Introduction

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

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

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

Table 1 lists the chemicals measured in the *Second* and *Third Reports* and the years these chemicals were measured.

The new chemicals for the *Third Report* are—

- Pyrethroid insecticides.
- Additional polycyclic aromatic hydrocarbons (including benzo-[a]-pyrene).
- Aldrin, endrin, dieldrin.
- Additional phthalate metabolites.
- Additional pesticides and herbicides.
- Additional dioxins, furans, and polychlorinated biphenyls (PCBs).

We have not performed any analyses for differences in results between the 1999-2000 and 2001-2002 survey periods. As additional *Reports* are released every 2 years, it will become possible to analyze trends. Details on data analysis are presented in the section titled "Data Sources and Analysis."

Table 1. Chemicals Measured in the *Second* and *Third Reports*

Chemical	1999-2000	2001-2002
Metals		
Antimony	•	•
Barium	•	•
Beryllium	•	•
Cadmium	•	•
Cesium	•	•
Cobalt	•	•
Lead	•	•
Mercury	•	•
Molybdenum	•	•
Platinum	•	•
Tungsten	•	•
Thallium	•	•
Uranium	•	•
Tobacco Smoke		
Cotinine	•	•
Phytoestrogens		
Daidzein	•	•
Enterodiol	•	•
Enterolactone	•	•
Equol	•	•
Genistein	•	•
O-Desmethylangolensin	•	•

Chemical	1999-2000	2001-2002
Polycyclic Aromatic Hydrocarbons		
1-Hydroxybenz[a]anthracene	•	•
3-Hydroxybenz[a]anthracene and 9-Hydroxybenz[a]anthracene	•	•
1-Hydroxybenzo[c]phenanthrene	•	•
2-Hydroxybenzo[c]phenanthrene	•	•
3-Hydroxybenzo[c]phenanthrene	•	•
1-Hydroxychrysene		•
2-Hydroxychrysene		•
3-Hydroxychrysene	•	•
4-Hydroxychrysene		•
6-Hydroxychrysene	•	•
3-Hydroxyfluoranthene	•	
2-Hydroxyfluorene	•	•
3-Hydroxyfluorene	•	•
9-Hydroxyfluorene		•
1-Hydroxyphenanthrene	•	•
2-Hydroxyphenanthrene	•	•
3-Hydroxyphenanthrene	•	•
4-Hydroxyphenanthrene		•
9-Hydroxyphenanthrene		•
1-Hydroxypyrene	•	•
3-Hydroxybenzo[a]pyrene		•
1-Hydroxynapthalene		•
2-Hydroxynapthalene		•

