorine pesticides vary in their chemical structures and mechanisms of toxicity. They can be classified into four categories: dichlorodiphenylethanes (e.g., DDT), cyclodienes (e.g., heptachlor, dieldrin), chlorinated benzenes (e.g., hexachlorobenzene [HCB]), and cyclohexanes (e.g., hexachlorocyclohexane [HCH]). Table 226 shows the parent organochlorine pesticides and their metabolites that were measured for this *Report*. For example, DDT metabolizes to DDE. Measurements of these chemicals can reflect either recent or accumulated chronic exposures or both. Some of the metabolites can be produced from the metabolism of more than one pesticide. In addition to reflecting exposure to the parent pesticide, the level of the metabolite in a person's blood or urine may also reflect exposure to the metabolite itself if it was present in the person's environment. The health effects of exposure to organochlorine pesticides on the general population at current levels of exposure are unknown.

**Table 225. Organochlorine pesticides and their metabolites**

| **Organochlorine pesticide** (CAS number) | **Serum pesticide or metabolite(s)** (CAS number) | **Urinary pesticide or metabolite(s)** (CAS number) |
|---|---|---|
| Hexachlorobenzene (118-74-1) | Hexachlorobenzene (118-74-1) | Pentachlorophenol (87-86-5)<br>2,4,6-Trichlorophenol (88-06-2)<br>2,4,5-Trichlorophenol (95-95-4) |
| Hexachlorocyclohexanes | Hexachlorocyclohexane (608-73-1) including beta-HCH (319-85-7) and gamma-HCH (58-89-9) isomers | Pentachlorophenol (87-86-5)<br>2,4,6-Trichlorophenol (88-06-2)<br>2,4,5-Trichlorophenol (95-95-4) |
| Pentachlorophenol (87-86-5) | | Pentachlorophenol (87-86-5) |
| Trichlorophenols<br>Including 2,4,5-Trichlorophenol (95-95-4) and 2,4,6-Trichlorophenol (88-06-2) | | 2,4,5-Trichlorophenol (95-95-4)<br>2,4,6-Trichlorophenol (88-06-2) |
| DDT (50-29-3)<br>*p,p'*-DDT (50-29-3)<br>*o,p'*-DDT (789-02-6) | *p,p'*-DDE (72-55-9) | |
| Heptachlor (76-44-8) | Heptachlor epoxide (1024-57-3) | |
| Chlordane (12789-03-6) | Oxychlordane (27304-13-8) | |
| Mirex (2385-85-5) | Mirex (2385-85-5) | |
| Aldrin (309-00-02) | Aldrin (309-00-02)<br>Dieldrin (60-57-1) | |
| Dieldrin (60-57-1) | Dieldrin (60-57-1) | |
| Endrin (72-20-8) | Endrin (72-20-8) | |

# Hexachlorobenzene

CAS No. 118-74-1

## General Information

Hexachlorobenzene (HCB) is an organochlorine pesticide that was once used in the United States as a fungicide to pretreat grain. The U.S. EPA cancelled the use of HCB as a fungicide in 1984. Hexachlorobenzene may also be produced as a byproduct in the manufacturing process for certain chemicals.

Hexachlorobenzene is a relatively persistent compound in the environment. Because HCB does not dissolve easily in water, it is usually not present in high concentrations in drinking water. The U.S. EPA has issued an advisory for safe levels of HCB in drinking water. In the general population, the diet, including foods high in fats, is a significant source of exposure to HCB. Small amounts of HCB have also been detected in outdoor air. Workers in chemical manufacturing industries may be exposed to higher levels of HCB via inhalation or dermal pathways of exposure.

HCB interferes with the normal synthesis of heme in the body, resulting in the accumulation of abnormal heme precursors. This interference can adversely affect the skin as well as other organ systems. Chronic dietary overexposure to HCB also has caused serious health effects. For example, during the years 1955-1959, HCB-treated grain was processed into bread and consumed by people living in southeastern Turkey. Those with significant exposures developed porphyria cutanea tarda; hyperpigmentation of the skin; and other manifestations, including weakness, paresthesia, thyromegaly, and arthritis. Children born to mothers exposed during that time developed sores on their skin, and many died within the first 2 years of life (Peters et al., 1982). HCB has been associated with reproductive and developmental disorders in experimental animal studies. IARC classifies hexachlorobenzene as possibly carcinogenic to humans, and NTP classifies hexachlorobenzene as reasonably anticipated to be a human carcinogen.

### Table 226. Hexachlorobenzene (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 | 1702 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 2277 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 591 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 747 |
| 20 years and older | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1111 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1530 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 807 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1058 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 895 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1219 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 583 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 554 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 350 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 511 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 636 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1052 |

< 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.

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 increases of HCB in body fat have been consistently reported in studies of general populations (Bertram et al., 1986; Glynn et al., 2003; Becker et al.; 2002). Grimalt et al. (1994) reported that residents living near an HCB chemical plant had serum HCB levels that were about five-fold greater than levels of residents from a reference community. In another study, serum HCB levels in workers at an HCB plant were about five-fold greater than levels in the local population (Herrero et al., 1999).

Pentachlorophenol (PCP), 2,4,5-trichlorophenol (2,4,5-TCP), and 2,4,6-trichlorophenol (2,4,6-TCP) are urinary metabolites of HCB (To-Figueras et al., 1997). Urinary PCP can also result from exposure to other chlorinated hydrocarbons, such as pentachlorobenzene, hexachloro-cyclohexane, or pentachloronitrobenzene. Similarly, urinary 2,4,5-TCP and 2,4,6-TCP can result from exposure to other chlorinated hydrocarbons such as hexachlorocyclohexane. Because urinary PCP, 2,4,5-TCP, and 2,4,6-TCP can occur from exposures to chemicals other than HCB, measuring HCB in serum is a more specific indicator of exposure to HCB.

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 HCB Reported in the Tables

Serum hexachlorobenzene levels 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. In the NHANES 1999-2000 and 2001-2002 subsamples, hexachlorobenzene levels in serum were below the limit of detection. In a probability sample of the German population aged 18-69 years, the mean concentration of HCB in blood was 0.44 µg/L (Becker et al., 2002), which is slightly lower than the limit of

**Table 227. Hexachlorobenzene (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 | 1702 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 2277 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 591 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 747 |
| 20 years and older | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1111 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1530 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 807 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1058 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 895 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1219 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 583 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 554 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 350 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 511 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 636 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1052 |

< 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.

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 for use in the preplanting treatment of seeds although the U.S. EPA has recently required additional studies about and restrictions on these uses. Agricultural workers may be exposed to lindane via dermal, inhalation, or ingestion routes when applying the chemical. Lindane is also approved for use by the U.S. FDA in topical pharmaceutical products to treat human scabies and lice. At high doses, gamma-HCH (lindane) blocks inhibitory neurotransmitters in the central nervous system. Seizures and deaths among children have resulted from excess dermal application of 1% lindane lotions and from accidental ingestion of lindane vaporizer tablets used in the past. Workers who directly handled HCH have complained of headache, paresthesias, tremors, and memory loss (Nigam et al., 1986). Blood dyscrasias (anemia, leukopenia) have been reported after accidental or large exposures (Morgan et al., 1980; Rugman et al., 1990). Lindane and other HCH isomers are mainly metabolized to chlorophenols such as 2,4,6-trichlorophenol, 2,4,5-trichlorophenol, and 2,3,5-trichlorophenol. Beta-HCH has a blood elimination half-life of 7 years, whereas gamma-HCH has a shorter blood elimination half-life of only 20 hours.

IARC classifies hexachlorocyclohexane isomers as possibly carcinogenic to humans, and NTP classifies

### Table 228. beta-Hexachlorocylclohexane (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 | **9.68** (<LOD-10.9) | **< LOD** | **19.0** (16.0-21.6) | **42.0** (33.4-50.6) | **68.9** (50.6-87.6) | 1893 |
| | 01-02 | * | **< LOD** | **10.3** (9.08-11.0) | **23.6** (19.4-29.4) | **43.3** (32.4-55.2) | 2291 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **11.4** (<LOD-16.1) | 653 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **8.44** (<LOD-12.2) | 758 |
| 20 years and older | 99-00 | **10.9** (9.61-12.4) | **< LOD** | **21.0** (18.9-24.0) | **46.0** (35.9-56.8) | **73.4** (52.7-96.0) | 1240 |
| | 01-02 | * | **< LOD** | **11.2** (10.3-13.2) | **25.5** (21.2-33.5) | **46.2** (34.6-62.0) | 1533 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **14.5** (10.7-19.1) | **29.8** (23.3-38.7) | **44.6** (32.8-68.9) | 901 |
| | 01-02 | * | **< LOD** | **8.24** (7.15-10.1) | **17.7** (15.5-22.2) | **29.2** (22.7-35.8) | 1067 |
| Females | 99-00 | **11.1** (9.56-12.8) | **< LOD** | **22.0** (19.1-27.6) | **51.3** (42.2-67.6) | **81.1** (64.4-111) | 992 |
| | 01-02 | * | **< LOD** | **11.8** (10.4-14.5) | **30.6** (24.2-39.9) | **54.5** (39.9-71.5) | 1224 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **16.7** (13.7-20.2) | **15.5** (11.6-20.4) | **37.5** (29.6-47.3) | **97.9** (62.6-135) | **139** (99.8-199) | 632 |
| | 01-02 | * | **7.60** (<LOD-8.63) | **16.6** (13.4-21.1) | **44.0** (32.7-56.4) | **84.4** (55.2-107) | 563 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **14.7** (12.0-23.1) | **36.6** (30.0-41.7) | **48.9** (40.9-81.1) | 403 |
| | 01-02 | * | **< LOD** | **7.73** (<LOD-10.4) | **23.3** (11.8-47.3) | **45.9** (20.5-115) | 513 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **17.5** (14.1-20.5) | **34.4** (25.2-46.0) | **51.3** (40.0-70.8) | 702 |
| | 01-02 | * | **< LOD** | **9.27** (7.60-10.8) | **20.4** (17.1-24.3) | **33.5** (24.3-44.7) | 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.

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/toxprofiles.

### Interpreting Levels of Lipid-Adjusted Serum beta-HCH and gamma-HCH Reported in the Tables

Serum beta-HCH and gamma-HCH levels 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. Because of its longer half-life, beta-HCH is usually the isomer with the highest concentration in the general population.

The 95th percentile level of beta-HCH for the current 2001-2002 NHANES subsample is similar to the corresponding 95th percentile values reported in a study of adults in Germany (Wilhelm et al., 2003). Another study of New Zealand adults older than age 15 years that recently reported beta-HCH mean levels to be 19.7 ng/gram of lipid (Bates et al., 2004*b*), which are slightly higher than mean levels reported for the 1999-2000 subsample. The levels of beta-HCH in serum shown in this *Report* are far below a biological tolerance level of 25 µg/L (approximately 4,200 ng/gram of serum lipid) in serum or plasma for workers at the end of their shifts as defined by the Deutsche Forschungsgemeinchaft (2000).

Beta-HCH levels in the U.S. population have been declining since 1970 (Radomski et al., 1971; Stehr-Green et al., 1989; Kutz et al., 1991; Sturgeon et al., 1998). Kutz et al. (1991) estimated that in 1970 nearly 100% of the U.S. population had detectable beta-HCH in adipose tissue and that 80% had detectable concentrations in 1980, with the mean adipose beta-HCH level decreasing from 0.37 µg/gram of lipid (370 ng/gram) in 1971 to 0.10 µg/gram of lipid (100 ng/gram) in 1983. In 1976, the median serum lipid-adjusted level of beta-HCH was 119 ng/gram for a control population of 7,712 Danish females (Hoyer et al., 1998). The large difference between these 1976 levels and current U.S. levels may represent a

**Table 229. beta-Hexachlorocylclohexane (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 | **.058** (.051-.066) | **< LOD** | **.124** (.103-.146) | **.286** (.223-.359) | **.447** (.359-.558) | 1893 |
| | 01-02 | * | **< LOD** | **.066** (.058-.076) | **.160** (.132-.196) | **.296** (.218-.388) | 2291 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.055** (.047-.070) | 653 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.048** (.030-.066) | 758 |
| 20 years and older | 99-00 | **.067** (.059-.077) | **< LOD** | **.140** (.120-.162) | **.324** (.243-.412) | **.477** (.406-.616) | 1240 |
| | 01-02 | * | **< LOD** | **.077** (.067-.093) | **.175** (.145-.226) | **.312** (.240-.446) | 1533 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **.093** (.077-.117) | **.206** (.157-.249) | **.286** (.215-.474) | 901 |
| | 01-02 | * | **< LOD** | **.054** (.046-.061) | **.131** (.099-.166) | **.200** (.164-.254) | 1067 |
| Females | 99-00 | **.065** (.056-.077) | **< LOD** | **.149** (.122-.189) | **.383** (.303-.447) | **.556** (.422-.679) | 992 |
| | 01-02 | * | **< LOD** | **.082** (.070-.098) | **.204** (.165-.254) | **.368** (.290-.455) | 1224 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **.098** (.080-.119) | **.093** (.073-.110) | **.245** (.203-.307) | **.582** (.386-.844) | **.905** (.582-1.37) | 632 |
| | 01-02 | * | **.043** (.034-.052) | **.104** (.083-.129) | **.301** (.211-.453) | **.612** (.400-.851) | 563 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **.104** (.072-.142) | **.243** (.186-.293) | **.359** (.284-.465) | 403 |
| | 01-02 | * | **< LOD** | **.044** (.030-.070) | **.138** (.076-.265) | **.226** (.125-.674) | 513 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **.118** (.095-.142) | **.244** (.172-.339) | **.390** (.283-.508) | 702 |
| | 01-02 | * | **< LOD** | **.060** (.051-.070) | **.137** (.113-.169) | **.220** (.164-.310) | 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.

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)

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 | 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** | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 863 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1060 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 936 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1220 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 631 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 563 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 380 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 509 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 646 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1045 |

< 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 231. gamma Hexachlorocylclohexane (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 | 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** | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 863 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1060 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 936 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1220 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 631 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 563 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 380 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 509 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 646 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1045 |

< 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.

# Pentachlorophenol

CAS No. 87-86-5

## General Information

Pentachlorophenol (PCP) is used primarily as a fungicide to preserve wood in the United States. The use of PCP has decreased over the years as a result of regulations issued by the U.S. EPA in 1984. Compared with other organochlorine pesticides, PCP is not a highly persistent chemical in the environment. The general population may be exposed through food and water sources, which can be contaminated from either PCP releases or waste-site runoffs or from breakdown products of other organochlorine chemicals (e.g., hexachlorocyclohexane, hexachlorobenzene). Homes containing PCP-treated wood are another source of exposure. Workers who manufacture or apply PCP may inhale it or absorb the chemical through their skin. The U.S. EPA and OSHA have developed criteria for allowable levels of PCP in the environment and in workplaces.

PCP is not extensively metabolized and is eliminated from the body relatively rapidly over the course of hours to days. Some PCP is metabolized to tetrachlorhydroquinone and excreted to a minor extent as glucuronidated conjugates (Braun et al., 1979; Ahlborg et al., 1974). PCP in the body may also be the result of metabolism from HCB (To-Figueras et al., 1997). Acute overexposure to PCP can lead to the uncoupling of oxidative phosphorylation, resulting in severe hyperthermia. These effects have been observed when people ingest or inhale PCP or absorb it through the skin. IARC has determined that pentachlorophenol is possibly carcinogenic to humans. 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.

### Table 232. Pentachlorophenol

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, 1999-2002.

| | 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** | **.360** (<LOD-.930) | **1.30** (.480-2.10) | 1994 |
| | 01-02 | * | **< LOD** | **< LOD** | **1.23** (.590-1.76) | **1.94** (1.58-2.53) | 2528 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **< LOD** | **< LOD** | **.760** (<LOD-1.51) | **1.65** (.990-2.00) | 482 |
| | 01-02 | * | **< LOD** | **< LOD** | **1.37** (.890-1.70) | **2.08** (1.58-2.75) | 577 |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **.650** (<LOD-2.60) | **2.00** (.510-5.90) | 681 |
| | 01-02 | * | **< LOD** | **< LOD** | **1.48** (.850-2.30) | **2.30** (1.47-5.04) | 826 |
| 20-59 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **1.10** (.250-1.70) | 831 |
| | 01-02 | * | **< LOD** | **< LOD** | **1.01** (<LOD-1.76) | **1.86** (1.45-2.53) | 1125 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **.630** (<LOD-1.30) | **1.40** (.400-2.20) | 973 |
| | 01-02 | * | **< LOD** | **< LOD** | **1.31** (.680-1.80) | **1.94** (1.47-3.09) | 1190 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.860** (.280-2.00) | 1021 |
| | 01-02 | * | **< LOD** | **< LOD** | **1.10** (<LOD-1.78) | **1.92** (1.54-2.42) | 1338 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.650** (<LOD-1.90) | 696 |
| | 01-02 | * | **< LOD** | **< LOD** | **.990** (<LOD-2.37) | **1.60** (<LOD-3.14) | 680 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **.970** (<LOD-2.50) | **1.64** (.860-2.70) | 521 |
| | 01-02 | * | **< LOD** | **< LOD** | **1.73** (1.25-2.29) | **2.75** (2.02-3.67) | 696 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **.350** (<LOD-1.10) | **1.30** (<LOD-2.30) | 603 |
| | 01-02 | * | **< LOD** | **< LOD** | **1.16** (<LOD-1.76) | **1.91** (1.48-2.42) | 951 |

< 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.

### Interpreting Levels of Urinary Pentachlorophenol Reported in the Tables

Urinary levels of PCP 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 NHANES 2001-2002, urinary PCP levels at the 95th percentile were approximately five-fold lower than 95th percentile values measured in a nonrandom subsample from NHANES III participants (Hill et al., 1995). Urinary PCP levels at the 95th percentile in this *Report* were approximately two-fold lower than the corresponding 95th percentile values reported in a study of German adults aged 18-69 years (Becker et al., 2003) and approximately seven-fold lower than the 95th percentile levels for children aged 6-14 years (Seifert et al., 2000). Urinary levels of pentachlorophenol in the NHANES 2001-2002 subsample are far below allowable workplace BEIs (ACGIH, 2001).

Finding a measurable amount of PCP in urine does not mean that the level of the PCP will result in an adverse health effect. These data will help scientists plan and conduct research about the relation between exposure to PCP 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 PCP than levels found in the general population.

### Table 233. Pentachlorophenol (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** | **.720** (.643-.857) | **1.12** (.892-1.26) | 1994 |
| | 01-02 | * | **< LOD** | **< LOD** | **1.52** (1.25-1.75) | **2.26** (1.67-3.09) | 2527 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **< LOD** | **< LOD** | **.930** (.581-1.13) | **1.39** (.985-1.83) | 482 |
| | 01-02 | * | **< LOD** | **< LOD** | **1.83** (1.29-3.18) | **3.18** (1.83-3.89) | 577 |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **.525** (.277-1.53) | **1.26** (.400-2.75) | 681 |
| | 01-02 | * | **< LOD** | **< LOD** | **1.19** (.904-1.53) | **1.82** (1.25-2.82) | 825 |
| 20-59 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **1.06** (.857-1.20) | 831 |
| | 01-02 | * | **< LOD** | **< LOD** | **1.52** (1.25-1.75) | **2.06** (1.67-2.99) | 1125 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **.750** (.450-.947) | **1.13** (.857-1.80) | 973 |
| | 01-02 | * | **< LOD** | **< LOD** | **1.12** (.946-1.40) | **1.73** (1.25-2.92) | 1190 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **1.10** (.857-1.14) | 1021 |
| | 01-02 | * | **< LOD** | **< LOD** | **1.67** (1.52-1.99) | **2.69** (1.93-3.50) | 1337 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.947** (.643-1.68) | 696 |
| | 01-02 | * | **< LOD** | **< LOD** | **1.09** (.745-2.10) | **1.94** (1.06-3.55) | 680 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **.713** (.390-1.18) | **1.34** (.816-1.38) | 521 |
| | 01-02 | * | **< LOD** | **< LOD** | **1.30** (.780-1.66) | **1.94** (1.46-2.59) | 695 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **.750** (.614-.857) | **1.13** (.857-1.20) | 603 |
| | 01-02 | * | **< LOD** | **< LOD** | **1.52** (1.27-1.67) | **2.10** (1.67-3.08) | 951 |

< 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.

# 2,4,5-Trichlorophenol

CAS No. 95-95-4

# 2,4,6-Trichlorophenol

CAS No. 88-06-2

*Metabolites of Organochlorine Pesticides and Other Environmental Chemicals*

### General Information

The chemicals 2,4,5-trichlorophenol (2,4,5-TCP) and 2,4,6-trichlorophenol (2,4,6-TCP) are metabolites of several organochlorine chemicals, including hexachlorobenzene and hexachlorocyclohexane. Trichlorophenols are no longer intentionally manufactured, but they may be produced as byproducts of the manufacture of other chlorinated aromatic compounds. Small amounts of trichlorophenols can be produced during combustion of natural materials and from the chlorination of waste water that contains phenols. IARC classifies polychlorophenols (including trichlorophenols) as possibly carcinogenic to humans, and NTP classifies 2,4,6-TCP as 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 Urinary Trichlorphenol Reported in the Tables

Urinary levels of 2,4,5-TCP and 2,4,6-TCP were measured in a subsample of NHANES participants aged

## Table 234. 2,4,5-Trichlorophenol

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, 1999-2002.

| | 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** | **1.40** (.970-2.70) | **5.40** (2.50-14.0) | **16.0** (4.30-39.0) | 1998 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **2.31** (<LOD-7.81) | 2526 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **< LOD** | **1.30** (1.00-2.70) | **4.60** (2.30-11.0) | **11.0** (4.10-36.0) | 483 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **2.42** (<LOD-13.3) | 577 |
| 12-19 years | 99-00 | * | **< LOD** | **1.60** (.940-3.72) | **5.40** (2.50-24.0) | **24.0** (3.80-41.0) | 682 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **1.90** (<LOD-6.10) | 826 |
| 20-59 years | 99-00 | * | **< LOD** | **1.40** (.950-2.60) | **5.30** (2.30-15.0) | **18.0** (4.30-44.0) | 833 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **2.71** (<LOD-8.27) | 1123 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **1.40** (.950-3.40) | **5.30** (2.60-8.20) | **9.30** (5.30-27.0) | 974 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **5.57** (<LOD-15.8) | 1187 |
| Females | 99-00 | * | **< LOD** | **1.50** (.980-3.10) | **6.50** (2.30-27.0) | **21.0** (3.20-48.0) | 1024 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1339 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **.940** (<LOD-1.30) | **1.70** (1.40-3.50) | **8.50** (4.60-18.0) | **21.0** (8.90-33.0) | 697 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **14.2** (<LOD-121) | 680 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **1.20** (.900-2.20) | **4.80** (2.00-8.40) | **8.60** (3.50-63.0) | 524 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **2.31** (<LOD-9.03) | 696 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **1.40** (.920-3.60) | **4.50** (2.30-9.20) | **9.20** (4.30-27.0) | 603 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **2.42** (<LOD-8.27) | 949 |

< 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.

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 groups in 1999-2000 were compared after adjusting for the covariates of race/ethnicity, age, gender and urinary creatinine (data not shown). Adjusted geometric mean levels of urinary 2,4,6-TCP were slightly higher for children aged 6-11 years than for either groups aged 12-19 or 20-59 years, and the group aged 12-19 had higher levels than the group aged 20-59 years. It is unknown whether these differences associated with age represent differences in exposure, pharmacokinetics, or the relationship of dose per body weight.

Finding a measurable amount of 2,4,5-TCP or 2,4,6-TCP 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 2,4,5-TCP or 2,4,6-TCP 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 2,4,5-TCP or 2,4,6-TCP than levels found in the general population.

## Table 235. 2,4,5-Trichlorophenol (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 | **2.36** (1.54-3.16) | **5.50** (3.24-11.2) | **11.9** (4.96-19.6) | 1998 |
| | 01-02 | * | < LOD | < LOD | < LOD | **4.57** (3.18-7.11) | 2525 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | < LOD | **2.27** (1.19-4.78) | **5.79** (3.83-12.4) | **12.8** (5.28-25.4) | 483 |
| | 01-02 | * | < LOD | < LOD | < LOD | **5.64** (2.56-13.8) | 577 |
| 12-19 years | 99-00 | * | < LOD | **1.44** (.923-2.50) | **3.77** (1.93-11.2) | **11.2** (2.62-20.1) | 682 |
| | 01-02 | * | < LOD | < LOD | < LOD | **2.67** (2.21-5.82) | 825 |
| 20-59 years | 99-00 | * | < LOD | **2.46** (1.60-3.20) | **5.71** (3.37-11.5) | **11.7** (4.78-19.6) | 833 |
| | 01-02 | * | < LOD | < LOD | < LOD | **4.57** (3.37-7.11) | 1123 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | **1.67** (1.01-3.15) | **4.24** (3.05-8.02) | **9.55** (4.13-13.6) | 974 |
| | 01-02 | * | < LOD | < LOD | < LOD | **4.31** (2.56-8.37) | 1187 |
| Females | 99-00 | * | < LOD | **2.57** (1.79-4.00) | **7.73** (3.05-17.8) | **16.2** (5.00-29.3) | 1024 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1338 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **.980** (.726-1.33) | **2.49** (1.68-4.24) | **6.89** (4.17-12.4) | **11.8** (6.88-16.9) | 697 |
| | 01-02 | * | < LOD | < LOD | < LOD | **11.9** (1.83-48.9) | 680 |
| Non-Hispanic blacks | 99-00 | * | < LOD | **1.16** (.790-2.29) | **3.39** (2.15-6.32) | **6.79** (2.69-18.2) | 524 |
| | 01-02 | * | < LOD | < LOD | < LOD | **2.81** (1.33-9.17) | 695 |
| Non-Hispanic whites | 99-00 | * | < LOD | **2.44** (1.53-3.24) | **4.72** (3.47-8.43) | **9.55** (4.27-17.8) | 603 |
| | 01-02 | * | < LOD | < LOD | < LOD | **4.31** (3.20-7.21) | 949 |

< 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 236. 2,4,6-Trichlorophenol

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, 1999-2002.

| | 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 | **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 | **4.47** (3.36-5.95) | **3.72** (2.70-5.90) | **11.0** (4.71-18.0) | **24.0** (14.0-38.0) | **32.0** (20.5-46.0) | 481 |
| | 01-02 | * | **2.99** (1.91-4.32) | **7.79** (5.73-9.99) | **13.4** (10.6-17.3) | **19.2** (14.1-25.3) | 574 |
| 12-19 years | 99-00 | **3.56** (3.00-4.23) | **3.00** (2.60-3.60) | **6.00** (4.20-11.0) | **20.0** (9.60-37.0) | **37.0** (20.0-54.0) | 678 |
| | 01-02 | * | **3.26** (2.32-4.37) | **7.49** (6.45-9.40) | **13.5** (11.0-18.2) | **19.4** (17.3-26.6) | 820 |
| 20-59 years | 99-00 | **2.52** (2.23-2.85) | **2.40** (2.10-2.40) | **4.20** (3.50-5.20) | **11.6** (6.00-21.0) | **21.0** (11.0-37.0) | 830 |
| | 01-02 | * | **< LOD** | **4.83** (3.70-6.28) | **9.60** (8.72-10.7) | **13.2** (11.8-15.2) | 1109 |
| **Gender** | | | | | | | |
| Males | 99-00 | **2.92** (2.58-3.31) | **2.60** (2.40-2.80) | **5.10** (3.90-7.90) | **15.0** (8.30-23.0) | **26.0** (15.0-38.0) | 970 |
| | 01-02 | * | **2.36** (1.68-3.02) | **6.65** (5.98-7.53) | **12.1** (10.8-13.1) | **17.0** (13.6-22.2) | 1178 |
| Females | 99-00 | **2.78** (2.35-3.28) | **2.40** (2.10-2.45) | **4.80** (3.40-7.59) | **16.0** (6.00-32.0) | **25.0** (13.0-47.0) | 1019 |
| | 01-02 | * | **< LOD** | **4.69** (3.59-6.09) | **9.71** (8.25-11.6) | **13.1** (11.7-16.6) | 1325 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **2.70** (2.20-3.32) | **2.60** (2.10-3.10) | **4.80** (4.10-6.50) | **14.0** (8.20-23.0) | **22.0** (13.0-34.0) | 694 |
| | 01-02 | * | **2.07** (<LOD-3.23) | **5.31** (3.95-6.54) | **11.3** (8.51-12.8) | **15.6** (12.6-19.8) | 677 |
| Non-Hispanic blacks | 99-00 | **3.14** (2.40-4.12) | **2.80** (2.10-3.40) | **6.40** (3.40-14.0) | **18.0** (9.30-33.0) | **32.0** (16.0-68.0) | 519 |
| | 01-02 | * | **2.58** (1.32-4.02) | **6.45** (5.04-7.55) | **11.1** (8.87-14.9) | **17.9** (11.8-24.7) | 696 |
| Non-Hispanic whites | 99-00 | **2.74** (2.46-3.06) | **2.45** (2.30-2.70) | **4.60** (3.80-6.60) | **12.0** (6.40-21.0) | **20.0** (12.0-37.0) | 602 |
| | 01-02 | * | **1.57** (<LOD-2.20) | **6.10** (5.01-6.65) | **10.7** (9.67-12.3) | **14.6** (13.3-17.9) | 931 |

