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Appendix A. Limit of Detection Table

The analytical limit of detection (LOD) for each of the different chemical measurements is presented in the table below. The LOD is the level at which the measurement has a 95% probability of being greater than zero (Taylor, 1987). For most chemicals, the LOD is constant for each sample analyzed. However, for dioxins, furans, PCBs, organochlorine pesticides, and some other pesticides, each individual sample has its own LOD. These analyses have an individual LOD for each sample, mostly because the sample volume available for analysis differed for each sample. A higher sample volume results in a lower LOD and a better ability to detect low levels.

For chemicals with sample-specific LODs, we report in the table the maximum LOD among the samples analyzed. In general, the average LOD for these samples is about 40-50% of the maximum LOD. If a geometric mean or percentile estimate is less than the maximum LOD, it is noted in the results tables, and we do not report a number for that estimate. This conservative approach is to assure high confidence in all numbers reported in the results tables.

As analytical methods improve, LODs will often improve. For this reason, LOD results are reported by survey periods (e.g., 1999-2000, 2001-2002). Therefore, it is possible that the same chemical levels may be less than the LOD in 1999-2000 and greater than the LOD in 2001-2002.

Table A1. Limit of Detection for Chemicals Measured in the *Second* and *Third Reports*

Chemical	Matrix	Units	1999-2000	2001-2002
Metals				
Antimony	urine	µg/L	0.04	0.04
Barium	urine	µg/L	0.12	0.12
Beryllium	urine	µg/L	0.13	0.13
Cadmium	whole blood	µg/L	0.3	0.3
Cadmium	urine	µg/L	0.06	0.06
Cesium	urine	µg/L	0.14	0.14
Cobalt	urine	µg/L	0.07	0.07
Lead	whole blood	µg/dL	0.3	0.3
Lead	urine	µg/L	0.1	0.1
Mercury	whole blood	µg/L	0.14	0.14
Mercury	urine	µg/L	0.14	0.14
Molybdenum	urine	µg/L	0.8	0.8
Platinum	urine	µg/L	0.04	0.04
Thallium	urine	µg/L	0.02	0.02
Tungsten	urine	µg/L	0.04	0.04
Uranium	urine	µg/L	0.004	0.004
Tobacco Smoke				
Cotinine	serum	ng/mL	0.05	0.05
Polycyclic Aromatic Hydrocarbons				
1-Hydroxybenz[a]anthracene	urine	ng/L	4.7	3.9
3-Hydroxybenz[a]anthracene and 9-Hydroxybenz[a]anthracene	urine	ng/L	5.4	10.4
1-Hydroxybenzo[c]phenanthrene	urine	ng/L	5.7	3.4
2-Hydroxybenzo[c]phenanthrene	urine	ng/L	6.8	5.4
3-Hydroxybenzo[c]phenanthrene	urine	ng/L	4.9	5.4
1-Hydroxychrysene	urine	ng/L		5
2-Hydroxychrysene	urine	ng/L		5
3-Hydroxychrysene	urine	ng/L	9.9	8.3
4-Hydroxychrysene	urine	ng/L		2.8
6-Hydroxychrysene	urine	ng/L	3.4	2.4
3-Hydroxyfluoranthene	urine	ng/L	3.5	
2-Hydroxyfluorene	urine	ng/L	9.5	3.6
3-Hydroxyfluorene	urine	ng/L	15.1	2
9-Hydroxyfluorene	urine	ng/L		2.8
1-Hydroxyphenanthrene	urine	ng/L	15	3.5
2-Hydroxyphenanthrene	urine	ng/L	11.2	3.2
3-Hydroxyphenanthrene	urine	ng/L	15.3	3.6
4-Hydroxyphenanthrene	urine	ng/L		5.7
9-Hydroxyphenanthrene	urine	ng/L		3.1
1-Hydroxypyrene	urine	ng/L	2	3.3
3-Hydroxybenzo[a]pyrene	urine	ng/L		10.5
1-Hydroxynapthalene	urine	ng/L		6.2
2-Hydroxynapthalene	urine	ng/L		2.4