Chemical	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)	•	•
1,2,3,4,6,7,8-Heptachlorodibenzo-*p*-dioxin (HpCDD)	•	•
1,2,3,4,7,8-Hexachlorodibenzo-*p*-dioxin (HxCDD)		•
1,2,3,6,7,8-Hexachlorodibenzo-*p*-dioxin (HxCDD)	•	•
1,2,3,7,8,9-Hexachlorodibenzo-*p*-dioxin (HxCDD)	•	•
1,2,3,7,8-Pentachlorodibenzo-*p*-dioxin (PeCDD)	•	•
2,3,7,8-Tetrachlorodibenzo-*p*-dioxin (TCDD)	•	•
1,2,3,4,6,7,8,9-Octachlorodibenzofuran (OCDF)	•	•
1,2,3,4,6,7,8-Heptachlorodibenzofuran (HpCDF)	•	•
1,2,3,4,7,8,9-Heptachlorodibenzofuran (HpCDF)		•
1,2,3,4,7,8-Hexachlorodibenzofuran (HxCDF)	•	•
1,2,3,6,7,8-Hexachlorodibenzofuran (HxCDF)	•	•
1,2,3,7,8,9-Hexachlorodibenzofuran (HxCDF)	•	•
1,2,3,7,8-Pentachlorodibenzofuran (PeCDF)	•	•
2,3,4,6,7,8-Hexachlorodibenzofuran (HxCDF)	•	•
2,3,4,7,8-Pentachlorodibenzofuran (PeCDF)	•	•
2,3,7,8-Tetrachlorodibenzofuran (TCDF)	•	•
2,4,4'-Trichlorobiphenyl (PCB 28)	•	
2,3',4,4'-Tetrachlorobiphenyl (PCB 66)	•	•
2,4,4',5-Tetrachlorobiphenyl (PCB 74)	•	•
3,4,4',5-Tetrachlorobiphenyl (PCB 81)	•	•
2,3,3',4,4'-Pentachlorobiphenyl (PCB 105)	•	•
2,3',4,4',5-Pentachlorobiphenyl (PCB 118)	•	•
3,3',4,4',5-Pentachlorobiphenyl (PCB 126)	•	•
2,3,3',4,4',5-Hexachlorobiphenyl (PCB 156)	•	•
2,3,3',4,4',5'-Hexachlorobiphenyl (PCB 157)	•	•
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB 167)	•	•
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB 169)	•	•
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB 189)		•
Non-dioxin-like Polychlorinated Biphenyls		
2,2',5,5'-Tetrachlorobiphenyl (PCB 52)	•	•
2,2',3,4,5'-Pentachlorobiphenyl (PCB 87)		•
2,2',4,4',5-Pentachlorobiphenyl (PCB 99)	•	•
2,2',4,5,5'-Pentachlorobiphenyl (PCB 101)	•	•
2,3,3',4',6-Pentachlorobiphenyl (PCB 110)		•
2,2',3,3',4,4'-Hexachlorobiphenyl (PCB 128)	•	•
2,2',3,4,4',5' and 2,3,3',4,4',6-Hexachlorobiphenyl (PCB 138&158)	•	•
2,2',3,4',5,5'-Hexachlorobiphenyl (PCB 146)	•	•
2,2',3,4',5',6'-Hexachlorobiphenyl (PCB 149)		•
2,2',3,5,5',6-Hexachlorobiphenyl (PCB 151)		•
2,2',4,4',5,5'-Hexachlorobiphenyl (PCB 153)	•	•
2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB 170)	•	•
2,2',3,3',4,5,5'-Heptachlorobiphenyl (PCB 172)	•	•
2,2',3,3',4,5',6'-Heptachlorobiphenyl (PCB 177)	•	•
2,2',3,3',5,5',6-Heptachlorobiphenyl (PCB 178)	•	•
2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB 180)	•	•
2,2',3,4,4',5',6-Heptachlorobiphenyl (PCB 183)	•	•
2,2',3,4',5,5',6-Heptachlorobiphenyl (PCB 187)	•	•
2,2',3,3',4,4',5,5'-Octachlorobiphenyl (PCB 194)		•
2,2',3,3',4,4',5,6-Octachlorobiphenyl (PCB 195)		•
2,2',3,3',4,4',5,6' and 2,2',3,4,4',5,5',6-Octachlorobiphenyl (PCB196&203)		•
2,2',3,3',4,5,5',6-Octachlorobiphenyl (PCB 199)		•
2,2',3,3',4,4',5,5',6'-Nonachlorobiphenyl (PCB 206)		•
Other Pesticides		
N,N-Diethyl-3-methylbenzamide	•	•
ortho-Phenylphenol	•	•
2,5-Dichlorophenol	•	•
Carbamate Pesticides		
2-Isopropoxyphenol	•	•
Carbofuranphenol	•	•

Chemical	1999-2000	2001-2002
Phthalates		
Mono-methyl phthalate		•
Mono-ethyl phthalate	•	•
Mono-n-butyl phthalate	•	•
Mono-isobutyl phthalate		•
Mono-benzyl phthalate	•	•
Mono-cyclohexyl phthalate	•	•
Mono-2-ethylhexyl phthalate	•	•
Mono-(2-ethyl-5-oxohexyl) phthalate		•
Mono-(2-ethyl-5-hydroxyhexyl) phthalate		•
Mono-n-octyl phthalate	•	•
Mono-(3-carboxypropyl) phthalate		•
Mono-isononyl phthalate	•	•
Organochlorine Pesticides		
Hexachlorobenzene	•	•
Beta-hexachlorocyclohexane	•	•
Gamma-hexachlorocyclohexane	•	•
Pentachlorophenol	•	•
2,4,5-Trichlorophenol	•	•
2,4,6-Trichlorophenol	•	•
p,p'-DDT	•	•
p,p'-DDE	•	•
o,p'-DDT	•	•
Oxychlordane	•	•
trans-Nonachlor	•	•
Heptachlor epoxide	•	•
Mirex	•	•
Aldrin		•
Dieldrin		•
Endrin		•
Organophosphate Insecticides: Dialkyl Phosphate Metabolites		
Dimethylphosphate	•	•
Dimethylthiophosphate	•	•
Dimethyldithiophosphate	•	•
Diethylphosphate	•	•
Diethylthiophosphate	•	•
Diethyldithiophosphate	•	•
Organophosphate Insecticides: Specific Metabolites		
Malathion dicarboxylic acid	•	
para-Nitrophenol	•	•
3,5,6-Trichloro-2-pyridinol	•	•
2-Isopropyl-4-methyl-6-hydroxypyrimidine	•	•
2-(Diethylamino)-6-methylpyrimidin-4-ol/one		•
3-Chloro-7-hydroxy-4-methyl-2H-chromen-2-one/ol		•
Herbicides		
2,4,5-Trichlorophenoxyacetic acid	•	•
2,4-Dichlorophenoxyacetic acid	•	•
2,4-Dichlorophenol	•	•
Alachlor mercapturate	•	
Atrazine mercapturate	•	•
Acetochlor mercapturate		•
Metolachlor mercapturate		•
Pyrethroid Pesticides		
4-Fluoro-3-phenoxybenzoic acid		•
cis-3-(2,2-Dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid		•
trans-3-(2,2-Dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid		•
cis-3-(2,2-Dibromovinyl)-2,2-dimethylcyclopropane carboxylic acid		•
3-Phenoxybenzoic acid		•

