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NHATS Broad Scan Analysis: Population Estimates from Fiscal Year 1982 Specimens

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FINAL REPORT

NHATS BROAD SCAN ANALYSIS: POPULATION ESTIMATES FROM FISCAL YEAR 1982 SPECIMENS

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AUTHORS AND CONTRIBUTORS

The Broad Scan Study described in this report was a cooperative undertaking that benefitted from the contributions of many EPA and contract support staff. EPA participation came from the Design and Development Branch (DDB) and the Field Studies Branch (FSB) of the Exposure Evaluation Division (EED), Office of Toxic Substances (OTS). Contract support to OTS was provided by Battelle and the Midwest Research Institute (MRI).

Battelle

Developed the statistical methodology for data analysis; designed the specimen compositing plan; created and maintained the computer files of Patient Summary Reports (PSRs); analyzed the chemical measurement and demographic data; prepared the final Broad Scan Report.

Midwest Research Institute (MRI)

Prepared the composite samples of adipose tissue; developed the methodology and carried out the chemical analysis of the samples.

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EXECUTIVE SUMMARY

BACKGROUND

The National Human Monitoring Program (NHMP), operated by the United States Environmental Protection Agency's Office of Toxic Substances (USEPA/OTS) under the 1976 Toxic Substances Control Act (TSCA), is an ongoing national chemical monitoring program. The main operative program of the NHMP is the National Human Adipose Tissue Survey (NHATS). The NHATS is an annual survey to collect and analyze a nation-wide sample of adipose tissue specimens from autopsied cadavers and surgical patients. The purpose of the NHATS is to identify and quantify the prevalence and levels of selected compounds in human adipose tissue. The analysis results are used to establish an exposure-based chemicals list and to estimate baseline levels and trends of the selected chemicals.

In the past, NHATS data have been used to monitor levels of organochlorine pesticides and polychlorinated biphenyls (PCBs) in the U.S. NHATS data have shown that the estimated percentage of individuals with levels of PCBs greater than three parts per million decreased from 1977 to 1983. This decrease occurred after the passage of legislation in 1976 which limited the production of PCBs (USEPA 1985). NHATS studies on hexachlorobenzene and mirex have helped to identify regions of the country where relatively high levels of these pesticides were found in human tissue.

METHODS

Although the NHATS data have proved useful in the past, the chemicals that could be monitored were limited to selected semi-volatile organic compounds. To broaden the range of chemicals, EPA proposed to analyze specimens through high resolution gas chromatography/mass spectrometry (HRGC/MS).

The HRGC/MS method, however, required considerably more tissue mass than the previous method of analysis. In addition, the HRGC/MS protocol was significantly more expensive than the previous protocol, thereby limiting the number of analyses that could be performed. For these reasons, the individual adipose tissue specimens were physically mixed to form composite samples. The composite sample, rather than the individual specimen, was analyzed. The use of composite samples created a need to develop a new statistical analysis approach.

NHATS specimens collected in Fiscal Year 1982 (FY82) were selected for the Broad Scan Analysis Study, the first application of HRGC/MS to NHATS. For this analysis, 763 individual specimens were combined into two sets of composite samples: 46 composite samples used for analysis of volatile organic compounds, and 46 composite samples used for the analysis of semi-volatiles, dioxins, and furans. In total, 57 compounds, including some homolog groups and isomers, were target analytes for the composite samples analyzed for the study. Of these, 17 were volatile organic compounds; 30 were semi-volatile organic compounds; 5 were dioxins (polychlorinated dibenzo-para-dioxins, or PCDDs); and 5 were furans (polychlorinated dibenzofurans, or PCDFs).

RESULTS

Compounds Detected

Volatile Organic Compounds

Results of the analysis indicated that eight of the nine benzene related volatile organic compounds were detected in more than 90% of the composite samples. For instance, benzene was found in 96% of the composite samples and 1,4-dichlorobenzene was found in all the composite samples.

Semi-Volatile Organic Compounds

The incidence of detection of the composite samples varied considerably for the organochlorine pesticides; mirex was detected in 14% of the composite samples while ß-BHC and p,p'-DDE were detected in 93% and 100%, respectively. PCBs were detected in 86% of the composite samples.

Dioxins and Furans

Four out of five dioxins were detected in more than 90% of the composite samples. The one exception, 2,3,7,8-TCDD, was found in 74% of the composite samples. The incidence of detection for the furans ranged from 26% for 2,3,7,8-TCDF to 93% for 1,2,3,4,6,7-HPCDF.

Average Concentrations

To form the required tissue composites it was sometimes necessary, because of the limited number of individual samples available, to mix male and female, and Caucasian and non-Caucasian specimens, in the same composite. The need to estimate average concentration levels using measurement data on these mixed composites required a model-based approach to the analysis. A multiplicative statistical model, which relates average concentration levels of the composite samples to demographic characteristics of constituent specimens, was developed for this purpose.

The FY82 NHATS survey initiates new data series for the dioxins and furans, as well as members of the following semi-volatile classes: PCB homologs, aromatics, chlorinated benzenes, phthalates, and phosphates. Volatile organic compounds were also measured in the FY82 survey, but there are no plans to measure this class of chemicals in subsequent years. Comparisons to past years' results for organochlorine pesticides are limited in this report because of the change in chemical methods.

Estimates of average concentration levels in the nation and various geographic and demographic subpopulations (i,e., Census region, age group, sex, and race group) were derived for 22 of the 57 target compounds, those for which more than half of the composites had measured concentration values above the analytical limit of quantification. This restriction was adopted to avoid possible bias in estimating average concentrations for compounds where most of the measurements were imputed (a compound not detected in a particular composite was assumed to be present at a level of one half the limit of detection). The average concentration estimates serve as baseline levels against which data from other sources can be compared.

The national average concentrations for selected compounds of current interest to EPA were:

Benzene, 0.014 µg/g (wet weight);
1,4-dichlorobenzene, 0.12 µg/g (wet weight);
PCBs, 0.33 µg/g (lipid adjusted weight); and
2,3,7,8-TCDD, 6.1 pg/g (lipid adjusted weight).

Regional Differences

There were statistically significant differences between regional concentrations for five compounds: benzene, chlorobenzene, 1-4 dichlorobenzene, ß-BHC, and tetrachloroethene. The West and Northeast Census regions had the highest average levels for benzene, while the South had the highest levels for chlorobenzene and 1,4-dichlorobenzene, two volatile organics, and for ß-BHC, an organochlorine pesticide. Average levels for tetrachloroethene, a volatile organic, were higher in the Northeast and North Central Census regions than in the South and West.

Age Differences

Eight compounds had statistically significant differences between age groups. Average levels for ethylphenol, a volatile organic compound, significantly decreased with age group. Among the semi-volatiles, average concentration levels of total PCBs, pp'-DDE, and ß-BHC, an organochlorine pesticide, significantly increased with age group. Total equivalent DDT also significantly increased with age group. For the dioxins and furans, levels were highest in the "15-44 years" age group for 2,3,7,8-TCDD, 1,2,3,7-PECDD and 2,3,4,7,8-PECDF. Levels for OCDD were higher in the "15-44 years" and in the oldest age group than in the youngest age group.

Sex Differences

Eight compounds were statistically significant with respect to sex differences. Males had significantly higher average levels than females for five volatile organics: chloroform, styrene, tetrachloroethene, toluene, and xylene; and for one semi-volatile compound, p,p'-DDE. The result for p,p'-DDE appears anomalous and is primarily attributable to a very low concentration in one pure female composite. Females had significantly higher levels of the dioxin, HXCDD, and the furan, HXCDF.

Racial Differences

Five compounds were statistically significant with respect to race differences. Caucasians had significantly higher average levels than non-Caucasians for toluene, chlorobenzene, ß-BHC, butyl benzyl phthalate, and 2,3,4,7,8-PECDF. There were no compounds for which non-Caucasians had significantly higher levels than Caucasians. Because the non-Caucasian sample size was too small to create composites that adequately represented this race group, the estimated race group effects should be interpreted cautiously.

Qualifications

In interpreting the statistical results of the survey, the reader should be aware of the following characteristics of its design. First, it is assumed that the average concentration levels of chemicals in the adipose tissue of surgical patients and autopsied cadavers is approximately equal to the average concentration levels in the U.S. population. Second, the survey is voluntary, and depends on the active participation of hospital pathologists and medical examiners (collectively known as "cooperators") who collect the adipose tissue samples that are to be analyzed. The cooperators are given quotas of specimens to fill, defined in terms of the age, race, and sex of donors; little additional information on donors is collected. In Fiscal Year 1982 approximately 50% of the planned number of samples were actually submitted for analysis by the survey cooperators. Third, the hospitals in the NHATS sample are all located in Standard Metropolitan Statistical Areas (SMSAs), and it is therefore plausible to expect that the distribution of survey specimens collected at these hospitals will be skewed toward individuals living in urban rather than rural areas. The impact on the estimated average concentrations, if any, attributable to these factors is not known.

1.0 INTRODUCTION

1.1 National Human Monitoring Program

The Toxic Substances Control Act (TSCA), enacted by Congress in 1976 as Public Law 94-469, directs the United States Environmental Protection Agency (USEPA) to prevent unreasonable chemical risk to the human population and the environment. To prevent or reduce such risk, it is necessary for the EPA to identify and evaluate those chemicals which contribute to unreasonable levels of risk to the human population or the environment.

EPA evaluates risk using both toxicity and exposure data. EPA determines whether a chemical is toxic enough to be harmful to human health or the environment through toxicological studies, quantitative assessments, and pharmacokinetic modeling. In addition, EPA determines if there is sufficient opportunity for humans or the environment to be exposed. Monitoring of both the environment and the population is one approach used by the EPA to estimate exposure. TSCA Section 10 (Research, Development, Collection, Dissemination, and Utilization of Data) allows the EPA to develop monitoring data, techniques, and instruments to detect toxic chemicals and to assess the degree of chemical risk they represent.

In response to TSCA, the EPA's Office of Toxic Substances (OTS) operates the National Human Monitoring Program (NHMP). The NHMP was first established by the U.S. Public Health Service in 1967. It was transferred to the EPA in 1970 and operated by the Office of Pesticide Programs (OPP) until 1979, when the program was assigned to the Exposure Evaluation Division (EED) of the newly created OTS.

The NHMP is an ongoing chemical monitoring program in which human media are sampled and analyzed to determine the extent of human exposure to toxic substances in the environment. By measuring the concentrations of toxic chemicals in human tissue and fluids, evidence of actual exposure is obtained.

Monitoring these levels over time provides the EPA with a means to assess and subsequently to address, through TSCA Section 4 (Testing of Chemical Substances and Mixtures) and TSCA Section 6 (Regulation of Hazardous Chemical Substances and Mixtures) those chemicals that are most likely to be associated with significant health concerns. Historically, the EPA has prioritized chemicals on the basis of significant toxicological findings and surrogate measures of exposure, such as production volume. The NHMP offers the EPA a means to prioritize chemicals using direct measures of exposure.

1.2 National Human Adipose Tissue Survey

The National Human Adipose Tissue Survey (NHATS) is the main operative program of the NHMP. The NHATS is an annual survey, conducted since 1970, which collects and chemically analyzes adipose tissue specimens for the presence of selected compounds. The tissue specimens are collected by pathologists and medical examiners, whose participation in NHATS is voluntary, from a national sample of autopsied cadavers and surgical patients in Standard Metropolitan Statistical Areas (SMSAs) in the continental United States. Past NHATS monitoring efforts have focused on the monitoring of organochlorine pesticides and polychlorinated biphenyls (PCBs). The analysis results have been used to provide information on U.S. population exposure to the pesticides and PCBs.

1.2.1 NHATS Objectives

The primary purpose of the NHATS program is to collect data for the detection and quantification of selected toxic residues in the adipose tissue of the general population of the United States. The specific objectives are to:

Identify the presence of toxic chemicals in human adipose tissue;

Establish baseline levels of the selected chemicals in the U.S. population and various demographic subpopulations;

Measure time trends of these levels; and

Make statistical comparisons of these results across the various geographic regions and demographic groups.

1.2.2 NHATS Data Uses

The chemicals identified through the NHATS provide information on human exposure. Population estimates establish baseline levels and trends of these chemicals in adipose tissue. Baseline levels serve as values against which other exposure levels can be compared. NHATS data can be used to assist in prioritizing the EPA's chemical screening and testing activities.

Trend estimates of changes in prevalence and levels are used to help identify the need for regulatory action or, in the case of existing regulations, to assess the efficacy of such regulations. Observed decreases in human monitoring data provide evidence that chemical risk has been reduced. For instance, in 1976, legislation limiting the production and usage of PCBs was passed. Through NHATS monitoring of PCB levels, it was observed that the estimated percentage of individuals having total PCB levels greater than 3 parts per million (ppm) decreased during the period from 1977 to 1983 (USEPA 1985). This result demonstrated the efficacy of the 1976 legislation. On the other hand, increasing trends may help to uncover emerging problems.

Demographic and geographic data are used to estimate baseline levels and trends for various subpopulations of interest to EPA. This information identifies exposed segments of the population for further investigations of chemical risk and to supports resulting regulatory actions. Several past NHATS studies have resulted in the identification of such high risk populations. A geographical evaluation of NHATS data on hexachlorobenzene (HCB) levels in the U.S. found a high incidence

of levels greater than 0.09 parts per million, the ninetieth percentile of the data observed throughout the nation, in the western region of the country (Leczynski and Stockrahm 1985). Although the direct use of HCB as a pesticide decreased sharply through the 1970's, further investigation discovered that pesticides containing HCB were still used in several Pacific Northwest areas (USEPA 1986f). A follow-up study to investigate evidence of mirex exposure observed in the NHATS verified the increased prevalence of mirex in a section of the southern U.S. (USEPA 1980). Thus, the estimation of levels and trends through periodic monitoring provides an effective means to maintain surveillance of both the general population and selected subpopulations with respect to chemical exposure (Mack and Stanley 1984).

1.3 Broad Scan Analysis Study

Upon assuming the responsibility of operating the NHMP in 1979, the OTS decided to expand the usefulness of the program by broadening the range of chemicals monitored by the NHATS. OTS proposed a Broad Scan Analysis Study of additional semi-volatile organic compounds, including the dioxins and furans, as well as volatile organic compounds and trace elements (Mack and Stanley 1984).

Previous NHATS chemical analyses were carried out by packed column gas chromatography/electron capture detector (PGC/ECD) methods. These methods permitted analysis of individual tissue specimens. However, since the PGC/ECD protocol was limited to the analysis of selected organochlorine pesticides and PCBs and was not readily expandable to additional chemicals (USEPA 1986c), several changes in the approach to analyzing adipose tissue specimens were required.

First, analytical methods based on high resolution gas chromatography/mass spectrometry (HRGC/MS) techniques were needed for the detection of semi-volatile and volatile organic compounds

(USEPA 1986a). The HRGC/MS method provided a greater degree of certainty in compound determination than PGC/ECD since identification is based on matching both retention time and mass spectra.

The HRGC/MS method, however, required more tissue mass per analysis sample than was collected from each individual NHATS donor. Furthermore, additional sample preparation work and sophisticated analytical equipment were needed to perform the chemical analyses. These factors greatly increased the cost of analyzing each sample and thereby reduced the number of samples that could be analyzed. For these reasons, individual tissue specimens had to be composited prior to chemical analysis.

Compositing is a process in which a specific amount of tissue is taken from each of several individual specimens and physically mixed to form a single sample. The composite sample, rather than the individual specimens, is then chemically analyzed. A compositing design was needed to ensure that each composite sample would have sufficient tissue mass available for analysis and that estimates of average concentration levels for subpopulations and the general population could be obtained. The design specified which types of specimens, in terms of their geographic and demographic makeup, to include in each composite sample. The composite design led to a major change in the statistical analysis of the NHATS chemical analysis data. A statistical model was developed to make inferences concerning average concentration levels for subpopulations and the general population.

To do this, a relationship was assumed between the concentration of a composite and its geographic and demographic make-up. That is, the concentration of a composite was assumed to have a geographic component, age group, sex, and race components and random error components. The statistical model made it possible to estimate the components from the observed concentrations of the composites. Once the components were

estimated, estimates of the average concentration levels of geographic and demographic subpopulations and the national population could be made.

Reliable estimates of prevalence, the proportion of the population with concentration levels above a specific threshold, cannot be computed from the composited data using the multiplicative model adopted for the NHATS FY82 survey. Work is currently underway on the development of a new modeling approach which will allow such prevalence estimates to be made in future surveys.

To further expand the range of chemicals monitored by the NHATS, multi-elemental techniques were needed for the detection of trace elements. The two procedures that were identified, however, were only used for the analysis of nine selected individual specimens (USEPA 1986e). Thus, compositing was unnecessary. Average concentration levels of trace elements for the U.S. population were not estimated.

1.3.1 Study Objectives

The specific objectives of the Broad Scan Analysis Study were to:

- Identify the presence of a wider range of chemicals in the adipose tissue of the U.S. population than had been identified in the past;
- Estimate the FY82 average levels of the chemicals for the entire U.S. and for selected geographic and demographic subpopulations; and
- Make comparisons of the estimated average levels across these various demographic and geographic subpopulations.

To accomplish these objectives, several activities were required. They were to:

- Develop, refine, and conduct a preliminary evaluation of appropriate analytical protocols based on HRGC/MS and the two proposed multi-elemental techniques;

- Derive a statistically based compositing design for the FY82 specimens that would provide a high degree of sensitivity for detecting chemicals (Mack and Stanley 1984), and permit appropriate estimates to be made for populations of interest.

- Develop, implement, and initially assess an appropriate statistical analysis methodology.

1.3.2 Study Schedule

Specimens collected during Fiscal Year 1982 (FY82) were selected from the NHATS repository for use in the Broad Scan Analysis Study. These specimens were collected from October, 1981 through September, 1982. Two sets of composite samples were prepared for chemical analysis, one set for the semi-volatile analyses, including the dioxins and the furans analyses, and one set for the volatiles analyses. Both sets of composite samples were prepared for chemical analysis during February and March of 1984. The semi-volatiles analyses were performed between April and June, 1984; the volatiles analyses were performed during June and July, 1984; the dioxins and furans analyses were performed from October, 1984 through March, 1985. The chemical analysis results for the semi-volatile and volatile compounds were completed in November, 1985. The dioxin and furan results were completed in March, 1986. The statistical analysis procedures were performed between December, 1985 and May, 1989.

1.3.3 Report Overview

This report summarizes the analysis approach adopted for the Broad Scan Analysis Study. It describes the statistical methodology and provides population estimates of the average concentration levels obtained for the volatile and semi-volatile organic compounds and the dioxins (polychlorinated dibenzo-para-dioxins, or PCDDs) and furans (polychlorinated dibenzofurans, or PCDFs). Additional information on the chemical analysis procedures used in the analysis of these compounds, the results

for trace elements, and related quality assurance efforts is found in the five volume series, "Broad Scan Analysis of Human Adipose Tissue" (USEPA 1986a-e).

2.0 RESULTS

Fifty-seven compounds, including some homolog groups and isomers, were the target compounds for the composite samples analyzed for the Broad Scan Analysis Study. Seventeen of these were volatiles; thirty were semi-volatiles; five were dioxins; and five were furans. The volatile organics are members of six chemical classes: benzene, substituted benzenes, alkyl benzenes, chlorinated benzenes, trihalomethanes, and halocarbons. The semi-volatile organics are also members of six chemical classes: PCB homologs, organochlorine pesticides, aromatics, chlorinated benzenes, phthalates, and phosphates. The results presented in this report are grouped into these chemical classes. The 57 compounds and their CAS numbers are listed in Table 2-1. The compound 1,2-dichlorobenzene was included in both the volatile and semi-volatile compound lists because it could be measured by both the volatile and semi-volatile protocols.

Estimates of population average concentration levels derived from the statistical model for analysis of composite sample data were obtained for those compounds for which at least half of the reported concentrations were above the limit of quantificaton. Twenty-two of the 57 compounds met this condition. These compounds are listed in Table 2-2.

For the volatile organic compounds, the statistical analyses were based on wet weight concentration levels. For the semi-volatile compounds, including the dioxins and furans, the analyses were based on lipid adjusted concentrations. The concentrations for the volatiles were not lipid adjusted. To do so would have required further handling of samples, which increases the potential for volatile compounds to escape. Concentrations were reported in parts per million ($\mu g/g$) for volatiles and semi-volatiles and in parts per trillion (pg/g) for the dioxins and furans.