Chemical	Matrix	Units	1999-2000	2001-2002
Polychlorinated Dibenzo-p-dioxins, Dibenzofurans, Coplanar and Mono-Ortho-Substituted Biphenyls				
1,2,3,4,6,7,8,9-Octachlorodibenzo-*p*-dioxin (OCDD)	serum	pg/g of lipid	329*	319*
1,2,3,4,6,7,8-Heptachlorodibenzo-*p*-dioxin (HpCDD)	serum	pg/g of lipid	55.9*	10.3*
1,2,3,4,7,8-Hexachlorodibenzo-*p*-dioxin (HxCDD)	serum	pg/g of lipid		9.00*
1,2,3,6,7,8-Hexachlorodibenzo-*p*-dioxin (HxCDD)	serum	pg/g of lipid	20.1*	9.10*
1,2,3,7,8,9-Hexachlorodibenzo-*p*-dioxin (HxCDD)	serum	pg/g of lipid	20.3*	9.30*
1,2,3,7,8-Pentachlorodibenzo-*p*-dioxin (PeCDD)	serum	pg/g of lipid	14.2*	6.00*
2,3,7,8-Tetrachlorodibenzo-*p*-dioxin (TCDD)	serum	pg/g of lipid	12.1*	5.80*
1,2,3,4,6,7,8,9-Octachlorodibenzofuran (OCDF)	serum	pg/g of lipid	35.6*	21.0*
1,2,3,4,6,7,8-Heptachlorodibenzofuran (HpCDF)	serum	pg/g of lipid	13.5*	7.00*
1,2,3,4,7,8,9-Heptachlorodibenzofuran (HpCDF)	serum	pg/g of lipid		7.00*
1,2,3,4,7,8-Hexachlorodibenzofuran (HxCDF)	serum	pg/g of lipid	12.7*	6.50*
1,2,3,6,7,8-Hexachlorodibenzofuran (HxCDF)	serum	pg/g of lipid	12.6*	6.10*
1,2,3,7,8,9-Hexachlorodibenzofuran (HxCDF)	serum	pg/g of lipid	12.7*	6.00*
1,2,3,7,8-Pentachlorodibenzofuran (PeCDF)	serum	pg/g of lipid	13.2*	5.80*
2,3,4,6,7,8-Hexachlorodibenzofuran (HxCDF)	serum	pg/g of lipid	12.9*	5.80*
2,3,4,7,8-Pentachlorodibenzofuran (PeCDF)	serum	pg/g of lipid	12.7*	5.50*
2,3,7,8-Tetrachlorodibenzofuran (TCDF)	serum	pg/g of lipid	11.9*	5.20*
2,4,4'-Trichlorobiphenyl (PCB 28)	serum	ng/g of lipid	32.4*	
2,3',4,4'-Tetrachlorobiphenyl (PCB 66)	serum	ng/g of lipid	12.4*	12.4*
2,4,4',5-Tetrachlorobiphenyl (PCB 74)	serum	ng/g of lipid	12.4*	10.5*
3,4,4',5-Tetrachlorobiphenyl (PCB 81)	serum	pg/g of lipid	68.4*	26.8*
2,3,3',4,4'-Pentachlorobiphenyl (PCB 105)	serum	ng/g of lipid	12.4*	10.5*
2,3',4,4',5-Pentachlorobiphenyl (PCB 118)	serum	ng/g of lipid	12.5*	10.5*
3,3',4,4',5-Pentachlorobiphenyl (PCB 126)	serum	pg/g of lipid	23.2*	10.8*
2,3,3',4,4',5-Hexachlorobiphenyl (PCB 156)	serum	ng/g of lipid	12.5*	10.5*
2,3,3',4,4',5'-Hexachlorobiphenyl (PCB 157)	serum	ng/g of lipid	12.5*	10.5*
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB 167)	serum	ng/g of lipid	12.4*	10.5*