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

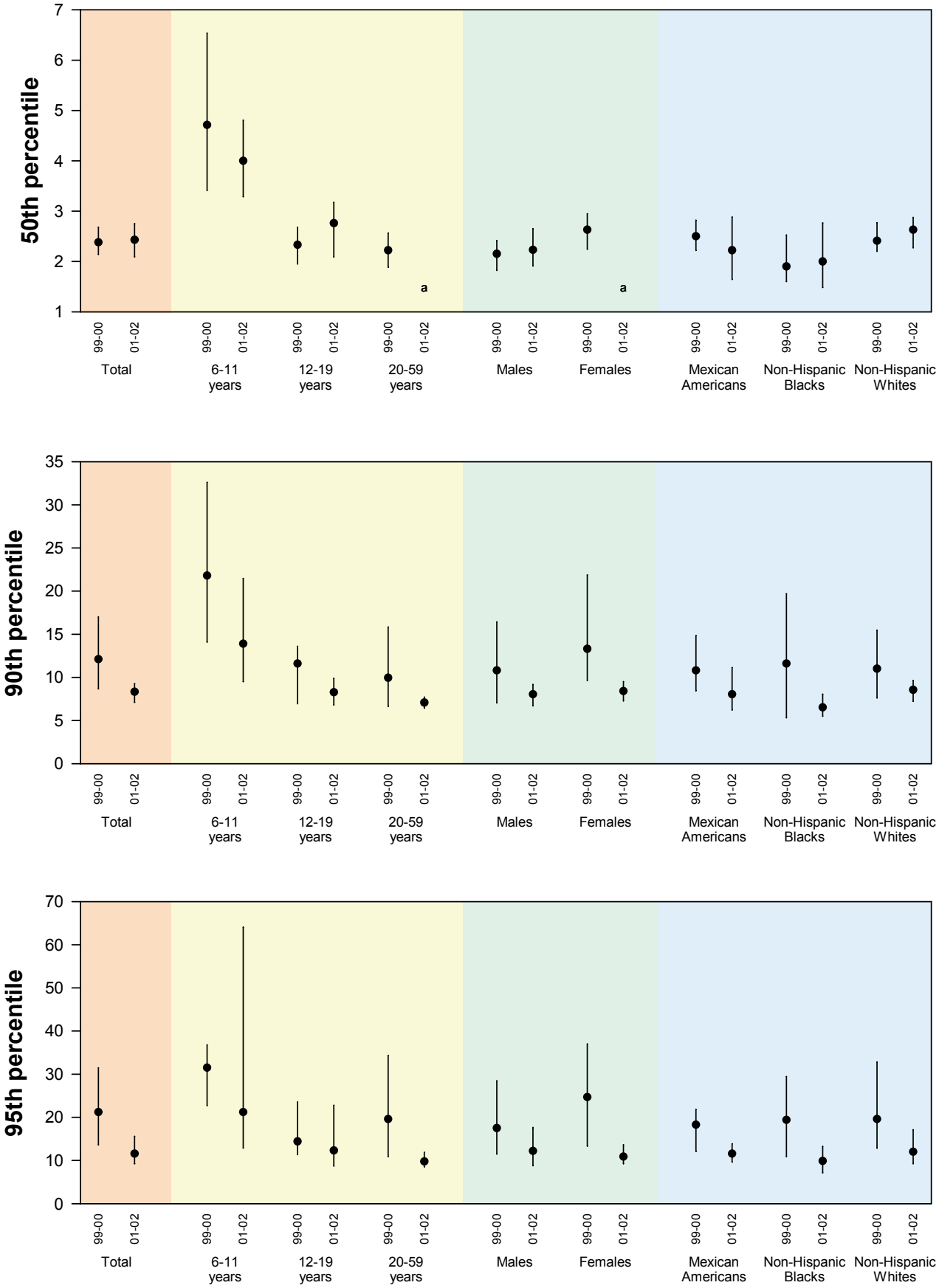
Geometric mean and selected percentiles of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6-59 years, National Health and Nutrition Examination Survey, 1999-2002.

| | 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 | **2.54** (2.30-2.81) | **2.38** (2.14-2.68) | **4.91** (3.83-6.49) | **12.1** (8.67-17.0) | **21.2** (13.6-31.5) | 1989 |
| | 01-02 | * | **2.43** (2.09-2.75) | **4.36** (4.14-4.70) | **8.33** (7.10-9.26) | **11.6** (9.25-15.6) | 2502 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **4.82** (3.87-6.00) | **4.71** (3.41-6.53) | **11.5** (7.63-15.3) | **21.8** (14.1-32.6) | **31.5** (22.7-36.8) | 481 |
| | 01-02 | * | **4.00** (3.29-4.81) | **8.26** (6.16-10.4) | **13.9** (9.51-21.5) | **21.2** (12.9-64.1) | 574 |
| 12-19 years | 99-00 | **2.40** (2.08-2.78) | **2.33** (1.95-2.68) | **4.27** (3.13-6.00) | **11.6** (6.94-13.6) | **14.4** (11.3-23.6) | 678 |
| | 01-02 | * | **2.76** (2.09-3.17) | **4.52** (3.83-5.92) | **8.28** (6.81-9.89) | **12.3** (8.73-22.8) | 819 |
| 20-59 years | 99-00 | **2.32** (2.04-2.63) | **2.22** (1.89-2.56) | **4.25** (3.38-5.63) | **9.95** (6.64-15.9) | **19.6** (10.9-34.4) | 830 |
| | 01-02 | * | **< LOD** | **4.05** (3.66-4.38) | **7.08** (6.43-7.72) | **9.77** (8.53-11.9) | 1109 |
| **Gender** | | | | | | | |
| Males | 99-00 | **2.24** (1.99-2.53) | **2.15** (1.82-2.42) | **4.41** (3.56-5.88) | **10.8** (7.04-16.4) | **17.5** (11.5-28.5) | 970 |
| | 01-02 | * | **2.23** (1.91-2.65) | **4.22** (3.77-4.73) | **8.05** (6.70-9.17) | **12.2** (8.79-17.7) | 1178 |
| Females | 99-00 | **2.88** (2.49-3.33) | **2.63** (2.24-2.95) | **5.53** (3.88-7.23) | **13.3** (9.65-21.9) | **24.7** (13.3-37.0) | 1019 |
| | 01-02 | * | **< LOD** | **4.53** (4.19-5.11) | **8.40** (7.27-9.51) | **10.9** (9.26-13.6) | 1324 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **2.43** (2.06-2.87) | **2.50** (2.22-2.82) | **5.43** (3.87-7.10) | **10.8** (8.46-14.9) | **18.3** (12.1-21.8) | 694 |
| | 01-02 | * | **2.22** (1.64-2.88) | **4.25** (3.47-5.76) | **8.05** (6.21-11.1) | **11.6** (9.63-13.9) | 677 |
| Non-Hispanic blacks | 99-00 | **2.13** (1.65-2.76) | **1.90** (1.60-2.52) | **3.97** (2.76-8.02) | **11.6** (5.32-19.7) | **19.4** (10.9-29.5) | 519 |
| | 01-02 | * | **2.00** (1.48-2.76) | **3.83** (3.15-4.81) | **6.52** (5.50-8.06) | **9.87** (7.14-13.2) | 695 |
| Non-Hispanic whites | 99-00 | **2.59** (2.33-2.88) | **2.41** (2.20-2.77) | **4.87** (3.83-6.06) | **11.0** (7.62-15.5) | **19.6** (12.9-32.8) | 602 |
| | 01-02 | * | **2.63** (2.27-2.88) | **4.60** (4.29-4.98) | **8.56** (7.22-9.65) | **12.0** (9.25-17.1) | 931 |

< 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 29. 2,4,6-Trichlorophenol (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.




[a] Estimate is less than the limit of detection (LOD). See Appendix A for LODs.

# 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-dichloro-ethenylidene)-bis[4-chlorobenzene] (DDE) and 1,1'-dichloro-(2,2-bis(p-chlorophenyl) ethane (DDD). All of these chemicals are highly persistent in the environment and can be found in soil, air, and water. The biodegradation half-life of DDT in soil varies from 2 years to 15 years, depending on conditions.

In the general population, food is the primary source of exposure to DDT. Many foods and commodities contain detectable residues of DDT or its degradation products. The estimated food intake of DDT in the United States has decreased since the 1950s (Walker et al., 1954; Durham et al., 1965; Duggan and Corneliussen, 1972). However, food imported into the United States from other countries that still use DDT may contain DDT or DDE residues. In addition, local spraying with DDT can add greatly to body burdens. For example, after a single application of DDT for malaria control, DDT levels were seven-fold higher in people tested 1 year after the application than in a comparison population (Dua et al., 1996).

After DDT enters the body, it is metabolized to DDE. DDT and DDE are widely distributed to different organs in the body, particularly fatty tissues. The concentration of DDT and metabolites in fatty tissues may be several

### Table 238. *p,p'*-DDT (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 | **28.0** (21.9-34.0) | 1679 |
| | 01-02 | * | < LOD | < LOD | < LOD | **26.5** (22.4-32.7) | 2305 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 677 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 756 |
| 20 years and older | 99-00 | * | < LOD | < LOD | < LOD | **30.5** (23.0-37.3) | 1002 |
| | 01-02 | * | < LOD | < LOD | < LOD | **28.1** (23.8-39.0) | 1549 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | **25.1** (<LOD-39.3) | 799 |
| | 01-02 | * | < LOD | < LOD | < LOD | **21.6** (<LOD-25.8) | 1073 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | **29.4** (23.0-35.8) | 880 |
| | 01-02 | * | < LOD | < LOD | **18.1** (<LOD-21.9) | **36.3** (25.5-54.3) | 1232 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | **61.3** (27.0-155) | **150** (59.3-590) | 635 |
| | 01-02 | * | < LOD | < LOD | **83.1** (33.3-236) | **236** (104-541) | 566 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | **22.2** (<LOD-31.5) | **31.5** (23.2-65.0) | 356 |
| | 01-02 | * | < LOD | < LOD | **22.1** (<LOD-40.9) | **40.9** (21.2-95.8) | 514 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 564 |
| | 01-02 | * | < LOD | < LOD | < LOD | **17.7** (<LOD-20.7) | 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.

hundred 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)**

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** | **.172** (.131-.218) | 1679 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.184** (.161-.221) | 2305 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 677 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 756 |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.187** (.147-.228) | 1002 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.201** (.167-.257) | 1549 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.147** (.107-.188) | 799 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.153** (.121-.184) | 1073 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.190** (.142-.232) | 880 |
| | 01-02 | * | **< LOD** | **< LOD** | **.131** (.110-.146) | **.239** (.175-.398) | 1232 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **.393** (.188-.998) | **.998** (.331-4.26) | 635 |
| | 01-02 | * | **< LOD** | **< LOD** | **.512** (.253-1.34) | **1.56** (.569-4.01) | 566 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **.123** (.090-.168) | **.170** (.141-.420) | 356 |
| | 01-02 | * | **< LOD** | **< LOD** | **.134** (.079-.285) | **.229** (.121-.532) | 514 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 564 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.125** (.103-.141) | 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.

reported in studies of adults in New Zealand (Bates et al., 2004*b*) and ten times lower than serum measurements reported in adults in Slovakia (Pavuk et al., 2004).

The 95th percentile value for serum levels of *p,p*'-DDT and *p,p*'-DDE in the NHANES 2001-2002 subsample were approximately 15-fold and three-fold lower, respectively, than measurements reported in a nonrandom subsample from NHANES II (1976-1980) participants (Stehr-Green et al., 1989). Serum *p,p*'-DDT levels in the NHANES 2001-2002 subsample were many times lower than levels in women in Spain (Botella et al., 2004), or in men in India (Bhatnagar et al., 2004).

In the NHANES 1999-2000 and 2001-2002 subsamples, serum levels of *o,p*'-DDT were below the limit of detection.

### Comparing Adjusted Geometric Means

Geometric mean levels of serum *p,p*'-DDE for the demographic groups were compared after adjusting for the covariates of race/ethnicity, age, gender, log serum cotinine, and lipid level (data not shown). In NHANES 2001-2002, adjusted geometric mean levels in the group aged 20 years and older were more than a two-fold higher level of *p,p*'-DDE than the group aged 12-19 years. These findings are consistent with previous measurements in NHANES II (1976-1980) participants, in whom levels of *p,p*'-DDE were also observed to be higher in older age groups (Stehr-Green et al., 1989). The adjusted geometric mean levels of *p,p*'-DDE in Mexican Americans was approximately two-fold higher than in non-Hispanic blacks and approximately three-fold higher in than in non-Hispanic whites. Non-Hispanic blacks had higher levels than non-Hispanic whites. Other studies have also reported higher serum levels of *p,p*'-DDE in Mexican Americans (Akkina et al., 2004). In a study of African-American farmers, Martin et al. (2002) reported higher median lipid-adjusted levels of DDE than the median values that appear in this *Report*. It is unknown

**Table 240. *p,p'*-DDE (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 | **260** (226-298) | **226** (184-278) | **537** (476-631) | **1150** (976-1350) | **1780** (1410-2300) | 1964 |
| | 01-02 | **295** (267-327) | **250** (227-277) | **597** (521-699) | **1400** (1210-1500) | **2320** (1830-2780) | 2298 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | **118** (102-135) | **108** (97.7-119) | **185** (141-237) | **339** (243-479) | **528** (339-812) | 686 |
| | 01-02 | **124** (106-146) | **112** (98.5-138) | **213** (172-253) | **319** (282-389) | **456** (343-722) | 758 |
| 20 years and older | 99-00 | **297** (256-344) | **267** (213-323) | **608** (530-693) | **1250** (1030-1550) | **2020** (1520-2620) | 1278 |
| | 01-02 | **338** (303-376) | **285** (249-337) | **689** (590-798) | **1470** (1310-1700) | **2550** (1980-3080) | 1540 |
| **Gender** | | | | | | | |
| Males | 99-00 | **249** (220-283) | **222** (182-262) | **493** (380-578) | **992** (789-1130) | **1430** (1080-2160) | 937 |
| | 01-02 | **285** (252-323) | **245** (222-285) | **520** (441-619) | **1160** (937-1360) | **1900** (1570-2390) | 1069 |
| Females | 99-00 | **270** (226-322) | **234** (184-302) | **601** (490-707) | **1350** (1040-1720) | **2170** (1570-2810) | 1027 |
| | 01-02 | **305** (273-341) | **256** (219-297) | **704** (567-844) | **1480** (1400-1690) | **2630** (1940-3300) | 1229 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **674** (574-792) | **623** (545-701) | **1350** (1090-1660) | **3090** (2040-4950) | **4940** (3070-9350) | 657 |
| | 01-02 | **652** (569-747) | **551** (455-690) | **1380** (1050-1950) | **4110** (2520-6550) | **7030** (3080-15600) | 566 |
| Non-Hispanic blacks | 99-00 | **295** (241-362) | **251** (199-313) | **651** (492-874) | **1850** (1040-2220) | **2300** (1560-5680) | 416 |
| | 01-02 | **324** (262-400) | **248** (223-296) | **744** (583-999) | **1580** (1180-2980) | **3260** (1270-6900) | 515 |
| Non-Hispanic whites | 99-00 | **217** (189-249) | **191** (162-238) | **438** (355-507) | **825** (647-1010) | **1160** (1010-1350) | 732 |
| | 01-02 | **253** (226-284) | **224** (203-254) | **463** (402-558) | **1140** (878-1340) | **1640** (1410-1940) | 1053 |

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.

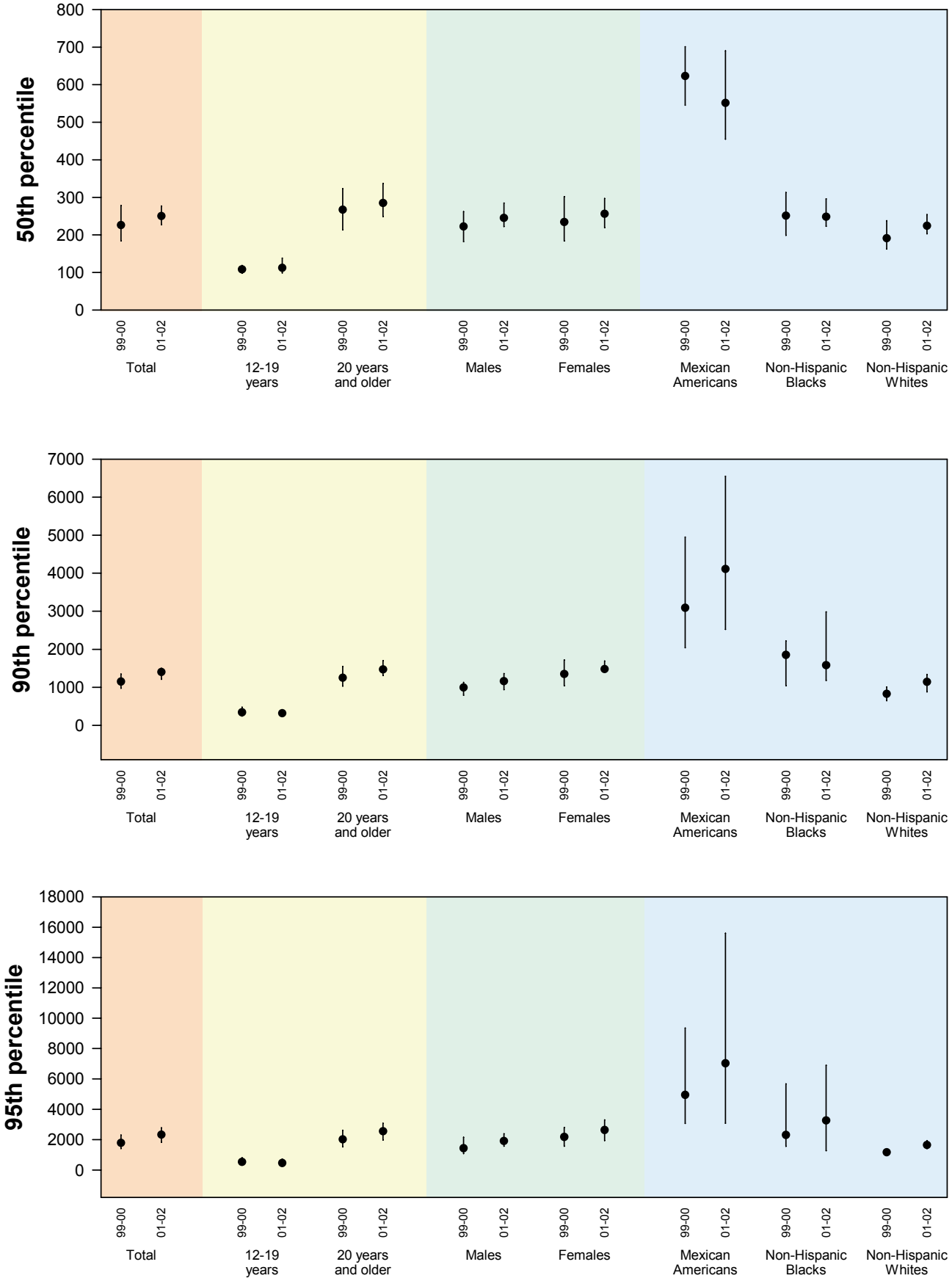
## Table 241. *p,p'*-DDE (whole weight)

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 | **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 |
| Non-Hispanic blacks | 99-00 | **1.63** (1.31-2.02) | **1.34** (1.11-1.66) | **3.80** (3.01-5.69) | **11.1** (6.57-13.2) | **14.6** (8.88-35.2) | 416 |
| | 01-02 | **1.82** (1.46-2.28) | **1.38** (1.22-1.72) | **4.39** (3.52-6.06) | **10.5** (7.24-17.6) | **19.3** (8.51-49.3) | 515 |
| Non-Hispanic whites | 99-00 | **1.32** (1.14-1.53) | **1.13** (1.01-1.35) | **2.85** (2.34-3.36) | **5.71** (4.62-6.53) | **8.04** (6.32-9.81) | 732 |
| | 01-02 | **1.57** (1.39-1.76) | **1.41** (1.27-1.58) | **3.10** (2.56-3.68) | **7.00** (6.02-8.34) | **11.3** (8.60-13.7) | 1053 |

## Figure 30. *p,p'*-DDE (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 242. *o,p'*-DDT (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 | 1669 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 2279 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 667 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 756 |
| 20 years and older | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1002 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1523 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 796 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1059 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 873 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1220 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 632 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 565 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 354 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 507 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 560 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1045 |

< 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 243. *o,p'*-DDT (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 | 1669 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 2279 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 667 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 756 |
| 20 years and older | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 1002 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1523 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 796 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1059 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 873 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1220 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 632 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 565 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 354 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 507 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 560 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1045 |

< 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.

# Chlordane

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

# Heptachlor

CAS No. 76-44-8

### General Information

Chlordane is an organochlorine pesticide that was once used on agricultural crops and lawns and in buildings to kill termites and other insects. In 1988, the U.S. EPA cancelled registration for the production and use of chlordane in the United States. Heptachlor is another organochlorine pesticide that has a chemical structure and mechanism of toxicity similar to that of chlordane. The use of heptachlor in the United States is restricted to include limited applications for controlling fire ants.

The technical-grade formulation of chlordane may consist of more than 50 related chemicals. The main components are *cis*- and *trans*-chlordane, *trans*-nonachlor, and heptachlor. Chlordane is metabolized in the environment and in the body to oxychlordane. Heptachlor is metabolized to heptachlor epoxide. Chlordane is an unlikely source of exposure if heptachlor epoxide is found in the absence of either oxychlordane or *trans*-nonachlor.

Heptachlor, chlordane, and their metabolites are highly persistent chemicals in the environment as well as in the body. Fatty foods are the most likely source of exposure to these chemicals in the general population. In Hawaii during 1981 and 1982, heptachlor was used on pineapples, and the remnant pineapple tops (chops) were fed to milk-producing cows, resulting in human exposure when people drank the milk. (Takahashi and Parks, 1982). Consequently, increased levels of heptachlor epoxide were found in the breast milk of lactating

### Table 244. Oxychlordane (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 | **20.6** (17.8-23.0) | **34.4** (30.5-38.6) | **44.8** (40.2-49.6) | 1661 |
| | 01-02 | **11.4** (<LOD-12.5) | **11.1** (<LOD-12.5) | **21.7** (19.2-24.4) | **36.3** (31.4-41.4) | **49.7** (42.0-61.2) | 2249 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 663 |
| | 01-02 | * | < LOD | < LOD | < LOD | **11.4** (<LOD-12.6) | 752 |
| 20 years and older | 99-00 | * | < LOD | **23.3** (21.0-25.9) | **37.7** (32.3-43.5) | **47.7** (43.1-50.8) | 998 |
| | 01-02 | **12.9** (11.7-14.3) | **13.2** (11.4-14.9) | **23.9** (21.2-26.6) | **38.4** (33.4-45.7) | **53.1** (44.1-65.9) | 1497 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | **17.8** (16.1-19.5) | **31.2** (25.8-37.5) | **42.3** (35.3-49.6) | 793 |
| | 01-02 | **11.1** (<LOD-12.6) | **11.1** (<LOD-12.5) | **20.6** (16.5-24.5) | **33.1** (27.5-43.8) | **48.1** (40.2-56.9) | 1049 |
| Females | 99-00 | * | < LOD | **22.3** (20.1-25.9) | **36.7** (31.4-39.1) | **46.1** (39.1-51.8) | 868 |
| | 01-02 | **11.7** (10.7-12.7) | **11.0** (<LOD-12.9) | **23.1** (20.7-25.0) | **37.4** (34.5-42.1) | **52.5** (42.7-70.0) | 1200 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | **16.2** (<LOD-19.7) | **28.9** (18.8-42.0) | **39.8** (26.8-61.0) | 628 |
| | 01-02 | * | < LOD | **13.9** (11.0-18.4) | **27.1** (21.0-33.1) | **37.9** (29.9-42.0) | 557 |
| Non-Hispanic blacks | 99-00 | * | < LOD | **18.5** (<LOD-32.2) | **39.9** (26.5-47.3) | **47.5** (43.5-65.5) | 350 |
| | 01-02 | **11.7** (<LOD-13.6) | < LOD | **22.6** (17.2-28.3) | **41.2** (30.6-53.7) | **55.3** (41.8-73.5) | 501 |
| Non-Hispanic whites | 99-00 | * | < LOD | **21.8** (18.6-24.6) | **34.1** (28.9-40.9) | **43.5** (37.2-49.8) | 559 |
| | 01-02 | **12.1** (11.0-13.3) | **11.7** (10.5-13.9) | **22.9** (20.0-25.6) | **37.4** (31.5-44.1) | **50.8** (41.0-67.4) | 1031 |

< 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.

women. Indoor inhalational exposure to chlordane may occur for decades after the termite treatment of a residence. It is estimated that 80 million homes have been treated with chlordane. Indoor-air concentrations of chlordane have been measured that are higher than outdoor-air concentrations (U.S. EPA, 1990; Whitemore et al., 1994).

Chlordane, heptachlor, and their metabolites distribute widely in the body and accumulate in fatty tissues. The metabolites of chlordane and heptachlor are eliminated from the body very slowly over the course of months to years. At high doses, chlordane and heptachlor block inhibitory neurotransmitters in the central nervous system. In cases of human poisoning , headache, nausea, gastrointestinal inflammation, confusion, tremors, and seizures have been reported. For this class of chemicals, animal studies demonstrate liver, hematologic, and developmental toxicities and immunological effects. IARC considers chlordane and heptachlor as possibly carcinogenic to humans.

Information about external exposure (i.e., environmental levels) and health effects of chlordane is available from ATSDR's Toxicological Profiles at http://www.atsdr.cdc.gov/toxprofiles/tp31.html and for heptachlor at http://www.atsdr.cdc.gov/tfacts12.html.

### Interpreting Levels of Lipid-Adjusted Serum Oxychlordane, *trans*-Nonachlor, and Heptachlor Epoxide Reported in the Tables

Serum levels of oxychlordane, *trans*-nonachlor, and heptachlor epoxide 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.

