

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-dichlorophenol) 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)	94-75-7 120-83-2	2,4-Dichlorophenoxyacetic acid 2,4-Dichlorophenol (minor)
Alachlor	15972-60-8	Alachlor mercpturate
Atrazine	1912-24-9	Atrazine mercpturate
Acetochlor	34256-82-1	Acetochlor mercpturate
Metolachlor	51218-45-2	Metolachlor mercpturate

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., 1974a).

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-tetrachlorodibenzodioxin). 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)				Sample size
			50th	75th	90th	95th	
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)				Sample size
			50th	75th	90th	95th	
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)				Sample size
			50th	75th	90th	95th	
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-dichlorophenol, 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 95th percentile value was 45 µg/g creatinine (Hill et al., 1995). The geometric mean level of 2,4 dichlorophenol 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)				Sample size
			50th	75th	90th	95th	
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-dichlorophenol 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-dichlorophenol 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.

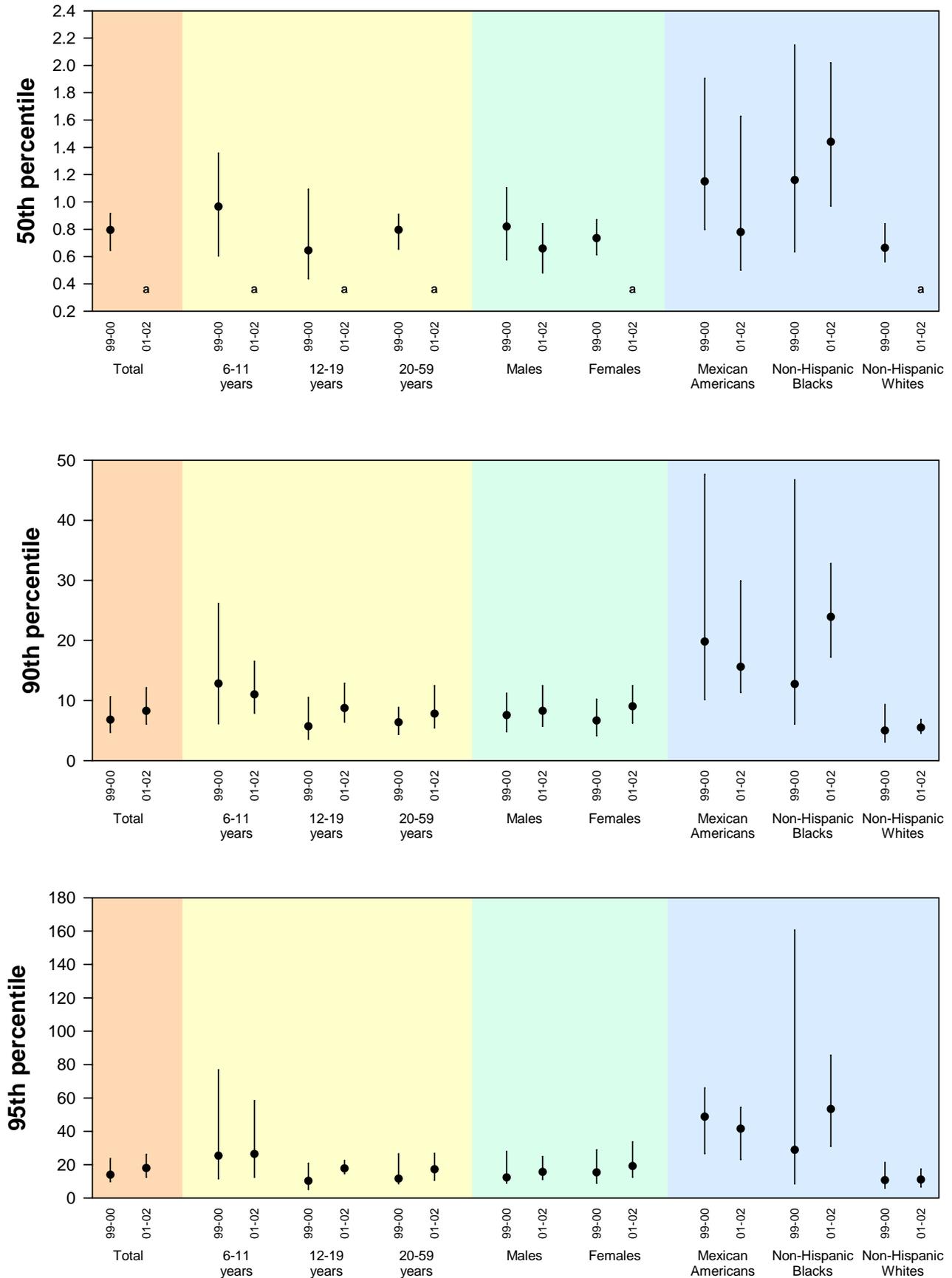
	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval)				Sample size
			50th	75th	90th	95th	
Total, age 6 and older	99-00	.994 (.790-1.25)	.794 (.645-.917)	2.15 (1.31-3.64)	6.79 (4.68-10.6)	13.9 (9.89-23.7)	1990
	01-02	*	< LOD	2.62 (2.09-3.17)	8.24 (6.06-12.1)	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 $\mu\text{g/g}$ 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, 2003a). 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, 2003b). 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 $\mu\text{g/g}$ 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 $\mu\text{g/g}$ 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 $\mu\text{g/g}$ 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