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB 169)	serum	pg/g of lipid	27.0*	11.0*
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB 189)	serum	ng/g of lipid		10.5*
Non-dioxin-like Polychlorinated Biphenyls				
2,2',5,5'-Tetrachlorobiphenyl (PCB 52)	serum	ng/g of lipid	12.5*	12.4*
2,2',3,4,5'-Pentachlorobiphenyl (PCB 87)	serum	ng/g of lipid		10.5*
2,2',4,4',5-Pentachlorobiphenyl (PCB 99)	serum	ng/g of lipid	12.5*	10.5*
2,2',4,5,5'-Pentachlorobiphenyl (PCB 101)	serum	ng/g of lipid	25.7*	10.5*
2,3,3',4',6-Pentachlorobiphenyl (PCB 110)	serum	ng/g of lipid		10.5*
2,2',3,3',4,4'-Hexachlorobiphenyl (PCB 128)	serum	ng/g of lipid	12.4*	10.5*
2,2',3,4,4',5' and 2,3,3',4,4',6-Hexachlorobiphenyl (PCB 138&158)	serum	ng/g of lipid	41.1*	10.5*
2,2',3,4',5,5'-Hexachlorobiphenyl (PCB 146)	serum	ng/g of lipid	12.4*	10.5*
2,2',3,4',5',6-Hexachlorobiphenyl (PCB 149)	serum	ng/g of lipid		10.5*
2,2',3,5,5',6-Hexachlorobiphenyl (PCB 151)	serum	ng/g of lipid		10.5*
2,2',4,4',5,5'-Hexachlorobiphenyl (PCB 153)	serum	ng/g of lipid	55.6*	10.5*
2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB 170)	serum	ng/g of lipid	17.2*	10.5*
2,2',3,3',4,5,5'-Heptachlorobiphenyl (PCB 172)	serum	ng/g of lipid	12.5*	10.5*
2,2',3,3',4,5',6'-Heptachlorobiphenyl (PCB 177)	serum	ng/g of lipid	12.5*	10.5*
2,2',3,3',5,5',6-Heptachlorobiphenyl (PCB 178)	serum	ng/g of lipid	12.4*	10.5*
2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB 180)	serum	ng/g of lipid	28.2*	10.5*
2,2',3,4,4',5',6-Heptachlorobiphenyl (PCB 183)	serum	ng/g of lipid	12.4*	10.5*
2,2',3,4',5,5',6-Heptachlorobiphenyl (PCB 187)	serum	ng/g of lipid	12.4*	10.5*
2,2',3,3',4,4',5,5'-Octachlorobiphenyl (PCB 194)	serum	ng/g of lipid		10.5*
2,2',3,3',4,4',5,6-Octachlorobiphenyl (PCB 195)	serum	ng/g of lipid		28.1*
2,2',3,3',4,4',5,6' and 2,2',3,4,4',5,5',6-Octachlorobiphenyl (PCB196&203)	serum	ng/g of lipid		10.5*
2,2',3,3',4,5,5',6'-Octachlorobiphenyl (PCB 199)	serum	ng/g of lipid		10.5*
2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl (PCB 206)	serum	ng/g of lipid		28.1*
Phytoestrogens				
Daidzein	urine	µg/L	0.5	1.6
Enterodiol	urine	µg/L	0.8	1.5
Enterolactone	urine	µg/L	0.6	1.9
Equol	urine	µg/L	3	3.3
Genistein	urine	µg/L	0.3	0.8
O-Desmethylangolensin	urine	µg/L	0.2	0.4