Table 2-1. Target Compounds Identified in the Broad Scan Analysis Study

Class	Compound	CAS Number
VOLATILE ORGANIC COMPOUNDS		
Benzene	Benzene	71-43-2
Substituted Benzenes	Styrene	100-42-5
	Ethylphenol	25429-37-2
Alkyl Benzenes	Toluene	188-88-3
	Ethylbenzene	100-41-4
	Xylene	1330-20-7
Chlorinated Benzenes	Chlorobenzene	108-90-7
	1,2-Dichlorobenzene	95-50-1
	1,4-Dichlorobenzene	106-46-7
Trihalomethanes	Chloroform	67-66-3
	Bromodichloromethane	75-27-4
	Dibromochloromethane	124-48-1
	Bromoform	75-25-2
Halocarbons	1,1,1-Trichloroethane	71-55-6
	1,1,2-Trichloroethane	79-00-5
	1,1,2,2-Tetrachloroethane	79-34-5
	Tetrachloroethene	127-18-4
SEMI-VOLATILE ORGANIC COMPOUNDS		
PCBs	PCBs	1336-36-3
	Trichlorobiphenyl	25323-68-6
	Tetrachlorobiphenyl	26914-33-0
	Pentachlorobiphenyl	25429-29-2
	Hexachlorobiphenyl	26601-64-9
	Heptachlorobiphenyl	28655-71-2
	Octachlorobiphenyl	31472-83-0
	Nonachlorobiphenyl	53742-07-7
	Decachlorobiphenyl	2051-24-3
Organochlorine Pesticides	ß-BHC	319-85-7
	p,p'-DDE	72-55-9
	p,p'-DDT	50-29-3
	Mirex	2385-85-5
	trans-Nonachlor	39765-80-5
	Heptachlor Epoxide	1024-57-3
	Dieldrin	60-57-1

Table 2-1.(Continued) Target Compounds Identified in the Broad Scan Analysis Study

Class	Compound	CAS Number
Aromatics	Naphthalene	91-20-3
	Phenanthrene	85-01-8
	Pyrene	129-00-0
Chlorinated Benzenes	1,2-Dichlorobenzene	95-50-1
	1,2,4-Trichlorobenzene	120-82-1
	Pentachlorobenzene	608-93-5
	Hexachlorobenzene	118-74-1
Phthalates	Diethyl Phthalate	84-66-2
	Di-n-butyl Phthalate	84-74-2
	Di-n-octyl Phthalate[1]	117-84-0
	Butyl Benzyl Phthalate	85-68-7
Phosphates	Triphenyl Phosphate	115-86-6
	Tributyl Phosphate	126-73-8
	Tris (2-Chloroethyl) Phosphate	115-96-8
DIOXINS AND FURANS		
Dioxins	2,3,7,8-TCDD	1746-01-6
	1,2,3,7,8-PECDD	40321-76-4
	HXCDD	34465-46-8
	1,2,3,4,7,8,9-HPCDD	35822-46-9
	OCDD	3268-87-9
Furans	2,3,7,8-TCDF	51207-31-9
	2,3,4,7,8-PECDF	57117-31-4
	HXCDF	55684-94-1
	1,2,3,4,6,7,8-HPCDF	67562-39-4
	OCDF	39001-02-0

[1] The chemical actually identified was diethyl hexyl phthalate, an isomeric compound to di-n-octyl phthalate, that exhibits many of the same chemical and physical properties.

Table 2-2. Compounds for Which Statistical Model Analyses Were Performed

Class	Compound
VOLATILE ORGANIC COMPOUNDS	
Benzene	Benzene
Substituted Benzenes	Styrene Ethylphenol
Alkyl Benzenes	Toluene Ethylbenzene Xylene
Chlorinated Benzenes	Chlorobenzene 1,4-Dichlorobenzene
Trihalomethanes	Chloroform
Halocarbons	Tetrachloroethene
SEMI-VOLATILE ORGANIC COMPOUNDS	
Organochlorine Pesticides	ß-BHC p,p'-DDE
PCBs	PCBs
Phthalates	Butyl Benzyl Phthalate
DIOXINS AND FURANS	
Dioxins	2,3,7,8-TCDD 1,2,3,7,8-PECDD HXCDD 1,2,3,4,7,8,9-HPCDD OCDD
Furans	2,3,4,7,8-PECDF HXCDF 1,2,3,4,6,7,8-HPCDF

Average concentration levels were estimated for the entire nation and for various geographic (Census region) and demographic (age group, sex, and race group) subpopulations. Data on the percentage of composite samples having detectable levels of the 57 compounds were also obtained.

2.1 Population Estimates of Average Concentration Level

For the Broad Scan Analysis Study, 763 individual specimens, collected from the nine U.S. Census divisions, three age groups, two sexes and two race groups, were composited into two sets of 46 composite samples each prior to chemical analysis. One set was prepared for the analysis of the volatiles, and the other for the analysis of the semi-volatiles and the dioxins and furans. The compositing procedures were performed following a design which ensured that estimates of the average concentration levels for populations of interest could be obtained from an eight parameter statistical model. The model has eight parameters to be estimated from 46 samples. Estimates for 48 target subpopulations, corresponding to the 4 Census regions, 3 age groups, 2 race groups and 2 sexes (4 x 3 x 2 x 2 = 48), were derived from the model. These estimates were then weighted to obtain estimated average concentrations for the selected subpopulations, as well as for the entire nation. The weights corresponded to the 1980 U.S. Census population counts for the 48 target subpopulations.

The estimated average concentration levels as well as their relative standard errors are provided in Table 2-3. This table is reproduced in Appendix A, Table A-1 with standard errors rather than relative standard errors. A summary of the results of significance testing for differences between populations is presented in Table 2-4.

2.1.1 National Estimates

Figures 2-1, 2-2, and 2-3 graphically show the national estimates of the average concentration levels for 22 compounds classified as volatiles, semi-volatiles, and dioxins and furans, respectively. For selected compounds of current interest to EPA, the estimated average concentration levels were 0.014 µg/g for benzene, 0.12 µg/g for 1,4-dichlorobenzene, 0.33 µg/g PCBs, and 6.1 pg/g for 2,3,7,8-TCDD.

2.1.2 Geographical Estimates

The graphs in Figures 2-5, 2-6 and 2-7 depict the estimated average concentration levels of the volatiles, semi-volatiles, and dioxins and furans, for each of the four Census regions shown in the map of the continental United States in Figure 2-4. There were statistically significant regional differences at the p-values shown in Table 2-4 for five of the 22 compounds: benzene, chlorobenzene, 1,4-dichlorobenzene, tetrachloroethene, and ß-BHC:

- Benzene concentrations ranged from a low of 0.010 µg/g in the North Central and South regions to a high of 0.019 µg/g in the West;
- Chlorobenzene concentrations ranged from 0.0025 µg/g in the North Central region to 0.0072 µg/g in the South;
- 1,4-dichlorobenzene concentrations ranged from 0.052 µg/g in the West to 0.20 µg/g in the South;
- Tetrachloroethene levels were higher in the North Central region (0.044 µg/g) and in the Northeast (0.041 µg/g) than they were in the South (0.016 µg/g) or the West (0.0086 µg/g); and
- ß-BHC concentrations ranged from 0.097 µg/g in the West region to 0.31 µg/g in the South.

Table 2-3. Weighted Estimates (and Associated Relative Standard Errors)[1] of the Average Concentration Levels for the Entire Nation and for Each Census Region, Age Group, Race Group, and Sex

Compound	Entire Nation	Census Region[2]				Age Groups			Race Groups		Sex	
		NE	NC	S	W	0-14 yrs	15-44 yrs	45+ yrs	White	Non-White	Male	Female
Population Percentages		22	26	33	19	23	46	31	83	17	49	51
VOLATILE[3]												
Benzene												
Benzene	0.014 (12)	0.018 (21)	0.010 (19)	0.010 (16)	0.019 (26)	0.016 (19)	0.014 (17)	0.012 (17)	0.015 (12)	0.0096 (29)	0.017 (20)	0.010 (21)
Substituted Benzenes												
Styrene	0.096 (20)	0.095 (38)	0.059 (37)	0.10 (31)	0.13 (40)	0.12 (24)	0.10 (23)	0.075 (22)	0.095 (21)	0.10 (33)	0.14 (24)	0.050 (25)
Ethylphenol	0.085 (26)	0.13 (47)	0.029 (45)	0.090 (37)	0.10 (51)	0.17 (33)	0.065 (31)	0.050 (31)	0.079 (27)	0.12 (47)	0.096 (34)	0.076 (37)
Alkyl Benzenes												
Toluene	0.046 (37)	0.023 (52)	0.062 (48)	0.046 (47)	0.051 (59)	0.036 (48)	0.056 (44)	0.038 (43)	0.053 (38)	0.013 (63)	0.080 (45)	0.014 (47)
Ethylbenzene	0.077 (41)	0.072 (72)	0.076 (70)	0.10 (59)	0.039 (75)	0.063 (47)	0.090 (44)	0.068 (44)	0.078 (42)	0.070 (58)	0.11 (47)	0.048 (48)
Xylene	0.30 (42)	0.20 (71)	0.25 (71)	0.49 (59)	0.12 (72)	0.27 (45)	0.33 (43)	0.26 (43)	0.31 (42)	0.23 (51)	0.43 (44)	0.17 (45)
Chlorinated Benzenes												
Chlorobenzene	0.0044 (16)	0.0033 (30)	0.0025 (24)	0.0072 (24)	0.0030 (33)	0.0038 (24)	0.0051 (20)	0.0037 (22)	0.0048 (17)	0.0018 (28)	0.0057 (23)	0.0032 (25)
1,4-Dichlorobenzene	0.12 (17)	0.075 (32)	0.11 (29)	0.20 (23)	0.052 (39)	0.12 (28)	0.13 (24)	0.11 (24)	0.11 (19)	0.19 (39)	0.13 (29)	0.11 (31)

[1]Relative standard error expressed as a percentage of the estimate.

[2]NE = North East S = South
NC = North Central W = West

[3]Volatile average concentrations are expressed in wet weight in parts per million ($\mu g/g$).

Table 2-3. (continued)

Compound	Entire Nation	Census Region				Age Groups			Race Groups		Sex	
		NE	NC	S	W	0-14 yrs	15-44 yrs	45+ yrs	White	Non-White	Male	Female
Population Percentages		22	26	33	19	23	46	31	83	17	49	51
VOLATILE ORGANICS[3]												
Trihalomethanes												
Chloroform	0.047 (42)	0.021 (67)	0.041 (64)	0.049 (58)	0.081 (72)	0.053 (51)	0.053 (49)	0.033 (47)	0.046 (44)	0.052 (69)	0.081 (49)	0.014 (53)
Halocarbons												
Tetrachloroethene	0.027 (29)	0.041 (45)	0.044 (42)	0.016 (37)	0.0086 (52)	0.017 (37)	0.030 (35)	0.031 (34)	0.029 (30)	0.019 (52)	0.044 (37)	0.011 (40)
SEMI-VOLATILE ORGANICS[4]												
PCBs												
PCBs	0.33 (23)	0.31 (42)	0.23 (36)	0.51 (32)	0.20 (53)	0.071 (34)	0.30 (31)	0.57 (30)	0.32 (26)	0.41 (47)	0.35 (36)	0.32 (40)
Organochlorine Pesticides												
Beta-BHC	0.19 (16)	0.19 (25)	0.11 (21)	0.31 (22)	0.097 (33)	0.071 (23)	0.17 (20)	0.31 (21)	0.21 (17)	0.088 (30)	0.19 (24)	0.19 (29)
P,P'-DDE	1.3 (23)	1.1 (36)	0.73 (32)	1.9 (31)	1.3 (45)	0.75 (32)	1.3 (30)	1.8 (29)	1.4 (25)	0.73 (44)	2.0 (32)	0.64 (40)
Total DDT	1.6 (26)	1.4 (37)	0.87 (33)	2.4 (33)	1.7 (47)	0.98 (36)	1.7 (32)	2.1 (30)	1.7 (27)	1.1 (52)	2.4 (33)	0.93 (46)
Phthalates												
Butyl benzyl phthalate	0.39 (50)	0.11 (73)	0.45 (68)	0.62 (66)	0.21 (86)	0.46 (67)	0.31 (58)	0.46 (61)	0.45 (52)	0.095 (84)	0.54 (67)	0.24 (69)

[3] Volatile average concentrations are expressed in wet weight in parts per million (μg/g).

[4] Semi-volatile average concentrations are expressed in lipid adjusted weight in parts per million (μg/g).

Table 2-3. (continued)

Compound	Entire Nation	Census Region				Age Groups			Race Groups		Sex	
		NE	NC	S	W	0-14 yrs	15-44 yrs	45+ yrs	White	Non-White	Male	Female
Population Percentages		22	26	33	19	23	46	31	83	17	49	51
DIOXINS[5]												
2,3,7,8-TCDD	6.1 (13)	6.6 (25)	7.1 (22)	6.1 (19)	4.1 (28)	4.1 (20)	7.8 (17)	5.0 (19)	6.4 (14)	4.3 (30)	6.7 (21)	5.5 (24)
1,2,3,7,8-PECDD	75 (23)	120 (39)	62 (34)	60 (30)	73 (42)	54 (30)	130 (27)	11 (31)	83 (24)	39 (46)	100 (34)	49 (39)
HXCDD	120 (20)	160 (32)	110 (29)	100 (25)	120 (39)	92 (29)	120 (26)	130 (26)	120 (21)	110 (42)	70 (27)	160 (31)
1,2,3,4,7,8,9-HPCDD	140 (19)	160 (32)	160 (28)	110 (24)	100 (39)	89 (29)	150 (25)	150 (25)	140 (21)	140 (42)	89 (27)	180 (31)
OCDD	820 (13)	750 (24)	920 (21)	780 (18)	850 (30)	410 (21)	920 (18)	990 (18)	810 (14)	880 (31)	760 (22)	880 (24)
FURANS[5]												
2,3,4,7,8-PECDF	40 (16)	49 (30)	38 (26)	30 (24)	52 (34)	36 (25)	53 (22)	25 (24)	44 (18)	22 (39)	51 (27)	30 (31)
HXCDF	24 (15)	20 (24)	29 (22)	24 (19)	23 (30)	18 (22)	27 (19)	26 (20)	26 (16)	18 (31)	13 (20)	35 (23)
1,2,3,4,6,7,8-HPCDF	21 (13)	18 (24)	26 (21)	22 (17)	15 (29)	19 (21)	22 (18)	20 (18)	20 (14)	25 (30)	16 (20)	25 (23)

[5]Dioxin and furan average concentrations are expressed in lipid adjusted weight in parts per trillion (pg/g).

Table 2-4. Summary of Significance Testing for Differences Between Subpopulations[a]

Chemical	Effect Due To... Census Region	Age	Race	Sex
VOLATILES				
Benzene				
Benzene	.059*	.411	.161	.158
Substituted Benzenes				
Styrene	.502	.194	.882	.001***
Ethylphenol	.138	.002***	.595	.674
Alkyl Benzenes				
Toluene	.505	.621	.034**	.016**
Ethylbenzene	.757	.526	.779	.116
Xylene	.450	.438	.244	.006***
Chlorinated Benzenes				
Chlorobenzene	.049**	.242	.001***	.108
1,4-Dichlorobenzene	.038**	.879	.310	.734
Trihalomethanes				
Chloroform	.524	.596	.954	.011**
Halocarbons				
Tetrachloroethene	.078*	.219	.695	.013**
SEMI-VOLATILES				
PCBs				
PCBs	.385	.000***	.545	.823
Organochlorine Pesticides				
Beta-BHC	.012**	.000***	.022**	.958
p,p′-DDE	.145	.064*	.169	.045**
Total DDT	.166	.010***	.254	.141
Phthalates				
Butyl benzyl phthalate	.232	.732	.078*	.384
DIOXINS				
2,3,7,8-TCDD	.569	.029**	.276	.590
1,2,3,7,8-PECDD	.464	.000***	.102	.230
HXCDD	.712	.643	.936	.078*
1,2,3,4,7,8,9-HPCDD	.412	.215	.734	.142
OCDD	.875	.003***	.658	.751
FURANS				
2,3,4,7,8-PECDF	.506	.043**	.091*	.280
HXCDF	.663	.349	.333	.008***
1,2,3,4,6,7,8-HPCDF	.339	.815	.440	.244

* Indicates significance at the .10 level.
** Indicates significance at the .05 level.
*** Indicates significance at the .01 level.

[a] The table entries are p-values, which indicate the exact level of significance at which a statistical difference can be declared, given the observed data.

Note in Table 2-4 that the estimated regional effect on average concentration was not declared to be statistically significant for the other compounds. In these cases the total survey and laboratory variability may preclude detecting differences that may be present. See section 2.1.4 below for a discussion of race group influences on regional estimates.

2.1.3 Age Group Estimates

The NHATS classifies specimens into one of three age groups: 0 to 14 years, 15 to 44 years, and 45 years and older, as displayed in Figure 2-8. The age group estimates for the volatiles, the semivolatiles, and the dioxins and furans are displayed in Figures 2-9, 2-10, and 2-11, respectively. Eight of the twenty-two chemicals had statistically significant differences between age groups. Only one volatile organic compound, ethylphenol, had statistically significant age group differences. For ethylphenol, average concentration decreased as age group increased.

In the semi-volatiles, PCBs, p,p'-DDE, and ß-BHC had statistically significant differences between age groups. For these three chemicals, average concentrations increased for the older age groups. Total Equivalent DDT, which was calculated from measured concentrations, also was significant with respect to age, and average concentrations increased as age group increased.

Four of the eight chemicals with statistically significant age group differences were dioxins and furans. These four chemicals were:

2,3,7,8-TCDD,
1,2,3,7,8-PECDD,
OCDD, and
2,3,4,7,8-PECDF.

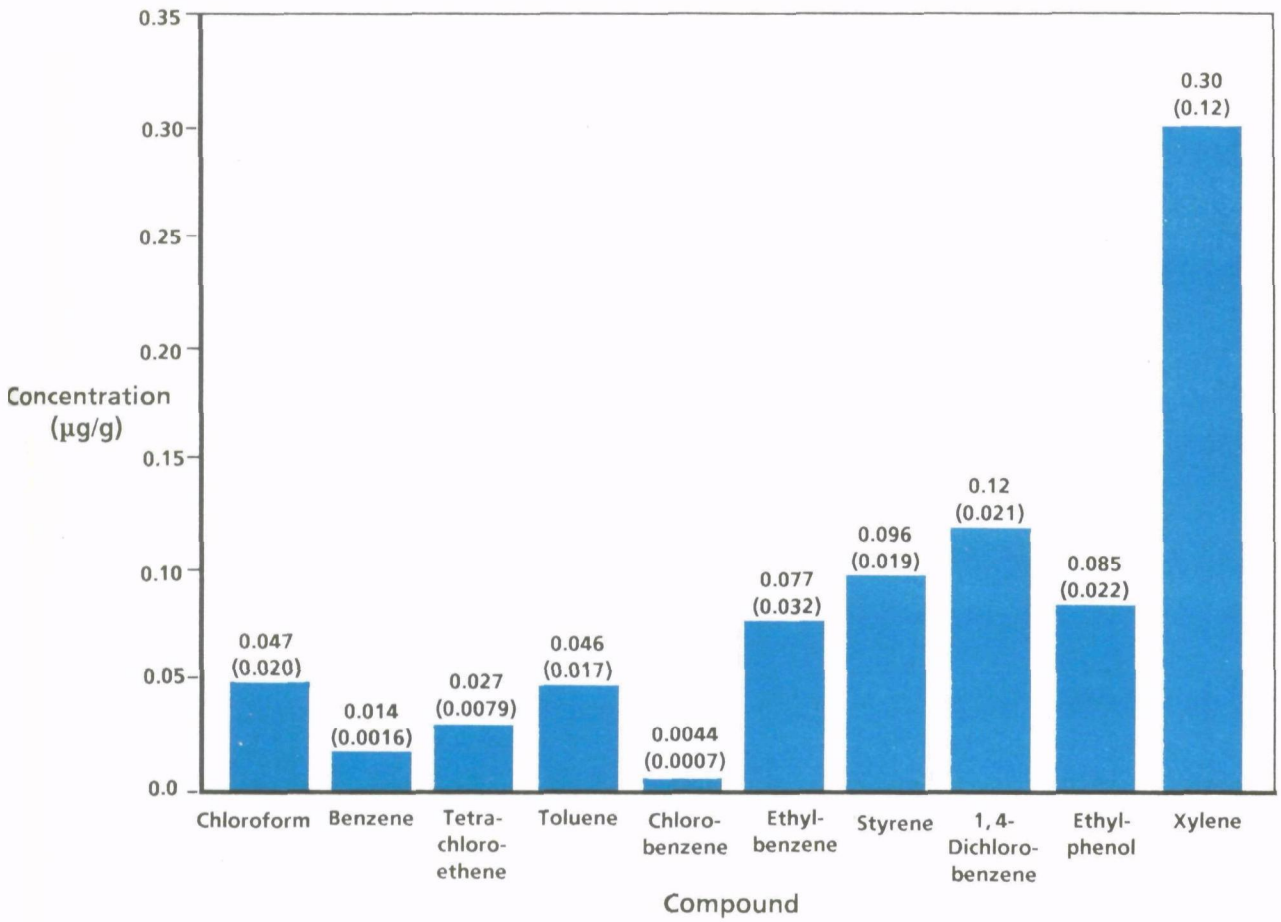


Figure 2-1. Weighted estimates of the average concentration levels of volatiles (wet weight, µg/g) for the U.S. population. (Standard errors of the estimates are in parentheses.)