Serum oxychlordane levels in both the NHANES 1999-2000 and the 2001-2002 subsamples are comparable to levels measured in Swedish men and women (Glynn et al., 2003). Levels of oxychlordane exceeding the 95th percentile in this *Report* were reported in a study of an Inuit population in Greenland (Van Oostdam et al., 2004). Serum *trans*-nonachlor levels in the NHANES 2001-2002 subsample were similar to levels in adult

**Table 245. Oxychlordane (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 | **.134** (.119-.150) | **.255** (.202-.287) | **.310** (.290-.343) | 1661 |
| | 01-02 | **.070** (.063-.077) | **.069** (.058-.078) | **.143** (.126-.160) | **.248** (.215-.297) | **.352** (.289-.441) | 2249 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 663 |
| | 01-02 | * | < LOD | < LOD | < LOD | **.058** (.050-.068) | 752 |
| 20 years and older | 99-00 | * | < LOD | **.154** (.136-.179) | **.279** (.228-.304) | **.328** (.299-.398) | 998 |
| | 01-02 | **.082** (.074-.091) | **.084** (.074-.094) | **.157** (.137-.180) | **.267** (.225-.318) | **.370** (.307-.449) | 1497 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | **.122** (.101-.135) | **.216** (.182-.279) | **.303** (.264-.343) | 793 |
| | 01-02 | **.069** (.061-.079) | **.067** (.058-.082) | **.133** (.116-.160) | **.231** (.189-.299) | **.319** (.252-.426) | 1049 |
| Females | 99-00 | * | < LOD | **.143** (.126-.173) | **.267** (.202-.306) | **.319** (.291-.401) | 868 |
| | 01-02 | **.071** (.065-.077) | **.069** (.059-.078) | **.146** (.132-.163) | **.258** (.228-.308) | **.365** (.278-.513) | 1200 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | **.100** (.082-.130) | **.203** (.127-.317) | **.282** (.186-.413) | 628 |
| | 01-02 | * | < LOD | **.097** (.065-.126) | **.194** (.144-.238) | **.278** (.210-.363) | 557 |
| Non-Hispanic blacks | 99-00 | * | < LOD | **.113** (.070-.174) | **.237** (.171-.288) | **.311** (.244-.426) | 350 |
| | 01-02 | **.066** (.055-.077) | < LOD | **.127** (.094-.168) | **.259** (.181-.349) | **.349** (.241-.560) | 501 |
| Non-Hispanic whites | 99-00 | * | < LOD | **.139** (.124-.165) | **.264** (.198-.296) | **.316** (.281-.376) | 559 |
| | 01-02 | **.075** (.068-.083) | **.076** (.066-.086) | **.151** (.131-.172) | **.253** (.219-.312) | **.365** (.280-.449) | 1031 |

< 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.

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

Geometric means levels of serum *trans*-nonachlor and oxychlordane in the demographic groups were compared after adjusting for the covariates of race/ethnicity, age, gender, log serum cotinine, and lipid level (data not shown). Some comparisons are not possible due to a low detection rate for some demographic groups. For the adjusted geometric means levels of *trans*-nonachlor in NHANES 2001-2002, Mexican Americans were lower than non-Hispanic blacks and non-Hispanic whites. For the adjusted geometric means levels of oxychlordane in NHANES 2001-2002, improved detections limits permitted comparison of several demographic groups, but no differences were found.

Finding a measurable amount of oxychlordane, *trans*-nonachlor, or heptachlor epoxide 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 heptachlor or chlordane 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 heptachlor and chlordane than levels found in the general population.

**Table 246. *trans*-Nonachlor (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 | **18.3** (16.7-20.0) | **17.8** (16.0-19.8) | **31.9** (28.9-36.0) | **55.1** (48.4-62.6) | **79.4** (67.6-88.1) | 1933 |
| | 01-02 | **17.0** (15.2-18.9) | **17.9** (15.5-20.5) | **33.7** (30.2-37.2) | **56.3** (49.6-65.9) | **78.2** (63.6-111) | 2286 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **18.8** (<LOD-20.2) | **23.4** (19.1-28.4) | 664 |
| | 01-02 | * | **< LOD** | **< LOD** | **13.3** (11.8-16.2) | **18.9** (15.2-23.5) | 758 |
| 20 years and older | 99-00 | **20.8** (19.0-22.8) | **20.6** (18.0-23.5) | **35.2** (30.9-40.0) | **59.9** (51.8-67.6) | **82.2** (74.9-89.6) | 1269 |
| | 01-02 | **19.8** (17.6-22.3) | **20.8** (18.8-23.0) | **36.6** (32.8-40.9) | **60.6** (52.5-69.9) | **84.9** (66.0-123) | 1528 |
| **Gender** | | | | | | | |
| Males | 99-00 | **17.7** (16.5-19.1) | **17.1** (14.6-19.6) | **30.0** (27.7-34.2) | **51.1** (47.3-58.6) | **78.2** (60.2-88.1) | 922 |
| | 01-02 | **17.0** (14.8-19.5) | **18.3** (14.8-21.1) | **34.4** (28.3-38.9) | **54.8** (45.0-68.9) | **77.2** (58.9-105) | 1062 |
| Females | 99-00 | **18.8** (16.7-21.1) | **18.4** (16.1-22.2) | **32.9** (29.0-38.3) | **58.7** (48.4-67.6) | **80.8** (71.5-95.5) | 1011 |
| | 01-02 | **17.0** (15.4-18.7) | **17.5** (15.0-20.3) | **32.8** (30.2-36.4) | **56.4** (51.9-65.5) | **76.8** (65.5-111) | 1224 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **25.0** (22.7-29.5) | **40.7** (35.1-51.8) | **55.9** (45.8-77.2) | 650 |
| | 01-02 | **11.9** (<LOD-14.6) | **10.6** (<LOD-14.4) | **26.0** (19.3-30.4) | **47.9** (36.3-57.2) | **59.8** (49.3-74.1) | 558 |
| Non-Hispanic blacks | 99-00 | **20.3** (17.0-24.1) | **17.5** (14.7-22.7) | **35.7** (28.3-45.4) | **77.0** (60.8-90.7) | **106** (84.0-143) | 404 |
| | 01-02 | **18.8** (15.4-22.9) | **19.2** (14.7-22.0) | **36.8** (28.2-50.3) | **72.9** (50.8-110) | **112** (68.7-160) | 514 |
| Non-Hispanic whites | 99-00 | **19.1** (17.2-21.1) | **18.8** (16.8-21.9) | **32.8** (28.0-37.6) | **52.5** (44.9-64.4) | **74.0** (62.3-86.7) | 722 |
| | 01-02 | **17.5** (15.6-19.7) | **18.8** (16.1-21.1) | **34.0** (29.7-38.1) | **55.5** (45.9-69.4) | **78.5** (59.1-126) | 1052 |

< 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 247. *trans*-Nonachlor (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.

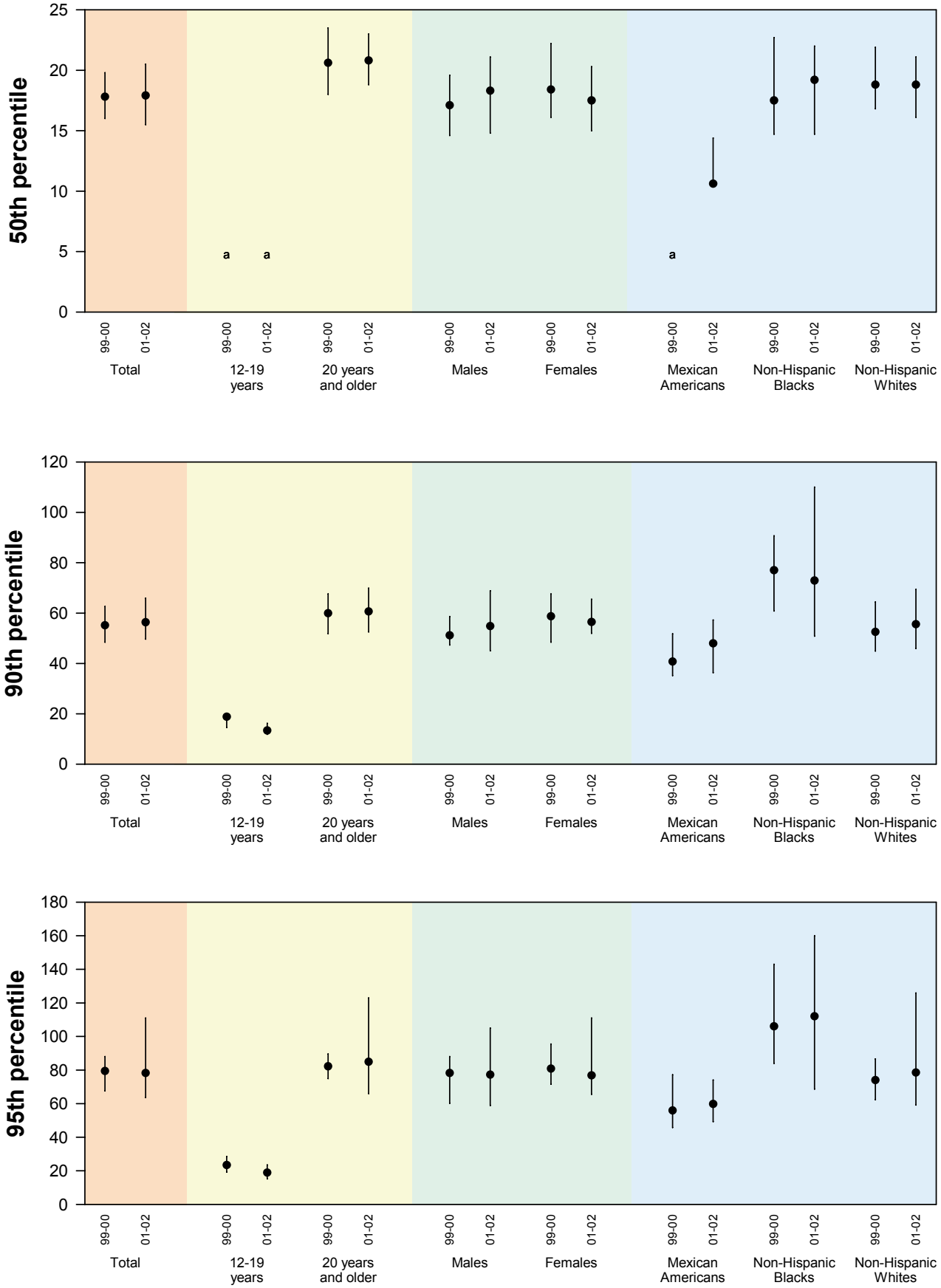
| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) 50th | 75th | 90th | 95th | Sample size |
|---|---|---|---|---|---|---|---|
| **Total, age 12 and older** | 99-00 | **.109** (.099-.119) | **.105** (.093-.123) | **.212** (.187-.233) | **.369** (.325-.418) | **.544** (.468-.628) | 1933 |
| | 01-02 | **.104** (.093-.116) | **.112** (.097-.124) | **.217** (.191-.243) | **.389** (.328-.470) | **.589** (.432-.797) | 2286 |
| **Age group** | | | | | | | |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **.089** (.063-.106) | **.111** (.100-.128) | 664 |
| | 01-02 | * | **< LOD** | **< LOD** | **.067** (.059-.083) | **.093** (.075-.125) | 758 |
| 20 years and older | 99-00 | **.128** (.116-.141) | **.126** (.107-.147) | **.233** (.212-.255) | **.401** (.360-.461) | **.573** (.494-.686) | 1269 |
| | 01-02 | **.125** (.111-.141) | **.133** (.118-.148) | **.241** (.213-.278) | **.418** (.347-.537) | **.642** (.469-.843) | 1528 |
| **Gender** | | | | | | | |
| Males | 99-00 | **.106** (.098-.114) | **.103** (.089-.118) | **.207** (.179-.224) | **.353** (.305-.401) | **.514** (.401-.628) | 922 |
| | 01-02 | **.105** (.091-.122) | **.112** (.091-.134) | **.224** (.192-.263) | **.379** (.310-.495) | **.579** (.390-.828) | 1062 |
| Females | 99-00 | **.111** (.099-.125) | **.112** (.093-.131) | **.220** (.185-.250) | **.383** (.310-.452) | **.573** (.463-.694) | 1011 |
| | 01-02 | **.103** (.093-.113) | **.109** (.094-.123) | **.214** (.184-.241) | **.395** (.341-.448) | **.589** (.429-.825) | 1224 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **.165** (.124-.205) | **.300** (.244-.344) | **.387** (.318-.520) | 650 |
| | 01-02 | **.071** (.056-.091) | **.064** (.044-.094) | **.156** (.123-.209) | **.328** (.272-.394) | **.465** (.354-.594) | 558 |
| Non-Hispanic blacks | 99-00 | **.112** (.093-.134) | **.101** (.082-.134) | **.215** (.174-.297) | **.481** (.340-.595) | **.748** (.511-.955) | 404 |
| | 01-02 | **.106** (.085-.131) | **.107** (.080-.125) | **.218** (.162-.313) | **.485** (.316-.680) | **.680** (.408-1.19) | 514 |
| Non-Hispanic whites | 99-00 | **.116** (.104-.129) | **.119** (.100-.137) | **.214** (.185-.244) | **.366** (.302-.437) | **.513** (.435-.632) | 722 |
| | 01-02 | **.108** (.096-.122) | **.117** (.101-.133) | **.220** (.191-.250) | **.388** (.305-.494) | **.596** (.402-.927) | 1052 |

< 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 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.




[a] Estimate is less than the limit of detection (LOD). See Appendix A for LODs.

## 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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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)

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** | **.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** | 741 |
| 20 years and older | 99-00 | * | **< LOD** | **< LOD** | **.125** (.097-.170) | **.188** (.125-.273) | 951 |
| | 01-02 | * | **< LOD** | **< LOD** | **.107** (.092-.141) | **.166** (.135-.187) | 1518 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.149** (.108-.184) | 760 |
| | 01-02 | * | **< LOD** | **< LOD** | **.099** (.088-.114) | **.148** (.106-.179) | 1047 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **.118** (.091-.192) | **.196** (.116-.310) | 829 |
| | 01-02 | * | **< LOD** | **< LOD** | **.103** (.084-.122) | **.166** (.126-.197) | 1212 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **.103** (.079-.170) | **.170** (.085-.318) | 598 |
| | 01-02 | * | **< LOD** | **< LOD** | **.089** (.069-.109) | **.114** (.098-.240) | 553 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.112** (.055-.192) | 336 |
| | 01-02 | * | **< LOD** | **< LOD** | **.092** (.069-.114) | **.129** (.102-.180) | 503 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **.116** (.090-.162) | **.184** (.109-.310) | 539 |
| | 01-02 | * | **< LOD** | **< LOD** | **.103** (.089-.128) | **.165** (.128-.187) | 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.

# Mirex

CAS No. 2385-85-5

## General Information

Mirex has not been produced or used in the United States since 1977. This chemical was formerly used in southern regions of the United States to control fire ants. It was also used as a flame-retardant additive. Mirex binds strongly to soil and is a highly persistent chemical in the environment. The most likely source of exposure to mirex in the general population is the diet. Some states and U.S. EPA have issued public advisories or warnings that fish from contaminated lakes and rivers may contain mirex.

After people are exposed to mirex, it accumulates in fatty tissues in the body and is not metabolized. At high doses, mirex blocks the action of inhibitory neurotransmitters in the central nervous system. This blocking action can cause abnormal excitation of the brain. Studies of workers exposed to chlordecone, an organochlorine insecticide structurally related to mirex, have reported adverse effects on the liver, nervous system, and reproductive system. IARC classifies mirex as possibly carcinogenic to humans, and NTP classifies mirex as 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 the ATSDR's Toxicological Profiles at http://www.atsdr.cdc. gov/toxprofiles.

## Interpreting Levels of Lipid-Adjusted Serum Mirex Reported in the Tables

Levels of mirex in serum 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.

In the NHANES 1999-2000 and 2001-2002 subsamples,

### Table 250. Mirex (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** | 1853 |
| | 01-02 | * | **< LOD** | **< LOD** | **15.8** (<LOD-73.7) | **57.1** (13.2-230) | 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** | **19.6** (<LOD-108) | **71.0** (14.6-305) | 1529 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 887 |
| | 01-02 | * | **< LOD** | **< LOD** | **16.1** (<LOD-65.6) | **50.8** (12.3-225) | 1052 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 966 |
| | 01-02 | * | **< LOD** | **< LOD** | **14.6** (<LOD-90.4) | **63.0** (12.0-374) | 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** | **15.5** (<LOD-42.2) | **39.5** (<LOD-115) | 398 |
| | 01-02 | * | **< LOD** | **13.5** (<LOD-44.2) | **48.2** (15.4-230) | **153** (30.5-425) | 500 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 688 |
| | 01-02 | * | **< LOD** | **< LOD** | **15.0** (<LOD-103) | **66.7** (12.5-291) | 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.

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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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.

# Aldrin
CAS No. 309-00-02

# Dieldrin
CAS No. 60-57-1

### General Information

Aldrin and dieldrin are organochlorine pesticides that are no longer produced or used in the United States. From the 1950s to 1970, both chemicals were widely used insecticides on agricultural commodities including cotton and corn. These agricultural uses were cancelled in 1970. Aldrin and dieldrin were also registered for use to control termites, but this use was cancelled in 1987. Dieldrin was also used as a sheep-dip pesticide.

Aldrin is rapidly converted to dieldrin in the environment. Aldrin volatilizes from soil after agricultural application or is converted to dieldrin, which volatilizes more slowly. The most likely source of exposure to aldrin and dieldrin in the general population is the diet. Inhalation exposure may also occur among people living in residences where aldrin was previously applied as a pesticide. The U.S. EPA, OSHA, and U.S. FDA have developed criteria on the allowable levels of aldrin in drinking water, workplaces, and foods, respectively.

After aldrin enters the body, it is metabolized to dieldrin. Dieldrin will accumulate in fatty tissues and its metabolites are excreted in bile and feces. It is also excreted in breast milk. The elimination half-life of dieldrin is approximately 1 year. At high doses, aldrin and dieldrin block inhibitory neurotransmitters in the central nervous system. This blocking action can cause abnormal excitation of the brain, leading to symptoms such as headache, confusion, muscle twitching, nausea, vomiting, and seizures.

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 Aldrin and Dieldrin Reported in the Tables

Serum aldrin and dieldrin levels 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.

### Table 252. Aldrin (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 | 2275 |
| **Age group** | | | | | | | |
| 12-19 years | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 756 |
| 20 years and older | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1519 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1057 |
| Females | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1218 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 559 |
| Non-Hispanic blacks | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 512 |
| Non-Hispanic whites | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1045 |

< 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 detectable in a study of New Zealand adults aged 15 years and older (Bates et al., 2004*b*).

In the NHANES 2001-2002 subsample, the 95th percentile value for serum dieldrin was approximately ten times lower than levels measured in a subsample from NHANES II (1976-1980). In New Zealanders aged 15 years and older (Bates et al., 2004*b*) and in Norwegian women (Ward et al., 2000), levels of lipid-adjusted serum dieldrin were lower than the 95th percentile value for dieldrin in this NHANES 2001-2002 subsample.

Finding a measurable amount of aldrin or dieldrin 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 aldrin or dieldrin 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 aldrin and dieldrin than levels found in the general population.

## Table 253. Aldrin (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 12 and older** | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 2275 |
| **Age group** | | | | | | | |
| 12-19 years | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 756 |
| 20 years and older | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1519 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1057 |
| Females | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1218 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 559 |
| Non-Hispanic blacks | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 512 |
| Non-Hispanic whites | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1045 |

< 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 254. Dieldrin (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** | **15.2** (14.3-17.0) | **20.3** (18.7-22.4) | 2159 |
| **Age group** | | | | | | | |
| 12-19 years | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 716 |
| 20 years and older | 01-02 | * | **< LOD** | **10.5** (<LOD-11.6) | **16.4** (15.1-18.2) | **21.3** (19.1-24.0) | 1443 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | **< LOD** | **< LOD** | **15.7** (14.4-18.7) | **20.2** (18.5-23.6) | 1007 |
| Females | 01-02 | * | **< LOD** | **< LOD** | **15.2** (13.4-17.0) | **19.8** (18.0-21.6) | 1152 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | **< LOD** | **< LOD** | **11.6** (<LOD-15.1) | **15.4** (12.6-17.6) | 539 |
| Non-Hispanic blacks | 01-02 | * | **< LOD** | **< LOD** | **15.0** (11.8-19.1) | **20.2** (15.8-25.2) | 484 |
| Non-Hispanic whites | 01-02 | * | **< LOD** | **< LOD** | **15.5** (14.8-17.7) | **20.7** (18.9-23.6) | 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 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 percentiles (95% confidence interval) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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.

# Endrin

CAS No. 72-20-8

## General Information

Endrin, a stereoisomer of dieldrin, is an organochlorine pesticide that is no longer registered for use in the United States. Production and use of endrin was discontinued in 1986. In contrast to aldrin and dieldrin, endrin was not extensively used for termite control in residences. Endrin is a persistent chemical in the environment, particularly in soils. It is transformed in the environment and the human body to metabolites including endrin aldehyde and endrin ketone. The main sources of human exposure to endrin come from residues on food items imported from countries where endrin is still used and living or working near hazardous waste sites where the chemical was produced.

After a person is exposed to endrin, most of the chemical is metabolized and eliminated from the body relatively quickly compared with length of time it takes for other organochlorine pesticides to be metabolized and excreted. Endrin does not accumulate in body tissues, and elimination occurs via its metabolites, which are excreted in the feces. At high doses, endrin blocks inhibitory neurotransmitters in the central nervous system. This blocking action can cause an abnormal excitation of the brain, producing seizures.

Information about external exposure (i.e., environmental levels) and health effects of endrin is available from ATSDR's Toxicological Profiles at http://www.atsdr.cdc.gov/toxprofiles.

## Interpreting Levels of Lipid-Adjusted Serum Endrin Reported in the Tables

Serum endrin levels 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. In the NHANES 2001-2002 subsample, serum levels of endrin were below the limit of detection. This finding is consistent the study of New Zealanders aged 15 years and older in whom levels of endrin were also below the limit of detection (Bates et al., 2004*b*). In another study of women in Spain, endrin was detected in 9% of serum samples at a mean concentration of 2.25 ng/mL (about 2.25 ng/g of serum) (Botella et al., 2004).

Finding a measurable amount of endrin 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 endrin 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 endrin than levels found in the general population.

### Table 256. Endrin (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** | **5.10** (<LOD-5.20) | 2187 |
| **Age group** | | | | | | | |
| 12-19 years | 01-02 | * | **< LOD** | **< LOD** | **5.10** (<LOD-5.30) | **5.60** (5.40-5.70) | 730 |
| 20 years and older | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1457 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **5.20** (<LOD-5.20) | 1022 |
| Females | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1165 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **5.20** (<LOD-6.50) | 547 |
| Non-Hispanic blacks | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **5.30** (<LOD-6.10) | 487 |
| Non-Hispanic whites | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **5.10** (<LOD-5.30) | 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.

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

## Table 257. Endrin (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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.

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

# 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 plastics manufacturing, but they do not have insecticidal properties.

Exposure to organophosphates may occur by ingestion, inhalation, or dermal contact. Farm workers, pesticide applicators, and manufacturers of these pesticides may have higher levels of exposure. The acute effects of the organophosphates from intentional and unintentional overdoses or from high-dose exposure are well known and include neurologic dysfunction that results from inhibition of acetylcholine breakdown in the central and peripheral nervous systems. This dysfunction results from the inhibitory effect of organophosphates on the enzyme acetylcholinesterase. Symptoms may include nausea, vomiting, cholinergic effects, weakness, paralysis, and seizures.

About 75% of registered organophosphate pesticides will be metabolized to measurable dialkyl phosphate metabolites. In contrast to the organophosphates, the dialkyl phosphate metabolites do not inhibit acetylcholinesterase enzymes. Dialkyl phosphates themselves are not considered toxic, but they are markers of exposure to organophosphates. Dialkyl phosphate metabolites can be present in urine after low-level organophosphate exposures that do not cause clinical symptoms (Davies and Peterson, 1997; Franklin et al., 1981). Measurement of these metabolites reflects recent exposure that has occurred predominantly in the last few days.

Dialkyl phosphates may also be present in the environment from the degradation of organophosphates (Lu et al., 2005). Therefore, in addition to reflecting exposure to the parent pesticides, the level of the metabolite in a person's urine may reflect exposure to the metabolite itself, if it was present in the person's environment. Generally, health-related guidelines for urinary levels of these metabolites have not been established.

This *Report* provides measurements in urine for the following six dialkyl phosphate metabolites of organophosphate pesticides:

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

Table 259 shows the six urinary metabolites and their parent organophosphate pesticides. For example, chlorpyrifos is metabolized to both diethylphosphate and diethythiophosphate. Each of the six urinary dialkyl phosphate metabolites can be produced from the metabolism of more than one organophosphate pesticide. Therefore, without other information, the presence of dialkyl phosphate metabolites cannot be linked to exposure to a specific organophosphate pesticide.

### Interpreting Levels of Urinary Dialkyl Phosphate Metabolites Reported in the Tables

Urinary organophosphate metabolite levels 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 2001-2002 NHANES subsample, mean urinary dialkyl phosphate levels were generally lower than levels reported in smaller studies of children (Aprea et al., 2000) and adults (Aprea et al., 1996) in Italy. In those studies, DMTP and DMP were most frequently detected. Urinary dialkyl phosphate levels in the 2001-2002 NHANES subsample were also significantly lower than levels reported in a large study of children and adults in Germany (Heudorf and Angerer, 2001*c*). The measurement of dialkyl phosphates in urine has been used to document exposure of farmers, agricultural workers and their families, pest-control workers, and others to organophosphorus pesticides (Curl et al., 2002; Krieger and Dinoff, 2000; Takamiya, 1994; Davies and Peterson, 1997; Franklin et al., 1981). In occupational studies, reported levels of dialkyl phosphates often exceed levels seen in the general population by up to 50-fold.

**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 | • | • | • | | | |
| Disulfoton | | | | • | • | • |
| Ethion | | | | • | • | • |
| Fenitrothion | • | • | | | | |
| Fenthion | • | • | | | | |
| Isazaphos-methyl | • | • | | | | |
| Malathion | • | • | • | | | |
| Methidathion | • | • | • | | | |
| Methyl parathion | • | • | | | | |
| Naled | • | | | | | |
| Oxydemeton-methyl | • | • | | | | |
| Parathion | | | | • | • | |
| Phorate | | | | • | • | • |
| Phosmet | • | • | • | | | |
| Pirimiphos-methyl | • | • | | | | |
| Sulfotepp | | | | • | • | |
| Temephos | • | • | | | | |
| Terbufos | | | | • | • | • |
| Tetrachlorvinphos | • | | | | | |

### Comparing Adjusted Geometric Means

Geometric mean levels of urinary dialkyl phosphate metabolite for the demographic groups were compared after adjusting for the covariates of race/ethnicity, age, gender, and urinary creatinine (data not shown). Due to insufficient detection rates in the two NHANES surveys, only a few comparisons could be made. For adjusted geometric mean levels of DMTP and DEP in NHANES 1999-2000, the groups aged 6-11 years were about twofold higher than the groups aged 20-59 years and for only DMTP, males had slightly higher levels than females. For adjusted geometric mean levels of DETP in NHANES 2001-2002, non-Hispanic blacks had slightly higher levels than non-Hispanic whites. Studies in other countries have reported higher levels of urinary dialkyl phosphate metabolites in children than in adults (Aprea et al., 2000). 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.

Finding a measurable amount of organophosphate metabolites 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 organophosphates 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 organophosphates than levels found in the general population.