* Maximum LOD. Each person's sample has its own LOD. See text at beginning of Appendix for details.

Chemical	Matrix	Units	1999-2000	2001-2002
Phthalates				
Mono-methyl phthalate	urine	µg/L		0.2
Mono-ethyl phthalate	urine	µg/L	1.2	0.9
Mono-n-butyl phthalate	urine	µg/L	0.9	1.1
Mono-isobutyl phthalate	urine	µg/L		1
Mono-benzyl phthalate	urine	µg/L	0.8	0.3
Mono-cyclohexyl phthalate	urine	µg/L	0.9	0.3
Mono-2-ethylhexyl phthalate	urine	µg/L	1.2	1
Mono-(2-ethyl-5-oxohexyl) phthalate	urine	µg/L		1.1
Mono-(2-ethyl-5-hydroxyhexyl) phthalate	urine	µg/L		1
Mono-n-octyl phthalate	urine	µg/L	0.9	1
Mono-(3-carboxypropyl) phthalate	urine	µg/L		0.4
Mono-isononyl phthalate	urine	µg/L	0.8	0.8
Organochlorine Pesticides				
Hexachlorobenzene	serum	ng/g of lipid	118*	31.4*
Beta-hexachlorocyclohexane	serum	ng/g of lipid	9.36*	6.76*
Gamma-hexachlorocyclohexane	serum	ng/g of lipid	14.5*	10.5*
Pentachlorophenol	urine	µg/L	0.25	0.5
2,4,5-Trichlorophenol	urine	µg/L	0.9	0.9
2,4,6-Trichlorophenol	urine	µg/L	1	1.3
p,p' -DDT	serum	ng/g of lipid	20.7*	17.4*
p,p' -DDE	serum	ng/g of lipid	18.6*	8.3*
o,p' -DDT	serum	ng/g of lipid	20.7*	17.4*
Oxychlordane	serum	ng/g of lipid	14.5*	10.5*
trans -Nonachlor	serum	ng/g of lipid	14.5*	10.5*
Heptachlor Epoxide	serum	ng/g of lipid	14.6*	10.5*
Mirex	serum	ng/g of lipid	14.6*	10.5*
Aldrin	serum	ng/g of lipid		5.94*
Dieldrin	serum	ng/g of lipid		10.5*
Endrin	serum	ng/g of lipid		5.09*
Organophosphate Insecticides: Dialkyl Phosphate Metabolites				
Dimethylphosphate	urine	µg/L	0.58	0.5
Dimethylthiophosphate	urine	µg/L	0.18	0.4
Dimethyldithiophosphate	urine	µg/L	0.08	0.1
Diethylphosphate	urine	µg/L	0.2	0.2
Diethylthiophosphate	urine	µg/L	0.09	0.1
Diethyldithiophosphate	urine	µg/L	0.05	0.1
Organophosphate Insecticides: Specific Metabolites				
Malathion dicarboxylic acid	urine	µg/L	2.64*	
para -Nitrophenol	urine	µg/L	0.80*	0.1
3,5,6-Trichloro-2-pyridinol	urine	µg/L	0.4	0.4
2-Isopropyl-4-methyl-6-hydroxypyrimidine	urine	µg/L	7.21*	0.7
2-(diethylamino)-6-methylpyrimidin-4-ol/one	urine	µg/L		0.2
3-chloro-7-hydroxy-4-methyl-2H-chromen-2-one/ol	urine	µg/L		0.2
Herbicides				
2,4,5-Trichlorophenoxyacetic acid	urine	µg/L	1.20*	0.1
2,4-Dichlorophenoxyacetic acid	urine	µg/L	0.952*	0.2
2,4-Dichlorophenol	urine	µg/L	0.3	0.3
Alachlor mercapturate	urine	µg/L	1.18*	
Atrazine mercapturate	urine	µg/L	0.791*	0.3
Acetochlor mercapturate	urine	µg/L		0.1
Metolachlor mercapturate	urine	µg/L		0.2
Pyrethroid Pesticides				
4-Fluoro-3-phenoxybenzoic acid	urine	µg/L		0.2
Cis-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid	urine	µg/L		0.1
Trans-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid	urine	µg/L		0.4
Cis-3-(2,2-dibromovinyl)-2,2-dimethylcyclopropane carboxylic acid	urine	µg/L		0.1
3-Phenoxybenzoic acid	urine	µg/L		0.1
Other Pesticides				
N,N-diethyl-3-methylbenzamide	urine	µg/L	0.449	0.1
ortho -Phenylphenol	urine	µg/L	0.3	0.3
2,5-Dichlorophenol	urine	µg/L	0.1	0.1
Carbamate Pesticides				
2-Isopropoxyphenol	urine	µg/L	1.1	0.4
Carbofuranphenol	urine	µg/L	0.4	0.4

* Maximum LOD. Each person's sample has its own LOD. See text at beginning of Appendix for details.

Appendix B. References for Biomonitoring Analytical Methods

Dioxins, Furans, PCBs, Organochlorine Pesticides

Barr JB, Maggio VL, Barr DB, Turner WE, Sjodin A, Sandau CD, et al. New high-resolution mass spectrometric approach for the measurement of polychlorinated biphenyls and organochlorine pesticides in human serum. J Chromatog B 2003;794:137-48.

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Olsson AO, Baker SE, Nguyen JV, Romanoff LC, Udunka SO, Walker RD, et al. A liquid chromatography-tandem mass spectrometry multiresidue method for quantification of specific metabolites of organophosphorus pesticides, synthetic pyrethroids, selected herbicides, and DEET in human urine. Anal Chem 2004;76(9):2453-61.

Polycyclic Aromatic Hydrocarbons

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Phthalate Metabolites

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Tobacco Smoke (Cotinine)

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Appendix C. Confidence Interval Estimation for Percentiles

A common practice to calculate confidence intervals from survey data is to use large-sample normal approximations. Ninety-five percent confidence intervals on point estimates of percentiles are often computed by adding and subtracting from the point estimate a quantity equal to twice its standard error. This normal approximation method may not be adequate, however, when estimating the proportion of subjects above or below a selected value (especially when the proportion is near 0.0 or 1.0 or when the effective sample size is small).

In addition, confidence intervals on proportions deviating from 0.5 are not theoretically expected to be symmetric around the point estimate. Further, adding and subtracting a multiple of the standard error to an estimate near 0.0 or 1.0 can lead to impossible confidence limits (i.e., proportion estimates below 0.0 or above 1.0).

We used the method of Korn and Graubard (1998) to compute Clopper-Pearson 95% confidence intervals about percentile estimates. We describe the method below, using SAS Proc Univariate and SUDAAN. SAS code for calculating these confidence intervals can be downloaded from http://www.cdc.gov/exposurereport.