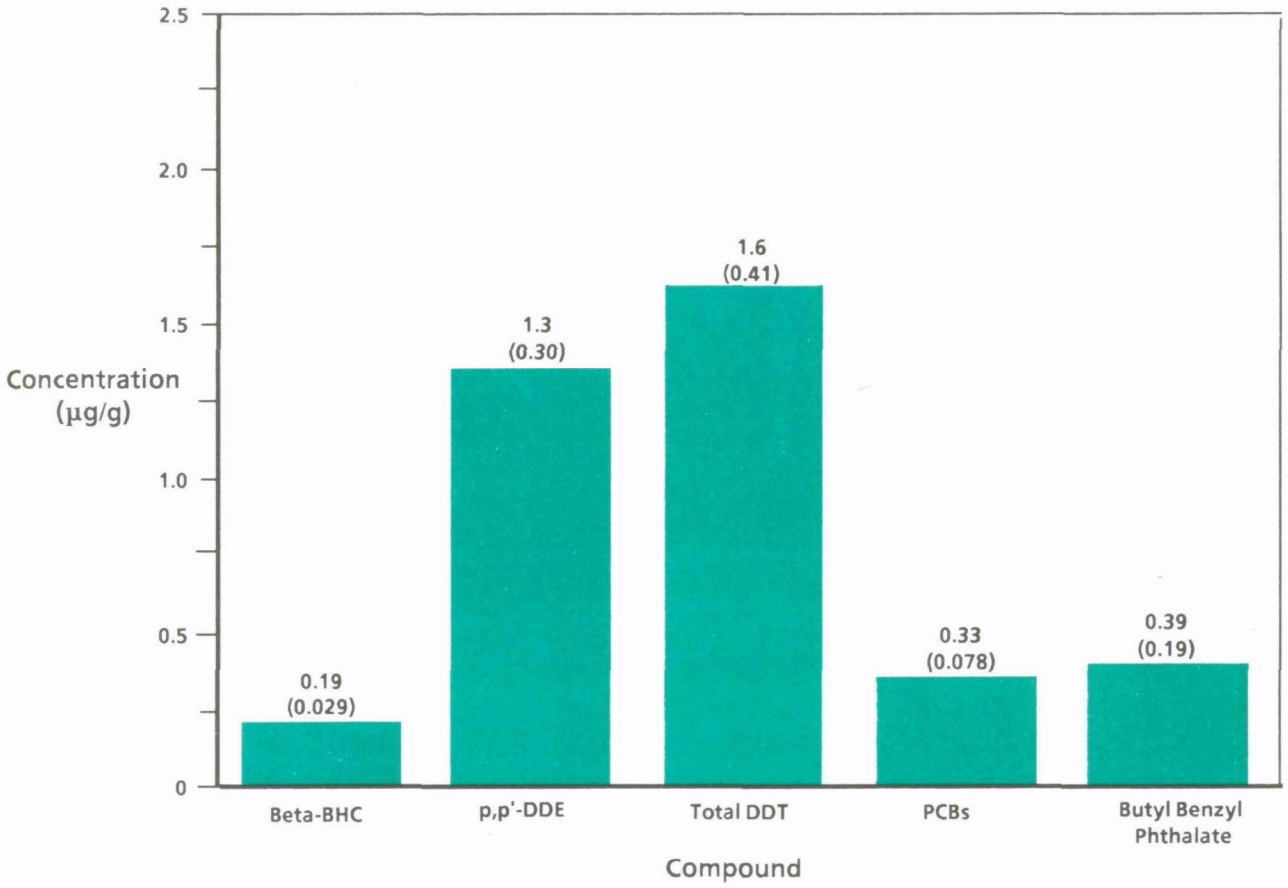


Figure 2-2. Weighted estimates of the average concentration levels of semi-volatiles (lipid adjusted, µg/g) for the U.S. population. (Standard errors of the estimates are in parentheses.)

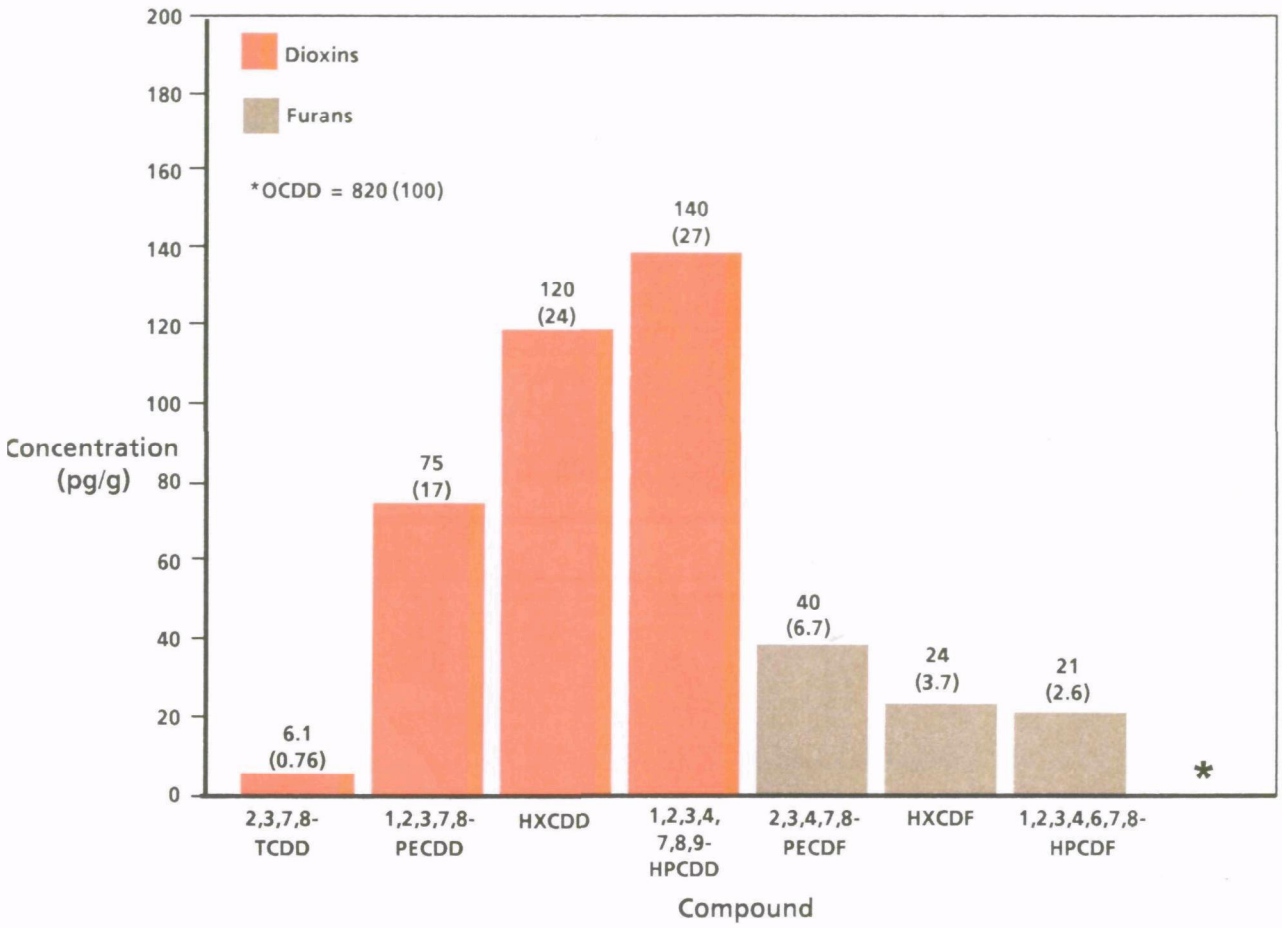


Figure 2-3. Weighted estimates of the average concentration levels of dioxins and furans (lipid adjusted, pg/g) for the U.S. population. (Standard errors of the estimates are in parentheses.)

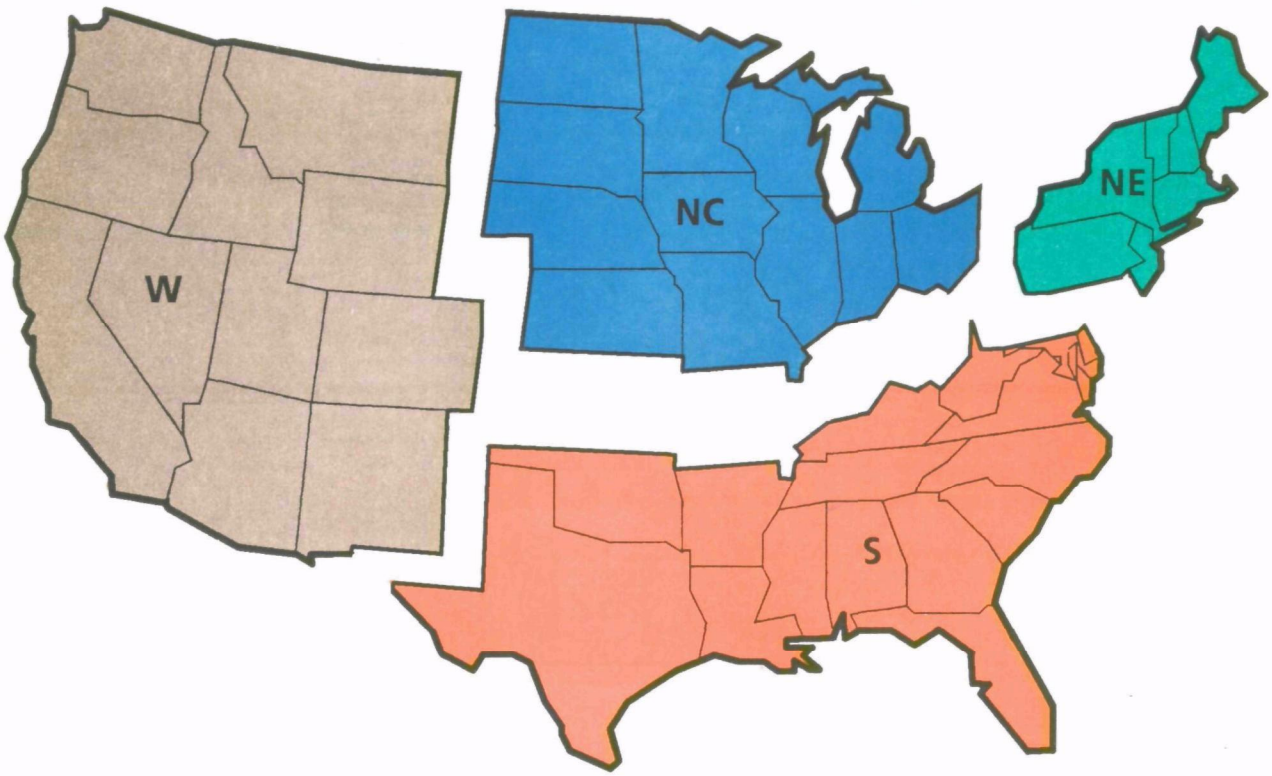
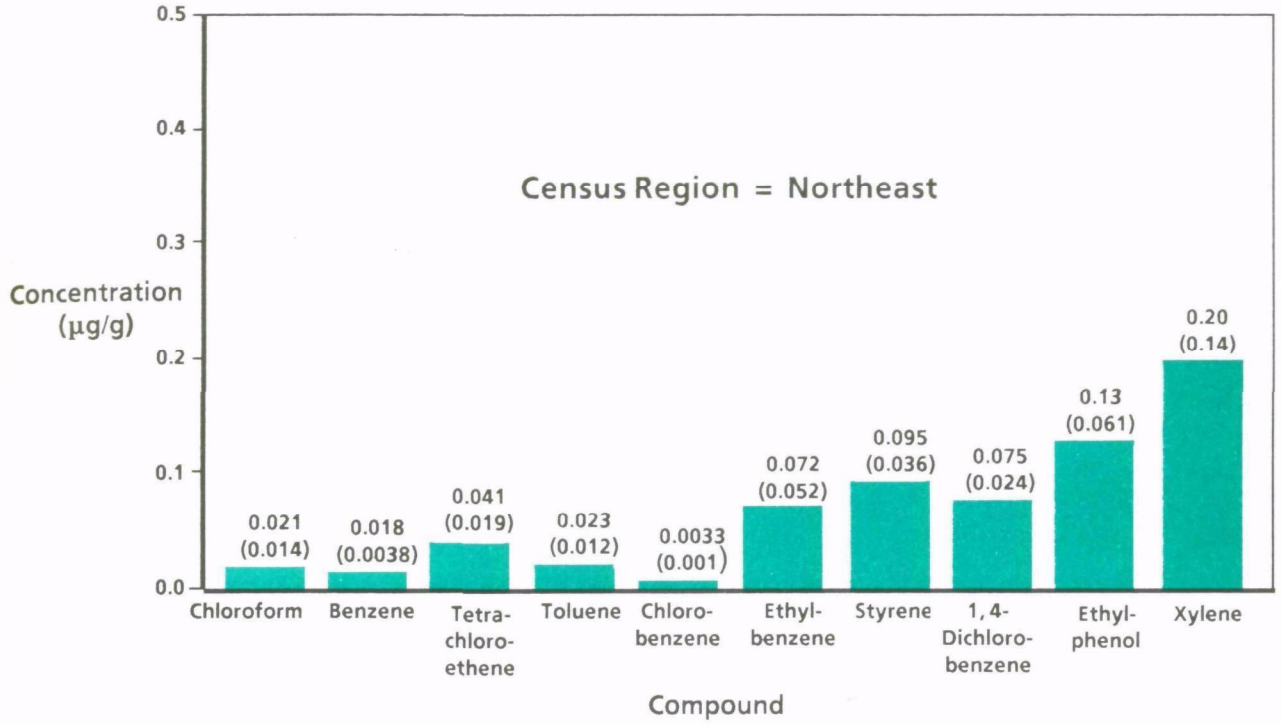


Figure 2-4. United States Census regions



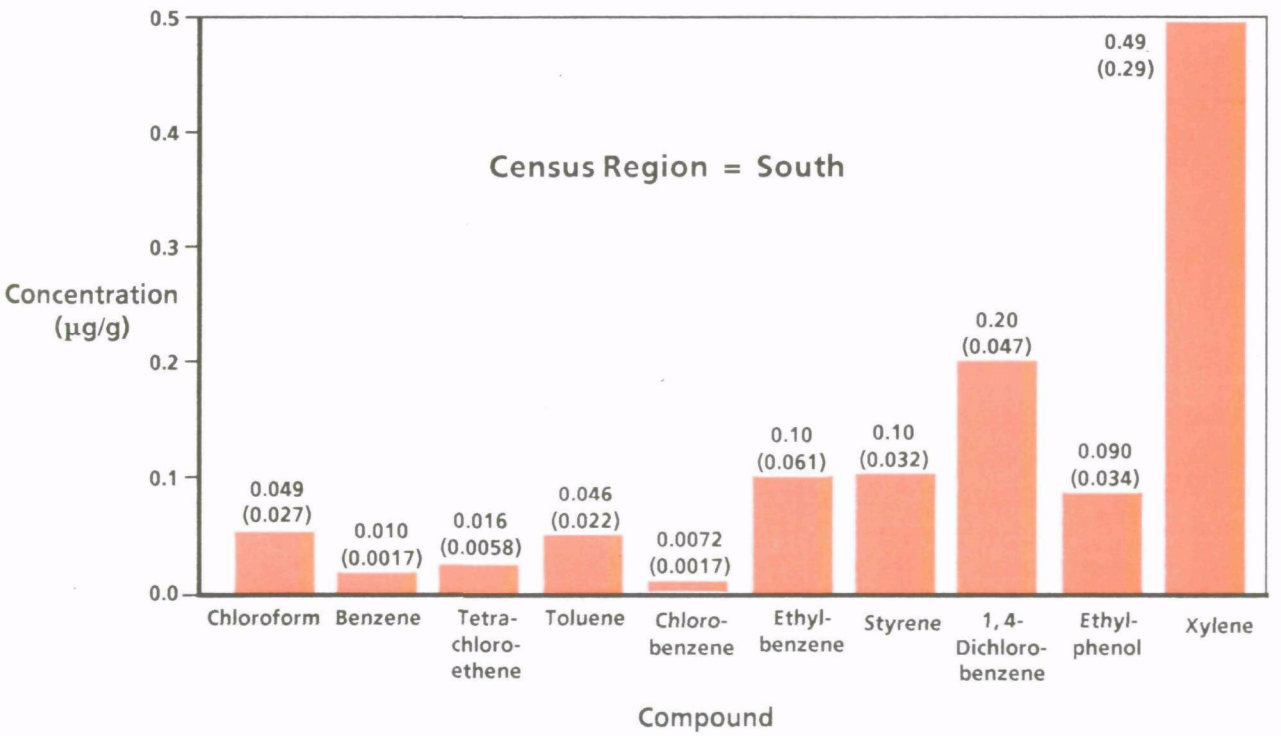
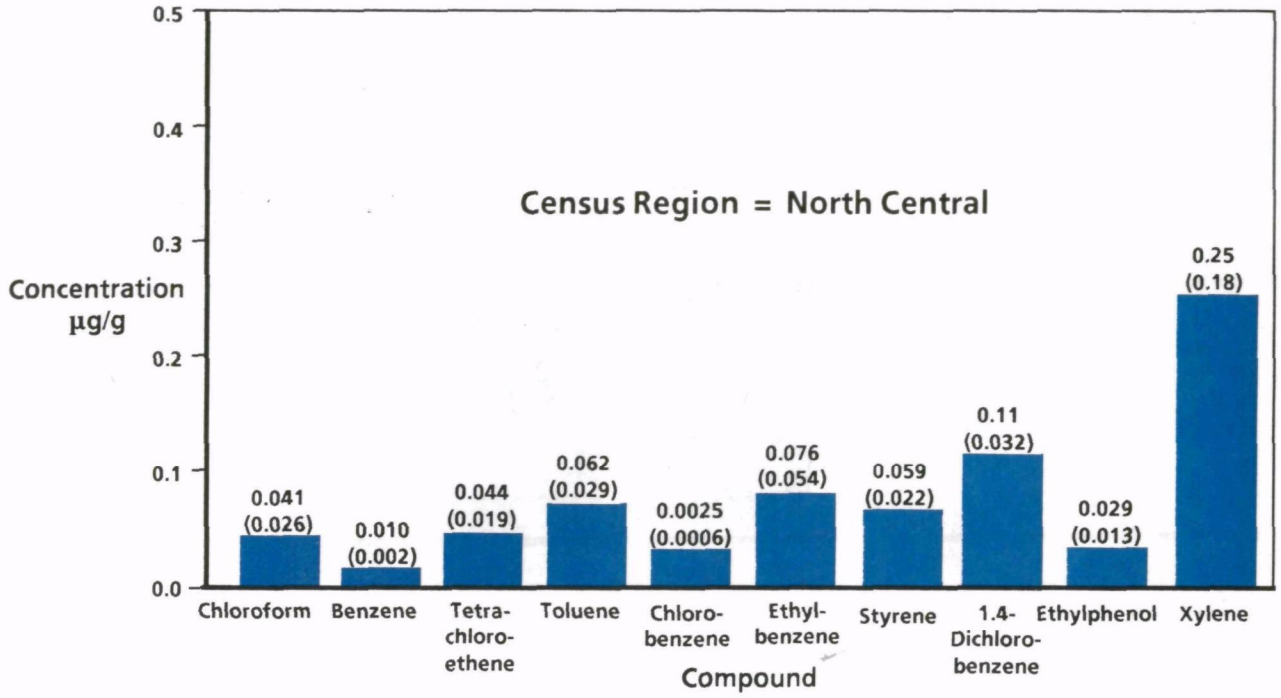


Figure 2-5. Weighted estimates of the average concentration levels of volatiles (wet weight, µg/g) for each census region. (Standard errors of the estimates are in parentheses.)