## Table 259. Dimethylphosphate

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, 1999-2002.

| | 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 | * | **.740** (<LOD-1.40) | **2.80** (2.10-3.80) | **7.90** (6.20-8.90) | **13.0** (10.0-18.0) | 1949 |
| | 01-02 | * | **< LOD** | **3.25** (2.76-3.67) | **8.22** (6.95-9.27) | **13.4** (10.9-15.6) | 2519 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **1.00** (.580-2.20) | **4.40** (2.80-6.80) | **10.0** (6.80-15.0) | **21.0** (13.0-26.0) | 471 |
| | 01-02 | * | **.970** (<LOD-2.00) | **5.03** (3.31-7.66) | **12.2** (9.10-15.1) | **18.2** (12.6-41.7) | 576 |
| 12-19 years | 99-00 | * | **.650** (<LOD-1.80) | **3.80** (2.50-4.90) | **9.90** (6.10-18.0) | **22.0** (12.0-29.0) | 664 |
| | 01-02 | * | **.670** (<LOD-1.31) | **4.27** (3.41-5.35) | **9.27** (7.80-12.3) | **14.6** (11.8-21.3) | 822 |
| 20-59 years | 99-00 | * | **.680** (<LOD-1.30) | **2.60** (1.80-3.60) | **6.50** (5.60-8.10) | **9.70** (8.80-14.0) | 814 |
| | 01-02 | * | **< LOD** | **2.93** (2.35-3.41) | **6.89** (5.80-8.82) | **11.5** (9.66-13.7) | 1121 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **.650** (<LOD-1.30) | **2.80** (2.10-3.90) | **7.90** (6.00-9.30) | **18.0** (10.0-24.0) | 952 |
| | 01-02 | * | **< LOD** | **3.40** (2.49-4.30) | **8.22** (6.67-10.3) | **12.6** (10.9-14.7) | 1187 |
| Females | 99-00 | * | **.780** (<LOD-1.50) | **2.80** (1.80-4.00) | **7.60** (5.70-9.00) | **10.0** (8.90-15.0) | 997 |
| | 01-02 | * | **< LOD** | **3.05** (2.59-3.63) | **8.34** (6.70-9.64) | **13.7** (10.9-17.2) | 1332 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **1.00** (<LOD-1.80) | **3.80** (2.70-5.10) | **9.50** (6.00-15.0) | **15.0** (8.60-28.0) | 672 |
| | 01-02 | * | **.660** (<LOD-1.51) | **3.22** (2.46-4.27) | **9.28** (7.10-10.7) | **14.4** (10.7-21.0) | 678 |
| Non-Hispanic blacks | 99-00 | * | **.980** (.620-1.40) | **3.60** (2.50-5.50) | **8.90** (6.70-14.0) | **21.0** (14.0-23.0) | 509 |
| | 01-02 | * | **.910** (<LOD-2.20) | **5.45** (3.81-6.78) | **11.5** (8.77-14.9) | **19.4** (14.1-23.3) | 695 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **2.90** (1.80-4.20) | **7.90** (5.90-9.00) | **10.0** (9.00-18.0) | 595 |
| | 01-02 | * | **< LOD** | **3.01** (2.33-3.49) | **7.39** (5.98-9.22) | **12.3** (9.63-14.6) | 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.

## Table 260. Dimethylphosphate (creatinine corrected)

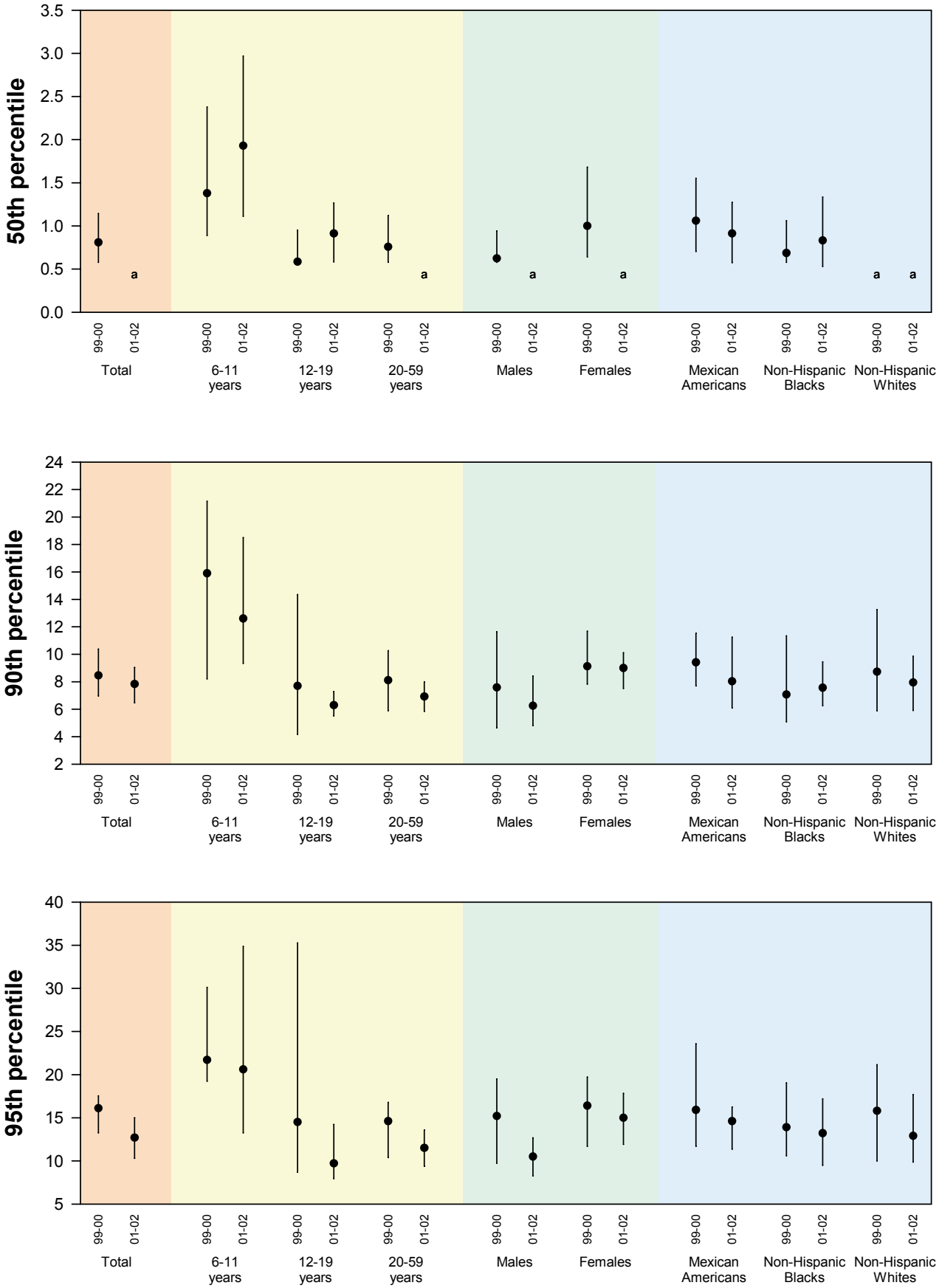
Geometric mean and selected percentiles of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6-59 years, National Health and Nutrition Examination Survey, 1999-2002.

| | 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 | * | **.809** (.569-1.15) | **2.93** (2.11-3.92) | **8.46** (6.96-10.4) | **16.1** (13.3-17.6) | 1949 |
| | 01-02 | * | **< LOD** | **3.00** (2.59-3.33) | **7.83** (6.47-9.04) | **12.7** (10.3-15.0) | 2518 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **1.38** (.889-2.38) | **4.48** (2.88-7.89) | **15.9** (8.21-21.2) | **21.7** (19.2-30.1) | 471 |
| | 01-02 | * | **1.93** (1.11-2.97) | **5.99** (4.32-8.28) | **12.6** (9.34-18.5) | **20.6** (13.3-34.8) | 576 |
| 12-19 years | 99-00 | * | **.586** (.451-.952) | **2.27** (1.70-2.80) | **7.70** (4.16-14.4) | **14.5** (8.70-35.3) | 664 |
| | 01-02 | * | **.913** (.584-1.27) | **3.28** (2.75-3.78) | **6.29** (5.51-7.30) | **9.70** (7.94-14.2) | 821 |
| 20-59 years | 99-00 | * | **.759** (.554-1.12) | **2.87** (1.89-3.99) | **8.11** (5.89-10.3) | **14.6** (10.4-16.8) | 814 |
| | 01-02 | * | **< LOD** | **2.55** (2.05-3.03) | **6.92** (5.85-8.00) | **11.5** (9.38-13.6) | 1121 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **.623** (.442-.942) | **2.38** (1.83-3.18) | **7.58** (4.64-11.6) | **15.2** (9.74-19.5) | 952 |
| | 01-02 | * | **< LOD** | **2.61** (2.07-3.07) | **6.25** (4.82-8.42) | **10.5** (8.28-12.7) | 1187 |
| Females | 99-00 | * | **1.00** (.641-1.68) | **3.53** (2.30-5.19) | **9.12** (7.82-11.7) | **16.4** (11.7-19.7) | 997 |
| | 01-02 | * | **< LOD** | **3.43** (2.74-4.27) | **9.00** (7.51-10.1) | **15.0** (11.9-17.8) | 1331 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **1.06** (.704-1.55) | **3.78** (2.54-5.45) | **9.41** (7.69-11.5) | **15.9** (11.7-23.6) | 672 |
| | 01-02 | * | **.913** (.575-1.27) | **3.01** (2.52-3.72) | **8.03** (6.09-11.3) | **14.6** (11.4-16.2) | 678 |
| Non-Hispanic blacks | 99-00 | * | **.686** (.527-1.06) | **2.67** (1.89-3.77) | **7.07** (5.09-11.3) | **13.9** (10.6-19.0) | 509 |
| | 01-02 | * | **.833** (.530-1.34) | **3.36** (2.68-4.29) | **7.56** (6.25-9.45) | **13.2** (9.50-17.2) | 694 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **3.15** (1.97-4.32) | **8.73** (5.89-13.3) | **15.8** (10.0-21.2) | 595 |
| | 01-02 | * | **< LOD** | **2.74** (2.20-3.37) | **7.94** (5.91-9.86) | **12.9** (9.85-17.7) | 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 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.




[a] Estimate is less than the limit of detection (LOD). See Appendix A for LODs.

## Table 261. Dimethylthiophosphate

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, 1999-2002.

| | 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 | **1.82** (1.36-2.44) | **2.70** (1.20-4.00) | **10.0** (8.10-15.0) | **38.0** (17.0-38.0) | **46.0** (38.0-62.0) | 1948 |
| | 01-02 | * | **.450** (<LOD-1.41) | **4.02** (2.90-5.60) | **16.2** (12.4-22.9) | **32.6** (26.6-45.3) | 2518 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **2.72** (1.93-3.85) | **4.10** (2.40-7.00) | **20.0** (13.0-28.0) | **40.0** (38.0-52.0) | **62.0** (40.0-92.0) | 471 |
| | 01-02 | * | **1.44** (.600-2.69) | **8.33** (5.75-14.0) | **28.2** (19.7-41.4) | **45.7** (28.5-74.5) | 575 |
| 12-19 years | 99-00 | **2.53** (1.64-3.92) | **3.60** (1.60-6.50) | **16.0** (8.80-24.0) | **37.0** (21.0-38.0) | **69.0** (38.0-260) | 664 |
| | 01-02 | * | **1.03** (<LOD-2.10) | **4.83** (3.35-6.48) | **20.8** (12.2-27.9) | **33.9** (23.6-54.7) | 822 |
| 20-59 years | 99-00 | **1.59** (1.17-2.16) | **2.20** (.830-3.80) | **9.10** (7.10-13.0) | **38.0** (15.0-38.0) | **38.0** (38.0-49.0) | 813 |
| | 01-02 | * | **< LOD** | **3.32** (2.28-4.87) | **13.6** (9.50-20.0) | **29.5** (20.5-45.3) | 1121 |
| **Gender** | | | | | | | |
| Males | 99-00 | **2.10** (1.48-2.98) | **3.40** (2.10-4.60) | **13.0** (8.00-22.0) | **38.0** (15.0-38.0) | **41.0** (38.0-53.0) | 952 |
| | 01-02 | * | **.610** (<LOD-1.41) | **4.21** (3.07-5.97) | **18.3** (12.2-27.2) | **30.4** (25.0-43.3) | 1187 |
| Females | 99-00 | **1.59** (1.23-2.06) | **2.00** (.570-3.60) | **9.70** (7.30-14.0) | **38.0** (20.0-38.0) | **52.0** (38.0-110) | 996 |
| | 01-02 | * | **< LOD** | **3.76** (2.50-5.71) | **15.9** (10.6-22.0) | **34.3** (23.2-47.3) | 1331 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **1.79** (1.05-3.05) | **2.00** (.530-4.40) | **10.0** (6.60-17.0) | **38.0** (32.0-62.0) | **130** (46.0-230) | 671 |
| | 01-02 | * | **< LOD** | **3.74** (2.66-5.18) | **15.1** (11.1-19.1) | **35.2** (19.1-46.0) | 678 |
| Non-Hispanic blacks | 99-00 | **2.13** (1.57-2.88) | **3.60** (2.10-4.70) | **11.0** (8.40-17.0) | **37.0** (19.0-41.0) | **39.0** (37.0-100) | 509 |
| | 01-02 | * | **1.25** (.650-2.05) | **5.54** (3.29-9.41) | **20.6** (15.6-27.7) | **42.2** (27.2-62.8) | 695 |
| Non-Hispanic whites | 99-00 | **1.77** (1.23-2.53) | **2.60** (.720-4.40) | **11.0** (7.50-17.0) | **38.0** (13.0-38.0) | **45.0** (38.0-69.0) | 595 |
| | 01-02 | * | **< LOD** | **3.99** (2.46-6.14) | **17.0** (10.1-25.0) | **32.6** (25.0-50.2) | 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 262. Dimethylthiophosphate (creatinine corrected)

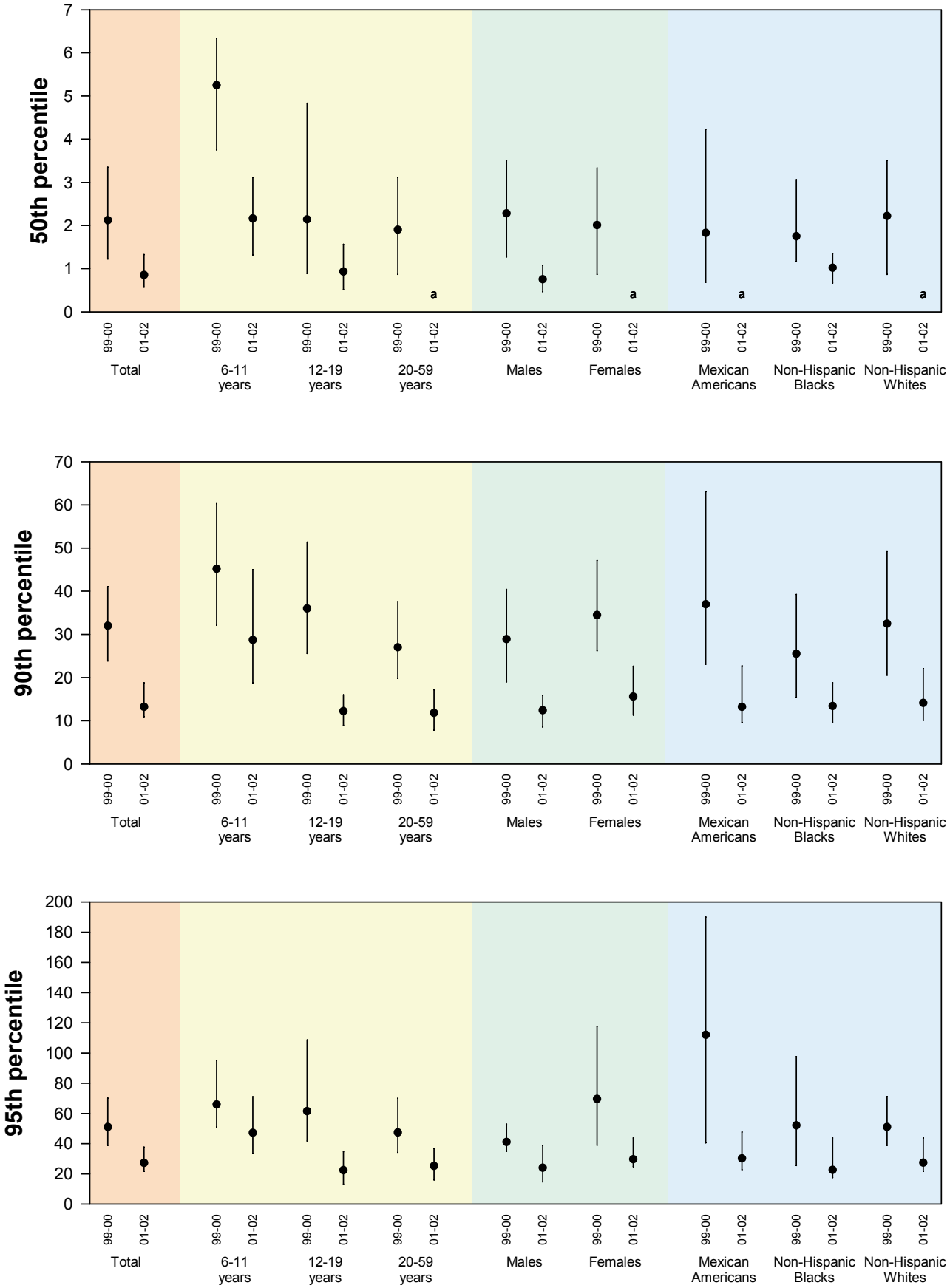
Geometric mean and selected percentiles of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6-59 years, National Health and Nutrition Examination Survey, 1999-2002.

| | 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 | **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.




[a] Estimate is less than the limit of detection (LOD). See Appendix A for LODs.

## Table 263. Dimethyldithiophosphate

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, 1999-2002.

| | 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** | **2.30** (1.30-3.90) | **12.0** (5.00-17.0) | **19.0** (17.0-38.0) | 1949 |
| | 01-02 | * | **< LOD** | **.890** (.210-1.30) | **2.49** (1.88-3.40) | **4.95** (3.55-8.35) | 2518 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **.730** (.080-1.80) | **4.30** (2.30-7.90) | **16.0** (5.30-19.0) | **32.0** (17.0-44.0) | 471 |
| | 01-02 | * | **< LOD** | **1.30** (.680-2.07) | **3.53** (2.20-4.50) | **7.33** (4.32-9.74) | 575 |
| 12-19 years | 99-00 | * | **< LOD** | **2.20** (1.30-4.50) | **12.0** (5.40-19.0) | **19.0** (17.0-30.0) | 664 |
| | 01-02 | * | **< LOD** | **.810** (.400-1.14) | **2.51** (1.85-3.07) | **4.63** (3.59-5.83) | 821 |
| 20-59 years | 99-00 | * | **< LOD** | **2.10** (.830-3.60) | **10.0** (3.80-17.0) | **16.0** (5.90-22.0) | 814 |
| | 01-02 | * | **< LOD** | **.840** (<LOD-1.31) | **2.32** (1.70-3.40) | **4.90** (2.90-9.52) | 1122 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **.110** (<LOD-.610) | **2.30** (1.10-4.80) | **16.0** (5.30-17.0) | **18.0** (17.0-38.0) | 952 |
| | 01-02 | * | **< LOD** | **.840** (.180-1.26) | **2.40** (1.83-3.28) | **5.13** (3.53-7.86) | 1187 |
| Females | 99-00 | * | **< LOD** | **2.10** (1.00-3.60) | **10.0** (4.00-17.0) | **20.0** (13.0-40.0) | 997 |
| | 01-02 | * | **< LOD** | **.950** (.170-1.38) | **2.52** (1.94-3.68) | **5.10** (3.31-10.6) | 1331 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **.240** (<LOD-.850) | **1.80** (1.10-2.80) | **5.70** (4.10-9.70) | **12.0** (5.80-28.0) | 672 |
| | 01-02 | * | **< LOD** | **.960** (.750-1.37) | **2.66** (2.07-3.41) | **4.47** (3.70-7.01) | 678 |
| Non-Hispanic blacks | 99-00 | * | **.330** (<LOD-1.20) | **3.20** (1.40-7.00) | **14.0** (5.50-24.0) | **18.0** (16.0-39.0) | 509 |
| | 01-02 | * | **< LOD** | **.750** (<LOD-1.67) | **2.11** (1.52-4.08) | **4.38** (2.51-8.66) | 695 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **2.00** (.800-4.00) | **13.0** (3.80-18.0) | **20.0** (14.0-40.0) | 595 |
| | 01-02 | * | **< LOD** | **.940** (<LOD-1.42) | **2.49** (1.83-3.65) | **5.74** (3.28-9.74) | 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 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

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, 1999-2002.

| | 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 | **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 |
| | 01-02 | * | **< LOD** | **2.76** (2.41-3.15) | **6.33** (5.64-7.46) | **11.4** (9.15-12.5) | 2520 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **1.32** (.757-2.29) | **1.40** (.800-2.50) | **4.50** (1.90-7.50) | **10.0** (4.80-16.0) | **15.0** (8.50-35.0) | 471 |
| | 01-02 | * | **.290** (<LOD-.990) | **3.41** (2.36-4.47) | **9.56** (6.33-18.0) | **20.0** (9.44-38.2) | 576 |
| 12-19 years | 99-00 | **1.21** (.758-1.94) | **1.30** (.950-2.00) | **3.70** (2.30-5.40) | **7.90** (4.70-19.0) | **20.0** (8.00-27.0) | 664 |
| | 01-02 | * | **< LOD** | **2.86** (1.96-3.95) | **7.58** (5.71-9.15) | **11.0** (9.35-12.4) | 822 |
| 20-59 years | 99-00 | **.955** (.623-1.47) | **1.00** (.650-1.50) | **3.00** (1.70-4.70) | **7.20** (4.70-11.0) | **10.0** (6.80-21.0) | 814 |
| | 01-02 | * | **< LOD** | **2.71** (2.34-3.12) | **5.79** (5.05-7.21) | **10.4** (7.43-12.3) | 1122 |
| **Gender** | | | | | | | |
| Males | 99-00 | **1.11** (.717-1.73) | **1.10** (.750-1.70) | **3.80** (2.50-5.00) | **8.00** (5.00-19.0) | **18.0** (7.00-30.0) | 952 |
| | 01-02 | * | **< LOD** | **3.13** (2.44-3.53) | **6.99** (5.79-7.80) | **11.5** (8.98-12.4) | 1187 |
| Females | 99-00 | **.954** (.599-1.52) | **1.10** (.570-1.70) | **2.90** (1.80-4.70) | **7.50** (4.60-11.0) | **11.0** (7.00-15.0) | 997 |
| | 01-02 | * | **.260** (<LOD-.750) | **2.58** (2.17-3.02) | **5.93** (4.55-8.19) | **10.4** (7.27-15.1) | 1333 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **1.22** (.740-2.01) | **1.10** (.770-1.60) | **4.10** (2.20-7.00) | **11.0** (5.80-14.0) | **17.0** (12.0-23.0) | 672 |
| | 01-02 | * | **.600** (<LOD-1.63) | **3.10** (2.27-3.72) | **6.22** (5.00-7.82) | **11.2** (7.82-12.3) | 678 |
| Non-Hispanic blacks | 99-00 | **1.56** (1.13-2.14) | **1.60** (1.30-1.70) | **4.20** (2.90-5.80) | **10.0** (5.50-18.0) | **18.0** (8.00-27.0) | 509 |
| | 01-02 | * | **.890** (<LOD-2.42) | **4.59** (3.30-6.52) | **10.2** (7.40-14.0) | **15.4** (9.93-24.2) | 696 |
| Non-Hispanic whites | 99-00 | **.981** (.579-1.66) | **1.10** (.380-1.80) | **3.30** (2.20-4.90) | **7.60** (4.70-14.0) | **14.0** (7.60-25.0) | 595 |
| | 01-02 | * | **< LOD** | **2.44** (2.06-2.91) | **5.48** (4.51-6.33) | **10.0** (7.52-11.9) | 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.

## Table 266. Diethylphosphate (creatinine corrected)

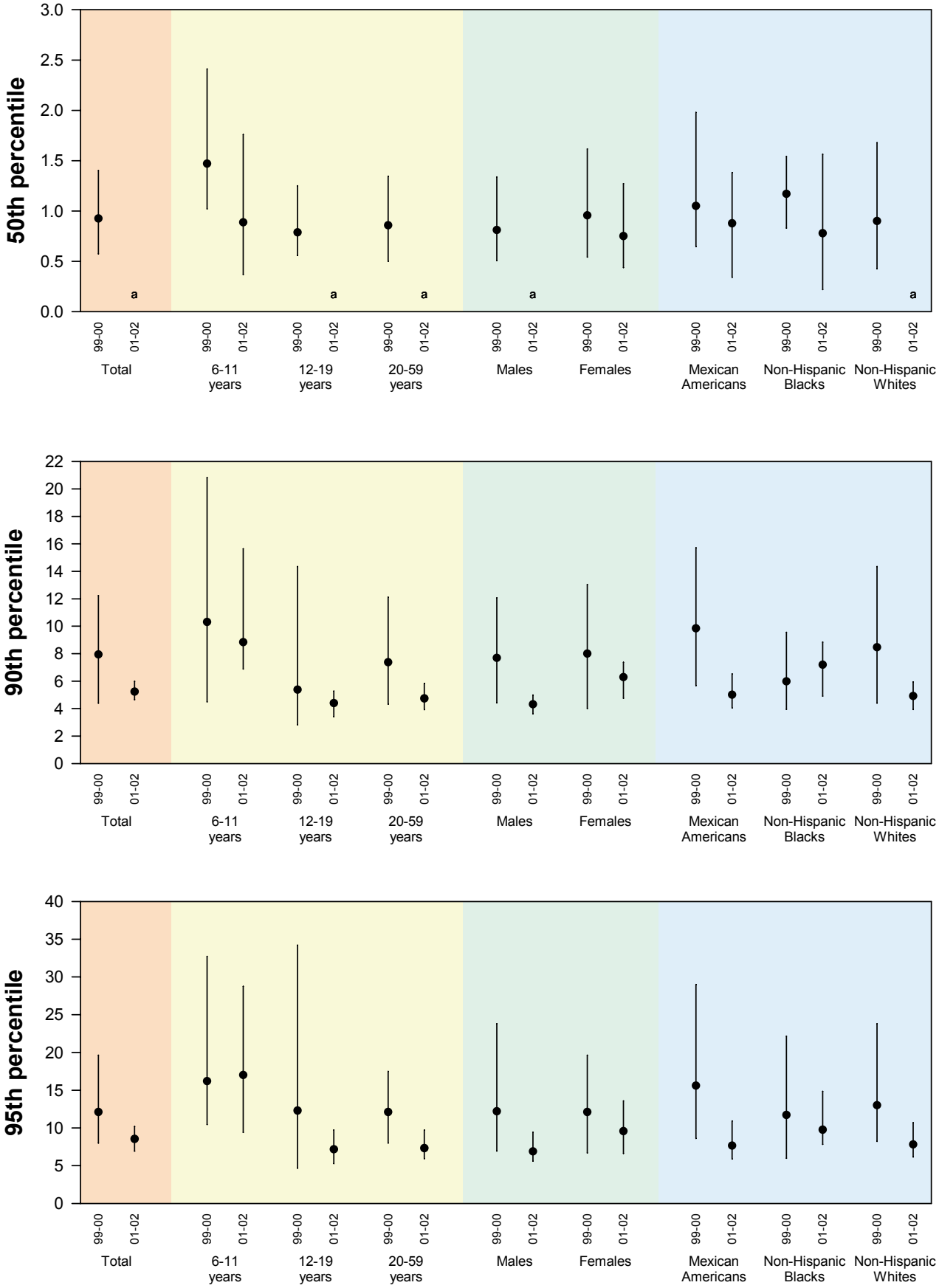
Geometric mean and selected percentiles of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6-59 years, National Health and Nutrition Examination Survey, 1999-2002.

| | 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 | **.924** (.608-1.41) | **.924** (.574-1.40) | **2.73** (1.68-4.60) | **7.94** (4.40-12.2) | **12.1** (8.00-19.6) | 1949 |
| | 01-02 | * | **< LOD** | **2.39** (2.06-2.69) | **5.23** (4.64-5.98) | **8.53** (6.94-10.2) | 2519 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **1.43** (.870-2.34) | **1.47** (1.02-2.41) | **3.94** (2.20-8.57) | **10.3** (4.49-20.8) | **16.2** (10.5-32.7) | 471 |
| | 01-02 | * | **.886** (.368-1.76) | **4.02** (2.87-5.25) | **8.84** (6.88-15.6) | **17.0** (9.40-28.8) | 576 |
| 12-19 years | 99-00 | **.818** (.533-1.26) | **.786** (.557-1.25) | **2.29** (1.37-3.75) | **5.38** (2.82-14.4) | **12.3** (4.66-34.2) | 664 |
| | 01-02 | * | **< LOD** | **2.05** (1.54-2.67) | **4.40** (3.40-5.28) | **7.16** (5.28-9.75) | 821 |
| 20-59 years | 99-00 | **.883** (.574-1.36) | **.857** (.500-1.35) | **2.63** (1.54-4.95) | **7.37** (4.32-12.1) | **12.1** (8.00-17.5) | 814 |
| | 01-02 | * | **< LOD** | **2.28** (2.01-2.56) | **4.74** (3.92-5.83) | **7.31** (5.93-9.72) | 1122 |
| **Gender** | | | | | | | |
| Males | 99-00 | **.855** (.566-1.29) | **.811** (.508-1.34) | **2.61** (1.76-4.03) | **7.69** (4.41-12.1) | **12.2** (6.94-23.8) | 952 |
| | 01-02 | * | **< LOD** | **2.04** (1.71-2.52) | **4.31** (3.62-5.00) | **6.88** (5.60-9.42) | 1187 |
| Females | 99-00 | **.996** (.620-1.60) | **.956** (.541-1.62) | **2.80** (1.45-5.85) | **8.00** (4.00-13.0) | **12.1** (6.67-19.6) | 997 |
| | 01-02 | * | **.750** (.438-1.27) | **2.66** (2.24-3.23) | **6.28** (4.75-7.37) | **9.57** (6.61-13.6) | 1332 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **1.09** (.633-1.89) | **1.05** (.645-1.98) | **3.78** (2.11-6.46) | **9.84** (5.66-15.7) | **15.6** (8.61-29.0) | 672 |
| | 01-02 | * | **.877** (.341-1.38) | **2.38** (1.79-3.13) | **5.00** (4.04-6.53) | **7.66** (5.88-10.9) | 678 |
| Non-Hispanic blacks | 99-00 | **1.07** (.773-1.47) | **1.17** (.828-1.54) | **2.55** (1.89-3.47) | **5.98** (3.94-9.56) | **11.7** (5.98-22.2) | 509 |
| | 01-02 | * | **.778** (.219-1.56) | **2.78** (2.40-3.40) | **7.19** (4.90-8.84) | **9.75** (7.82-14.9) | 695 |
| Non-Hispanic whites | 99-00 | **.932** (.549-1.58) | **.900** (.426-1.68) | **2.82** (1.51-5.88) | **8.46** (4.40-14.4) | **13.0** (8.21-23.8) | 595 |
| | 01-02 | * | **< LOD** | **2.29** (1.92-2.74) | **4.91** (3.93-5.93) | **7.80** (6.15-10.7) | 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 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.