Procedure to calculate confidence intervals about percentiles

Step 1: Use SAS (SAS Institute Inc., 1999) Proc Univariate to obtain a point estimate of the percentile of a chemical's results for the demographic group of interest (e.g., the 90th percentile of blood lead results for children aged 1-5 years). Use the Freq option to assign the correct sample weight for each chemical result.

Step 2: Use SUDAAN (SUDAAN Users Manual, 2001) Proc Descript with Taylor Linearization DESIGN = WR (i.e., sampling with replacement) and the proper sampling weight to estimate the proportion (p) of subjects with results below the percentile estimate obtained in Step 1 and to obtain the standard error (se_p) associated with this proportion estimate. Compute the degrees-of-freedom adjusted effective sample size

$$n_{df} = ((t_{num}/t_{denom})^2)p(1 - p)/(se_p^2) \quad (1)$$

where t_{num} and t_{denom} are 0.975 critical values of the Student's t distribution with degrees of freedom equal to the sample size minus 1 and the number of PSUs minus the number of strata, respectively. Note: the degrees of freedom for t_{denom} can vary with the demographic sub-group of interest (e.g., males).

Step 3: After obtaining an estimate of p (i.e., the proportion obtained in Step 2), compute the Clopper-Pearson 95% confidence interval ($P_L(x,n_{df})$, $P_U(x,n_{df})$) as follows:

$$P_L(x,n_{df}) = v_1F_{v1,v2}(0.025)/(v_2 + v_1F_{v1,v2}(0.025)) \quad \& \quad P_U(x,n_{df}) = v_3F_{v3,v4}(0.975)/(v_4 + v_3F_{v3,v4}(0.975)) \quad (2)$$

where x is equal to p times n_{df}, $v_1 = 2x$, $v_2 = 2(n_{df} - x + 1)$, $v_3 = 2(x + 1)$, $v_4 = 2(n_{df} - x)$, and $F_{d1,d2}(\beta)$ is the β quantile of an F distribution with d_1 and d_2 degrees of freedom. (Note: If n_{df} is greater than the actual sample size or if p is equal to zero, then the actual sample size should be used.) This step will produce a lower and an upper limit for the estimated proportion obtained in Step 2.

Step 4: Use SAS Proc Univariate (again using the Freq option to assign weights) to determine the chemical values that correspond to the proportion obtained in Step 2 and the lower and upper limits on this proportion obtained in Step 3.

Example:

To estimate the 75th percentile, use SAS Proc Univariate with the Freq option to get a weighted point estimate of the chemical value that corresponds to the 75th percentile. Then use SUDAAN to estimate the weighted proportion of subjects with results below the 75th percentile (which should be very near 0.75). Next, obtain a confidence interval on this proportion by computing the weighted Clopper-Pearson 95% confidence limits using the degrees-of-freedom adjusted effective sample size. Suppose these confidence limits are 0.67 and 0.81, then use SAS Proc Univariate with the Freq option to determine the chemical values corresponding to the weighted 67th and 81st percentiles. These point estimates are the lower and upper confidence limits on the 75th percentile.

Appendix D. Abbreviations and Acronyms

ACGIH	American Conference of Governmental Industrial Hygienists
ANCOVA	Analysis of covariance
ATSDR	Agency for Toxic Substances and Disease Registry
BAT	Biologischen arbeitsstoff-toleranz [German] or biological tolerance level
BEI	Biological exposure index
BLL	Blood lead level
CAS	Chemical Abstract Service
CDC	Centers for Disease Control and Prevention
CPSC	United States Consumer Product Safety Commission
IARC	International Agency for Research on Cancer
IUPAC	International Union of Pure and Applied Chemistry
LOD	Limit of detection
MSDS	Material Safety Data Sheets
NCEH	National Center for Environmental Health
NCHS	National Center for Health Statistics
NHANES	National Health and Nutrition Examination Survey
NIEHS	National Institute of Environmental Health Sciences
NIH	National Institutes of Health
NIOSH	National Institute for Occupational Safety and Health
NTP	National Toxicology Program
OSHA	Occupational Safety and Health Administration
TEF	Toxic equivalency factor
TEQ	Toxic equivalency
TLV	Threshold limit value
USDA	United States Department of Agriculture
U.S. DHHS	United States Department of Health and Human Services
U.S. DOE	United States Department of Energy
U.S. DOT	United States Department of Transportation
U.S. EPA	United States Environmental Protection Agency
U.S. FDA	United States Food and Drug Administration
U.S. HUD	United States Department of Housing and Urban Development
U.S. NRC	United States Nuclear Regulatory Commission
WHO	World Health Organization