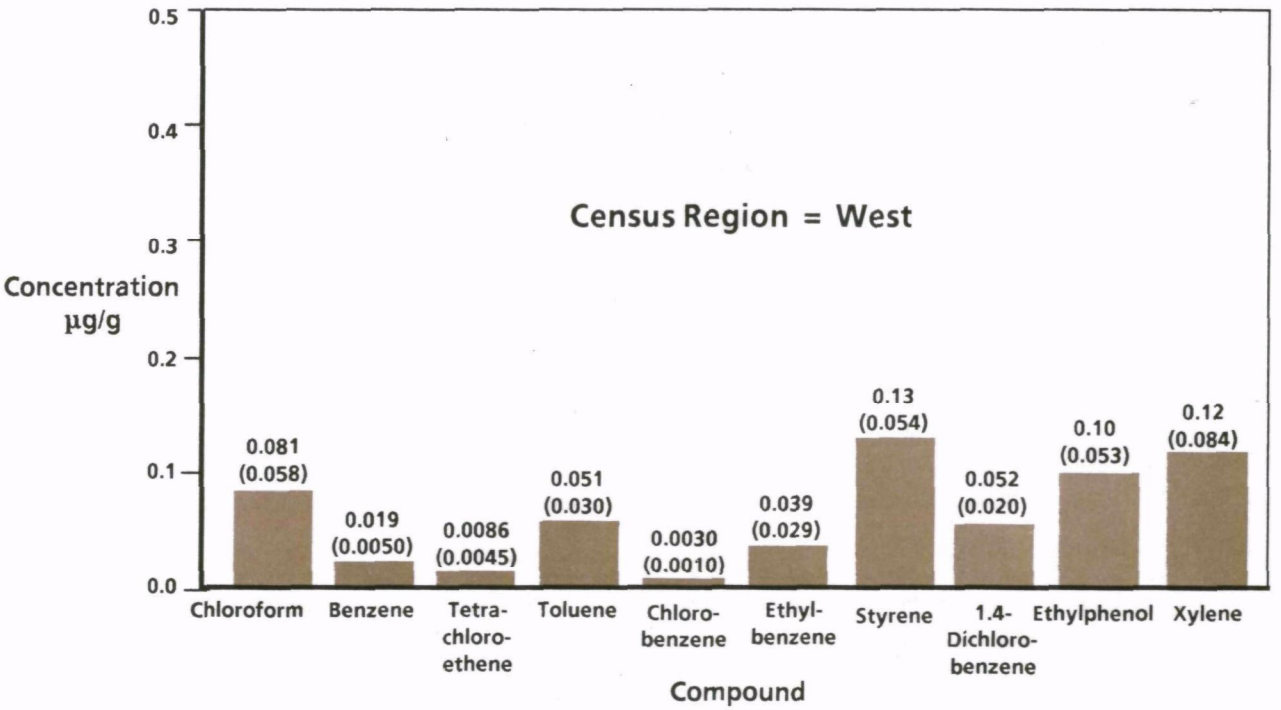
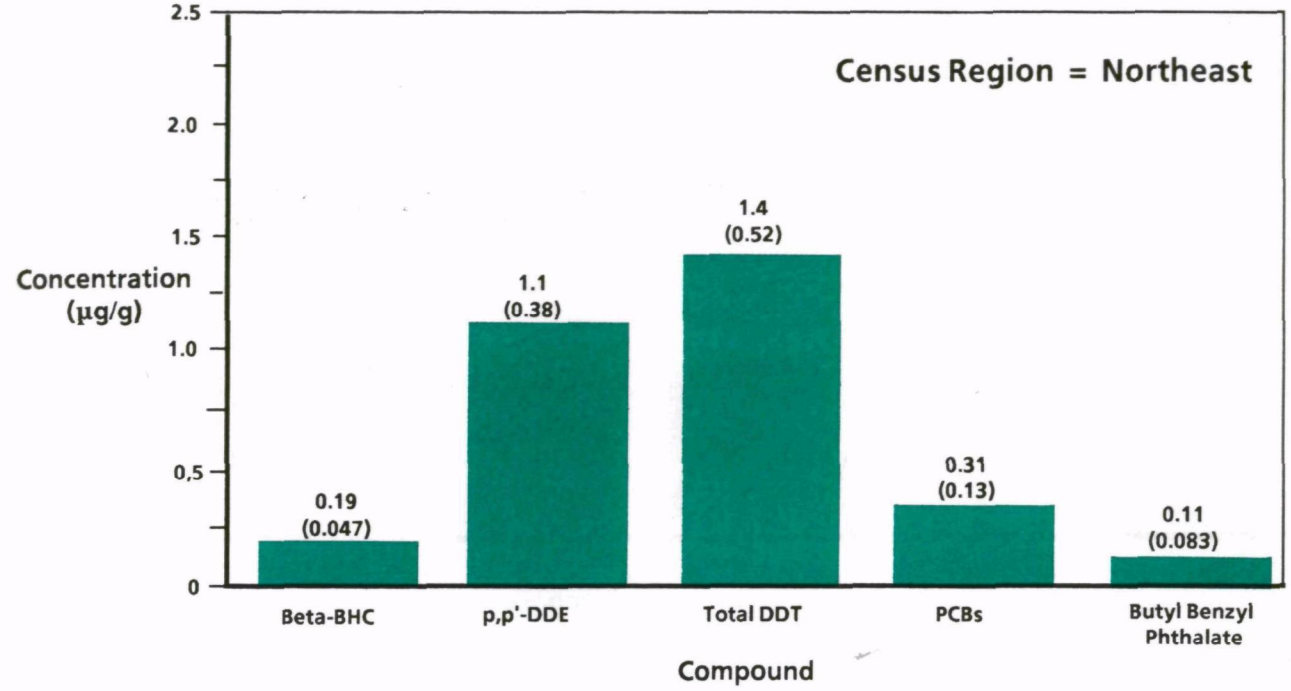


Figure 2-5 (Continued)



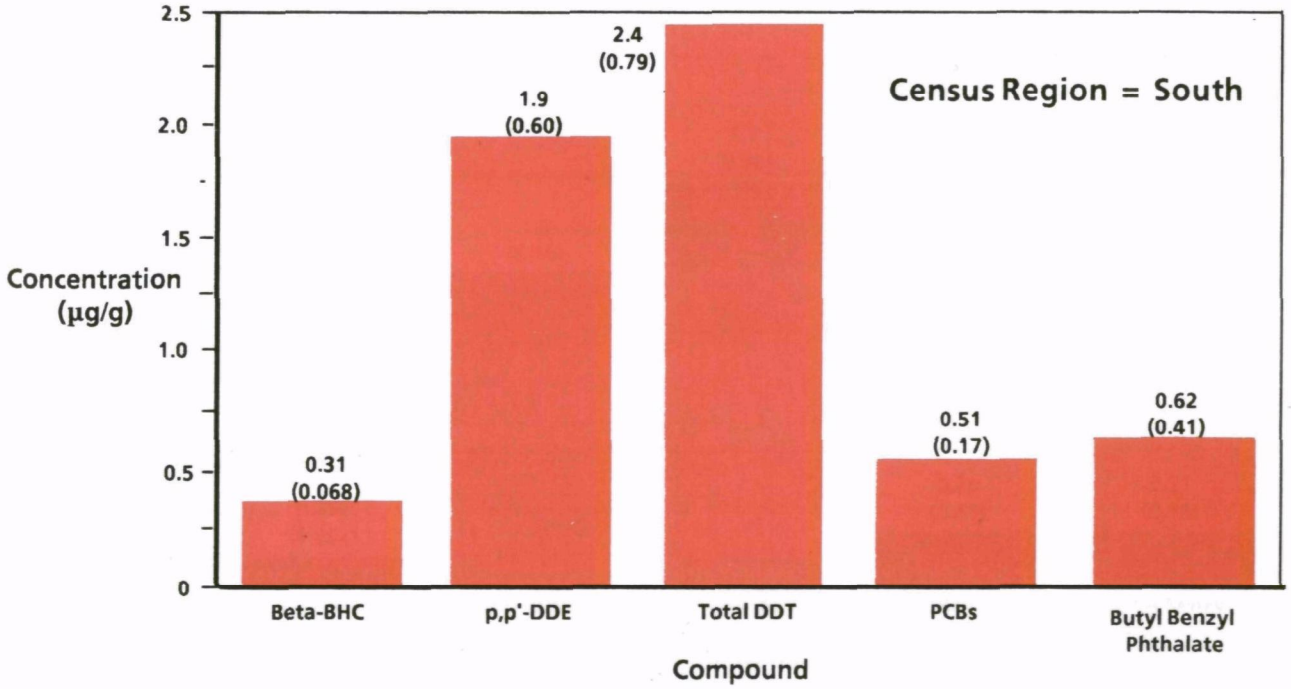
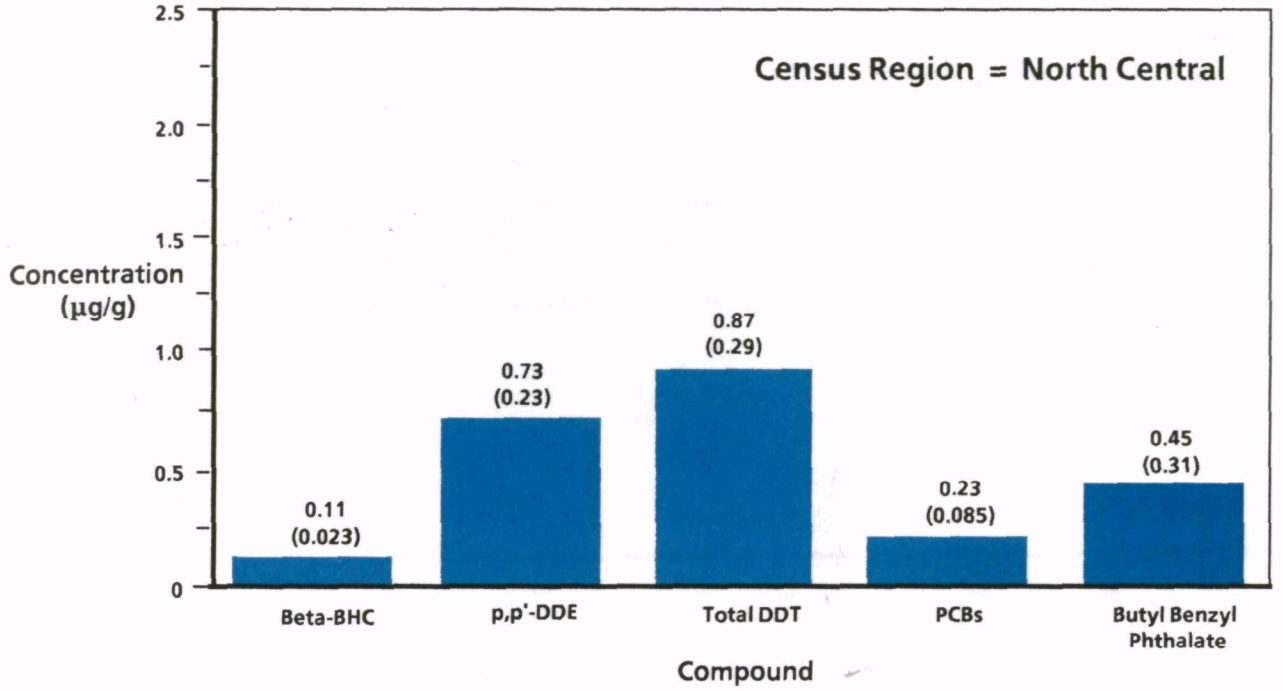


Figure 2-6. Weighted estimates of the average concentration levels of semi-volatiles (lipid adjusted, µg/g) for each census region. (Standard errors of the estimates are in parentheses.)



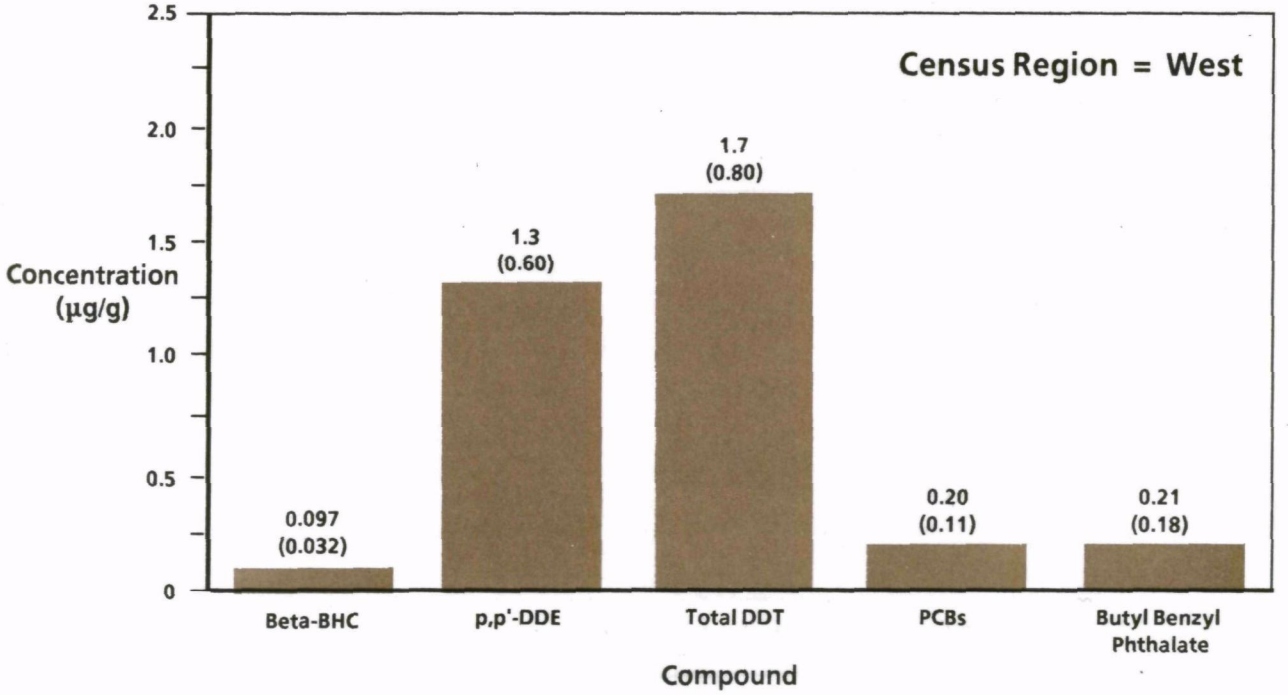
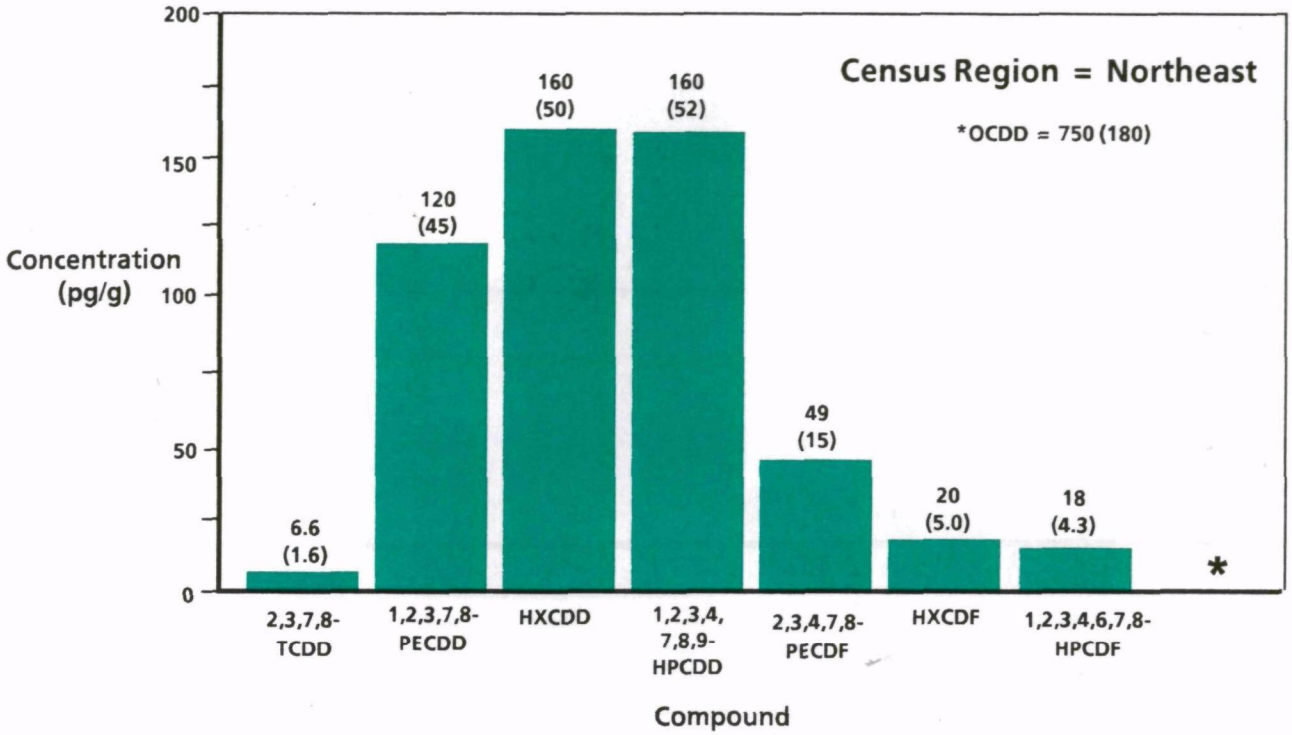


Figure 2-6. (Continued)



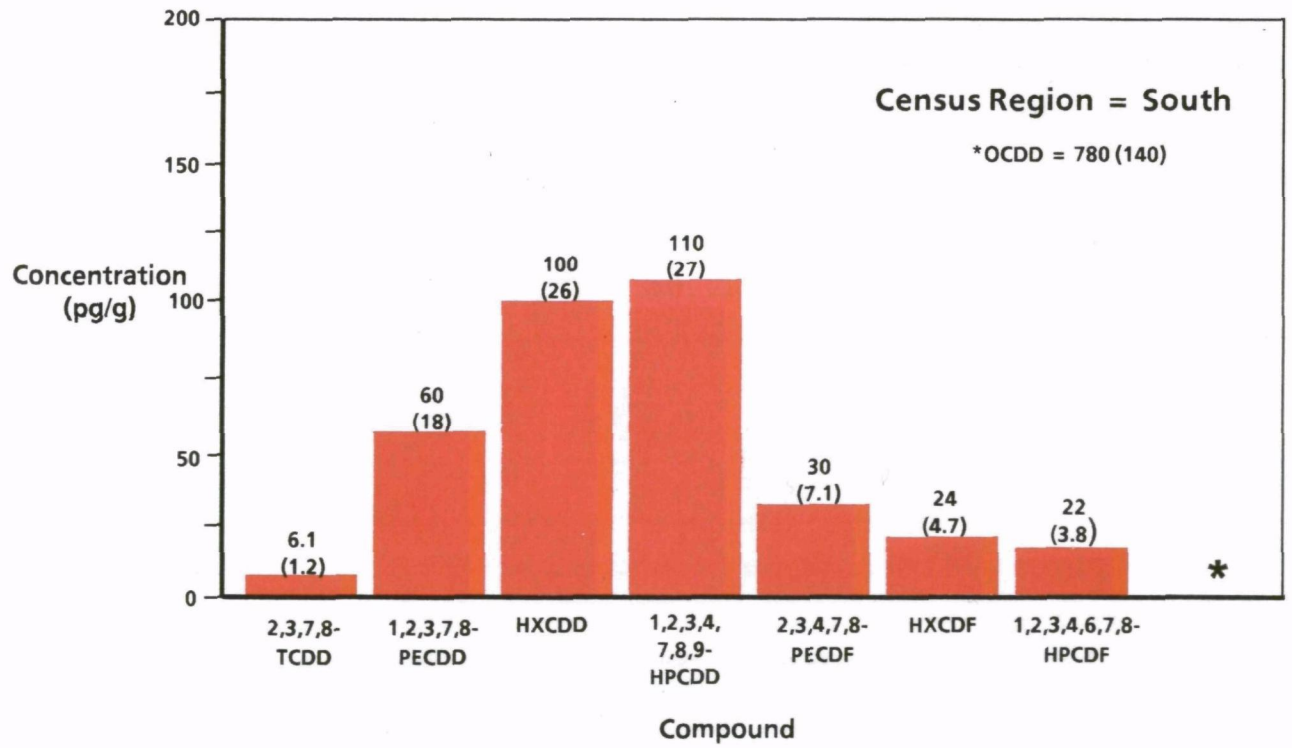
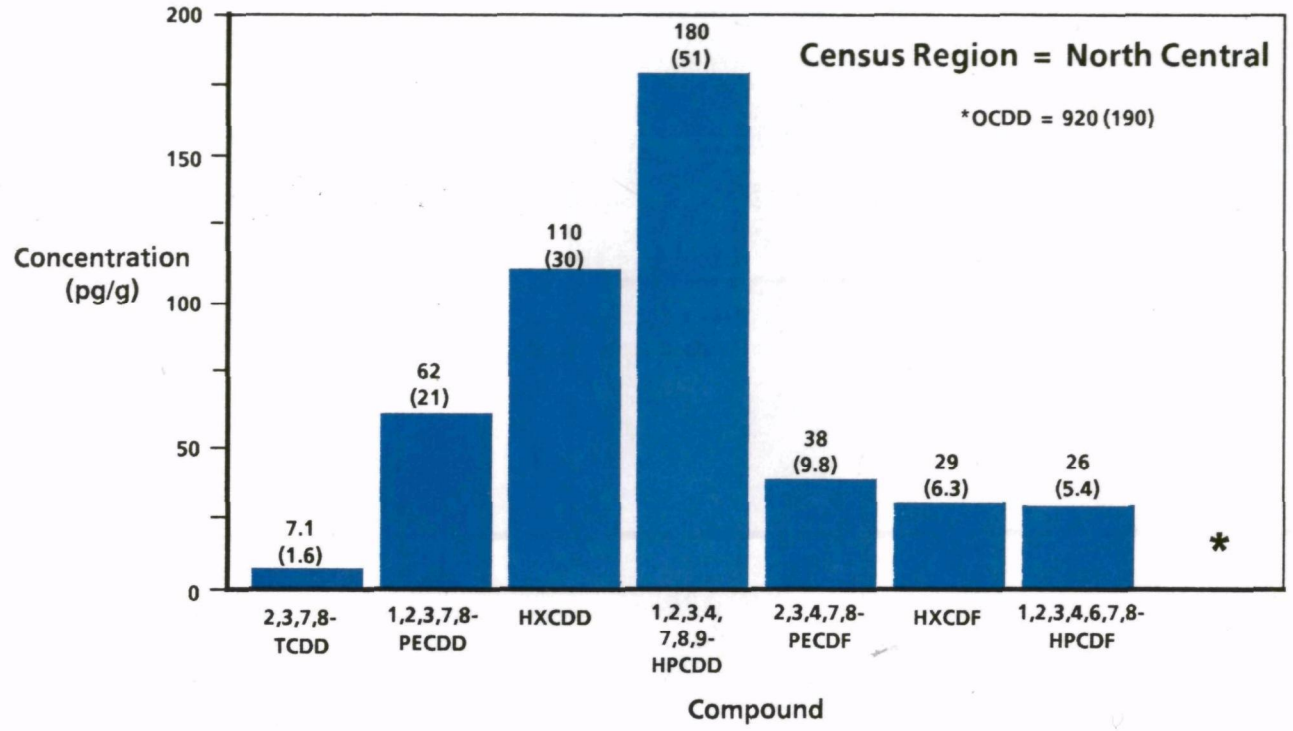


Figure 2-7. Weighted estimates of the average concentration levels of dioxins and furans (lipid adjusted, pg/g) for each census region. (Standard errors of the estimates are in parentheses.)