[a] Estimate is less than the limit of detection (LOD). See Appendix A for LODs.

## Table 267. Diethylthiophosphate

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, 1999-2002.

| | 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 | * | **.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/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **.560** (<LOD-.780) | **.840** (.740-.980) | **1.40** (1.20-1.80) | **2.20** (1.90-2.70) | 672 |
| | 01-02 | **.549** (.398-.759) | **.700** (.460-.950) | **1.38** (1.01-1.98) | **2.59** (1.97-3.35) | **3.98** (2.74-5.21) | 678 |
| Non-Hispanic blacks | 99-00 | * | **.560** (<LOD-.750) | **.810** (.690-1.20) | **1.80** (1.30-3.20) | **3.50** (2.00-4.80) | 509 |
| | 01-02 | **.749** (.592-.949) | **1.18** (.740-1.49) | **1.85** (1.74-1.99) | **3.54** (3.01-3.91) | **5.27** (3.89-6.74) | 695 |
| Non-Hispanic whites | 99-00 | * | **.160** (<LOD-.700) | **.730** (.580-1.10) | **1.30** (.880-1.60) | **1.80** (1.50-2.80) | 595 |
| | 01-02 | **.425** (.303-.597) | **.500** (.270-.900) | **1.46** (1.10-1.83) | **2.41** (2.05-3.17) | **3.73** (2.59-6.15) | 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.

## Table 268. Diethylthiophosphate (creatinine corrected)

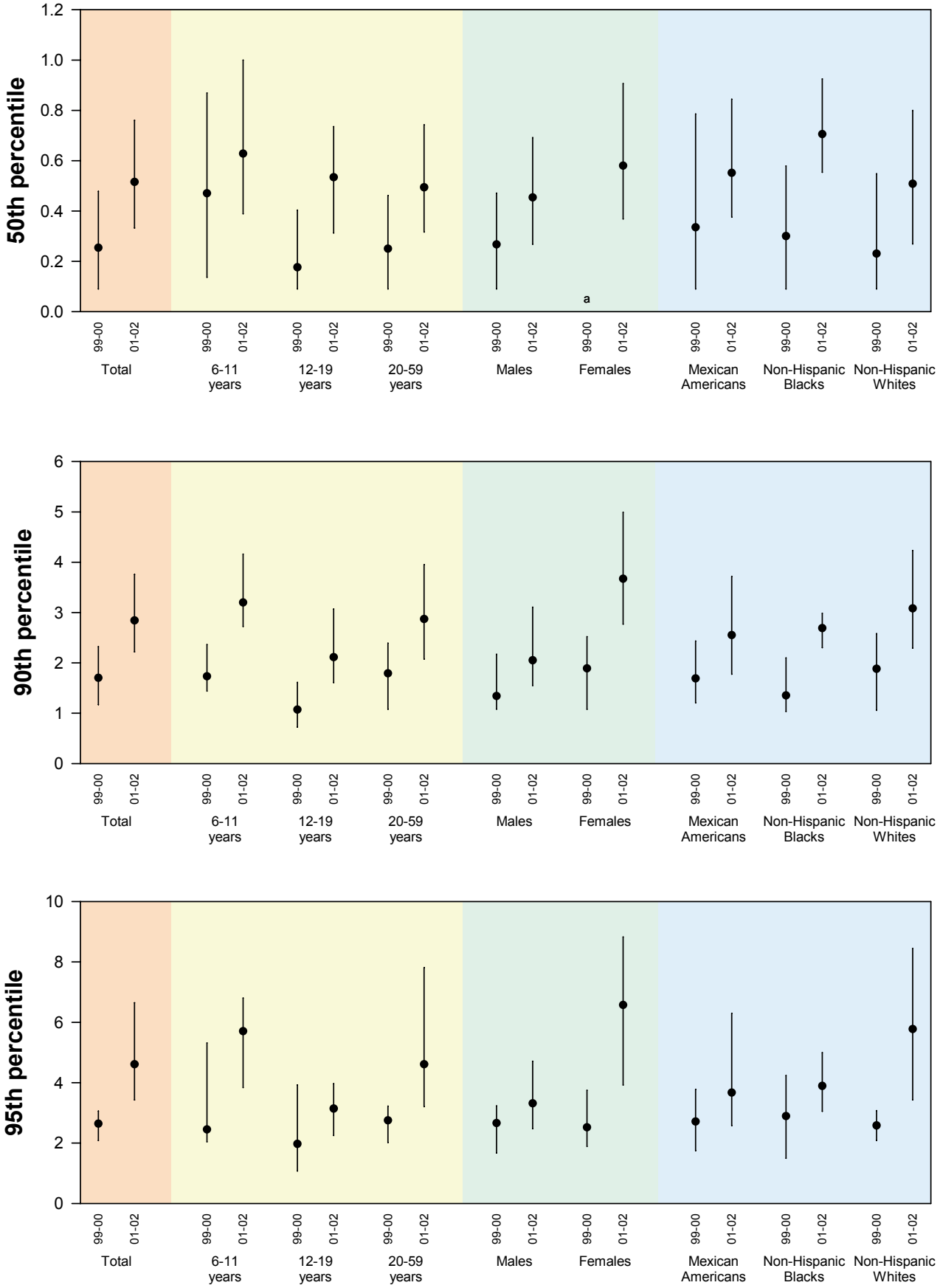
Geometric mean and selected percentiles of urine concentrations (in µg/g of creatinine) for the U.S. population aged 6-59 years, National Health and Nutrition Examination Survey, 1999-2002.

| | 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 (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.




[a] Estimate is less than the limit of detection (LOD). See Appendix A for LODs.

## Table 269. Diethyldithiophosphate

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, 1999-2002.

| | 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 | * | **.080** (<LOD-.130) | **.200** (.130-.290) | **.470** (.380-.640) | **.870** (.640-1.10) | 1949 |
| | 01-02 | * | **< LOD** | **< LOD** | **.610** (.410-.760) | **.830** (.700-1.19) | 2516 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **.080** (<LOD-.140) | **.190** (.130-.280) | **.430** (.300-.600) | **.850** (.470-1.00) | 471 |
| | 01-02 | * | **< LOD** | **< LOD** | **.630** (.380-.870) | **.940** (.690-1.42) | 576 |
| 12-19 years | 99-00 | * | **.080** (<LOD-.150) | **.260** (.120-.350) | **.640** (.420-.840) | **.900** (.720-1.30) | 664 |
| | 01-02 | * | **< LOD** | **< LOD** | **.560** (.330-.730) | **.820** (.610-.990) | 822 |
| 20-59 years | 99-00 | * | **.080** (<LOD-.130) | **.210** (.130-.290) | **.450** (.350-.640) | **.900** (.610-1.10) | 814 |
| | 01-02 | * | **< LOD** | **< LOD** | **.610** (.430-.760) | **.830** (.700-1.32) | 1118 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **.090** (<LOD-.130) | **.220** (.140-.310) | **.470** (.360-.650) | **.870** (.680-1.10) | 952 |
| | 01-02 | * | **< LOD** | **< LOD** | **.600** (.370-.730) | **.770** (.680-1.03) | 1187 |
| Females | 99-00 | * | **.080** (<LOD-.130) | **.190** (.110-.310) | **.450** (.320-.820) | **.850** (.440-1.40) | 997 |
| | 01-02 | * | **< LOD** | **< LOD** | **.660** (.460-.850) | **.990** (.700-1.42) | 1329 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **.100** (<LOD-.180) | **.310** (.230-.390) | **.650** (.530-.860) | **1.10** (.760-1.20) | 672 |
| | 01-02 | * | **< LOD** | **< LOD** | **.720** (.400-1.13) | **1.12** (.700-1.58) | 678 |
| Non-Hispanic blacks | 99-00 | * | **.090** (<LOD-.160) | **.270** (.130-.390) | **.560** (.400-.830) | **.850** (.650-1.20) | 509 |
| | 01-02 | * | **< LOD** | **< LOD** | **.630** (.410-.820) | **.820** (.730-.970) | 694 |
| Non-Hispanic whites | 99-00 | * | **.080** (<LOD-.150) | **.190** (.120-.280) | **.420** (.310-.720) | **.870** (.500-1.10) | 595 |
| | 01-02 | * | **< LOD** | **< LOD** | **.610** (.360-.780) | **.810** (.650-1.36) | 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 270. Diethyldithiophosphate (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 | * | **.074** (.053-.111) | **.196** (.143-.286) | **.549** (.385-.698) | **.859** (.667-1.14) | 1949 |
| | 01-02 | * | **< LOD** | **< LOD** | **.583** (.380-.733) | **1.01** (.705-1.43) | 2515 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **.102** (.067-.136) | **.193** (.148-.271) | **.571** (.409-.763) | **1.03** (.571-1.58) | 471 |
| | 01-02 | * | **< LOD** | **< LOD** | **.753** (.606-1.12) | **1.36** (1.02-1.86) | 576 |
| 12-19 years | 99-00 | * | **.051** (.038-.078) | **.167** (.098-.222) | **.435** (.225-.731) | **.731** (.382-1.09) | 664 |
| | 01-02 | * | **< LOD** | **< LOD** | **.355** (.250-.537) | **.667** (.375-.987) | 821 |
| 20-59 years | 99-00 | * | **.075** (.055-.114) | **.205** (.143-.313) | **.549** (.361-.733) | **.859** (.654-1.20) | 814 |
| | 01-02 | * | **< LOD** | **< LOD** | **.583** (.369-.740) | **1.03** (.699-1.60) | 1118 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **.066** (.042-.106) | **.186** (.135-.232) | **.415** (.339-.500) | **.719** (.524-.936) | 952 |
| | 01-02 | * | **< LOD** | **< LOD** | **.383** (.300-.650) | **.740** (.583-1.03) | 1187 |
| Females | 99-00 | * | **.087** (.057-.121) | **.219** (.143-.360) | **.667** (.407-.875) | **.886** (.656-1.62) | 997 |
| | 01-02 | * | **< LOD** | **< LOD** | **.686** (.492-1.00) | **1.24** (.798-1.86) | 1328 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **.094** (.061-.171) | **.302** (.192-.409) | **.812** (.573-.989) | **1.16** (.859-2.66) | 672 |
| | 01-02 | * | **< LOD** | **< LOD** | **.845** (.444-1.24) | **1.29** (.875-1.78) | 678 |
| Non-Hispanic blacks | 99-00 | * | **.067** (.042-.114) | **.175** (.114-.275) | **.450** (.302-.577) | **.692** (.504-1.02) | 509 |
| | 01-02 | * | **< LOD** | **< LOD** | **.446** (.326-.583) | **.723** (.507-.962) | 693 |
| Non-Hispanic whites | 99-00 | * | **.074** (.049-.118) | **.204** (.139-.308) | **.554** (.380-.733) | **.875** (.596-1.38) | 595 |
| | 01-02 | * | **< LOD** | **< LOD** | **.538** (.352-.746) | **1.03** (.636-1.67) | 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.

## Organophosphate Pesticides: Specific Metabolites

# Organophosphate Pesticides: Specific Metabolites

### General Information

These metabolites differ from the dialkyl phosphates because each specific metabolite derives from one or only a few parent pesticides. Table 272 shows the parent organophosphate pesticides and their metabolites. For example, malathion is metabolized to malathion dicarboxylic acid. *Para*-nitrophenol is a metabolite of parathion and methyl parathion and other chemicals. Chlorpyrifos and chlorpyrifos methyl are metabolized to 3,5,6-trichloro-2-pyridinol. In addition to reflecting exposure to the parent insecticide, the level of these metabolites in a person's urine may also reflect exposure to the metabolite if it was present in the person's food or environment.

Sources of potential exposure to organophosphates vary, depending on the chemical. Some organophosphates (including malathion and chlorpyrifos) are commonly used in agriculture, whereas the use of other organophosphates (such as parathion and methyl parathion) have been restricted significantly in the United States. Some organophosphates (malathion, naled) are used for the public health control of mosquitoes The U.S. FDA, USDA, U.S. EPA, and OSHA have developed criteria on allowable levels of these chemicals in foods, the environment, and the workplace, respectively.

The organophosphates share a common mechanism of toxicity that occurs through inhibition of the enzyme acetylcholinesterase in the nervous system. Symptoms of an acute overexposure may include nausea, vomiting, cholinergic effects, weakness, paralysis, and seizures. The specific metabolites reported in this section do not inhibit acetylcholinesterase enzymes but rather are an indicator of exposure to the parent compounds.

This *Report* provides measurements for the metabolites of six organophosphate pesticides. Information about external exposure (i.e., environmental levels) and health effects of specific organophosphate pesticides 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.

**Table 271. Organophosphate pesticides: specific metabolites**

| **Organophosphate pesticide** (CAS number) | **Primary urinary metabolite** (CAS number) |
|---|---|
| Malathion (121-75-5) | Malathion dicarboxylic acid (1190-28-9) |
| Parathion (56-38-2) | *para* -Nitrophenol (100-02-7) |
| Methyl parathion (298-00-0) | *para* -Nitrophenol (100-02-7) |
| Chlorpyrifos (2921-88-2) | 3,5,6-Trichloro-2-pyridinol (6515-38-4) |
| Chlorpyrifos methyl (5598-13-0) | 3,5,6-Trichloro-2-pyridinol (6515-38-4) |
| Diazinon (333-41-5) | 2-Isopropyl-4-methyl-6-hydroxypyrimidine (2814-20-2) |
| Pirimiphos methyl (29232-93-7) | 2-(Diethylamino)-6-methylpyrimidin-4-ol/one |
| Coumaphos (56-72-4) | 3-Chloro-7-hydroxy-4-methyl-2H-chromen-2-one/ol |

# Malathion Dicarboxylic Acid

CAS No. 1190-28-9

*Metabolite of Malathion, CAS No. 121-75-5*

## General Information

Malathion dicarboxylic acid is a metabolite of malathion, which is an organophosphate insecticide that is used on a variety of agricultural crops. There are also non-agricultural uses of this insecticide on lawns, gardens, ornamental trees, shrubs, and plants. Malathion is registered for use in public health mosquito control and in government programs such as the USDA's Boll Weevil Eradication Program. Approximately 16.7 million pounds of malathion, most of which is applied to cotton, are used annually in the United States. Malathion is also used medically in lotion form (0.5%) to kill body lice.

In addition to being a metabolite of malathion in the body, malathion dicarboxylic acid can also occur in the environment from the breakdown of the parent compound. Thus, the detection of malathion dicarboxylic acid in a person's urine may also reflect exposure to the metabolite if it was present in a person's food or environment.

Malathion is slowly absorbed through the skin but is more rapidly and efficiently absorbed via ingestion. It is metabolized in the body to malaoxon, malathion monocarboxylic acid, malathion dicarboxylic acid, and dialkylphosphate metabolites (see section titled "Organophosphate Pesticides: Dialkyl Phosphate Metabolites"). Malathion is rapidly eliminated from the body within 12-24 hours (Bouchard et al., 2003).

Symptoms of an acute overdose of malathion may include nausea, vomiting, cholinergic effects, weakness, paralysis, and seizures. Compared with other organophosphate insecticides, malathion has low acute toxicity. Malathion does not appear to produce human reproductive or teratogenic effects at environmental levels of exposure in human populations (Thomas et al., 1990; Grether et al., 1987). IARC considers malathion not classifiable as a human carcinogen.

## Interpreting Levels of Urinary Malathion Dicarboxylic Acid Reported in the Tables

Levels of urinary malathion dicarboxylic acid were measured in a subsample of NHANES participants aged 6-59 years. Note that no data are available for the NHANES 2001-2002 subsample. Participants were selected within the specified age range to be a

### Table 272. Malathion dicarboxylic 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, 1999-2000.

| | 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 | 1920 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | < LOD | < LOD | < LOD | **2.80** (<LOD-5.50) | 453 |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 660 |
| 20-59 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 807 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 937 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 983 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 680 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 498 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 580 |

< 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.

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 of malathion dicarboxylic acid at a detection limit about ten-fold lower than the detection limit used in the NHANES 1999-2000 analyses (Eskenazi et al., 2004). A study of agricultural workers reported urinary levels of malathion dicarboxylic acid ranging from 4-10 µg/gram creatinine, and no effect on cholinesterase activity was observed in these workers (Krieger and Dinoff, 2000). Such worker values are only slightly higher than those detected in the NHANES 1999-2000 subsample.

Finding a measurable amount of malathion dicarboxylic 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 malathion 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 malathion than those levels found in the general population.

**Table 273. Malathion dicarboxylic acid (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, 1999-2000.

| | 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** | 1920 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **3.74** (2.11-5.50) | 453 |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 660 |
| 20-59 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 807 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 937 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 983 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 680 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 498 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 580 |

< 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.

# *para*-Nitrophenol

CAS No. 100-02-7

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

## General Information

*Para*-nitrophenol is a metabolite of the pesticides methyl parathion, ethyl parathion, O-ethyl 4-nitrophenyl phenylphosphonothioate, and of nitrobenzene, which is not a pesticide. Methyl parathion is a restricted-use pesticide with limited applications in agriculture, and many agricultural uses of methyl parathion have been cancelled. Past peak domestic use was once as high as 4 million pounds per year. Methyl parathion is not registered for residential use in the United States. Ethyl parathion had been a restricted-use pesticide with limited applications on certain agricultural crops, but in 2002 voluntary cancellation of all registrations occurred.

In addition to being a metabolite of methyl and ethyl parathion in the body, *para*-nitrophenol can also occur in the environment from the breakdown of the parent compounds. Thus, the detection of *para*-nitrophenol in a person's urine may also reflect exposure to the metabolite if it was present in a person's food or environment

In animal studies, methyl parathion is rapidly absorbed after ingestion, more slowly absorbed through the skin, and is eliminated rapidly after exposure (Kramer et al., 2002). In addition to being metabolized to *para*-nitrophenol, parathion and methyl parathion are metabolized to dialkyl phosphates (see section titled "Organophosphate Pesticides: Dialkyl Phosphate Metabolites").

## Table 274. *para*-Nitrophenol

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, 1999-2002.

| | 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** | **2.40** (1.40-4.50) | **5.00** (2.90-11.0) | 1989 |
| | 01-02 | * | **< LOD** | **1.32** (1.20-1.48) | **2.70** (2.40-3.02) | **3.70** (3.38-3.93) | 2477 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **< LOD** | **.910** (<LOD-2.40) | **2.63** (1.70-3.80) | **4.20** (2.70-6.40) | 479 |
| | 01-02 | * | **.790** (<LOD-.910) | **1.48** (1.34-1.61) | **2.83** (2.22-3.58) | **3.90** (3.01-4.74) | 565 |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **3.40** (1.60-5.70) | **5.70** (2.60-19.0) | 680 |
| | 01-02 | * | **.720** (<LOD-.910) | **1.44** (1.32-1.61) | **2.61** (2.15-3.11) | **3.34** (3.11-4.01) | 813 |
| 20-59 years | 99-00 | * | **< LOD** | **< LOD** | **2.30** (1.20-5.30) | **4.50** (2.20-9.50) | 830 |
| | 01-02 | * | **< LOD** | **1.27** (1.08-1.45) | **2.69** (2.32-3.10) | **3.72** (3.37-4.24) | 1099 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **2.40** (1.40-4.20) | **4.40** (2.50-12.0) | 971 |
| | 01-02 | * | **.760** (.300-.910) | **1.49** (1.30-1.66) | **2.99** (2.59-3.23) | **4.00** (3.37-4.91) | 1164 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **2.50** (1.30-5.70) | **5.20** (2.90-9.50) | 1018 |
| | 01-02 | * | **< LOD** | **1.18** (.990-1.37) | **2.26** (1.92-2.69) | **3.46** (3.18-3.71) | 1313 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **1.60** (<LOD-3.40) | **5.80** (2.60-23.0) | **21.0** (3.50-36.0) | 695 |
| | 01-02 | * | **.690** (<LOD-.840) | **1.32** (1.08-1.54) | **2.62** (1.91-3.44) | **3.85** (2.70-6.05) | 660 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **1.17** (<LOD-2.50) | **2.90** (1.70-6.00) | **4.80** (2.50-9.20) | 518 |
| | 01-02 | * | **.860** (<LOD-1.12) | **1.80** (1.37-2.16) | **3.21** (2.55-4.38) | **5.60** (4.02-6.79) | 679 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **2.10** (<LOD-4.70) | **4.20** (2.10-11.0) | 603 |
| | 01-02 | * | **< LOD** | **1.27** (1.11-1.42) | **2.71** (2.30-3.10) | **3.70** (3.28-4.01) | 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.

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 95$^{th}$ 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 95$^{th}$ 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

*Metabolite of Chlorpyrifos, CAS No. 2921-88-2 and Chlorpyrifos-methyl, CAS No. 5598-13-0*

## General Information

The chemical 3,5,6-trichloro-2-pyridinol (TCPy) is a specific metabolite of chlorpyrifos and chlorpyrifos-methyl. Chlorpyrifos is an organophosphate insecticide that is used to control insect pests on a variety of agricultural crops in the United States. Approximately 10 million pounds have been applied annually in agriculture. Chlorpyrifos is no longer registered for most indoor residential uses in the United States. Not registered for residential use, chlorpyrifos-methyl is an organo phosphate pesticide used in agriculture. Approximately 80,000 pounds are used per year.

In addition to being a metabolite of chlorpyrifos and chlorpyrifos-methyl in the body, TCPy can also occur in the environment from the breakdown of the parent compounds. Thus, the detection of TCPy in a person's urine may also reflect exposure to the metabolite if it was present in a person's food or environment. In 142 urban homes and preschools of North Carolina, chlorpyrifos and TCPy were detected in all indoor air and dust samples (Morgan et al., 2004)

Chlorpyrifos is not well absorbed through the skin but is rapidly absorbed once ingested. Nolan et al. (1984) found that TCPy is eliminated from the body in the urine with a half-life of approximately 27 hours. Chlorpyrifos, chlorpyrifos-methyl, and other organophosphate pesticides share a common mechanism of toxicity, inhibiting the activity of acetylcholinesterase enzymes in the nervous system. The metabolite TCPy does not inhibit acetylcholinesterase enzymes.

## Table 276. 3,5,6-Trichloro-2-pyridinol

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, 1999-2002.

| | 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 | **1.77** (1.46-2.14) | **1.70** (1.40-2.10) | **3.50** (2.50-5.10) | **7.30** (4.80-10.0) | **9.90** (7.60-14.0) | 1994 |
| | 01-02 | **1.76** (1.52-2.03) | **2.20** (1.86-2.61) | **4.95** (4.55-5.29) | **8.80** (7.74-9.77) | **12.4** (10.4-15.3) | 2509 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **2.88** (1.99-4.16) | **2.70** (1.60-4.80) | **6.90** (3.40-10.0) | **11.0** (7.70-17.0) | **16.0** (10.0-26.0) | 481 |
| | 01-02 | **2.67** (2.13-3.35) | **3.08** (2.46-4.22) | **6.36** (4.97-7.97) | **10.7** (7.98-15.3) | **14.9** (11.5-24.0) | 573 |
| 12-19 years | 99-00 | **2.37** (1.89-2.97) | **2.10** (1.60-2.90) | **4.50** (2.90-6.70) | **8.00** (5.50-14.0) | **12.5** (8.00-24.0) | 681 |
| | 01-02 | **2.71** (2.19-3.35) | **3.57** (2.60-4.30) | **6.57** (5.61-7.59) | **11.2** (8.66-15.1) | **18.0** (13.7-23.7) | 823 |
| 20-59 years | 99-00 | **1.53** (1.29-1.82) | **1.50** (1.20-1.70) | **2.80** (2.20-4.10) | **5.90** (3.90-8.90) | **8.60** (6.70-11.0) | 832 |
| | 01-02 | **1.51** (1.32-1.72) | **1.91** (1.44-2.26) | **4.42** (3.90-4.80) | **7.78** (7.00-8.91) | **10.9** (9.52-12.4) | 1113 |
| **Gender** | | | | | | | |
| Males | 99-00 | **1.92** (1.60-2.32) | **1.90** (1.50-2.40) | **3.50** (2.70-5.60) | **7.30** (5.04-10.0) | **9.90** (7.40-14.0) | 972 |
| | 01-02 | **2.13** (1.81-2.51) | **2.66** (2.19-3.16) | **5.37** (4.83-6.25) | **9.63** (8.20-11.3) | **14.9** (10.9-18.9) | 1183 |
| Females | 99-00 | **1.63** (1.31-2.02) | **1.50** (1.20-1.80) | **3.30** (2.30-5.30) | **7.20** (4.30-12.0) | **10.0** (7.10-15.0) | 1022 |
| | 01-02 | **1.45** (1.24-1.70) | **1.72** (1.39-2.21) | **4.38** (3.72-4.95) | **7.71** (6.30-9.20) | **10.4** (8.47-13.2) | 1326 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **1.61** (1.31-2.00) | **1.67** (1.30-2.20) | **3.20** (2.60-3.80) | **5.00** (3.80-7.30) | **7.40** (5.10-17.0) | 697 |
| | 01-02 | **2.02** (1.79-2.28) | **2.63** (2.24-3.01) | **4.55** (4.05-5.39) | **9.02** (7.04-10.8) | **12.2** (10.8-15.7) | 660 |
| Non-Hispanic blacks | 99-00 | **2.17** (1.59-2.97) | **1.90** (1.40-2.70) | **4.20** (2.50-8.30) | **9.40** (6.30-12.9) | **13.0** (9.40-26.0) | 521 |
| | 01-02 | **2.19** (1.68-2.84) | **2.89** (2.28-3.47) | **5.47** (4.77-6.96) | **9.27** (7.47-11.6) | **12.3** (10.1-16.8) | 701 |
| Non-Hispanic whites | 99-00 | **1.76** (1.51-2.05) | **1.60** (1.50-2.00) | **3.40** (2.50-4.80) | **7.10** (4.30-10.5) | **10.0** (7.20-14.0) | 602 |
| | 01-02 | **1.71** (1.43-2.03) | **2.15** (1.62-2.64) | **4.94** (4.41-5.31) | **8.68** (7.47-9.97) | **12.3** (9.77-15.9) | 947 |

### 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 representative sample of the U.S. population. In the current NHANES 2001-2002 subsample, TCPy levels appeared roughly similar to values reported for a nonrandom subsample of NHANES III (1988-1994) participants (Hill et al., 1995) and to levels reported in a studies of healthy adults in Germany (Koch et al., 2001) and Italy (Aprea et al., 1999). In a probability-based sample of 102 Minnesota children aged 3-13 years, the weighted population mean of TCPy measurements was approximately three times higher (Adgate, 2001) than the corresponding values reported for the group aged 6-11 years in this *Report*. In another study of adults in Maryland, MacIntosh et al. (1999) found that mean urinary TCPy levels were about three times higher than the levels for adults documented in this *Report*. Of 482 pregnant women living in an agricultural community, 76% had detectable levels of TCPy, and levels were similar to those reported for NHANES 1999-2000 (Eskenazi et al., 2004). Higher levels of TCPy have been measured in urine samples obtained from pesticide applicators. In one study of male pesticide applicators, the geometric mean levels of TCPy in urine samples ranged from 169-262 µg/g creatinine (Hines et al., 2001). These levels are more than 100-fold higher than the geometric mean values for males documented in this *Report*.