Public Health Uses of the *Report*

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

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

Data Presented for Each Environmental Chemical

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

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

Percentiles (50^{th}, 75^{th}, 90^{th}, and 95^{th}) are given to provide additional information about the shape of the distribution. In the *Third Report*, 10^{th} and 25^{th} percentiles are no longer included in order to provide adequate space in the tables to cover multiple years of data. Many of the tables in the *Report* are heavily filled with data. For tables with data entered for the 50^{th}, 90^{th}, and 95^{th} percentiles, figures showing these percentiles have also been included to help readers visualize the analytical results. Vertical lines above and below the point estimate of the percentile in these graphs represent the 95% confidence interval, which gives an estimate of uncertainty for that percentile. Percentile estimates for both survey periods are plotted.

For urine measurements, data are shown for the both the concentration in urine and the concentration corrected for urine-creatinine level. Serum measurements for chemicals that concentrate in lipid (e.g., dioxins, furans, PCBs, organochlorine pesticides) are presented per gram of total lipid in the serum and also per whole weight of serum.

General information is provided for each chemical that also aids the interpretation of levels.

A brief overview of information about each chemical is provided in the text to address common uses, sources of human exposure, disposition in the body, and known human health effects or major consistent effects in animals. Additionally, studies from other populations where blood and urine levels are available are presented for comparison.

The text also discusses briefly differences among demographic groups obtained by comparing the geometric means adjusted for the demographic covariates of age, gender, race/ethnicity, and when applicable, urinary creatinine, serum cotinine, or a lipid level. These adjusted geometric means are not shown in the tables. See the section titled “Data Sources and Data Analysis” for more details.

Interpreting *Report* Exposure Data: Important Factors

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

NHANES is designed to provide estimates for the civilian, noninstitutionalized U.S. population. The NHANES design does not select or exclude participants on the basis of their potential for low or high exposure to a chemical. The current design does not permit examination of exposure levels by locality, state, or region; seasons of the year; proximity to sources of exposure; or use of particular products. For example, it is not possible to extract a subset of the data and examine levels of blood lead that represent levels in a particular state’s population.

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

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

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

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

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

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

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

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

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

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

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

Concentrations of environmental chemicals in blood or urine are not the same as those in air, water, food, soil, or dust. For example, a chemical concentration of 10 µg/L in water does not produce a level of 10 µg/L in blood or urine. Blood or urine levels may reflect exposure from one or more sources, including air, water, food, soil, and dust.

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

exposure has occurred. Except for metals, most measurements in urine quantify chemical metabolites.

Biomonitoring Exposure Measurements

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

For chemicals measured in urine, levels are presented two ways: per volume of urine and per gram of creatinine. Levels per gram of creatinine (i.e., creatinine-corrected) adjust for urine dilution. For example, if one person has consumed more fluids than another person, his or her urine output is likely higher and the urine more dilute than that of the latter person. Creatinine is excreted from the body at a relatively constant rate over time, so expressing the result per gram of creatinine helps adjust for the effects of urinary dilution. The range and mean of creatinine levels were 2-650 mg/dL and 136.4 mg/dL in NHANES 1999-2000, and 5-774 mg/dL and 130.6 mg/dL in NHANES 2001-2002, respectively, results that are typical for the general U.S. population (see Barr et al., 2005). Creatinine corrects for urinary dilution in individual specimens, although this dilution variability has little effect on point estimates (e.g., means, percentiles). Interpretation of creatinine corrected results should also recognize that creatinine correction can also partially adjust for differences in lean body mass or renal function among persons.

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

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

Table 2. Units of Measurements and Conversions

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

Selection of Chemicals Included in the *Report*

Chemicals in the *Report* were selected on the basis of scientific data that suggested exposure in the U.S. population; the seriousness of health effects known or suspected to result from some levels of exposure; the need to assess the efficacy of public health actions to reduce exposure to a chemical; the availability of a biomonitoring analytical method with adequate accuracy, precision, sensitivity, specificity, and throughput; the availability of adequate blood or urine samples; and the incremental analytical cost to perform the biomonitoring analysis for the chemical. The availability of biomonitoring methods with adequate performance and acceptable cost was a major consideration.

In October 2002, CDC solicited nominations for candidate chemicals or categories of chemical to include in future *Reports* (*Federal Register*, Vol. 67, No. 194, October 7, 2002) and received nominations for hundreds of chemicals. Details on the prioritization process for scoring the nominated chemicals and the resulting scores are available at www.cdc.gov/exposurereport/chemical_nominations.htm.