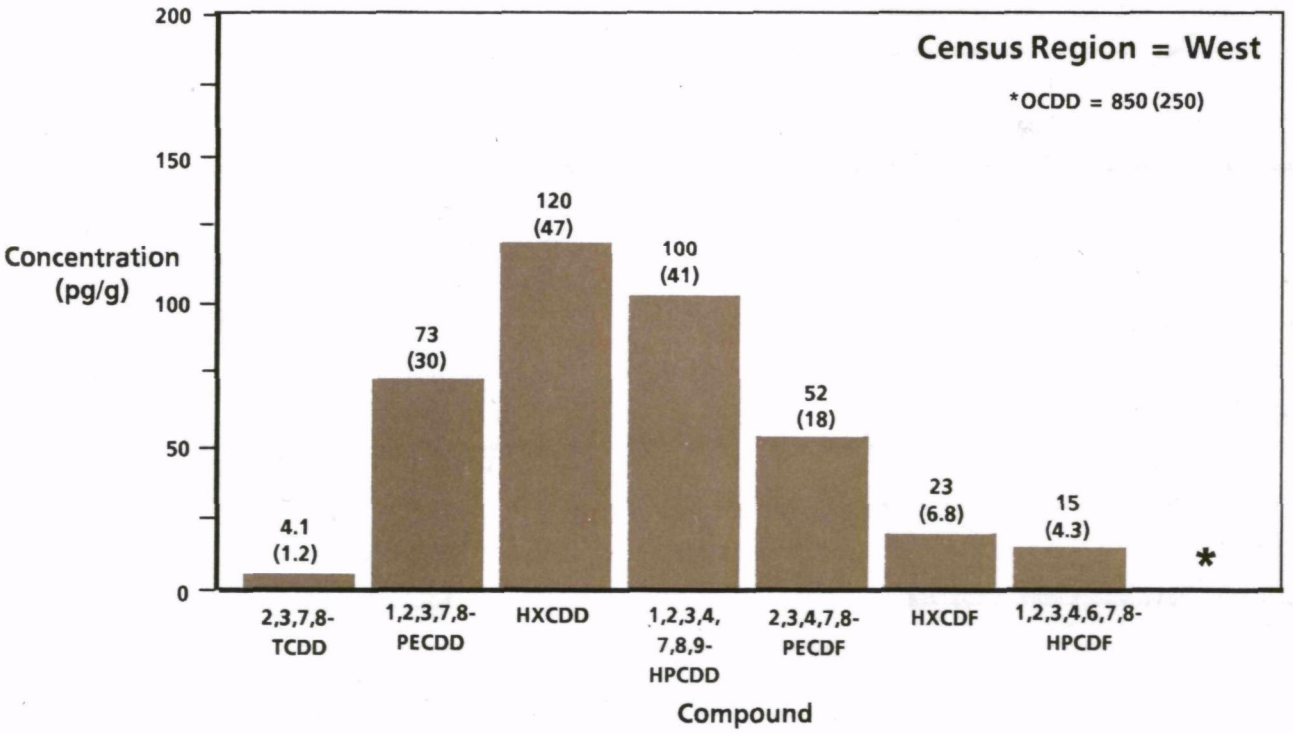


Figure 2-7. (Continued)

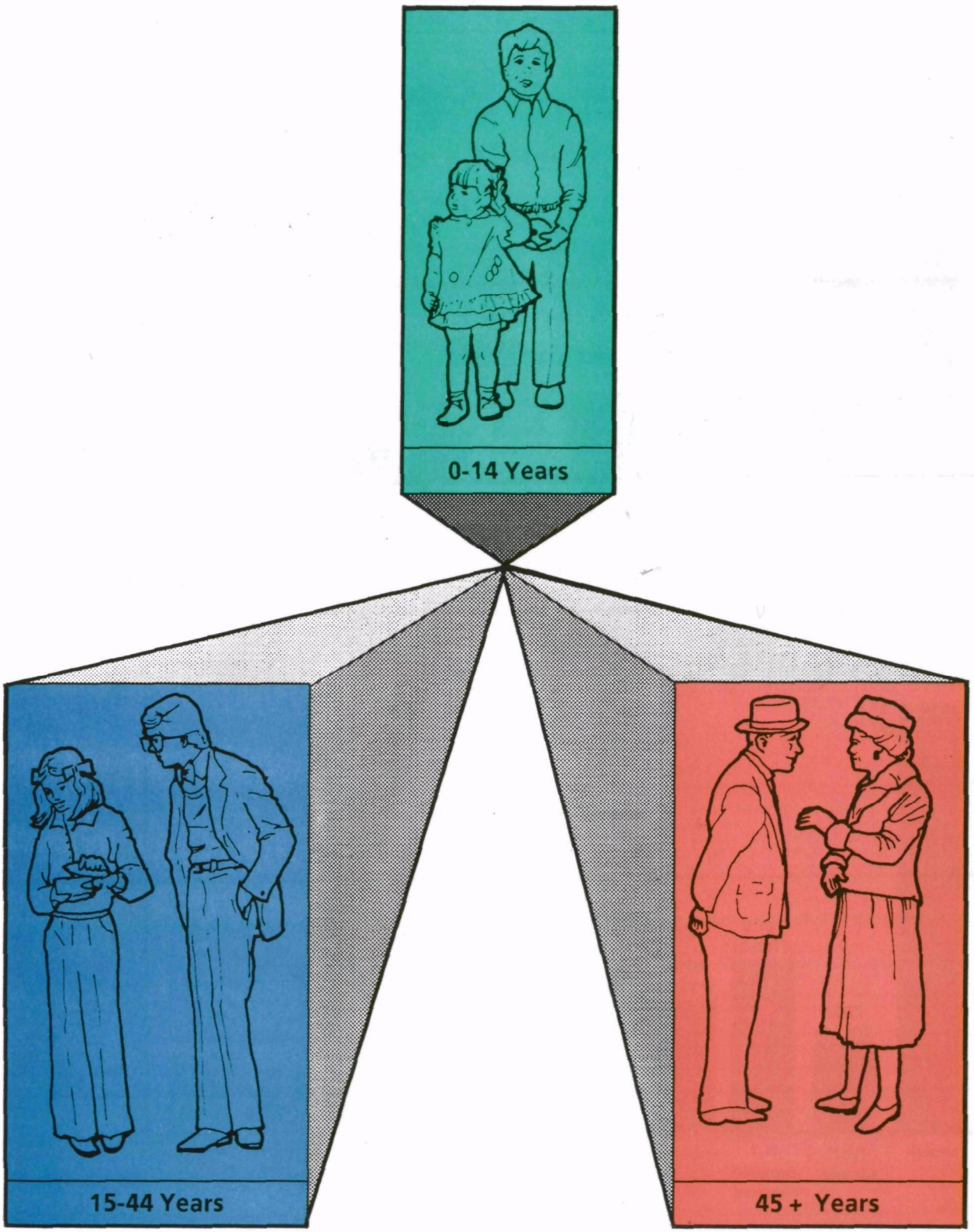


Figure 2-8. NHATS age groups

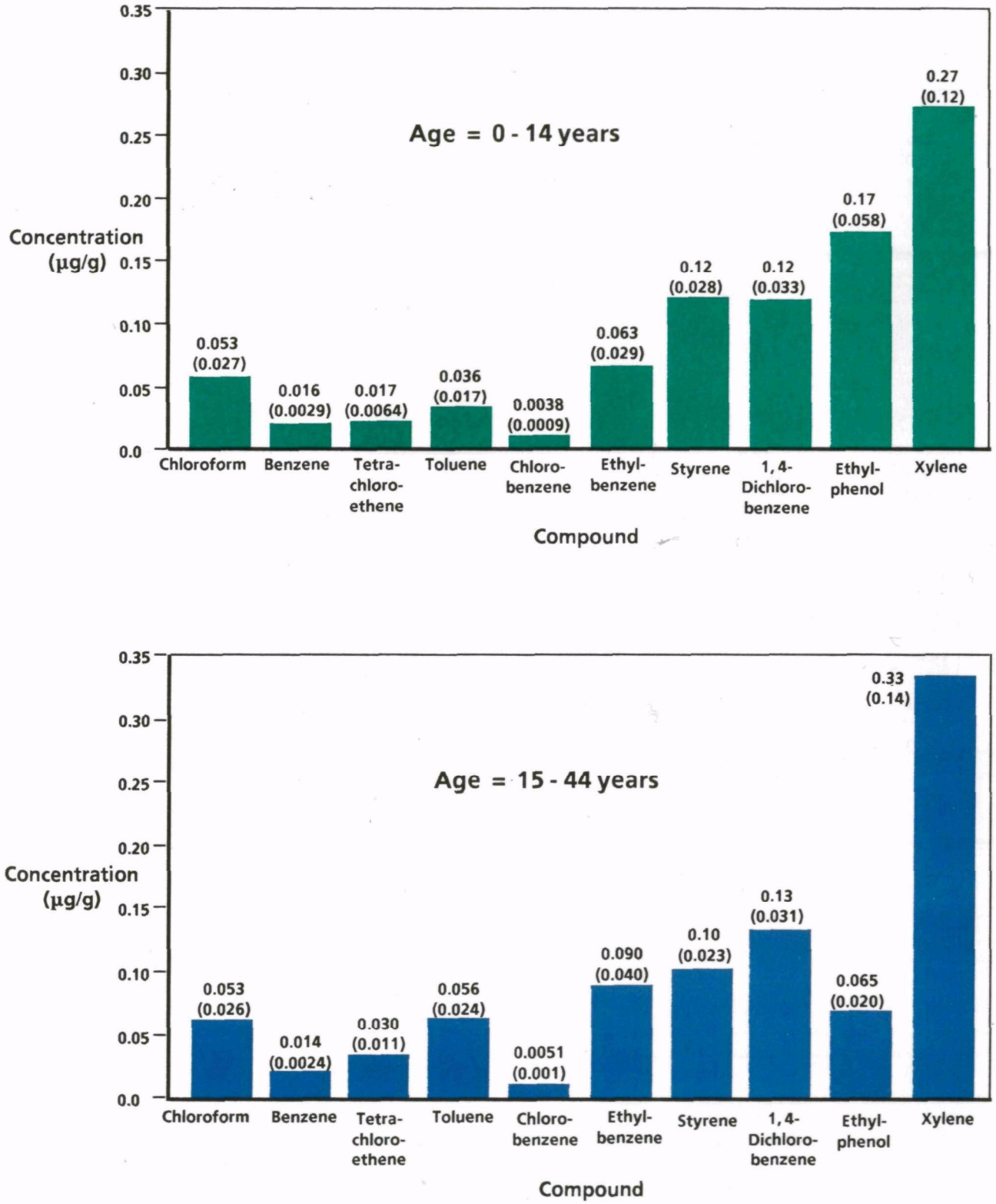


Figure 2-9. Weighted estimates of the average concentration levels of volatiles (wet weight, µg/g) for each age group. (Standard errors of the estimates are in parentheses.)

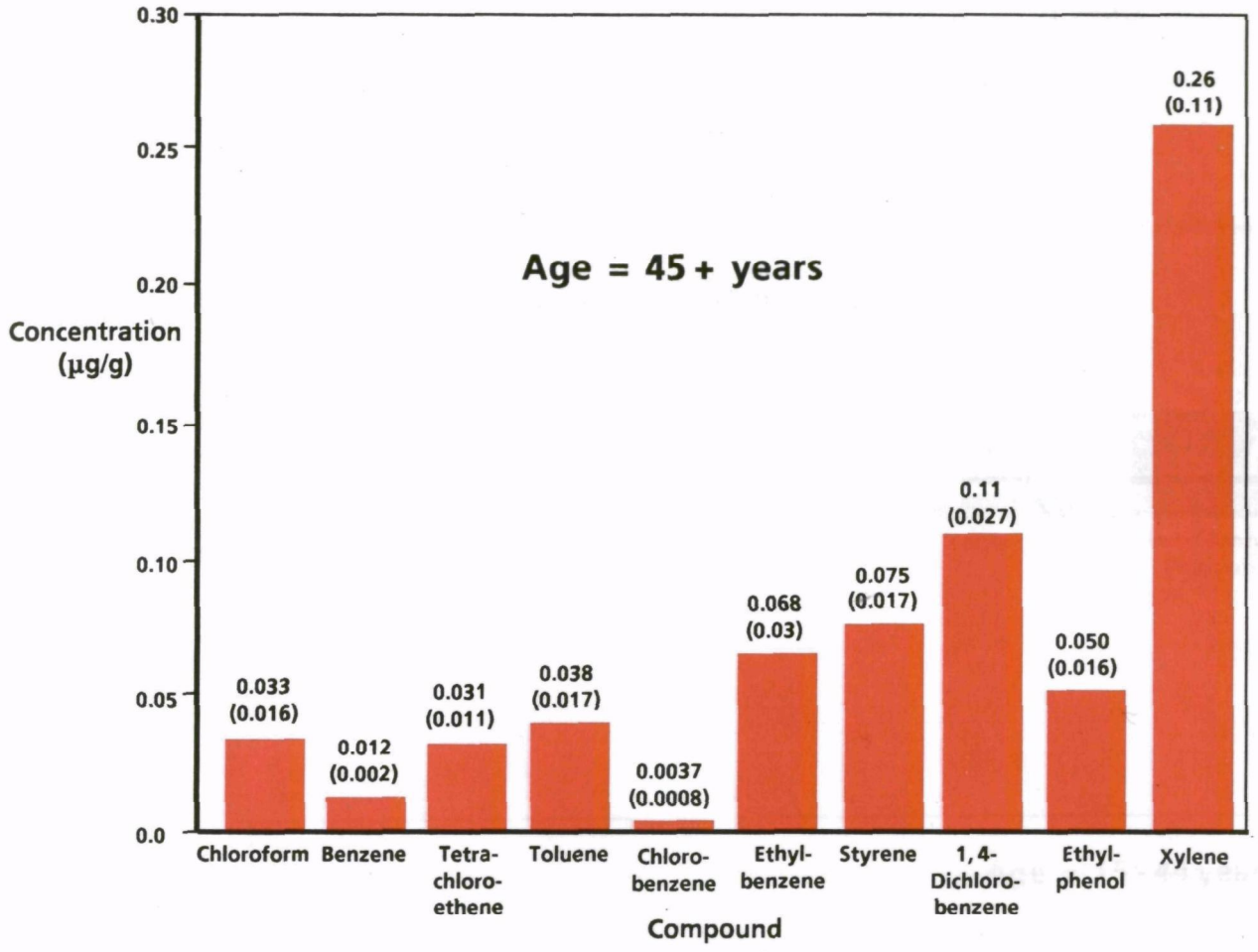
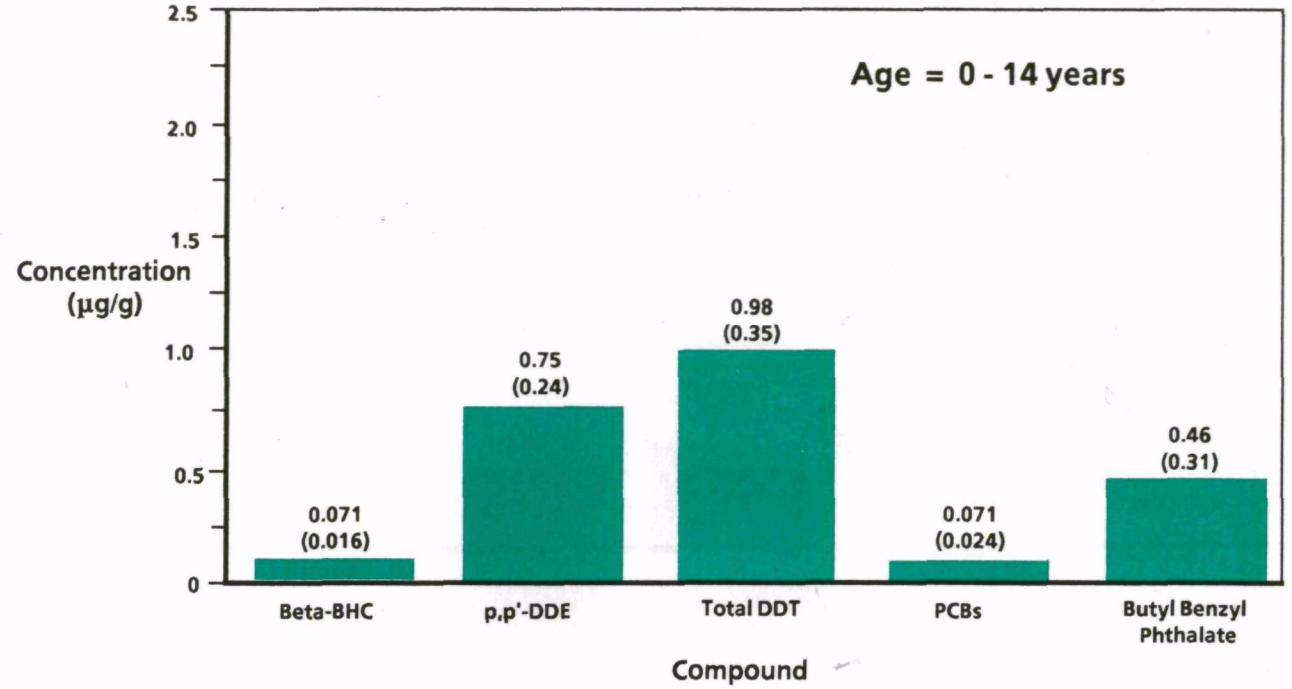


Figure 2-9. (Continued)



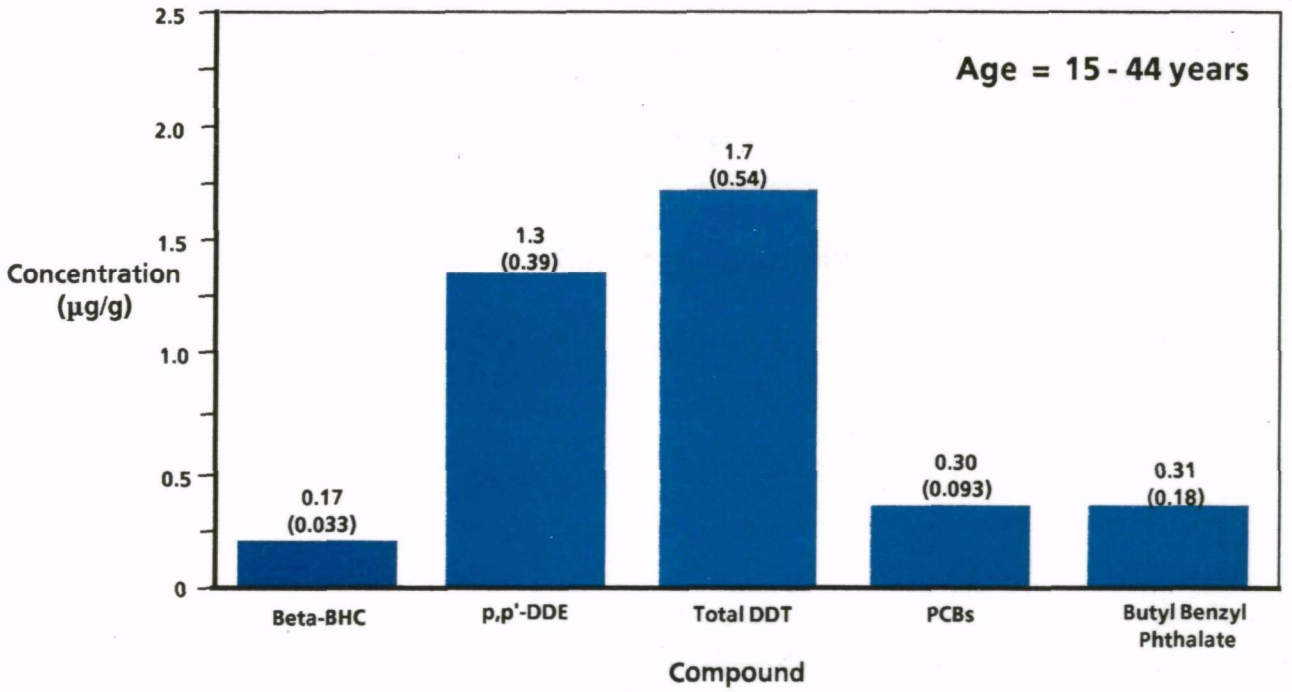


Figure 2-10. Weighted estimates of the average concentration levels of semi-volatiles (wet weight, µg/g) for each age group. (Standard errors of the estimates are in parentheses.)