### Comparing Adjusted Geometric Means

Geometric mean levels of urinary TCPy for the demographic groups were compared after adjusting for the covariates of race/ethnicity, age, gender, and urinary creatinine (data not shown). In NHANES 2002-2002, the group aged 6-11 years had higher adjusted geometric mean levels of urinary TCPy than the other two age groups, and the group aged 12-19 years had slightly higher urinary levels of TCPy than the group aged 20-59 years. It is unknown whether these differences associated

## Table 277. 3,5,6-Trichloro-2-pyridinol (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.

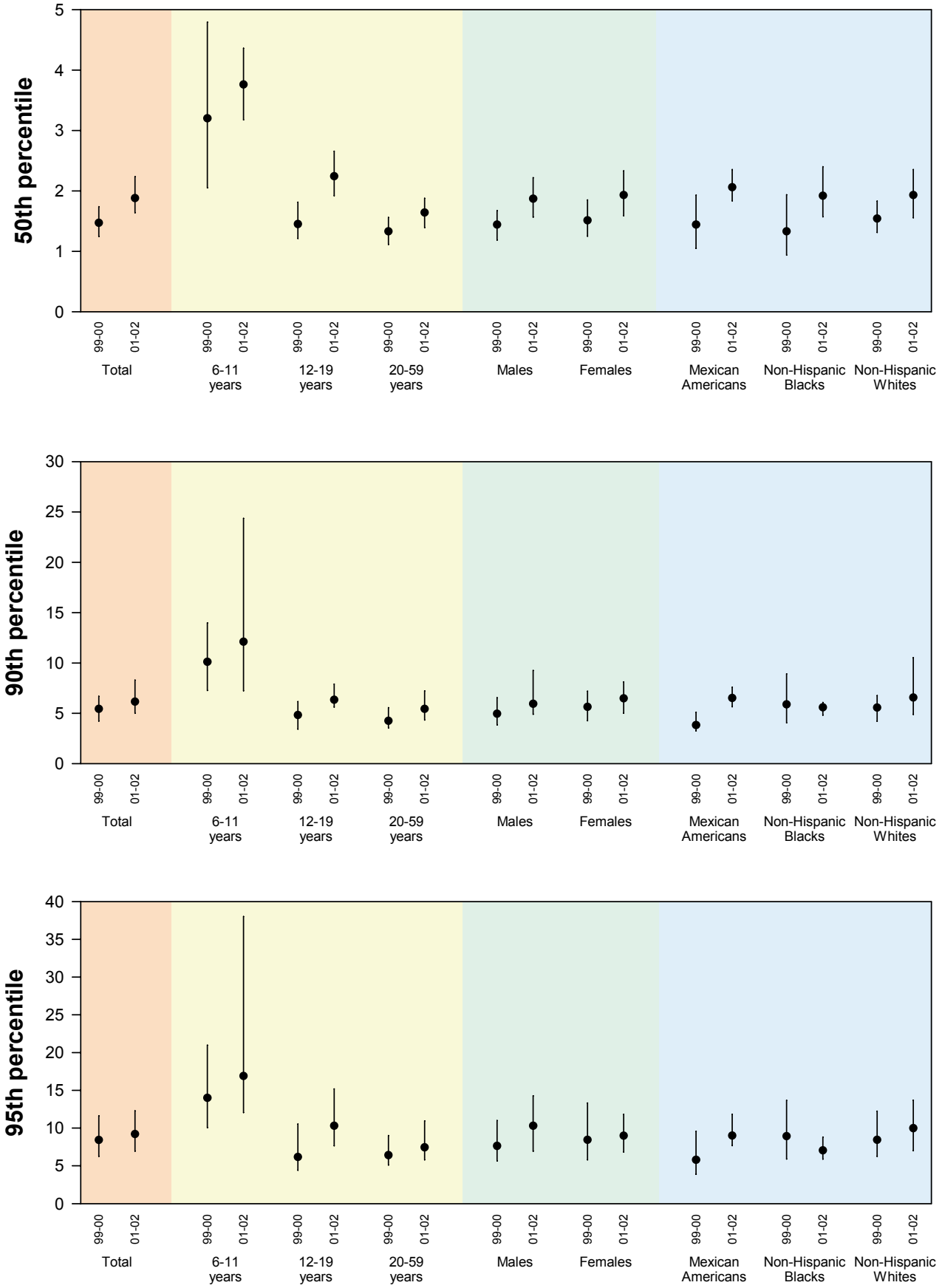
| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) 50th | 75th | 90th | 95th | Sample size |
|---|---|---|---|---|---|---|---|
| **Total, age 6 and older** | 99-00 | **1.58** (1.35-1.85) | **1.47** (1.24-1.74) | **2.85** (2.11-3.59) | **5.43** (4.22-6.68) | **8.42** (6.25-11.6) | 1994 |
| | 01-02 | **1.73** (1.49-2.01) | **1.88** (1.64-2.24) | **3.76** (2.91-4.62) | **6.15** (4.99-8.31) | **9.22** (6.94-12.3) | 2508 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **3.11** (2.31-4.19) | **3.20** (2.05-4.80) | **6.37** (4.14-8.19) | **10.1** (7.26-14.0) | **14.0** (10.1-21.0) | 481 |
| | 01-02 | **3.48** (2.80-4.32) | **3.76** (3.17-4.36) | **6.21** (4.88-8.57) | **12.1** (7.24-24.4) | **16.9** (12.1-38.0) | 573 |
| 12-19 years | 99-00 | **1.60** (1.34-1.91) | **1.45** (1.21-1.81) | **2.58** (1.97-3.92) | **4.82** (3.44-6.16) | **6.16** (4.43-10.6) | 681 |
| | 01-02 | **2.09** (1.72-2.55) | **2.24** (1.92-2.66) | **3.97** (3.30-4.72) | **6.33** (5.62-7.89) | **10.3** (7.65-15.2) | 822 |
| 20-59 years | 99-00 | **1.41** (1.23-1.62) | **1.33** (1.11-1.56) | **2.37** (1.87-3.01) | **4.25** (3.53-5.56) | **6.42** (5.11-9.02) | 832 |
| | 01-02 | **1.49** (1.30-1.71) | **1.64** (1.39-1.88) | **3.11** (2.60-3.91) | **5.43** (4.33-7.23) | **7.44** (5.80-11.0) | 1113 |
| **Gender** | | | | | | | |
| Males | 99-00 | **1.48** (1.27-1.72) | **1.44** (1.19-1.68) | **2.52** (2.05-3.38) | **4.95** (3.84-6.54) | **7.63** (5.65-11.0) | 972 |
| | 01-02 | **1.71** (1.47-2.00) | **1.87** (1.57-2.22) | **3.46** (2.82-4.28) | **5.93** (4.90-9.24) | **10.3** (6.94-14.3) | 1183 |
| Females | 99-00 | **1.69** (1.42-2.01) | **1.51** (1.25-1.85) | **2.96** (2.24-4.01) | **5.63** (4.26-7.19) | **8.44** (5.79-13.3) | 1022 |
| | 01-02 | **1.75** (1.49-2.07) | **1.93** (1.59-2.33) | **3.91** (3.06-4.85) | **6.47** (5.00-8.11) | **8.98** (6.83-11.8) | 1325 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **1.46** (1.20-1.77) | **1.44** (1.05-1.93) | **2.38** (2.09-2.96) | **3.82** (3.24-5.08) | **5.79** (3.88-9.57) | 697 |
| | 01-02 | **1.86** (1.63-2.12) | **2.06** (1.83-2.35) | **3.81** (3.17-4.56) | **6.52** (5.64-7.58) | **9.00** (7.66-11.8) | 660 |
| Non-Hispanic blacks | 99-00 | **1.47** (1.09-1.99) | **1.33** (.936-1.94) | **2.86** (1.58-5.05) | **5.88** (4.05-8.93) | **8.93** (5.91-13.7) | 521 |
| | 01-02 | **1.56** (1.19-2.03) | **1.92** (1.57-2.40) | **3.52** (2.85-4.28) | **5.58** (4.80-6.08) | **7.06** (5.88-8.82) | 700 |
| Non-Hispanic whites | 99-00 | **1.66** (1.45-1.90) | **1.54** (1.31-1.83) | **2.93** (2.09-3.97) | **5.56** (4.21-6.75) | **8.44** (6.25-12.3) | 602 |
| | 01-02 | **1.78** (1.49-2.14) | **1.93** (1.56-2.35) | **3.82** (2.70-4.97) | **6.55** (4.88-10.5) | **9.98** (7.00-13.7) | 947 |

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.

## Figure 36. 3,5,6-Trichloro-2-pyridinol (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.




[a] Estimate is less than the limit of detection (LOD). See Appendix A for LODs.

# 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

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, 1999-2002.

| | 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** | 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** | 632 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 829 |
| 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** | 1344 |
| **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** | **1.35** (<LOD-1.98) | 700 |
| 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.

### 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 µg/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

### Table 280. 2-(Diethylamino)-6-methylpyrimidin-4-ol/one

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** | **.470** (.210-.730) | 2481 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | * | **< LOD** | **< LOD** | **.230** (<LOD-.820) | **.820** (.210-1.64) | 567 |
| 12-19 years | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.610** (<LOD-1.94) | 810 |
| 20-59 years | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.430** (<LOD-.670) | 1104 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.840** (.300-1.55) | 1165 |
| Females | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.200** (<LOD-.460) | 1316 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.400** (<LOD-1.15) | 669 |
| Non-Hispanic blacks | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 687 |
| Non-Hispanic whites | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.490** (.200-.840) | 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.

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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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

The chemical 3-chloro-7-hydroxy-4-methyl-2H-chromen-2-one/ol is a specific metabolite of coumaphos. Coumaphos is an organophosphate insecticide that is used to control insects on beef cattle, dairy cows, swine, and certain other farm animals. It is not registered for residential use in the United States.

Coumaphos and other organophosphate pesticides share a common mechanism of toxicity, inhibiting the activity of acetylcholinesterase enzymes in the nervous system. Coumaphos is considered to be an organophosphate of moderate-to-high acute toxicity. Its metabolite, 3-chloro-7-hydroxy-4-methyl-2H-chromen-2-one/ol, does not inhibit acetylcholinesterase enzymes.

### Interpreting Levels of 3-Chloro-7-hydroxy-4-methyl-2H-chromen-2-one/ol Reported in the Tables

Urinary levels of 3-chloro-7-hydroxy-4-methyl-2H-chromen-2-one/ol 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 3-chloro-7-hydroxy-4-methyl-2H-chromen-2-one/ol were below the limit of detection. In a previous nonrandom study of urine specimens obtained from adults and children in the United States, Olsson et al. (2003) found that levels of 3-chloro-7-hydroxy-4-methyl-2H-chromen-2-one/ol were also below the limit of detection.

Finding a measurable amount of 3-chloro-7-hydroxy-4-methyl-2H-chromen-2-one/ol 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 coumaphos 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 coumaphos than levels found in the general population.

### Table 282. 3-Chloro-7-hydroxy-4-methyl-2H-chromen-2-one/ol

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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 2481 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 567 |
| 12-19 years | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 815 |
| 20-59 years | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1099 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1169 |
| Females | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1312 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 659 |
| Non-Hispanic blacks | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.200** (<LOD-.270) | 701 |
| Non-Hispanic whites | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 920 |

< 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 283. 3-Chloro-7-hydroxy-4-methyl-2H-chromen-2-one/ol (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 2480 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 567 |
| 12-19 years | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 814 |
| 20-59 years | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1099 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1169 |
| Females | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1311 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 659 |
| Non-Hispanic blacks | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.373** (.255-.560) | 700 |
| Non-Hispanic whites | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 920 |

< 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.

# 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 U.S. during 2001 (U.S. EPA, 2004). The herbicides measured in this *Report* can be classified into these categories: chlorophenoxy acids (2, 4, 5-trichlorophenoxyacetic acid, 2, 4-dichlorophenoxyacetic acid); triazines (atrazine); and chloroacetanilides (alachlor, metolachlor, and acetochlor).

The general population may be exposed to herbicides from their use in residential, forestry, or agricultural applications, or from their diet or drinking water. Workers who manufacture, formulate, or apply these chemicals also may be exposed to herbicides. The U.S. FDA, U.S. EPA, and OSHA have developed criteria for the allowable levels for some of these chemicals in foods, drinking water, and the workplace, respectively.

Table 285 shows the various urinary metabolites and their parent herbicides. For example, atrazine is metabolized to atrazine mercapturate. The presence of these chemicals in a person generally reflects recent exposure to herbicides. In addition to reflecting exposure to the parent herbicide, the level of certain metabolites (such as 2, 4-dichlorphenol) in a person's blood or urine may also reflect exposure to the metabolite itself if it was present in the person's environment.

**Table 284. Herbicides and their metabolites**

| Herbicide | CAS number | Urine metabolite |
|---|---|---|
| Salts and esters of 2,4,5-Trichlorophenoxyacetic acid (2,4,5-T) | 93-76-5 | 2,4,5-Trichlorophenoxyacetic acid |
| Salts and esters of 2,4-Dichlorophenoxyacetic acid (2,4-D) | 94-75-7<br>120-83-2 | 2,4-Dichlorophenoxyacetic acid<br>2,4-Dichlorophenol (minor) |
| Alachlor | 15972-60-8 | Alachlor mercpaturate |
| Atrazine | 1912-24-9 | Atrazine mercpaturate |
| Acetochlor | 34256-82-1 | Acetochlor mercpaturate |
| Metolachlor | 51218-45-2 | Metolachlor mercpaturate |

# 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*a*).

Chlorophenoxyacetic acid herbicides have been associated with weakness, headache, dizziness, nausea, and abdominal pain as a result of overexposure in occupational settings. Some epidemiological studies have reported associations between herbicides containing 2,4,5-T and certain forms of cancer, as well as with other health effects, although it is unclear whether or not these associations indicate a causal relationship (Institute of Medicine, 2003). It is also unclear whether these associations are related to 2,4,5-T or contaminants in the herbicide formulation itself (specifically 2,3,7,8-tetrachlordibenzodioxin). IARC considers the chlorophenoxyacetic acids group of chemicals as possibly carcinogenic to humans.

## Interpreting Levels of Urinary 2,4,5-T Reported in the Table

Urinary levels of 2,4,5-T 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 285. 2,4,5-Trichlorophenoxyacetic 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, 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 | 1814 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 2538 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 430 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 580 |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 618 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 831 |
| 20-59 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 766 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1127 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 891 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1192 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 923 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1346 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 652 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 679 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 483 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 701 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 531 |
| | 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.

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 µg/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)

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 | 1814 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 2537 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 430 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 580 |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 618 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 830 |
| 20-59 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 766 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1127 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 891 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1192 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 923 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1345 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 652 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 679 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 483 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 700 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 531 |
| | 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.

# 2,4-Dichlorophenoxyacetic Acid

CAS No. 94-75-7

## General Information

Widely used throughout the United States, the chlorophenoxy herbicide 2,4-dichlorophenoxyacetic acid (2,4-D) controls broadleaf weeds in residential, agricultural, and aquatic environments. Approximately 28-33 million pounds of 2,4-D were used in the U.S. in 2001 (U.S. EPA, 2004). The general population may be exposed to 2,4-D by using it on lawns, crops, or in forests as well as by consuming food or drinking water that contains 2, 4-D.

This herbicide is rapidly absorbed via oral and inhalation routes but is not well absorbed through the skin. Dermal exposure may be of some significance for herbicide workers who are exposed to high concentrations of 2,4-D or are exposed for prolonged periods. Once absorbed, 2,4-D distributes widely in the body and is eliminated predominantly unchanged in the urine, with an elimination half-life ranging from 10 hours to 33 hours (Kohli et al., 1974b; Sauerhoff et al., 1977). Direct skin contact may have irritant effects. Chlorophenoxyacetic acid herbicides have been associated with weakness, headache, dizziness, nausea, and abdominal pain as a result of overexposure in occupational settings. IARC considers the chlorophenoxyacetic acids group of chemicals as possibly carcinogenic to humans.

## Interpreting Levels of Urinary 2,4-D Reported in the Tables

Urinary levels of 2,4-D 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. The 95th percentile of the 2001-2002 subsample is similar to the

### Table 287. 2,4-Dichlorophenoxyacetic 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, 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** | 1977 |
| | 01-02 | * | **< LOD** | **.230** (<LOD-.320) | **.690** (.550-.890) | **1.27** (1.02-1.37) | 2413 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **1.30** (<LOD-1.50) | 477 |
| | 01-02 | * | **< LOD** | **.300** (<LOD-.400) | **.740** (.550-1.13) | **1.55** (1.00-2.21) | 546 |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **1.00** (<LOD-1.60) | 677 |
| | 01-02 | * | **< LOD** | **.250** (<LOD-.380) | **.660** (.440-1.16) | **1.24** (.690-1.66) | 797 |
| 20-59 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 823 |
| | 01-02 | * | **< LOD** | **.210** (<LOD-.310) | **.690** (.530-.910) | **1.27** (.930-1.49) | 1070 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **1.10** (<LOD-1.60) | 962 |
| | 01-02 | * | **< LOD** | **.320** (.230-.480) | **.930** (.680-1.22) | **1.51** (1.27-2.08) | 1135 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1015 |
| | 01-02 | * | **< LOD** | **< LOD** | **.480** (.370-.640) | **.890** (.670-1.22) | 1278 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 695 |
| | 01-02 | * | **< LOD** | **.250** (<LOD-.340) | **.730** (.600-.910) | **1.18** (.960-1.36) | 659 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **1.20** (<LOD-1.70) | 520 |
| | 01-02 | * | **< LOD** | **< LOD** | **.610** (.420-.890) | **1.06** (.810-1.48) | 668 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 589 |
| | 01-02 | * | **< LOD** | **.240** (<LOD-.410) | **.760** (.560-1.10) | **1.32** (1.05-2.03) | 892 |

< 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.

95th percentile value from a nonrandom subsample from NHANES III (1988-1994) (Hill et al., 1995).

Levels in children in the 2001-2002 NHANES subsample were similar to values previously reported among children from a community in Arkansas (Hill et al., 1989). In contrast, higher levels of 2,4-D have been measured in herbicide applicators. Mean urinary levels of 2,4-D among workers involved in mixing, loading, and applying this herbicide ranged 5-837 µg /L (Frank et al., 1985). Another study of farmers who reported applying 2,4-D found a geometric mean urinary concentration of 5.36 µg /L (Arbuckle et al., 2002).

Finding a measurable amount of 2,4-D in urine does not mean that the level of the 2,4-D will result in an adverse health effect. These data will help scientists plan and conduct research about the relation between exposure to 2,4-D 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-D than levels found in the general population.

### Table 288. 2,4-Dichlorophenoxyacetic acid (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** | **< LOD** | **< LOD** | 1977 |
| | 01-02 | * | **< LOD** | **.378** (.326-.412) | **.667** (.583-.737) | **1.08** (.926-1.26) | 2412 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **1.32** (.785-2.24) | 477 |
| | 01-02 | * | **< LOD** | **.485** (.378-.679) | **1.13** (.825-1.35) | **1.40** (1.27-1.73) | 546 |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.570** (.333-1.05) | 677 |
| | 01-02 | * | **< LOD** | **.274** (.209-.376) | **.476** (.326-.646) | **.662** (.517-.918) | 796 |
| 20-59 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 823 |
| | 01-02 | * | **< LOD** | **.378** (.326-.412) | **.667** (.575-.770) | **1.04** (.789-1.27) | 1070 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.667** (.447-1.16) | 962 |
| | 01-02 | * | **< LOD** | **.336** (.268-.412) | **.640** (.564-.789) | **1.14** (.893-1.39) | 1135 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1015 |
| | 01-02 | * | **< LOD** | **< LOD** | **.700** (.609-.778) | **1.06** (.809-1.26) | 1277 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 695 |
| | 01-02 | * | **< LOD** | **.344** (.311-.386) | **.720** (.562-.853) | **1.10** (.778-1.56) | 659 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.570** (.393-1.19) | 520 |
| | 01-02 | * | **< LOD** | **< LOD** | **.438** (.325-.560) | **.778** (.520-.906) | 667 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 589 |
| | 01-02 | * | **< LOD** | **.405** (.368-.452) | **.737** (.609-.875) | **1.14** (.933-1.39) | 892 |

< 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.

# 2,4-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-dichlorophenol is well absorbed via dermal, inhalation, and ingestion routes. Studies in other countries have frequently detected 2,4-dichlorophenol in urine samples obtained from the general population (Angerer et al., 1992). IARC considers the polychlorophenol class of chemicals, including 2,4-dichlorphenol, as possibly carcinogenic to humans.

## Interpreting Levels of Urinary 2,4-Dichlorophenol Reported in the Tables

Urinary levels of 2,4-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. Urinary levels of 2,4-dichlorophenol from the NHANES 2001-2002 and NHANES 1999-2000 subsamples are lower than levels obtained from a nonrandom sample of NHANES III (1988-1994) participants. In NHANES III, the mean concentration of 2,4-dichlorophenol was 9.3 µg/g creatinine, and the 95$^{th}$ percentile value was 45 µg/g creatinine (Hill et al., 1995). The geometric mean level of 2,4 dichlorphenol for the group aged 20-59 years in the NHANES 2001-2002 was about two-fold higher than the geometric mean reported by Becker et al. (2003) for adults aged 18-69 years in a German study.

### Table 289. 2,4-Dichlorophenol

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, 1999-2002.

| | 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 | **1.11** (.858-1.44) | **.750** (.620-.980) | **2.90** (1.50-5.30) | **11.0** (6.00-18.0) | **22.0** (16.0-31.0) | 1990 |
| | 01-02 | * | **< LOD** | **3.43** (2.79-4.58) | **12.0** (8.65-16.5) | **23.9** (15.3-35.5) | 2503 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **1.27** (.847-1.90) | **.820** (.570-1.30) | **3.30** (1.40-7.80) | **17.0** (6.10-27.0) | **29.0** (11.0-91.0) | 481 |
| | 01-02 | * | **< LOD** | **2.94** (1.41-5.60) | **10.9** (7.53-17.1) | **27.8** (14.6-50.7) | 574 |
| 12-19 years | 99-00 | **1.30** (.892-1.89) | **.950** (.680-1.50) | **3.50** (1.70-5.97) | **11.0** (5.20-23.0) | **21.6** (11.0-43.0) | 679 |
| | 01-02 | * | **< LOD** | **4.36** (3.16-5.21) | **13.6** (9.41-18.4) | **25.9** (20.9-37.7) | 820 |
| 20-59 years | 99-00 | **1.05** (.830-1.34) | **.700** (.570-.900) | **2.50** (1.40-4.80) | **9.40** (5.20-17.0) | **21.0** (15.0-31.0) | 830 |
| | 01-02 | * | **< LOD** | **3.40** (2.52-4.75) | **11.8** (8.18-16.5) | **24.0** (14.2-38.0) | 1109 |
| **Gender** | | | | | | | |
| Males | 99-00 | **1.35** (.933-1.95) | **1.00** (.640-1.70) | **3.80** (1.90-7.20) | **12.0** (6.30-18.0) | **21.0** (14.0-31.0) | 971 |
| | 01-02 | * | **.510** (<LOD-1.07) | **4.71** (3.33-5.82) | **13.2** (10.1-17.0) | **23.9** (15.2-38.0) | 1178 |
| Females | 99-00 | **.920** (.739-1.15) | **.590** (.490-.730) | **2.20** (1.22-3.50) | **8.30** (3.90-19.0) | **25.0** (11.0-34.0) | 1019 |
| | 01-02 | * | **< LOD** | **2.59** (1.83-3.40) | **9.55** (6.43-18.5) | **24.5** (15.3-37.7) | 1325 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **1.80** (1.20-2.71) | **1.00** (.700-2.00) | **5.90** (3.50-10.0) | **23.0** (15.0-31.0) | **50.0** (28.0-70.0) | 695 |
| | 01-02 | * | **.800** (<LOD-2.37) | **5.88** (3.68-9.52) | **18.6** (13.7-28.9) | **40.1** (22.5-82.8) | 677 |
| Non-Hispanic blacks | 99-00 | **2.24** (1.37-3.65) | **1.60** (.810-2.80) | **8.80** (2.30-18.0) | **22.0** (11.7-59.0) | **39.0** (18.0-140) | 518 |
| | 01-02 | * | **2.35** (1.62-3.15) | **10.7** (8.09-14.2) | **34.2** (25.0-52.7) | **74.5** (39.8-105) | 696 |
| Non-Hispanic whites | 99-00 | **.892** (.688-1.16) | **.620** (.470-.740) | **2.00** (1.10-4.30) | **7.20** (3.50-15.0) | **17.0** (8.20-29.0) | 603 |
| | 01-02 | * | **< LOD** | **2.31** (1.71-2.96) | **8.04** (5.66-11.1) | **15.0** (10.0-24.0) | 931 |

< 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.

### 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)

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.