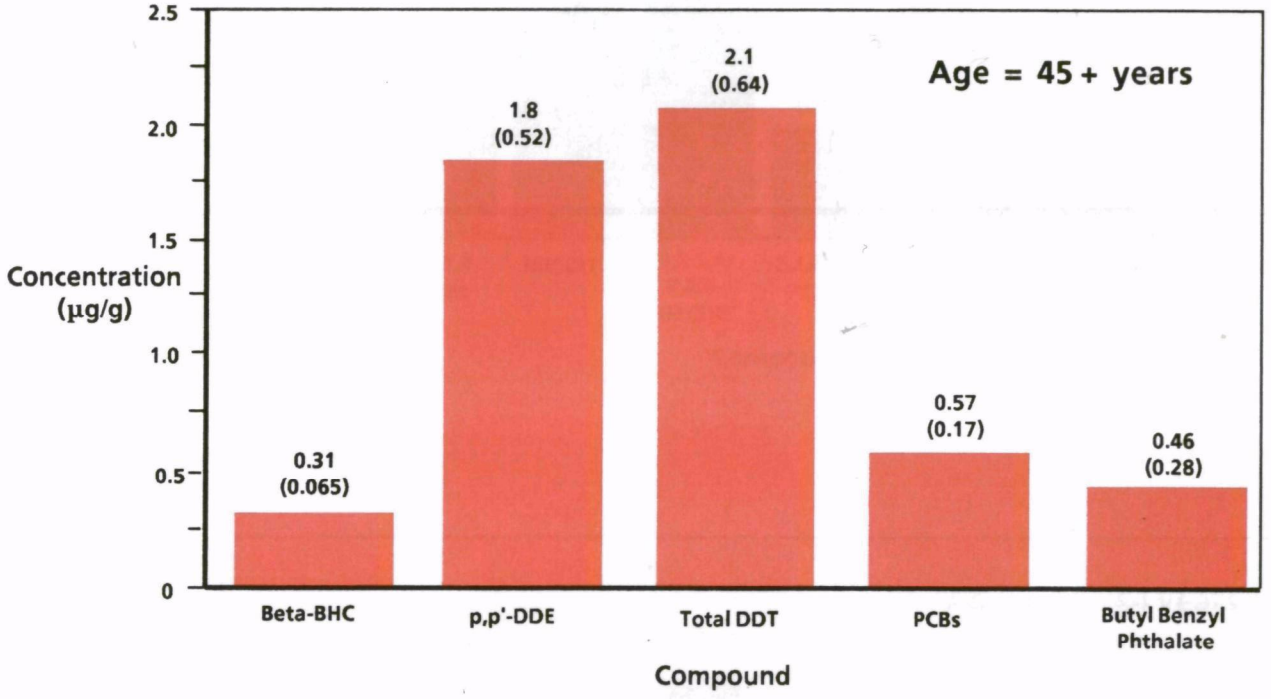
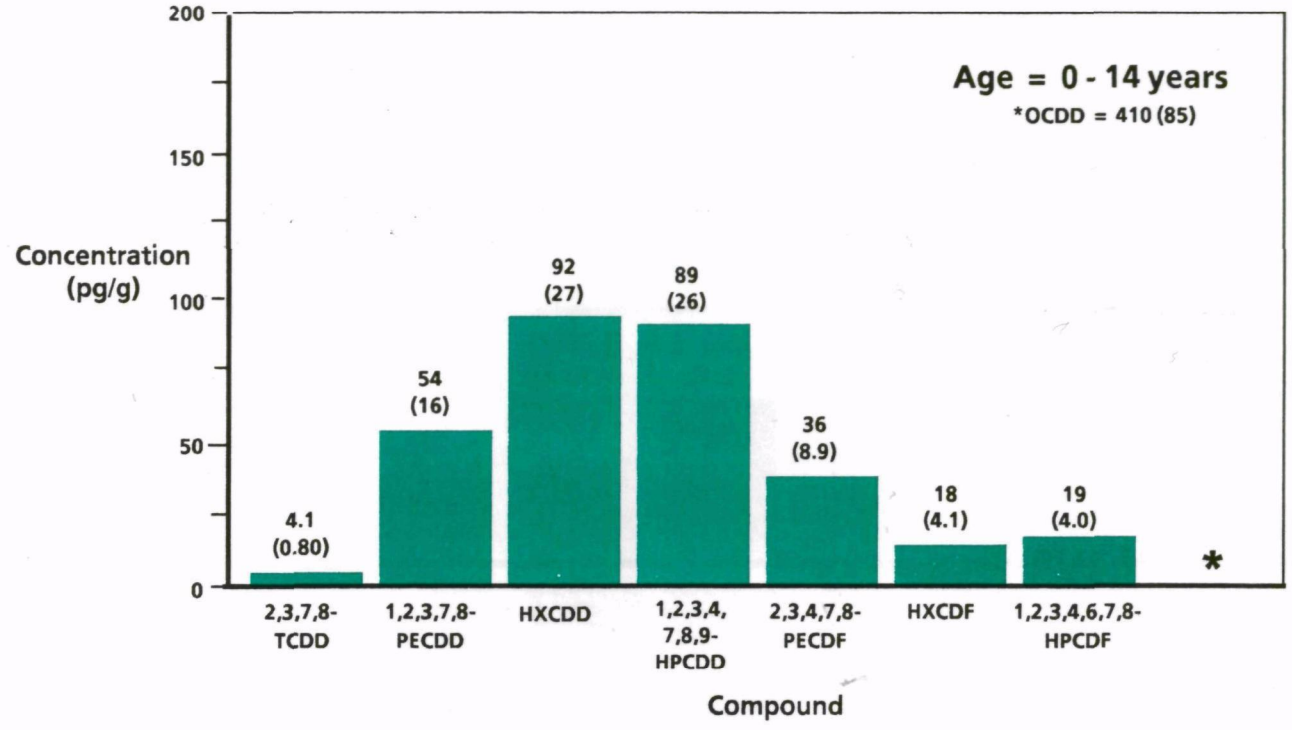


Figure 2-10. (Continued)



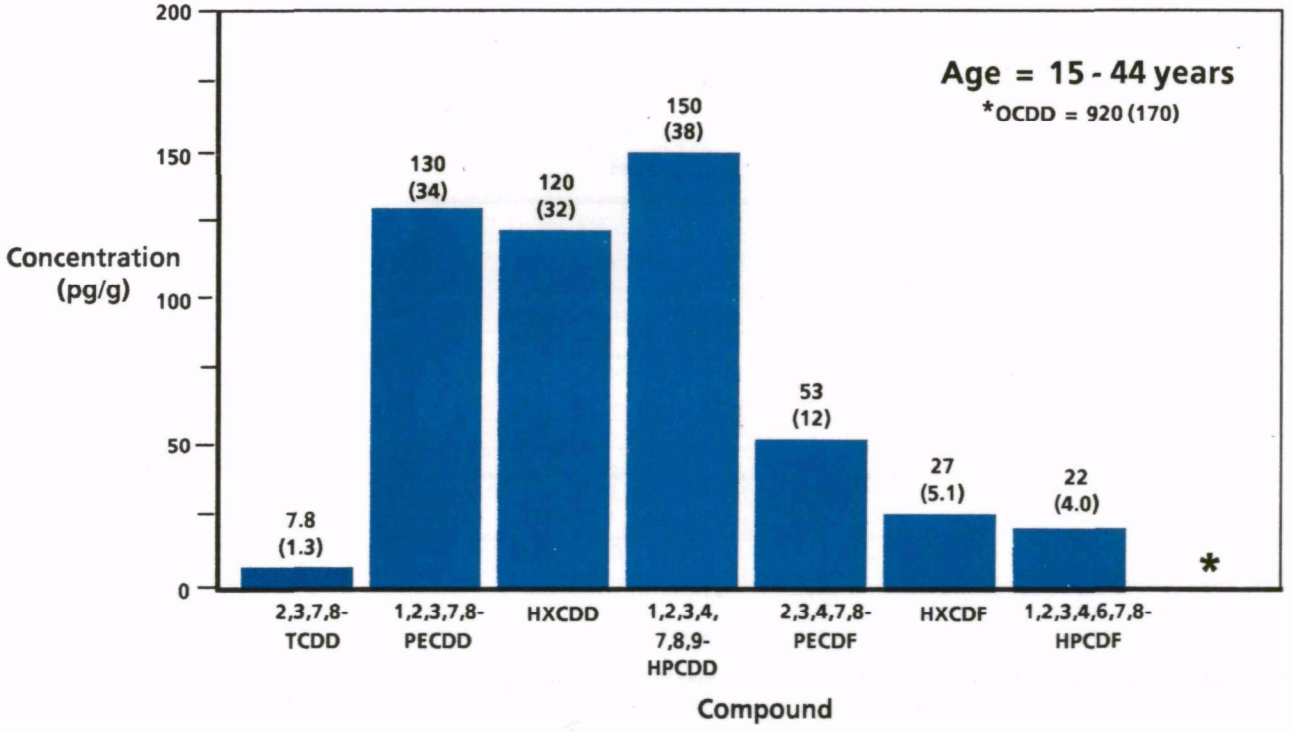


Figure 2-11. Weighted estimates of the average concentration levels of dioxins and furans (lipid adjusted, pg/g) for each age group. (Standard errors of the estimates are in parentheses.)

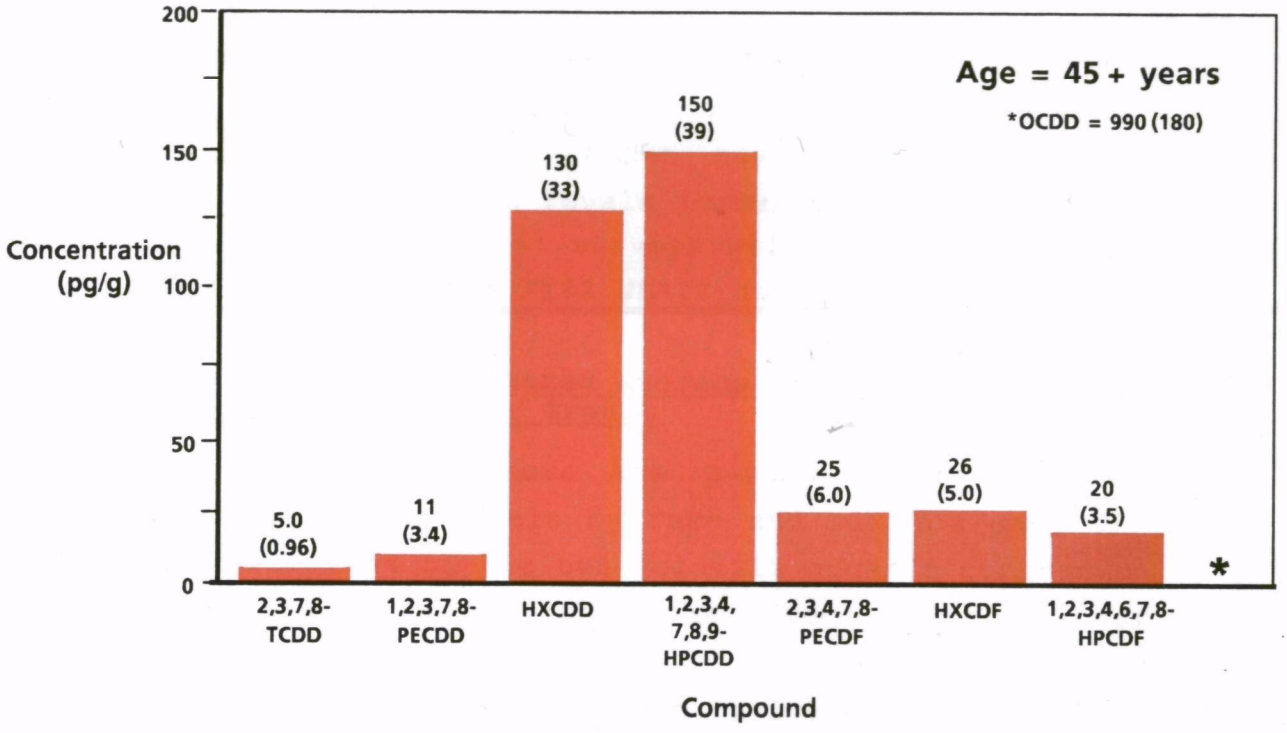


Figure 2-11. (Continued)

Concentrations of 2,3,7,8-TCDD, 1,2,3,7,8-PECDD, and 2,3,4,7,8-PECDF were higher in the 15 to 44 age group than in other two age groups. Concentration levels of OCDD were higher in both the adult groups (15-44 and 45 years and older) than in the youngest (0-14 years) age group. For the dioxin 1,2,3,7,8-PECDD, the oldest age group had a much lower concentration than either of the other two age groups. This did not appear to be an artifact of the model, as the concentrations of the composite samples from the oldest age group, with one exception, were clustered at the lower end of the range. Other researchers have found that 2,3,7,8-TCDD concentration levels increase with age (Patterson et al., 1986). Future years' surveys will be closely monitored to see if the results of the FY82 NHATS survey are replicated.

2.1.4 Comparison of Estimated Average Concentration Levels Across Sex and Race Groups

Table 2-4 shows the p-values for comparisons of average concentration levels by race and sex for each of the 22 compounds. For five of the ten volatile organic compounds there was a statistically significant sex effect, with the estimated average concentration levels for males being greater in each case. These compounds were styrene, toluene, xylene, chloroform, and tetrachloroethene.

Among the semi-volatiles, the average concentration of p,p'-DDE was significantly greater for males. The sex difference in p,p'-DDE appears anomalous and is primarily attributable to a very low concentration in one pure female composite. The model-based average concentration estimate was less than twice as high for males as for females when this composite was omitted, and the difference was no longer statistically significant. Historically, p,p'-DDE estimates from the Human Monitoring Program for the two sexes have been about the same.

Among the dioxins and furans, the average concentration levels for females were significantly greater for the dioxin HXCDD and the furan HXCDF.

The average concentration levels of five compounds different significantly by race group. Toluene, chlorobenzene, ß-BHC, butyl benzyl phthalate, and 2,3,4,7,8-PECDF each showed an average concentration level for Caucasians that was greater than the average level for non-Caucasians.

However, because all six of the pure non-Caucasian composites were located in the South and no composite outside of the South was more than [illegible] non-Caucasian, the estimation of the race group effect in the model was driven almost entirely by the data in the South. Therefore, the validity of the national race group effect estimated by the multiplicative model depends on accepting the assumption that there is no interaction between race and region, and that race-group effects observed in the South apply elsewhere.

In fact, for the chemicals ß-BHC and chlorobenzene, where the model declared a statistically significant race group effect on concentration, the arithmetic mean concentrations of non-Caucasian composites in the South were not much different than the mean concentrations of the Caucasian composites outside the South. In comparison, the means of the Caucasian composites in the South were higher than those of the non-Caucasians in the South. The combination of these data result in a model-based estimate of a significant regional effect--the South higher than the other regions--and a significant race group effect--Caucasians higher. This situation did not occur for the three other chemicals showing significant differences by race; the average concentrations of these chemicals were less for non-Caucasian composites in the South than for Caucasian composites in all regions. Also, all chemicals showing significant average concentration differences by region but not by race group (benzene, 1,4-dichlorobenzene, and tetrachloroethene) had mean

concentrations in Caucasican composites in the South that were similar to the levels observed in non-Caucasian composites in the South.

Because of the lack of empirical support for estimating race group differences in regions other than the South, the model-based estimate of a national race group effect should be interpreted cautiously. Race group effects estimated in future surveys will be monitored closely to see if the results of the NHATS FY82 survey are replicated.

2.1.5 Relative Standard Errors

The precision of each of the average concentration estimates at the national level, and by region, age group, race group, and sex is measured by an associated standard error. Contributing to the standard error of the estimated average concentration are errors due to sampling Standard Metropolitan Statistical Areas (SMSA's) and individual specimens within SMSA, errors in tissue preparation and chemical analysis, and possible errors introduced because of model mis-specification. The standard error of the estimated average concentration is also a function of the underlying variability of the concentration in the population. Estimates of the standard errors are shown in Table 2-3, where they are expressed as relative standard errors, which are percentages of the associated average concentration estimates. Note that at the national level the relative standard errors range from a low of 12 percent for benzene, to a high of 50 percent for butyl benzyl phthalate; 10 of the relative standard errors are less than 20 percent, 8 are between 20 and 30 percent, and the other 5--toluene, xylene, ethylbenzene, chloroform, and butyl benzyl phthalate--exceed 30 percent. The high relative standard errors of 37 percent for toluene and 42 percent for chloroform are primarily attributable to a few composites with extreme concentration values. The relative standard errors of 50 percent for butyl benzyl phthalate and 42

percent for xylene were high because the concentrations of these chemicals had a greater degree of variability across the composites than the other chemicals and their distribution did not fit the multiplicative model as well. In the case of 1,2,3,7,8-PECDD the two highest measured concentrations were so much greater than the rest of the distribution that they were deemed to be outliers and removed from the analysis to avoid distorting the estimate of average concentration level. A detailed explanation of the rationale for this decision is contained in Section 8.5.

2.2 Incidence of Detection for Compounds Identified in the Composite Samples

Results on the percentage of composite samples having detectable levels do not necessarily imply that the percentages of detected levels for individual samples were similar. For example, if a compound is detected in all of the composite samples, it may or may not be present in all of the individual specimens contained in the composite samples. The estimation of prevalence in composite samples is addressed in a separate study (Orban et al. 1987).

2.2.1 Volatile Organic Compounds

The incidence of detection for volatile organic compounds varied across the chemical classes. Eight of the nine compounds from the four benzene related classes were detected in greater than 90% of the composite samples. For instance, benzene was detected in 96% of composite samples and 1,4-dichlorobenzene was found in all the composite samples. The compound 1,2-dichlorobenzene, which was detected in 63% of the composites, was the lone exception.

Several compounds, specifically styrene, ethylphenol, xylene, and 1,4-dichlorobenzene, were detected in all of the composite samples. Bromodichloromethane, dibromochloromethane,

bromoform and 1,1,2-trichloroethane from the trihalomethane and halocarbon chemical classes were not detected in any of the composites. Incidence data for the volatile compounds are provided in graphical format in Figure 2-12 for benzenes, and in Figure 2-13 for trihalomethanes and halocarbons. These data are listed in tabular format in Appendix B, Table B-1.

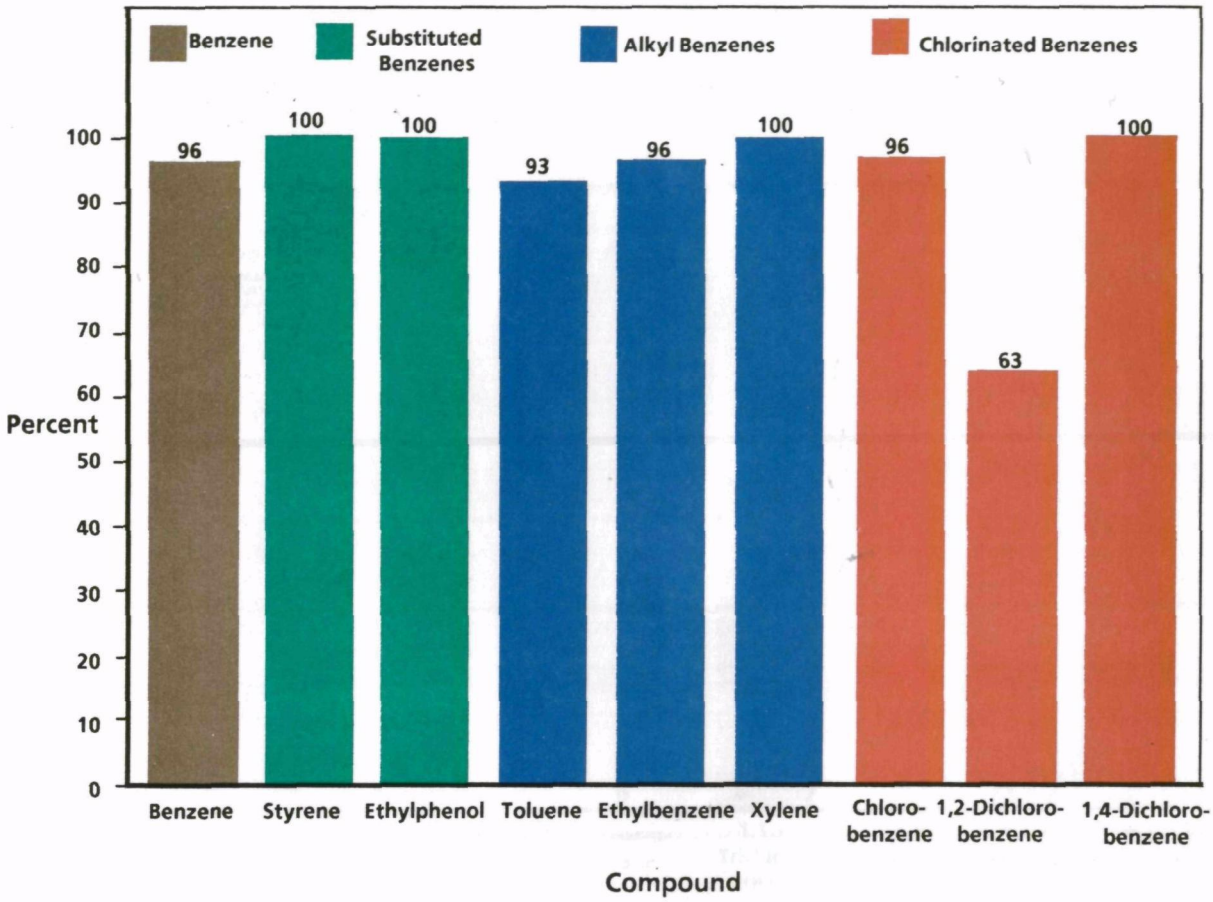


Figure 2-12. Percentage of FY82 composite samples in which benzenes were detected

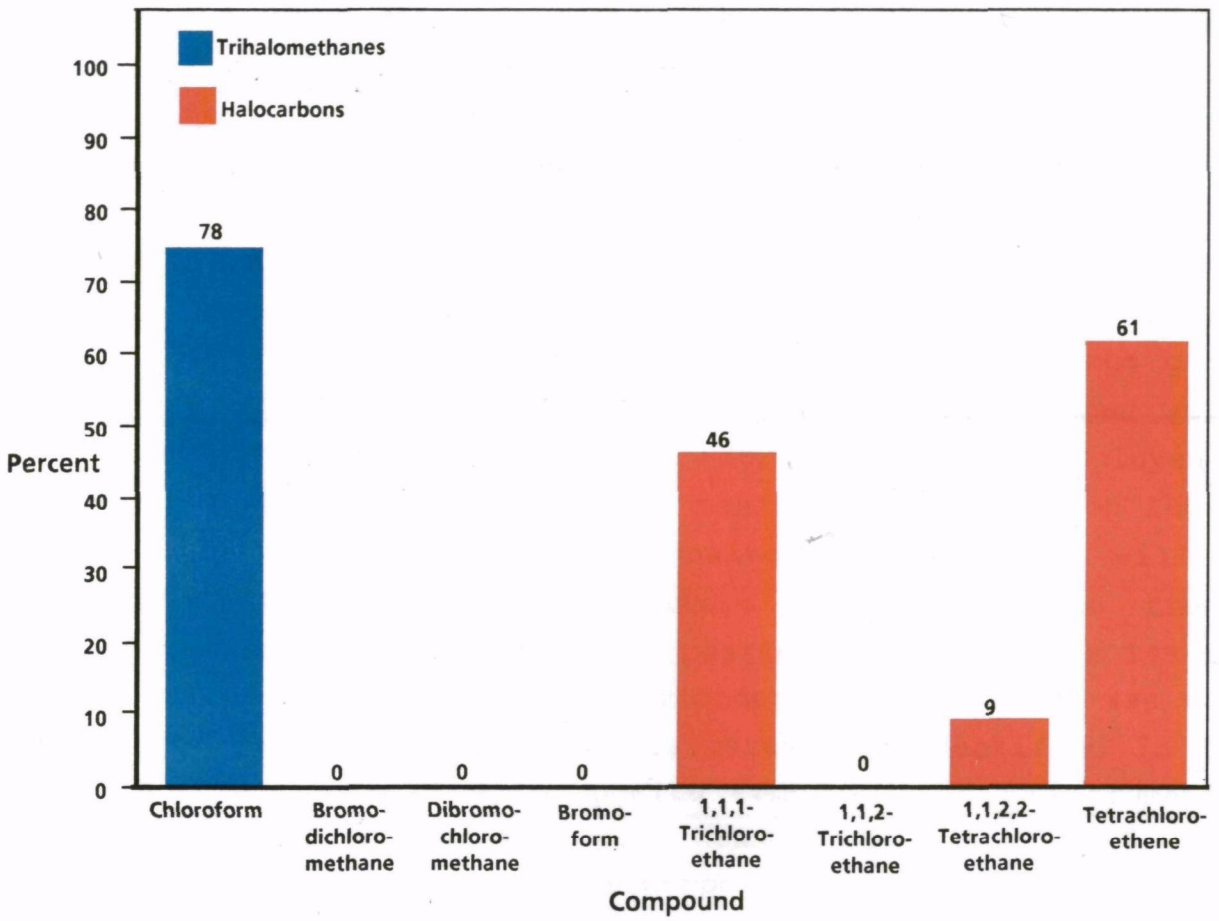


Figure 2-13. Percentage of FY82 composite samples in which trihalomethanes and halocarbons were detected

2.2.2 Semi-Volatile Organic Compounds

The semi-volatile organic compounds were detected in various degrees across and within the chemical classes. For the PCB homolog groups, the incidence of detection ranged from 7% for decachlorobiphenyl to 75% for hexachlorobiphenyl. PCBs were detected in 38 out of 44 of the composites, or approximately 86% of the sample. All six of the composites where PCBs were not detected were from the youngest age group. This result is at variance with what was observed in the survey of FY81--when all 422 individual samples including 94 from the youngest age were found to have detectable levels of PCBs--and the survey of FY83--when all 407 specimens including 63 from the youngest age group had detectable PCB levels. The surveys from these other years were not strictly comparable to FY82 since they employed a different analytical procedure and measured concentration levels on individual specimens, not composites. PCB levels will be closely monitored in future surveys to clarify the trend. Percentages for the organochlorine pesticides ranged from 14% for mirex to 100% for p,p'-DDE. The incidence for p,p'-DDT was 68%. Only these two of the six DDT isomers were identified in the Broad Scan Analysis Study composite samples. Of the aromatics and chlorinated benzenes, only hexachlorobenzene (79%) was detected in more than 50% of the composite samples.

The phthalates were detected in more of the composite samples than the phosphates. Tributyl phosphate and tris(2-chlorethyl) phosphate were detected in only 2% of the composite samples. Graphs depicting the incidence of detection for semi-volatile compounds are provided in Figures 2-14, 2-15, 2-16, and 2-17 for PCBs, organochlorine pesticides, aromatics and chlorinated benzenes, and phthalates and phosphates, respectively. These data are listed in tabular format in Appendix B, Table B-2. In general the detection percentages were lower for the FY82 composite samples than they were for the FY81 and FY83 individual specimens. For example, p,p'-DDT was

detected in only 68% and hexachlorobenzene in only 79% of the FY82 composites, in contrast to the other two years when more than 99% of the survey specimens were found to have detectable amounts of both compounds. One exception to the general rule is the compound mirex, which was detected in 14% of the FY82 composites but in less than 1% of the FY81 and FY83 specimens.

2.2.3 Dioxins and Furans

Four of the five dioxins were detected in more than 90% of the composite samples. The exception was 2,3,7,8-TCDD which was detected in 74% of the composites. The percentage detected for the furans ranged from 26% for 2,3,7,8-TCDF to 93% for 1,2,3,4,6,7,8-HPCDF. Graphs for percentage detected data are provided in Figure 2-18. These data are listed in tabular format in Appendix B, Table B-3.

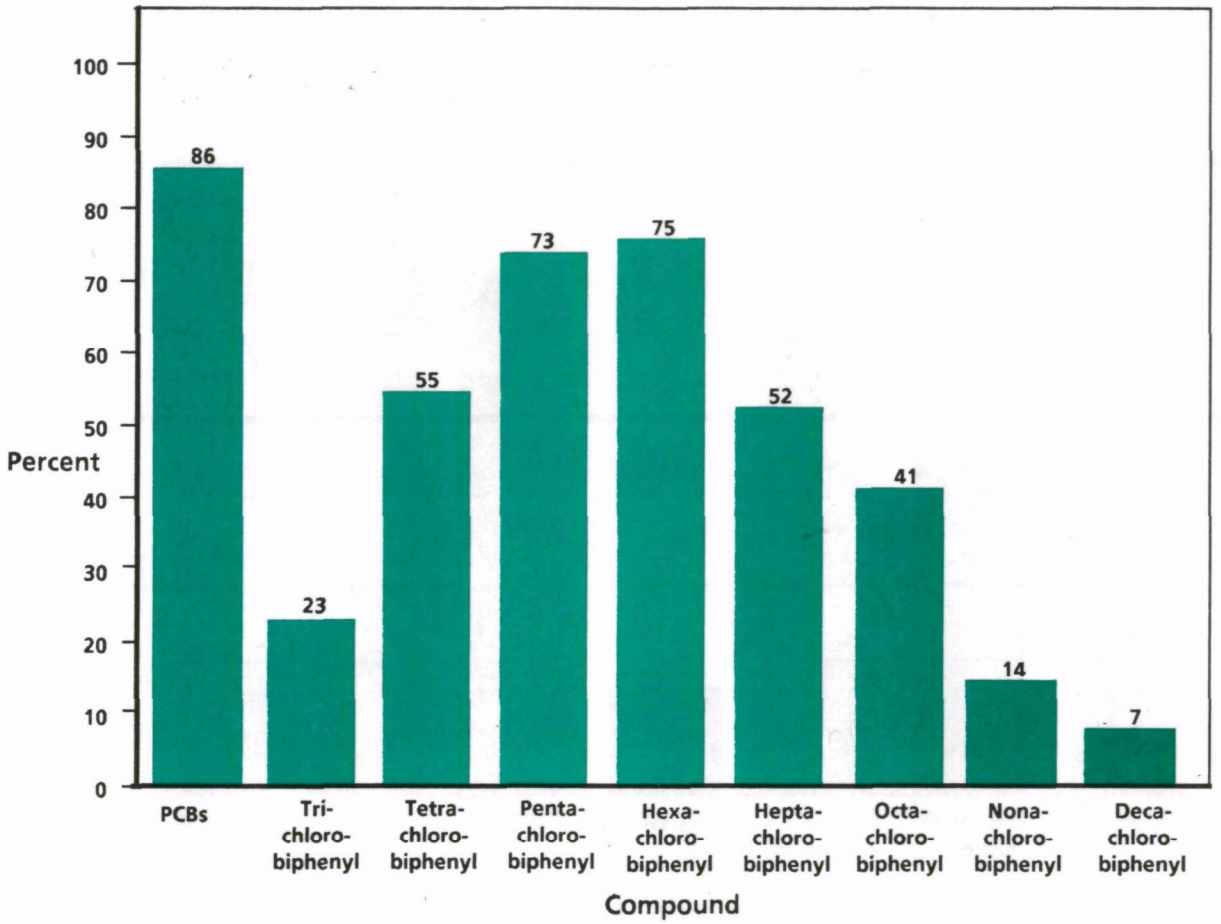


Figure 2-14. Percentage of FY82 composite samples in which PCB homolog groups were detected

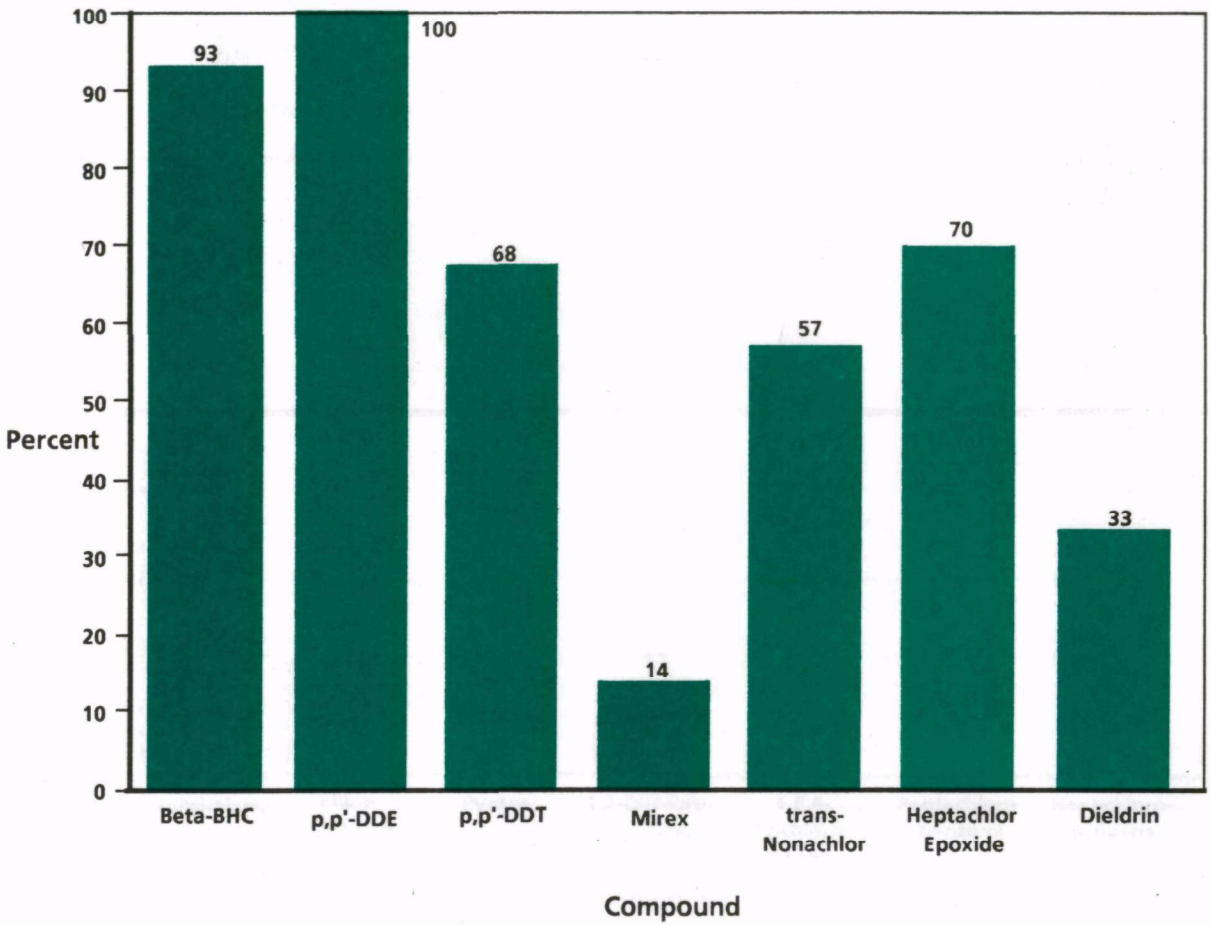


Figure 2-15. Percentage of FY82 composite samples in which organochlorine pesticides were detected

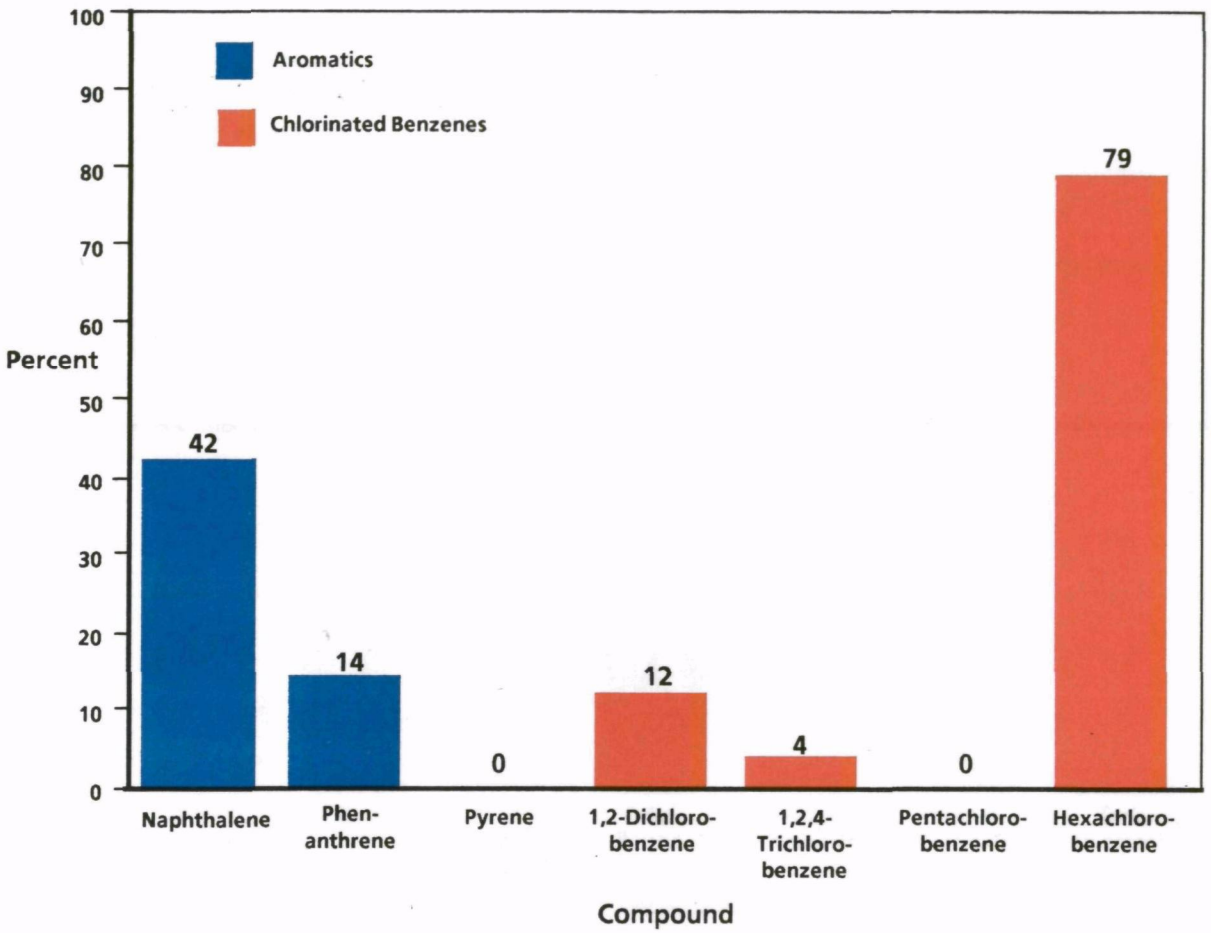


Figure 2-16. Percentage of FY82 composite samples in which aromatics and chlorinated benzenes were detected

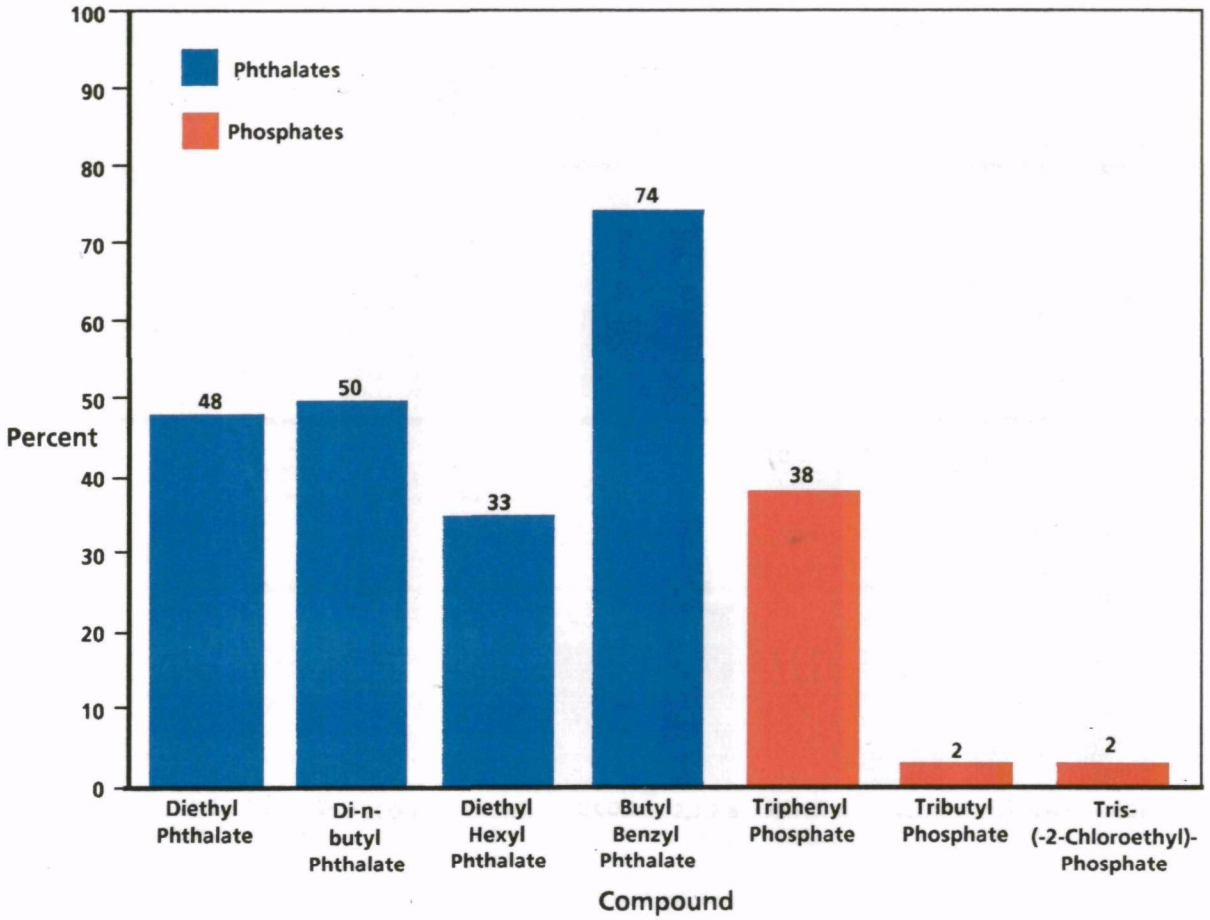


Figure 2-17. Percentage of FY82 composite samples in which phthalates and phosphates were detected

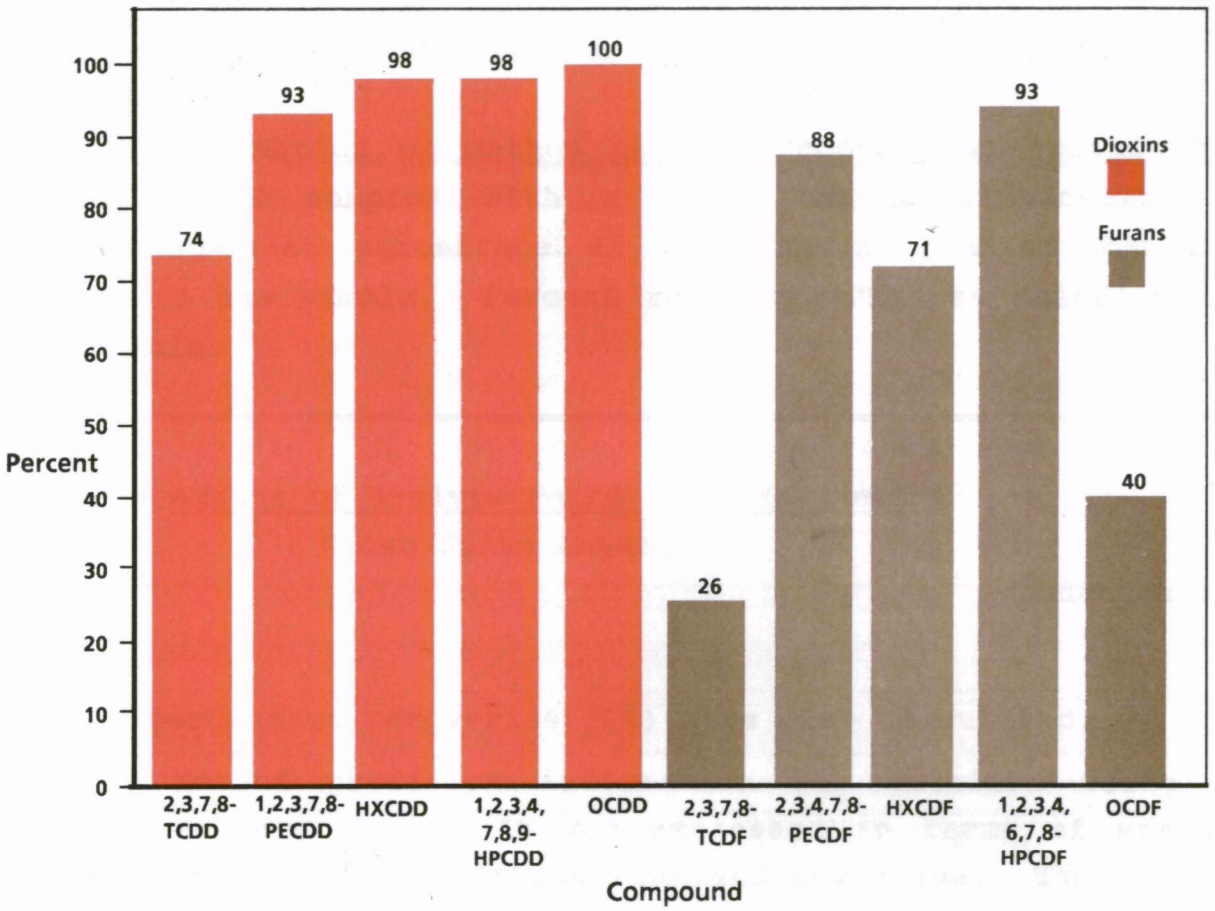


Figure 2-18. Percentage of FY82 composite samples in which dioxins and furans were detected

3.0 QUALITY ASSURANCE

An extensive quality assurance/quality control (QA/QC) effort accompanied the analysis of the Broad Scan Analysis Study composite samples. The results of this effort were used to assess the performance of the HRGC/MS method. Percent recovery, precision and estimated limit of detection (LOD) data were reported.