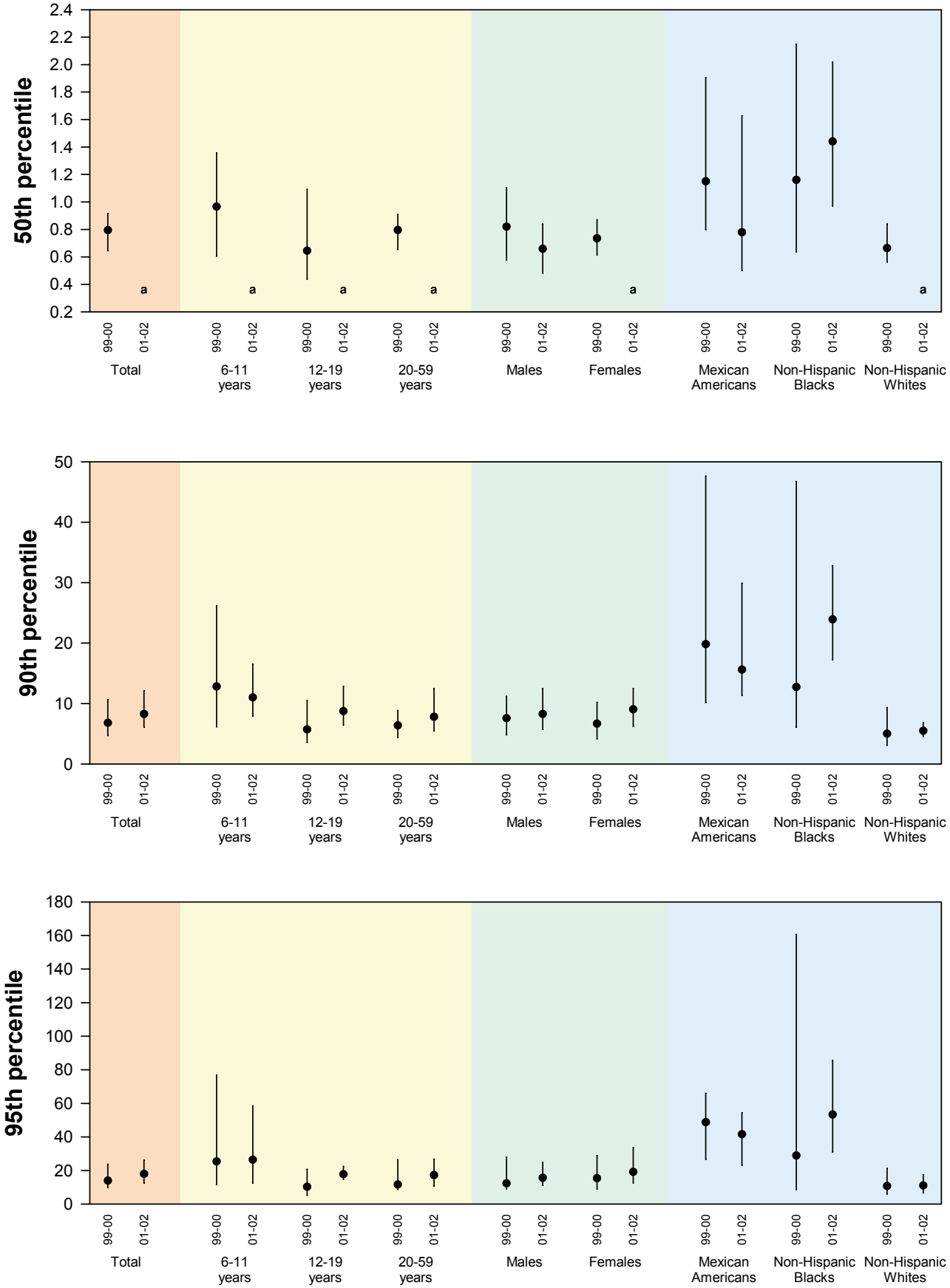
| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) 50th | 75th | 90th | 95th | Sample size |
|---|---|---|---|---|---|---|---|
| **Total, age 6 and older** | 99-00 | **.994** (.790-1.25) | **.794** (.645-.917) | **2.15** (1.31-3.64) | **6.79** (4.68-10.6) | **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** (.742-1.44) | **.819** (.577-1.11) | **2.51** (1.27-4.77) | **7.55** (4.81-11.2) | **12.3** (8.98-27.9) | 971 |
| | 01-02 | * | **.658** (.481-.840) | **2.82** (2.45-3.23) | **8.25** (5.70-12.5) | **15.6** (11.1-24.9) | 1178 |
| Females | 99-00 | **.955** (.791-1.15) | **.735** (.613-.870) | **1.91** (1.36-2.67) | **6.66** (4.12-10.2) | **15.3** (8.84-28.9) | 1019 |
| | 01-02 | * | **< LOD** | **2.37** (1.50-3.36) | **9.02** (6.23-12.5) | **19.1** (12.5-33.8) | 1324 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **1.62** (1.11-2.37) | **1.15** (.798-1.90) | **4.00** (2.61-7.14) | **19.8** (10.2-47.6) | **48.7** (26.7-65.9) | 695 |
| | 01-02 | * | **.779** (.500-1.63) | **4.28** (2.96-7.15) | **15.6** (11.3-29.9) | **41.5** (23.1-54.5) | 677 |
| Non-Hispanic blacks | 99-00 | **1.52** (.923-2.51) | **1.16** (.636-2.15) | **5.12** (1.62-8.82) | **12.7** (6.06-46.8) | **28.9** (8.60-161) | 518 |
| | 01-02 | * | **1.44** (.970-2.02) | **6.68** (4.47-8.57) | **23.9** (17.2-32.8) | **53.3** (31.0-85.5) | 695 |
| Non-Hispanic whites | 99-00 | **.843** (.666-1.07) | **.663** (.562-.840) | **1.58** (1.14-2.39) | **5.00** (3.06-9.33) | **10.7** (6.00-21.3) | 603 |
| | 01-02 | * | **< LOD** | **1.91** (1.36-2.57) | **5.49** (4.55-6.86) | **11.0** (6.64-17.4) | 931 |

< 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 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.




[a] Estimate is less than the limit of detection (LOD). See Appendix A for LODs.

# 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 months to break down in the environment, depending on conditions. Hydroxylated metabolites of atrazine are formed in plants and chlorinated metabolites and dealkylated degradates formed in animal tissues and the environment.

The general population may be exposed to atrazine from consuming foods or drinking water that contain this herbicide or from using it on lawns or crops. In people, atrazine is metabolized predominantly to atrazine mercapturate. Results of studies of adults occupationally exposed to atrazine have shown that it is rapidly eliminated from the body (Perry et al., 2000). Animal studies have shown that atrazine has low acute toxicity, but atrazine has been associated with adverse developmental and reproductive outcomes in animals when exposed over long periods (Hayes et al., 2002; U.S. EPA, 2003*b*). It is unclear whether or not this association is a causal relationship. The chlorinated metabolites may

### Table 291. Atrazine 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, 1999-2002.

| | 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 | 1878 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 2477 |
| **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 | 809 |
| 20-59 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 790 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1100 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 919 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1162 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 959 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1315 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 667 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 676 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 498 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 684 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 550 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 918 |

< 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.

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)

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 | 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 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1100 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 919 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1162 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 959 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1314 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 667 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 676 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 498 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 683 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 550 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 918 |

< 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.

# 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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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)

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, 1999-2000.

| | 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 | 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.

# Acetochlor Mercapturate

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

### General Information

Acetochlor is a selective herbicide for controlling annual grasses and broadleaf weeds in cornfields. It degrades in the environment over a period of days to weeks. In animal studies, acetochlor generally has been shown to be of low acute toxicity. The U.S. EPA has classified acetochlor as likely to be carcinogenic to humans.

### Interpreting Levels of Urinary Acetochlor Mercapturate Reported in the Tables

Urinary levels of acetochlor mercapturate 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, urine acetochlor mercapturate levels were below the limit of detection. Note that measurements were not made in 1999-2000.

Finding a measurable amount of acetochlor 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 acetochlor 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 acetochlor mercapturate than levels found in the general population.

### Table 295. Acetochlor 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, 2001-2002.

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 2501 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 576 |
| 12-19 years | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 820 |
| 20-59 years | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1105 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1178 |
| Females | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1323 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 678 |
| Non-Hispanic blacks | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 673 |
| Non-Hispanic whites | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 952 |

< 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 296. Acetochlor mercapturate (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 2500 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 576 |
| 12-19 years | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 819 |
| 20-59 years | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1105 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1178 |
| Females | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1322 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 678 |
| Non-Hispanic blacks | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 672 |
| Non-Hispanic whites | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 952 |

< 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.

# Metolachlor Mercapturate

*Metabolite of Metolachlor, CAS No. 51218-45-2*

## General Information

Metolachlor is a broad-spectrum herbicide used for general weed control on many agricultural crops, lawns, turf, rights-of-way, and in forests. This herbicide degrades in the environment over a period of weeks to months. In animal studies, metolachlor mercapturate generally has been shown to be of low acute toxicity. It is listed by the U.S. EPA as a possible human carcinogen.

## Interpreting Levels of Urinary Metolachlor Mercapturate Reported in the Tables

Urinary levels of metolachlor mercapturate 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 metolachlor mercapturate were mostly below the limit of detection. A study of herbicide applicators detected metolachlor mercapturate in 60% of urine samples, at concentrations ranging from 2-9 µg/L (Hines et al., 2003).

Finding a measurable amount of metolachlor 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 metolachlor 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 metolachlor than levels found in the general population.

### Table 297. Metolachlor 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, 2001-2002.

| | Survey years | Geometric mean (95% conf. interval) | Selected percentiles (95% confidence interval) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 2538 |
| **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** | 1127 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.200** (<LOD-.210) | 1192 |
| Females | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1346 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 679 |
| 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.

## Table 298. Metolachlor mercapturate (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 2537 |
| Age group | | | | | | | |
| 6-11 years | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 580 |
| 12-19 years | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 830 |
| 20-59 years | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1127 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.424** (.389-.467) | 1192 |
| Females | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1345 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 679 |
| Non-Hispanic blacks | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 700 |
| 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.

# Results by Chemical Group

## Pyrethroid Pesticides

# Pyrethroids Pesticides

### General Information

Pyrethroid pesticides are synthetic analogues of pyrethrins, which are natural chemicals found in chrysanthemum flowers. Pyrethroid pesticides are used to control a wide range of insects on agricultural fields, and in residences, public and commercial buildings, animal facilities, warehouses, and greenhouses. Certain pyrethroid insecticides (such as permethrin, resmethrin, and sumithrin) are also registered for use in mosquito-control programs in the United States. Pyrethroids are generally formulated as a complex mixture of different chemical isomers. National estimates for amounts of pyrethroids applied in the United States range from approximately 175,000 pounds (cyfluthrin, cypermethrin) to 1 million pounds (permethrin) (ATSDR, 2003).

Exposure of the general population to pyrethroid insecticides occurs primarily from the ingestion of food or from residential use. Permethrin is also used in skin lotion and shampoo to treat lice and scabies and has limited systemic absorption through the skin. Pesticide applicators can be exposed to pyrethroid pesticides via dermal and inhalation routes from powders and liquid formulations.

The average daily intake of permethrin (the most frequently used pyrethroid in the United States) for a man weighing 70 kilograms is estimated at about 3.2 micrograms per day. This value is about 1,000 times lower than the acceptable daily intake of permethrin derived by the United Nations' Food and Agriculture Organization and the World Health Organization. The U.S. FDA and USDA, the U.S. EPA, and OSHA have developed criteria on allowable levels of pyrethroids in foods, the environment, and the workplace, respectively.

Pyrethroid insecticides are currently undergoing regulatory review for a re-registration eligibility decision by the U.S. EPA.

Pyrethroids are not well absorbed through the skin. After a person inhales or ingests pyrethroids, the chemicals are rapidly metabolized and eliminated from the body. Elimination half-lives ranging from 5 to 8 hours have been measured for certain pyrethroids after human exposure (Kuhn et al., 1999). Researchers in other countries have frequently detected specific and nonspecific pyrethroid metabolites in urine samples obtained from adults and children in the general population (Heudorf and Angerer, 2001*d*).

Compared with other classes of insecticides (including organochlorines, organophosphates, and carbamates), pyrethroids have less toxicity in animals and people. Most adverse effects are related to the action of pyrethroids on the nervous system, where these chemicals open sodium channels when a nerve cell is excited (Soderlund et al., 2002). This effect can result in abnormal skin sensations (paresthesias) after dermal exposure, a transient symptom which is most commonly reported among pesticide applicators after direct contact with certain types of pyrethroid insecticides. Cases of systemic poisoning are rare and usually result from accidental or intentional ingestion of pyrethroid insecticides. Signs and symptoms of acute pyrethroid poisoning include tremor, salivation, choreoathetosis, and seizures (Ray et al., 2000).

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

**Table 299. Pyrethroid pesticides and their metabolites**

| Pyrethroid (CAS number) | Urine metabolite (CAS number) |
|---|---|
| Cyfluthrin (68359-37-5) | 4-Fluoro-3-phenoxybenzoic acid (77279-89-1) |
| *cis*-Permethrin (61949-76-6)<br>Cyfluthrin (68359-37-5) and<br>*cis*-Cypermethrin (52315-07-8) | *cis*-3-(2,2-Dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid (55701-05-8 ) |
| *trans*-Permethrin (61949-77-7)<br>Cyfluthrin (68359-37-5) and<br>*trans*-Cypermethrin (65732-07-2) | *trans*-3-(2,2-Dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid (55701-03-6) |
| Deltamethrin (52918-63-5) | *cis*-3-(2,2-Dibromovinyl)-2,2-dimethylcyclopropane carboxylic acid |
| Cypermethrin (52315-07-8)<br>Deltamethrin (52918-63-5)<br>Permethrin (52645-53-1) | 3-Phenoxybenzoic acid (3739-38-6) |

# 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. 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 4-fluoro-3-phenoxybenzoic 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 suspected residential insecticide exposure, the geometric mean concentration of 4-fluoro-3-phenoxybenzoic acid was 0.95 µg/L (Baker et al., 2004). In an investigation of adults and children in the general population in Germany, researchers detected 4-fluoro-3-phenoxybenzoic acid in 16% of urine samples (Heudorf and Angerer, 2001*d*), with adults and children having similar metabolite levels.

Finding a measurable amount of 4-fluoro-3-phenoxybenzoic acid in urine does not mean that the level of the 4-fluoro-3-phenoxybenzoic acid will result in an adverse health effect. These data will help scientists plan and conduct research about the relation between exposure to cyfluthrin 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 cyfluthrin than levels found in the general population.

### Table 300. 4-Fluoro-3-phenoxybenzoic 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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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.

## Table 301. 4-Fluoro-3-phenoxybenzoic acid (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 2538 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 580 |
| 12-19 years | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 830 |
| 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 | 1345 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 680 |
| Non-Hispanic blacks | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 700 |
| 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.

# *cis*-3-(2,2-Dichlorovinyl)-2,2-dimethylcyclopropane Carboxylic Acid

CAS No. 55701-05-8

*Metabolite of* cis-*Permethrin, CAS No.61949-76-6; Cyfluthrin, CAS No.68359-37-5; and* cis-*Cypermethrin, CAS No. 52315-07-8*

## General Information

*Cis*-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid is a metabolite of *cis*-permethrin and other pyrethroid insecticides. *Cis*-permethrin is an isomer that is commonly present in insecticide formulations containing permethrin as an active ingredient. Permethrin is the most commonly used pyrethroid on agricultural crops in the United States, and it is the most commonly detectable pyrethroid in foods. Permethrin is also used in residences to control home and garden pests and in public health programs to control mosquitos. The *cis*-isomer of permethrin has more potent insecticidal activity than *trans*-permethrin. The metabolic transformation of *cis*-permethrin to *cis*-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid can also occur in the environment (George, 1985). Thus, in addition to reflecting exposure to *cis*-permethrin and other pyrethroids, the detection of *cis*-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane carboxyclic acid in the urine may also reflect exposure to the metabolite if it was present in the person's food or environment.

The chemical *cis*-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid is also a metabolite of other pyrethroids, including cypermethrin and cyfluthrin (Kuhn et al., 1999). Thus, the detection of *cis*-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid in the urine may reflect multiple sources of environmental exposure to different pyrethroid insecticides.

## Interpreting Levels of Urinary *cis*-3-(2,2-Dichlorovinyl)-2,2-dimethylcyclopropane Carboxylic Acid Reported in the Tables

Urinary levels of *cis*-3-(2,2-dichlorovinyl)-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. The 95$^{th}$ percentile values in the 2001-2002 subsample are similar to the corresponding 95$^{th}$ percentile values reported in a study of children and adults in Germany (Schettgen, et al., 2002*a*). Other investigators in Germany detected *cis*-3-(2,2-

### Table 302. *cis*-3-(2,2-Dichlorovinyl)-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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | * | **< LOD** | **.160** (.120-.200) | **.490** (.380-.670) | **.890** (.740-1.10) | 2539 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | * | **< LOD** | **.110** (<LOD-.170) | **.360** (.280-.590) | **.730** (.490-.870) | 580 |
| 12-19 years | 01-02 | * | **< LOD** | **.150** (<LOD-.210) | **.430** (.300-.630) | **.720** (.630-.920) | 831 |
| 20-59 years | 01-02 | * | **< LOD** | **.160** (.120-.220) | **.510** (.390-.720) | **.960** (.790-1.28) | 1128 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | **< LOD** | **.140** (.100-.200) | **.470** (.370-.610) | **.880** (.650-1.35) | 1193 |
| Females | 01-02 | * | **< LOD** | **.180** (.120-.240) | **.500** (.360-.740) | **.880** (.790-1.08) | 1346 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | **< LOD** | **.130** (.100-.180) | **.290** (.250-.380) | **.510** (.380-.580) | 680 |
| Non-Hispanic blacks | 01-02 | * | **< LOD** | **.270** (.220-.350) | **.640** (.570-.700) | **.840** (.710-1.24) | 701 |
| Non-Hispanic whites | 01-02 | * | **< LOD** | **.130** (<LOD-.200) | **.500** (.330-.790) | **.890** (.670-1.28) | 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.

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)**

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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | * | **< LOD** | **.219** (.198-.248) | **.436** (.373-.521) | **.778** (.629-1.03) | 2538 |
| Age group | | | | | | | |
| 6-11 years | 01-02 | * | **< LOD** | **.250** (.184-.318) | **.596** (.430-.703) | **.745** (.636-.886) | 580 |
| 12-19 years | 01-02 | * | **< LOD** | **.154** (.123-.200) | **.303** (.250-.382) | **.500** (.367-.778) | 830 |
| 20-59 years | 01-02 | * | **< LOD** | **.227** (.210-.255) | **.444** (.386-.556) | **.891** (.640-1.08) | 1128 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | **< LOD** | **.171** (.149-.189) | **.350** (.302-.412) | **.675** (.449-1.03) | 1193 |
| Females | 01-02 | * | **< LOD** | **.263** (.226-.304) | **.500** (.432-.564) | **.920** (.745-1.11) | 1345 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | **< LOD** | **.165** (.148-.189) | **.297** (.263-.350) | **.535** (.373-.636) | 680 |
| Non-Hispanic blacks | 01-02 | * | **< LOD** | **.179** (.143-.219) | **.385** (.292-.545) | **.837** (.545-1.11) | 700 |
| Non-Hispanic whites | 01-02 | * | **< LOD** | **.242** (.206-.269) | **.444** (.389-.563) | **.837** (.583-1.14) | 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.

# *trans*-3-(2,2-Dichlorovinyl)-2,2-dimethylcyclopropane Carboxylic Acid

CAS No. 55701-03-6

*Metabolite of* trans-*Permethrin, CAS No. 61949-77-7; Cyfluthrin, CAS No.68359-37-5; and* trans-*Cypermethrin, CAS No. 65732-07-2*

## General Information

The chemical *trans*-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid is a metabolite of *trans*-permethrin and other pyrethroid insecticides. *trans*-Permethrin is an isomer that is commonly present in insecticide formulations containing permethrin as an active ingredient. Permethrin is the most commonly used pyrethroid on agricultural crops in the United States, and it is the most commonly detectable pyrethroid in foods. Permethrin is also used in residences to control home and garden pests and in public health programs to control mosquitos. The *trans*- isomer of permethrin has less potent insecticidal activity than cis-permethrin. The metabolic transformation of *trans*-permethrin to *trans*-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid can also occur in the environment (George, 1985). Thus, in addition to reflecting exposure to *trans*-permethrin, the detection of *trans*-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid in the urine may also reflect exposure to the metabolite if it were present in the person's food or environment.

*Trans*-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid is also a metabolite of other pyrethroids, including cypermethrin and cyfluthrin (Kuhn et al., 1999). Thus, the detection of detection of *trans*-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid in the urine may reflect multiple sources of environmental exposure to different pyrethroid insecticides.

### Interpreting Levels of Urinary *trans*-3-(2,2-Dichlorovinyl)-2,2-dimethylcyclopropane Carboxylic Acid Reported in the Tables

Urinary levels of *trans*-3-(2,2-dichlorovinyl)-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. The 95$^{th}$ percentile values in the 2001-2002 subsample are similar to the corresponding 95$^{th}$ percentile values reported in a study of children and

**Table 304. *trans*-3-(2,2-Dichlorovinyl)-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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | * | **< LOD** | **.410** (<LOD-.550) | **1.20** (.910-1.77) | **2.50** (1.68-3.70) | 2525 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | * | **< LOD** | **.470** (<LOD-.680) | **1.39** (1.03-1.68) | **2.50** (1.55-3.49) | 576 |
| 12-19 years | 01-02 | * | **< LOD** | **.490** (<LOD-.670) | **1.17** (.780-1.58) | **1.94** (1.49-3.77) | 826 |
| 20-59 years | 01-02 | * | **< LOD** | **< LOD** | **1.16** (.850-1.85) | **2.56** (1.64-4.66) | 1123 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | **< LOD** | **.400** (<LOD-.490) | **1.09** (.810-1.63) | **2.37** (1.55-4.48) | 1184 |
| Females | 01-02 | * | **< LOD** | **.430** (<LOD-.640) | **1.26** (.920-1.95) | **2.56** (1.76-3.58) | 1341 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | **< LOD** | **.410** (<LOD-.500) | **.900** (.680-1.16) | **1.59** (1.11-2.01) | 680 |
| Non-Hispanic blacks | 01-02 | * | **< LOD** | **.570** (.460-.730) | **1.26** (1.03-1.68) | **1.94** (1.68-2.95) | 690 |
| Non-Hispanic whites | 01-02 | * | **< LOD** | **.400** (<LOD-.610) | **1.19** (.840-1.90) | **2.60** (1.60-4.66) | 954 |

< 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.

adults in Germany (Schettgen et al., 2002*a*). Other investigators in Germany detected *trans*-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid in 65% 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. Higher levels (up to 13.4 µg/L) of *trans*-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid have been reported in pesticide applicators following the application of pyrethroid insecticides (Leng et al., 2003).

Finding a measurable amount of *trans*-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 305. *trans*-3-(2,2-Dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | * | **< LOD** | **.718** (.636-.778) | **1.45** (1.22-1.88) | **2.55** (2.07-2.98) | 2524 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | * | **< LOD** | **.903** (.697-1.13) | **2.16** (1.40-2.61) | **2.80** (2.34-3.44) | 576 |
| 12-19 years | 01-02 | * | **< LOD** | **.528** (.431-.651) | **.966** (.778-1.12) | **1.56** (1.07-2.60) | 825 |
| 20-59 years | 01-02 | * | **< LOD** | **< LOD** | **1.47** (1.20-1.98) | **2.47** (2.07-3.11) | 1123 |
| **Gender** | | | | | | | |
| Males | 01-02 | * | **< LOD** | **.519** (.475-.571) | **1.04** (.875-1.32) | **2.20** (1.45-2.57) | 1184 |
| Females | 01-02 | * | **< LOD** | **.875** (.789-1.00) | **1.68** (1.47-2.15) | **2.81** (2.30-3.19) | 1340 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | **< LOD** | **.569** (.509-.622) | **1.08** (.933-1.22) | **1.87** (1.27-2.15) | 680 |
| Non-Hispanic blacks | 01-02 | * | **< LOD** | **.475** (.413-.537) | **1.12** (.800-1.37) | **1.98** (1.20-2.68) | 689 |
| Non-Hispanic whites | 01-02 | * | **< LOD** | **.772** (.700-.848) | **1.48** (1.27-2.07) | **2.48** (2.15-3.02) | 954 |

< 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.

# *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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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.

Finding a measurable amount of *cis*-3-(2,2-dibromovinyl)-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 deltamethrin 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 deltamethrin than levels found in the general population.

**Table 307. *cis*-3-(2,2-Dibromovinyl)-2,2-dimethylcyclopropane carboxylic acid (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 2538 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 580 |
| 12-19 years | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 830 |
| 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 | 1345 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 680 |
| Non-Hispanic blacks | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 700 |
| 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 µg/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 µg/L.

### Table 308. 3-Phenoxybenzoic 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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **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** (.271-.364) | **.270** (.210-.340) | **.670** (.530-.780) | **1.64** (1.27-2.34) | **3.25** (2.51-6.16) | 1128 |
| **Gender** | | | | | | | |
| Males | 01-02 | **.328** (.277-.387) | **.290** (.230-.370) | **.680** (.560-.750) | **1.55** (1.26-2.16) | **3.23** (2.56-5.78) | 1193 |
| Females | 01-02 | **.315** (.266-.373) | **.250** (.210-.320) | **.730** (.530-.920) | **1.76** (1.47-2.35) | **3.28** (2.34-6.16) | 1346 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | **.297** (.238-.369) | **.250** (.190-.340) | **.650** (.480-.810) | **1.30** (.830-2.26) | **2.71** (1.51-3.44) | 680 |
| Non-Hispanic blacks | 01-02 | **.507** (.428-.601) | **.510** (.430-.630) | **.950** (.840-1.12) | **2.00** (1.65-2.28) | **3.25** (2.52-4.62) | 701 |
| Non-Hispanic whites | 01-02 | **.298** (.246-.362) | **.230** (.180-.320) | **.590** (.470-.800) | **1.72** (1.27-2.46) | **3.38** (2.25-7.64) | 957 |

### Comparing Adjusted Geometric Means

Geometric mean levels of urinary 3-phenoxybenzoic acid for the demographic groups were compared after adjusting for the covariates of race/ethnicity, age, gender, and urinary creatinine. For NHANES 2001-2002, children aged 6-11 years had slightly higher adjusted geometric mean levels of urinary 3-phenoxybenzoic acid than the group aged 12-19 years. Females had slightly higher levels than males. In addition, non-Hispanic blacks had slightly higher levels than Mexican Americans or non-Hispanic whites. 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.

Finding a measurable amount of 3-phenoxybenzoic 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 309. 3-Phenoxybenzoic acid (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) | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | | 50th | 75th | 90th | 95th | |
| **Total, age 6 and older** | 01-02 | **.316** (.274-.365) | **.283** (.243-.333) | **.582** (.490-.721) | **1.46** (1.13-1.91) | **3.10** (2.21-4.88) | 2538 |
| **Age group** | | | | | | | |
| 6-11 years | 01-02 | **.423** (.335-.534) | **.382** (.296-.500) | **.859** (.594-1.35) | **2.20** (1.61-2.95) | **3.32** (2.64-5.40) | 580 |
| 12-19 years | 01-02 | **.274** (.229-.328) | **.236** (.189-.313) | **.539** (.424-.730) | **1.10** (.864-1.63) | **2.35** (1.36-6.19) | 830 |
| 20-59 years | 01-02 | **.311** (.271-.357) | **.282** (.245-.328) | **.550** (.444-.673) | **1.44** (1.02-1.91) | **3.10** (1.91-4.92) | 1128 |
| **Gender** | | | | | | | |
| Males | 01-02 | **.264** (.226-.309) | **.238** (.200-.280) | **.490** (.413-.571) | **1.17** (.955-1.60) | **2.75** (1.60-4.00) | 1193 |
| Females | 01-02 | **.378** (.321-.446) | **.333** (.283-.391) | **.716** (.534-.932) | **1.66** (1.25-2.37) | **3.34** (2.25-5.19) | 1345 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 01-02 | **.275** (.230-.329) | **.241** (.206-.316) | **.512** (.404-.650) | **1.03** (.750-1.67) | **1.83** (1.15-2.74) | 680 |
| Non-Hispanic blacks | 01-02 | **.362** (.300-.437) | **.350** (.283-.415) | **.636** (.526-.757) | **1.36** (1.17-1.83) | **2.82** (1.63-3.80) | 700 |
| Non-Hispanic whites | 01-02 | **.312** (.261-.372) | **.279** (.233-.333) | **.554** (.438-.811) | **1.52** (1.09-2.35) | **3.43** (1.88-5.48) | 957 |

## Other Pesticides

# N,N-Diethyl-3-methylbenzamide

CAS No. 134-62-3

## General Information

N,N-diethyl-3-methylbenzamide (DEET) is an insect repellent that was first marketed in 1957. Commonly used to prevent mosquito bites, DEET can be applied to clothing and the skin. Insect repellents containing DEET are widely used by the general population. Commercial formulations of repellents containing DEET range in concentration from 4% to 100%. DEET is also used in combination with dermal sun screens. There are no registered uses of DEET on agricultural commodities.

The general population may be exposed to DEET from application to the skin and from inhalation of aerosol-repellent formulations. Eating food touched by hands that have been treated with DEET can also result in exposure. Absorption of DEET through the skin is limited, depending on the concentration and the presence of other chemicals in the formulation. After absorption, DEET is eliminated in the urine within approximately 24 hours (Selim et al., 1995). Bioaccumulation of DEET in the human body does not occur. People working in outdoor occupations may apply DEET more frequently or use higher concentration formulations resulting in higher levels of exposure.

Most reports of adverse effects from overexposure to DEET involve skin reactions (Bell et al., 2002). Neurological effects, including seizures, have been reported in a small number of studies involving human overexposure by ingestion or excessive dermal application, although it is unclear whether these effects have been caused by DEET (U.S. EPA, 1998). The toxicological mechanisms resulting in adverse effects from overexposure to DEET are not well understood. DEET is not rated by IARC or NTP with respect to

### Table 310. N,N-Diethyl-3-methylbenzamide (DEET)

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, 1999-2002.

| | 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** | 1977 |
| | 01-02 | * | **< LOD** | **< LOD** | **.100** (<LOD-.110) | **.170** (.140-.220) | 2535 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 480 |
| | 01-02 | * | **< LOD** | **< LOD** | **.120** (.100-.180) | **.200** (.120-.560) | 580 |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 672 |
| | 01-02 | * | **< LOD** | **< LOD** | **.120** (.110-.160) | **.220** (.130-.460) | 829 |
| 20-59 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 825 |
| | 01-02 | * | **< LOD** | **< LOD** | **.100** (<LOD-.110) | **.160** (.120-.210) | 1126 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 964 |
| | 01-02 | * | **< LOD** | **< LOD** | **.100** (<LOD-.110) | **.180** (.130-.250) | 1191 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1013 |
| | 01-02 | * | **< LOD** | **< LOD** | **.100** (<LOD-.120) | **.160** (.120-.200) | 1344 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 688 |
| | 01-02 | * | **< LOD** | **< LOD** | **.110** (<LOD-.130) | **.120** (.100-.150) | 678 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 518 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.130** (.100-.230) | 700 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 598 |
| | 01-02 | * | **< LOD** | **< LOD** | **.100** (<LOD-.110) | **.170** (.130-.250) | 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.

carcinogenicity.

### Interpreting Levels of Urinary DEET Reported in the Tables

Urinary levels of DEET 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. Urinary levels of DEET were characterized at the 90th and 95th percentiles in this 2001-2002 subsample at an improved limit of detection as compared with the NHANES 1999-2000 subsample for which measurements of DEET were usually not detectable. In a small study by Smallwood et al. (1992), urinary DEET levels as high as 5,690 µg/L were measured in eight park employees who applied 71% DEET once a day.

Finding a measurable amount of DEET 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 DEET 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 DEET than levels found in the general population.

**Table 311. N,N-Diethyl-3-methylbenzamide (DEET) (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** | **< LOD** | **< LOD** | 1977 |
| | 01-02 | * | **< LOD** | **< LOD** | **.269** (.233-.300) | **.412** (.350-.500) | 2534 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 480 |
| | 01-02 | * | **< LOD** | **< LOD** | **.333** (.219-.608) | **.632** (.280-1.93) | 580 |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 672 |
| | 01-02 | * | **< LOD** | **< LOD** | **.190** (.148-.241) | **.241** (.175-.333) | 828 |
| 20-59 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 825 |
| | 01-02 | * | **< LOD** | **< LOD** | **.267** (.229-.304) | **.407** (.368-.500) | 1126 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 964 |
| | 01-02 | * | **< LOD** | **< LOD** | **.194** (.163-.250) | **.314** (.250-.440) | 1191 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1013 |
| | 01-02 | * | **< LOD** | **< LOD** | **.327** (.292-.368) | **.500** (.400-.543) | 1343 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 688 |
| | 01-02 | * | **< LOD** | **< LOD** | **.185** (.163-.219) | **.280** (.226-.350) | 678 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 518 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **.187** (.140-.269) | 699 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 598 |
| | 01-02 | * | **< LOD** | **< LOD** | **.304** (.259-.333) | **.481** (.389-.545) | 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.

# *ortho*-Phenylphenol

CAS No. 90-43-7

## General Information

*Ortho*-phenylphenol (OPP) and its water-soluble salt, sodium *o*-phenylphenate (SOPP), are antimicrobial pesticides used in agriculture to control fungal and bacterial growth on stored crops, such as fruits and vegetables. These agents came into use in the mid 1930s. SOPP is applied topically to the crop and then rinsed off, leaving the chemical residue, *o*-phenylphenol. OPP offers additional protection to the crop from infection at scarred or injured sites (Johnson et al., 2001). OPP is also used as a disinfectant fungicide for industrial applications and at one time was used for applications inside the home.

The general population may be exposed to these chemicals via dermal, inhalational, or oral routes from residential use and by ingesting treated food or contaminated ground water. OPP has been detected in carpet dust in residential environments (Immerman and Shaum, 1990). Workers who manufacture, formulate, or apply these chemicals may have higher levels of exposure than other people.

OPP is not effectively absorbed through the skin but is efficiently absorbed from the gastrointestinal tract. Animal studies show that OPP appears to be eliminated rapidly from the body. The major urinary metabolites from SOPP exposure are OPP glucuronide and sulfate conjugates. The available evidence does not suggest that OPP accumulates in the body; however, OPP has been measured in human adipose tissue (Onstot and Stanley, 1989). After dermal exposure, OPP is rapidly eliminated in the urine within 24 hours (Timchalk et al., 1998). IARC has classified SOPP as a possible human carcinogen and OPP as not classifiable as a human carcinogen. The NTP conducted a 2-year experimental

### Table 312. *ortho*-Phenylphenol

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, 1999-2002.

| | 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 | **.494** (.387-.630) | **.490** (<LOD-.600) | **.850** (.600-1.30) | **1.46** (1.01-1.90) | **2.00** (1.50-2.80) | 1991 |
| | 01-02 | * | **< LOD** | **< LOD** | **.570** (.360-.830) | **1.27** (.710-2.85) | 2529 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **.507** (.399-.643) | **.490** (<LOD-.630) | **.890** (.610-1.50) | **1.80** (1.30-2.10) | **2.20** (1.80-3.90) | 480 |
| | 01-02 | * | **< LOD** | **< LOD** | **1.17** (.730-2.02) | **2.28** (1.28-3.61) | 577 |
| 12-19 years | 99-00 | **.506** (.369-.695) | **.490** (<LOD-.660) | **.890** (.570-1.50) | **1.60** (1.10-2.10) | **2.00** (1.40-6.30) | 681 |
| | 01-02 | * | **< LOD** | **< LOD** | **.740** (.470-1.25) | **2.05** (.800-3.09) | 827 |
| 20-59 years | 99-00 | **.490** (.385-.623) | **.490** (<LOD-.600) | **.810** (.600-1.20) | **1.41** (1.10-1.80) | **1.90** (1.50-2.90) | 830 |
| | 01-02 | * | **< LOD** | **< LOD** | **.440** (<LOD-.670) | **.930** (.540-2.23) | 1125 |
| **Gender** | | | | | | | |
| Males | 99-00 | **.495** (.386-.635) | **.460** (<LOD-.600) | **.820** (.600-1.30) | **1.60** (1.20-1.90) | **1.90** (1.50-3.20) | 973 |
| | 01-02 | * | **< LOD** | **< LOD** | **.610** (.350-1.03) | **1.27** (.750-2.85) | 1190 |
| Females | 99-00 | **.493** (.383-.634) | **.480** (<LOD-.590) | **.860** (.580-1.30) | **1.50** (1.00-2.00) | **2.10** (1.50-4.50) | 1018 |
| | 01-02 | * | **< LOD** | **< LOD** | **.520** (.370-.780) | **1.22** (.590-2.91) | 1339 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **.548** (.360-.834) | **.410** (<LOD-.950) | **1.10** (.490-1.90) | **2.20** (1.40-4.80) | **3.80** (2.30-7.10) | 695 |
| | 01-02 | * | **< LOD** | **< LOD** | **1.11** (<LOD-3.88) | **2.92** (.560-8.22) | 680 |
| Non-Hispanic blacks | 99-00 | **.564** (.428-.742) | **.560** (.410-.780) | **.970** (.690-1.50) | **1.60** (1.30-1.70) | **1.90** (1.60-2.20) | 520 |
| | 01-02 | * | **< LOD** | **< LOD** | **.770** (.570-.890) | **1.19** (.840-1.76) | 695 |
| Non-Hispanic whites | 99-00 | **.463** (.347-.619) | **.440** (<LOD-.600) | **.770** (.550-1.20) | **1.40** (.860-1.90) | **1.80** (1.40-5.10) | 603 |
| | 01-02 | * | **< LOD** | **< LOD** | **.430** (<LOD-.710) | **1.07** (.570-2.23) | 953 |

< 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.

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

### Interpreting Levels of Urinary *ortho*-Phenylphenol Reported in the Tables

Urinary OPP levels 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. Levels in this *Report* are less than levels measured following experimental dermal application in humans (Timchalk et al., 1998).

### Comparing Adjusted Geometric Means

Geometric mean levels of urinary OPP could not be calculated for the 2001-2002 subsample due to an insufficient detection rate. Geometric mean levels in the demographic groups for the previous 1999-2000 subsample were compared after adjustment for the covariates of age, race/ethnicity, gender and urinary creatinine. No differences between the demographic groups were observed.

Finding a measurable amount of OPP in urine does not mean that the level of the OPP will result in an adverse health effect. These data will help scientists plan and conduct research about exposure to OPP 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 OPP than levels found in the general population.

## Table 313. *ortho*-Phenylphenol (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 | **.442** (.351-.556) | **.413** (.313-.554) | **.840** (.619-1.11) | **1.84** (1.24-2.33) | **2.93** (2.04-4.29) | 1991 |
| | 01-02 | * | **< LOD** | **< LOD** | **.982** (.808-1.17) | **1.75** (1.21-2.33) | 2528 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | **.547** (.452-.663) | **.504** (.402-.667) | **1.02** (.800-1.27) | **1.96** (1.43-2.59) | **2.61** (2.09-3.58) | 480 |
| | 01-02 | * | **< LOD** | **< LOD** | **1.91** (1.08-2.53) | **2.53** (1.96-4.01) | 577 |
| 12-19 years | 99-00 | **.342** (.247-.472) | **.319** (.198-.497) | **.691** (.460-.913) | **1.14** (.867-1.96) | **1.96** (1.09-6.32) | 681 |
| | 01-02 | * | **< LOD** | **< LOD** | **.750** (.643-1.21) | **1.52** (.937-2.32) | 826 |
| 20-59 years | 99-00 | **.450** (.358-.566) | **.420** (.313-.562) | **.861** (.618-1.12) | **1.89** (1.24-2.47) | **3.28** (2.06-4.93) | 830 |
| | 01-02 | * | **< LOD** | **< LOD** | **.913** (.778-1.05) | **1.44** (1.05-2.30) | 1125 |
| **Gender** | | | | | | | |
| Males | 99-00 | **.380** (.299-.482) | **.353** (.239-.471) | **.752** (.548-.994) | **1.43** (1.08-1.93) | **2.07** (1.51-3.29) | 973 |
| | 01-02 | * | **< LOD** | **< LOD** | **.750** (.583-1.11) | **1.61** (.750-2.43) | 1190 |
| Females | 99-00 | **.512** (.400-.654) | **.459** (.382-.588) | **.909** (.646-1.46) | **2.04** (1.37-3.28) | **3.78** (2.06-5.96) | 1018 |
| | 01-02 | * | **< LOD** | **< LOD** | **1.11** (.913-1.35) | **1.75** (1.25-2.30) | 1338 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **.493** (.307-.789) | **.420** (.221-.808) | **1.11** (.548-2.14) | **2.99** (1.25-6.08) | **4.61** (2.40-13.4) | 695 |
| | 01-02 | * | **< LOD** | **< LOD** | **1.28** (.525-4.26) | **3.00** (.778-14.0) | 680 |
| Non-Hispanic blacks | 99-00 | **.382** (.287-.509) | **.375** (.259-.549) | **.672** (.509-.897) | **1.21** (.897-1.62) | **1.69** (1.43-2.13) | 520 |
| | 01-02 | * | **< LOD** | **< LOD** | **.669** (.477-.966) | **1.16** (.739-2.12) | 694 |
| Non-Hispanic whites | 99-00 | **.438** (.326-.588) | **.410** (.280-.608) | **.861** (.595-1.20) | **1.86** (1.12-2.59) | **2.93** (1.88-4.81) | 603 |
| | 01-02 | * | **< LOD** | **< LOD** | **.982** (.808-1.11) | **1.52** (1.11-1.91) | 953 |

< 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.

# 2,5-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

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, 1999-2002.

| | 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 | **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)

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 | **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 | 99-00 | **8.17** (4.79-13.9) | **11.3** (6.00-16.4) | **47.7** (29.4-78.0) | **247** (100-458) | **516** (267-762) | 480 |
| | 01-02 | * | **2.00** (.250-11.4) | **38.9** (20.6-100) | **248** (150-508) | **729** (361-1880) | 574 |
| 12-19 years | 99-00 | **3.95** (2.50-6.24) | **4.11** (2.60-5.72) | **19.4** (12.1-30.0) | **64.7** (46.9-211) | **233** (112-424) | 680 |
| | 01-02 | * | **1.92** (.146-6.69) | **25.6** (14.6-35.7) | **132** (81.0-256) | **541** (280-631) | 819 |
| 20-59 years | 99-00 | **5.36** (3.82-7.52) | **5.60** (4.30-7.55) | **24.5** (18.4-32.9) | **115** (69.0-179) | **280** (216-482) | 829 |
| | 01-02 | * | **1.38** (.365-4.47) | **20.8** (12.9-33.0) | **120** (82.5-238) | **514** (207-915) | 1108 |
| **Gender** | | | | | | | |
| Males | 99-00 | **5.25** (3.66-7.55) | **5.44** (4.11-7.34) | **24.1** (14.9-32.9) | **96.8** (65.9-208) | **289** (225-394) | 970 |
| | 01-02 | * | **1.99** (.280-5.84) | **24.0** (15.8-33.2) | **128** (88.5-207) | **500** (248-783) | 1178 |
| Females | 99-00 | **5.50** (3.52-8.61) | **6.15** (4.10-9.38) | **28.9** (20.1-43.2) | **136** (72.8-216) | **352** (228-509) | 1019 |
| | 01-02 | * | **1.10** (.333-4.45) | **23.9** (14.7-34.5) | **136** (88.8-291) | **589** (262-1050) | 1323 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | **12.9** (4.92-33.7) | **12.7** (6.36-30.2) | **72.7** (26.6-337) | **515** (134-1270) | **1170** (516-2810) | 695 |
| | 01-02 | * | **9.92** (4.16-21.3) | **82.2** (40.1-150) | **475** (225-1190) | **1500** (715-2170) | 677 |
| Non-Hispanic blacks | 99-00 | **10.7** (6.92-16.7) | **13.5** (7.65-22.5) | **57.8** (38.5-92.1) | **241** (138-311) | **433** (245-746) | 517 |
| | 01-02 | * | **20.6** (13.8-28.7) | **137** (84.2-248) | **829** (563-1210) | **2030** (1100-2650) | 695 |
| Non-Hispanic whites | 99-00 | **3.60** (2.27-5.71) | **3.81** (2.64-5.22) | **14.4** (11.5-18.9) | **57.4** (44.1-97.4) | **202** (97.4-299) | 603 |
| | 01-02 | * | **< LOD** | **11.7** (5.84-20.7) | **50.3** (35.0-88.5) | **131** (101-248) | 930 |

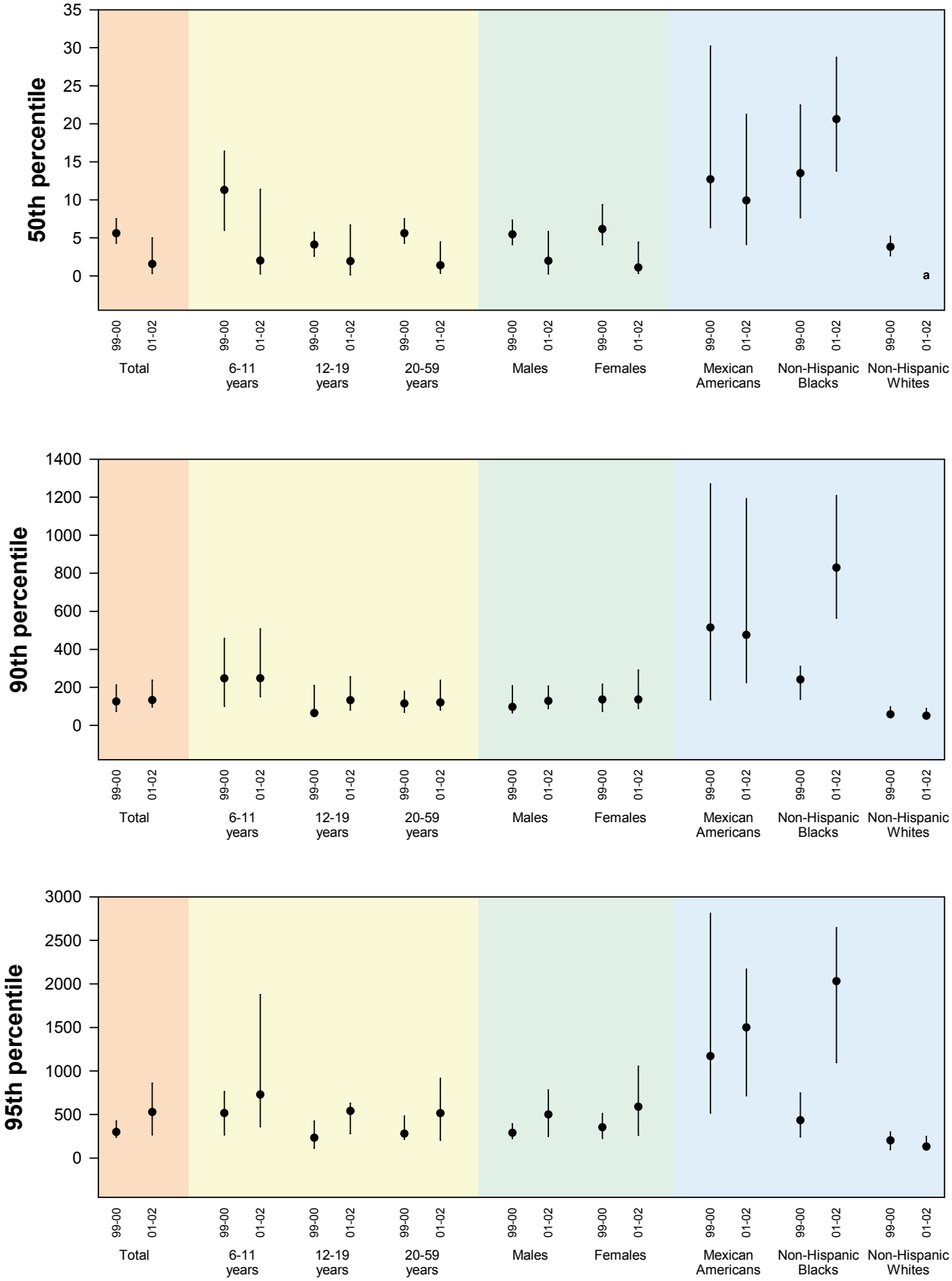
< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample. See Appendix A for LODs.

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

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.




[a] Estimate is less than the limit of detection (LOD). See Appendix A for LODs.

# Results by Chemical Group

## 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 carbamates ranged from 20,000 to 35,000 tons (International Programme on Chemical Safety, 1986). In the United States, uses of carbamate insecticides include agricultural crops, residential lawns and gardens, nurseries, and golf courses. Carbamate insecticides do not persist long in the environment, so they have a low potential for bioaccumulation. Some thiocarbamates and dithiocarbamates are used as herbicides and fungicides, and were not measured in this *Report*.

Exposure of the general population to these insecticides occurs primarily from ingestion of food products or from residential use. Other potential exposures to these chemicals occur during aerial spraying of these chemicals and during the manufacture, formulation, or application of these chemicals. Exposure may also occur among agricultural workers re-entering areas that have recently been treated with these chemicals. Carbamates can be absorbed through the skin, via inhalation, or by ingestion. Criteria on allowable levels of these chemicals in food, the environment, and the workplace have been developed by the U.S. FDA, U.S. EPA, and OSHA, respectively.

After acute overexposure, carbamate insecticides inhibit acetylcholinesterase enzymes. This inhibition leads to an increase of acetylcholine in the nervous system, resulting in symptoms including nausea, vomiting, cholinergic signs, weakness, paralysis, and seizures. The mechanism of toxicity of carbamate insecticides is similar to that of the organophosphate pesticides. Generally, carbamate insecticides inhibit acetylcholinesterase activity for a shorter amount of time than do organophosphate pesticides. Carbamate insecticides are rapidly eliminated from the body.

This *Report* provides measurements for the urinary metabolites derived from five carbamate insecticides. Table 316 shows the various metabolites measured in this *Report* and their parent carbamate pesticides. For example, propoxur is metabolized to 2-isopropoxyphenol. The presence of these chemicals generally reflects recent exposure to carbamate insecticides. In addition to reflecting exposure to the parent insecticide, the level of the metabolite in a person's urine may reflect exposure to the metabolite itself if it was present in their food or environment.

**Table 316. Carbamate insecticides and their metabolites**

| **Carbamate insecticide** (CAS number) | **Primary urinary metabolite** (CAS number) |
|---|---|
| Propoxur (114-26-1) | 2-Isopropoxyphenol (4812-20-8) |
| Carbofuran (1563-66-2) | Carbofuranphenol (1563-38-8) |
| Benfuracarb (82560-54-1) | Carbofuranphenol (1563-38-8) |
| Carbosulfan (55285-14-8) | Carbofuranphenol (1563-38-8) |
| Furathiocarb (65907-30-4) | Carbofuranphenol (1563-38-8) |

# 2-Isopropoxyphenol

CAS No. 4812-20-8

*Metabolite of Propoxur, CAS No. 114-26-1*

## General Information

The chemical 2-isopropoxyphenol is a metabolite of propoxur. Propoxur is a carbamate insecticide used in and around residences and commercial food-handling establishments. Propoxur may remain in the environment for weeks to months, longer than most carbamate insecticides.

Propoxur is effectively absorbed through the skin and from inhalation and ingestion pathways of exposure. Propoxur does not accumulate in blood or tissues in people and is eliminated rapidly from the body. The detection of 2-isopropoxyphenol in people's urine may reflect exposure to propoxur as well as to the metabolite itself if it was present in their food or environment.

Results of experimental studies in animals have shown that propoxur is of moderate acute toxicity. In contrast to propoxur, 2-isopropoxyphenol is not an inhibitor of acetylcholinesterase enzymes. The carcinogenic potential of propoxur has not been evaluated by either IARC or NTP.

## Interpreting Levels of Urinary 2-Isopropoxyphenol Reported in the Tables

Urinary 2-isopropoxyphenol levels 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 2-isopropoxyphenol levels in urine were below the limit of

### Table 317. 2-Isopropoxyphenol

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, 1999-2002.

| | 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 | 1917 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 2503 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 456 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 574 |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 655 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 820 |
| 20-59 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 806 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1109 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 936 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1178 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 981 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1325 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 664 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 677 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 500 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 696 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 585 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 931 |

< 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.

detection, which is lower than the limit of detection used in the previous NHANES 1999-2000 subsample. In a nonrandom subsample from NHANES III (1988-1994), the 95th percentile level of 2-isopropoxyphenol was 1.7 µg/L (Hill et al., 1995). Higher urinary levels of 2-isopropoxyphenol have been measured in pesticide applicators, ranging 45-306 µg/gram creatinine (Hardt and Angerer, 1999).

Finding a measurable amount of 2-isopropoxyphenol in urine does not mean that the level of the 2-isopropoxyphenol will result in an adverse health effect. These data will help scientists plan and conduct research about the relation of exposure to propoxur 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 propoxur than levels found in the general population.

**Table 318. 2-Isopropoxyphenol (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 | 1917 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 2502 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 456 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 574 |
| 12-19 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 655 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 819 |
| 20-59 years | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 806 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1109 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 936 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1178 |
| Females | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 981 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 1324 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 664 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 677 |
| Non-Hispanic blacks | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 500 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 695 |
| Non-Hispanic whites | 99-00 | * | < LOD | < LOD | < LOD | < LOD | 585 |
| | 01-02 | * | < LOD | < LOD | < LOD | < LOD | 931 |

< 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.

# Carbofuranphenol

CAS No. 1563-38-8

*Metabolite of Benfuracarb, Carbofuran, Furathiocarb, and Carbosulfan*

## General Information

Carbofuranphenol is a metabolite of the carbamate insecticides benfuracarb, carbofuran, furathiocarb, and carbosulfan. Only carbofuran is registered for use in the United States. Carbofuran is a broad-spectrum carbamate insecticide that has limited applications for use on certain agricultural commodities in the United States.

The detection of carbofuranphenol in people's urine may reflect exposure to carbofuran as well as to the metabolite itself if it was present in their food or environment. For example, benfuracarb undergoes metabolism in the environment to form carbofuran.

## Interpreting Levels of Urinary Carbofuranphenol Reported in the Tables

Urinary carbofuranphenol levels 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 urine levels of carbofuranphenol were below the limit of detection. In the NHANES 1999-2000 subsample, levels slightly above the limit of detection allowed characterization of the 95th percentile. In a nonrandom subsample from NHANES III (1988-1994), the 99th percentile level of carbofuranphenol was 2.1 µg/L (Hill et al., 1995). In a previous study of U.S. farmers and their families,

### Table 319. Carbofuranphenol

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, 1999-2002.

| | 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** | **.740** (<LOD-1.30) | 1994 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 2530 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.430** (<LOD-2.20) | 482 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 578 |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.570** (<LOD-1.20) | 681 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 827 |
| 20-59 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.840** (<LOD-1.50) | 831 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1125 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.740** (<LOD-1.30) | 973 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1190 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.840** (<LOD-1.50) | 1021 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1340 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **.570** (<LOD-2.00) | **1.90** (<LOD-4.90) | 696 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 680 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.430** (<LOD-1.60) | 521 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 696 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.740** (<LOD-1.30) | 603 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 953 |

< 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.

carbofuranphenol was detected in 6.7% of urine samples (Shealy et al., 1997). The 95th percentile value in that study was 0.73 µg/L.

Finding a measurable amount of carbofuranphenol in urine does not mean that the level of carbofuranphenol will result in an adverse health effect. These data will help scientists plan and conduct research about the relation between exposure to these carbamate pesticides 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 carbofuran than those levels found in the general population.

## Table 320. Carbofuranphenol (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** | **.777** (.636-1.00) | 1994 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 2529 |
| **Age group** | | | | | | | |
| 6-11 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.988** (.432-2.80) | 482 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 578 |
| 12-19 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.472** (.311-.853) | 681 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 826 |
| 20-59 years | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.824** (.638-1.06) | 831 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1125 |
| **Gender** | | | | | | | |
| Males | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.655** (.452-1.08) | 973 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1190 |
| Females | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.875** (.667-1.13) | 1021 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 1339 |
| **Race/ethnicity** | | | | | | | |
| Mexican Americans | 99-00 | * | **< LOD** | **< LOD** | **.778** (.350-1.94) | **1.83** (.560-4.16) | 696 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 680 |
| Non-Hispanic blacks | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.645** (.318-1.08) | 521 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 695 |
| Non-Hispanic whites | 99-00 | * | **< LOD** | **< LOD** | **< LOD** | **.717** (.636-.881) | 603 |
| | 01-02 | * | **< LOD** | **< LOD** | **< LOD** | **< LOD** | 953 |

< 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.

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