Information on method percent recovery was obtained by spiking QA/QC samples with a known amount of analyte and determining what percentage of that amount was estimated as present in the sample. Percent recovery (PR) was calculated by the formula:

$$PR = \frac{\text{Amount of Analyte Found in QA/QC Sample}}{\text{Known Spike Amount}} \times 100\%$$

(Equation 3-1)

Average percentage recoveries ($\overline{PR}$) were also calculated.

Method precision information was obtained using the percent recovery data. It was expressed in terms of standard deviation and percent relative standard deviation. The standard deviation (S) was calculated by the formula:

$$S^2 = (1/(N-1)) \sum_{i=1}^{N} (PR_i - \overline{PR})^2$$

(Equation 3-2)

where

PR_i is the percent recovery for the ith QA/QC sample;

$\overline{PR}$ is the average percent recovery of the QA/QC samples; and

N is the number of QA/QC samples.

The relative standard deviation (RSD) was calculated as:

$$RSD = 100\ S/\overline{PR} \qquad \text{(Equation 3-3)}$$

It is expressed as a percentage.

Estimated limits of detection (LODs) were reported only for those composite samples whose observed concentration level was below the level of quantification; that is, those composite samples whose concentration levels were determined to be either not detected or trace. The LODs were reported as total mass of target analyte detectable and as the equivalent concentration level. LOD concentrations were calculated based on wet weight for the volatiles analyses and extractable lipid weight for the semi-volatiles, dioxins and furans analyses. In this report, the maximum and minimum of the reported LOD amounts and equivalent concentrations are presented. For some chemicals, there were composite samples whose reported concentrations were above the limit of quantification but were also below the maximum LOD as presented in this section. This occurred because of variation between samples with respect to sample weight, minimum analyte mass detectable, or both.

This report presents a summary of some of the QA results obtained in the Broad Scan Analysis Study. Data for those QA/QC samples whose results are most comparable to the results obtained from the Broad Scan Analysis Study composite samples, that is, spiked human adipose tissue QC samples, are provided here. Percent recoveries calculated for the human adipose tissue QC samples include any possible background contribution from the adipose tissue itself. Additional information from results of other QA/QC samples is provided in USEPA a-e (1986).

3.1 Volatile Organic Compounds

Several types of QA/QC procedures were performed with the volatiles analyses of the Broad Scan Analysis Study composite samples. They included daily instrument performance checks through analyses of internal QC and external QC (performance audit) samples, analyses of spiked human adipose tissue samples, and analyses of internal standard responses. Concentrations were calculated based on wet weight.

Data from the analyses of five human adipose tissue QC samples, run with the first sample batches, were obtained for 14 of the 17 target analytes. Each QC sample was made up of 20 grams of spiked human adipose tissue. Spike levels ranged from 0.20 µg to 1.4 µg per 20 grams. These levels were equivalent to concentrations ranging from 0.010 µg/g to 0.070 µg/g. Results of these analyses found that the HRGC/MS method performed quite well with respect to bias. Average percent recoveries ranged from 85% for chloroform to 141% for styrene. The high recoveries for chemicals such as styrene may be due to background contribution from the adipose tissue itself. Precision data, however, were quite variable for the different compounds. The relative standard deviations ranged from 4% for benzene to 54% for bromodichloromethane. Styrene, tetrachloroethene, and 1,1,1-trichloroethane had both high recoveries and high relative standard deviations. In general, precision was better for compounds that were quantitated versus their associated deuterated analog than for compounds that were quantitated versus bromochloropropane, the internal standard for analyses in which a deuterated analog was not available. These results are summarized in Table 3-1.

Ranges of reported limits of detection for the 17 volatile compounds are provided in Table 3-2. In general, the LOD target of .05 to .10 µg/g was met.

Table 3-1. Summary of QC Results for Selected Volatile Organic Analytes in Spiked 20 Gram Aliquots of Human Adipose Tissue[a]

Chemical	Number of QC Samples[b]	Average Percent Recovery	Precision	
			Standard Deviation (Units = Percent)	Relative Standard Deviation[c]
Benzene				
Benzene[d]	4	100	4	4
Substituted Benzenes				
Styrene	5	141	71	50
Alkyl Benzenes				
Toluene[d]	5	97	27	27
Ethylbenzene[d]	5	105	10	10
Chlorinated Benzenes				
Chlorobenzene[d]	5	104	21	21
1,2-Dichlorobenzene[d]	3	103	8	7
Trihalomethanes				
Chloroform[d]	2	85	14	17
Bromodichloromethane	5	111	60	54
Dibromochloromethane	5	111	20	18
Bromoform	5	99	25	25
Halocarbons				
1,1,1-Trichloroethane	5	131	59	45
1,1,2-Trichloroethane	5	94	9	10
1,1,2,2-Tetrachloroethane[d]	5	103	8	8
Tetrachloroethene	5	122	55	45

[a] These samples were analyzed with the first sample batches of the Broad Scan Analysis Study composite samples. Spike levels were equivalent to concentration levels ranging from 0.01 μg/g to 0.075 μg/g.

[b] For half of the chemicals listed in Table 3-1, there are five QC samples. For the other chemicals, the number of QC samples is less than five for one of two reasons: percent recovery for the QC sample was not determined or percent recovery for the QC sample was determined by a method not comparable to other recoveries for that chemical.

[c] Relative standard deviation is the standard deviation expressed as a percentage of the Average Percent Recovery.

[d] Quantitation for these analytes was performed versus the deuterated analog of the specific compound. All other calculations were performed versus the internal standard, bromochloropropane.

Table 3-2. Ranges of Reported Limits of Detection of Volatile Organic Compounds for Composite Samples Whose Concentration Levels Were Declared Not Detected or Trace

	Reported Limit of Detection (µg)		Equivalent Concentration Wet Weight Basis (µg/g)	
Chemical	Minimum	Maximum	Mininum	Maximum
Benzene				
Benzene	0.080	0.095	0.0044	0.013
Substituted Benzenes				
Styrene[a]	--	--	--	--
Ethylphenol	0.005	0.005	0.0002	0.0002
Alkyl Benzenes				
Toluene	0.003	0.005	0.0002	0.0004
Ethylbenzene	0.010	0.050	0.0009	0.0027
Xylene[a]	--	--	--	--
Chlorinated Benzenes				
Chlorobenzene	0.004	0.040	0.0003	0.0026
1,2-Dichlorobenzene	0.001	0.020	0.0001	0.0015
1,4-Dichlorobenzene[a]	--	--	--	--
Trihalomethanes				
Chloroform	0.020	0.74	0.0008	0.10
Bromodichloromethane	0.53	5.4	0.021	0.50
Dibromochloromethane	0.030	0.50	0.0013	0.033
Bromoform	0.008	0.67	0.0004	0.050
Halocarbons				
1,1,1-Trichloroethane	0.04	2.7	0.0022	0.24
1,1,2-Trichloroethane	0.021	0.50	0.0010	0.050
1,1,2,2-Tetrachloroethane	0.001	0.090	0.0001	0.0052
Tetrachloroethene	0.020	0.80	0.0009	0.033

[a] This compound was detected in all composite samples.

3.2 Semi-Volatile Organic Compounds

Quality assurance/quality control procedures for the semi-volatiles analyses included analyses of method blanks, spiked blanks, porcine fat samples prepared by EPA/EMSL-LV, spiked human adipose tissue samples, and replicate analyses of homogenized human adipose tissue samples. Analyses for surrogate compounds and anthracene-d_{10}, the internal standard, were also performed for each composite sample. Results for adipose tissue samples were adjusted for extractable lipid weight. The results of the analyses of the spiked human adipose tissue samples are described in this section.

Fifty-two target analytes were analyzed in five human adipose tissue QC samples at spiking levels equivalent to concentrations of 0.10 µg/g. Each QC sample was a 20 gram aliquot of adipose tissue. Results for these samples were considerably more variable than the results for the volatile QC samples cited in Section 3.1. Average percent recoveries were lower for semi-volatiles than for volatiles. Seventeen of the 52 semi-volatiles listed in Table 3-3 had average percent recoveries of less than 50%. Thirty-three semi-volatiles had recoveries between 51 and 100%, while only two had recoveries exceeding 100%. For the fourteen volatiles listed in Table 3-1, five had recoveries between 85 and 100%, while nine had recoveries over 100%. The average recovery for 1,2-dichlorobenzene was 48% for the semi-volatiles protocol compared to 103% for the volatiles protocol.

The semi-volatile, p,p'-DDE, had an unusually high recovery of 204%. This recovery is believed to be due to the background contribution from the bulk adipose tissue itself.

Relative standard deviations (RSDs) for the semi-volatiles were higher in general than those for the volatiles. The relative standard deviations for semi-volatiles ranged from 12% to 74%. About three-fourths (38/52) of the semi-volatile

RSDs were 20% or greater. For volatiles, the range was 4% to 50% and half of the volatiles had RSDs of 20% or more.

There appeared to be differences in method performance between the compound classes. Highest average percent recoveries were observed for the organochlorine pesticides, ranging from 56% for o-p'-DDE to 93% for p,p'-DDD, as well as the 204% for p,p'-DDE. The phosphates, with average recoveries from 22% to 29%, had the lowest recoveries. The results are presented in Table 3-3.

Ranges of reported limits of detection are provided in Table 3-4. The reported limits of detection (LODs) for diethyl phthalate, di-n-butyl phthalate, and di-n-octyl phthalate are relatively high. These compounds were detected in the associated method blanks. This is not an unusual situation. (McLafferty 1980). In general, the target LOD concentrations of .05 to .10 µg/g were achieved.

3.3 Dioxins and Furans

The QA/QC procedures for the dioxins and furans analyses included the following:

- Analysis of method blanks;
- A check on the response factor each day;
- A check on the column resolution for 2,3,7,8-TCDD each day;
- Estimation of recovery of internal standards; and
- Qualitative verification of 2,3,7,8-TCDD in certain extracts.

Unlike the volatiles and semi-volatiles analyses, measurements on spiked human adipose tissue samples were not reported for the dioxins and furans analyses. Therefore, equivalent information on the bias and precision of the dioxins and furans method is not

available. The Limits of Detection for dioxins and furans were reported as lipid adjusted concentrations in picograms per gram. The minimum and maximum of these concentrations are presented in Table 3-5. The LOD goals for the analyses were 0.1 to 1 nanogram per gram. This is equivalent to 100 to 1000 picograms per gram. An inspection of Table 3-5 indicates that the LOD goals of the analysis appear to have been met.

Table 3-3. Summary of QC Results for Selected Semi-Volatile Organic Analytes in Spiked 20 Gram Aliquots of Human Adipose Tissue[a]

Chemical	Number of QC Samples[b]	Average Percent Recovery	Precision	
			Standard Deviation	Relative Standard Deviation
Organochlorine Pesticides				
α-BHC	5	83	19	23
ß-BHC	4	66	21	32
Δ-BHC	5	62	8	13
o-p'-DDE	5	56	10	18
p-p'-DDE	5	204[c]	20	10
o-o'-DDD	5	61	13	21
p-p'-DDD	5	93	31	33
o-p'-DDT	5	90	35	39
p-p'-DDT	5	84	39	46
Mirex	5	58	28	48
trans-Nonachlor	4	76	12	16
Heptachlor	5	73	13	18
Heptachlor Epoxide	5	91	18	20
Dieldrin	4	74	45	61
Aldrin	5	74	9	12
Aromatics				
Naphthalene	3	120	22	18
d_8-Naphthalene	5	39	17	44
Phenanthrene	5	70	11	16
Pyrene	5	78	16	21
Dimethyl phthalate	5	56	19	34

Table 3-3. (continued)

Chemical	Number of QC Samples[b]	Average Percent Recovery	Precision: Standard Deviation	Precision: Relative Standard Deviation
Phthalates				
Diethyl phthalate	5	65	13	20
Di-n-butyl phthalate	5	85	34	40
Butyl benzyl phthalate	5	41	23	56
Di-n-octyl phthalate	5	63	46	73
Phosphates				
Tris(1,dichloropropyl)phosphate	5	22	11	50
Triphenyl phosphate	5	29	15	52
Tri-m-tolyl phosphate	4	22	7	32
Chlorinated Benzenes				
1,2-Dichlorobenzene	3	48	8	17
1,2,4-Trichlorobenzene	3	51	10	20
$^{13}C_6$-1,2,4,5-Tetrachlorobenzene	5	39	16	41
Pentachlorobenzene	5	34	14	41
Hexachlorobenzene	5	49	12	24
$^{13}C_6$-Hexachlorobenzene	5	48	9	19
Bromobiphenyls				
4-Bromobiphenyl	5	52	13	25
4,4'-Dibromobiphenyl	5	95	14	15
2,4,6-Tribromobiphenyl	5	66	10	15
2,2',4',5-Tetrabromobiphenyl	5	87	33	38

Table 3-3. (continued)

Chemical	Number of QC Samples[b]	Average Percent Recovery	Precision: Standard Deviation	Precision: Relative Standard Deviation
Chlorodiphenyls				
4-Chlorodiphenyl ether	5	41	14	34
2,2',4,4',5-Pentachloro-diphenyl ether	5	73	21	29
Chloroterphenyls				
4-Chloro-p-terphenyl	5	45	18	40
2,5-Dichloro-o-terphenyl	5	58	25	43
2,4',5-Trichloro-o-terphenyl	5	72	53	74
2,4,4',6-Tetrachloro-o-terphenyl	5	80	57	71
Chlorophenols				
2,4-Dichlorophenol	4	74	24	32
2,4,6-Trichlorophenol	4	37	8	22
Other Compounds				
Acenaphthylene	5	44	13	30
Acenaphthene	5	46	16	35
Fluorene	5	50	15	30
Fluoranthene	5	82	14	17
τ-Chlordane	5	71	10	14
Chrysene	5	61	10	16
d_{12}-Chrysene	5	37	14	38

[a]Spike levels were equivalent to concentrations of 0.18 μg/g.

[b]In cases where the number of QC samples analyzed is less than 5, the percent recovery value was not determined for those remaining samples.

[c]High recovery rate due to contribution from the adipose tissue matrix.

Table 3-4. Ranges of Reported Limits of Detection of Semi-Volatile Organic Compounds for Composite Samples Whose Concentration Levels Were Declared Not Detected or Trace

	Reported Limit of Detection (µg)		Equivalent Concentration Lipid Weight Basis (µg/g)	
Chemical	Minimum	Maximum	Mininum	Maximum
Organochlorine Pesticides				
ß-BHC	0.20	0.20	0.012	0.036
p,p'-DDE	0.20	0.20	0.011	0.016
p,p'-DDT	0.20	0.20	0.0092	0.036
Mirex	0.20	0.20	0.0088	0.036
trans-Nonachlor	0.40	0.40	0.018	0.071
Heptachlor Epoxide	0.20	0.20	0.0088	0.036
Dieldrin	1.0	1.0	0.044	0.18
PCBs				
PCBs	0.20	0.20	0.014	0.036
Trichlorobiphenyl	0.20	0.20	0.0088	0.036
Tetrachlorobiphenyl	0.20	0.20	0.0088	0.036
Pentachlorobiphenyl	0.40	0.40	0.018	0.071
Hexachlorobiphenyl	0.40	0.40	0.018	0.071
Heptachlorobiphenyl	0.40	0.40	0.018	0.071
Octachlorobiphenyl	0.40	0.40	0.018	0.071
Nonachlorobiphenyl	0.40	0.40	0.018	0.071
Decachlorobiphenyl	1.0	1.0	0.044	0.18
Chlorinated Benzenes				
1,2-Dichlorobenzene	0.20	0.20	0.0088	0.036
1,2,4-Trichlorobenzene	0.20	0.20	0.0088	0.036
Pentachlorobenzene	0.20	0.20	0.0088	0.036
Hexachlorobenzene	0.20	0.20	0.0088	0.036

Table 3-4. (continued)

Chemical	Reported Limit of Detection (µg) Minimum	Reported Limit of Detection (µg) Maximum	Equivalent Concentration Lipid Weight Basis (µg/g) Mininum	Equivalent Concentration Lipid Weight Basis (µg/g) Maximum
Aromatics				
Naphthalene	0.20	0.20	0.0088	0.036
Phenanthrene	0.20	0.20	0.0088	0.036
Pyrene	0.20	0.20	0.0088	0.036
Phthalates				
Diethyl Phthalate	0.20	1.3	0.0089	0.077
Di-n-butyl Phthalate	0.20	3.3	0.0095	0.18
Diethyl Hexyl Phthalate	0.20	12.2	0.0089	0.69
Butyl Benzyl Phthalate	0.20	0.20	0.0089	0.019
Phosphates				
Triphenyl Phosphate	0.40	4.4	0.018	0.59
Tributyl Phosphate	1.0	1.0	0.044	0.13
Tris (2-Chloroethyl) Phosphate	0.80	0.80	0.035	0.14

Table 3-5. Ranges of Reported Limits of Detection of Dioxins and Furans for Composite Samples Whose Concentration Levels Were Declared Not Detected or Trace

Chemical	Number of Samples with Concentration ND or TR	Concentration Lipid Adjusted (pg/g)	
		Minimum	Maximum
Dioxins			
2,3,7,8-TCDD	13	1.3	24
1,2,3,7,8-PECDD	15	1.3	140
HXCDD	4	13	49
1,2,3,4,7,8,9-HPCDD	1	26	26
OCDD[a]	0	--	--
Furans			
2,3,7,8-TCDF	34	1.3	45
2,3,4,7,8-PECDF	9	1.3	46
HXCDF	19	3.0	51
1,2,3,4,6,7,8-HPCDF	7	3.5	19
OCDF	33	1.2	200

[a]This compound was detected in all composite samples.

4.0 SAMPLING AND COMPOSITING DESIGNS

4.1 Sampling Design

The human adipose tissue specimens analyzed in the Broad Scan Analysis Study were collected from October, 1981 through September, 1982, following the NHATS sampling design. The NHATS program uses a statistically based survey design to obtain adipose tissue specimens from autopsied cadavers and surgical patients. Although the NHATS target population is the general, non-institutionalized U.S. population, the sampling population is limited to cadavers and surgical patients due to the invasive nature of the process required to collect the adipose specimens from living persons.

The FY82 NHATS sampling design involved a two-stage selection process. In the first stage, Standard Metropolitan Statistical Areas (SMSAs) were randomly selected from the nine Census divisions of the continental United States, with probabilities proportional to their 1970 census population size. The number of SMSAs selected from each Census division was proportional to the population of the Census division relative to the total U.S. population. In the second stage, individual tissue specimens were collected by cooperating medical examiners and pathologists within the selected SMSAs using target quotas for various age, race and sex categories. The categories were:

- Age ("0-14 years," "15-44 years," "45+ years")
- Race (white, non-white)
- Sex (male, female)

The SMSA target quotas were proportional to the 1970 U.S. Census population counts for the Census Division in which the SMSA is located. The tissue specimens were selected in a nonprobalistic manner based on the judgment of the medical examiner or pathologist involved (Lucas et al. 1982). An

overview of the FY82 sampling design is provided in Figure 4-1. A map of the SMSAs selected for the FY82 NHATS collection is provided in Figure 4-2. These SMSAs are listed in Appendix C, Table C-1.

Because the survey required some divergence from strict probabilistic sampling, the validity of the statistical estimates derived from the data depends on several assumptions. First, the concentration of toxic substances in the adipose tissue of cadavers and surgical patients is assumed to be the same as in the general population. Second, it is assumed that the level of toxic substances in urban residents is approximately the same as in rural residents, and therefore the selection of only urban hospitals (i.e., located in SMSAs) does not introduce any significant bias into the estimates of average concentrations levels. Finally, it is assumed that no systematic bias is introduced by the fact that the participating pathologists and medical examiners were self-selected, and the specimens were non-probabilistically sampled according to pre-specified quotas.

The FY82 sampling design specified the collection of 40 specimens from each of 35 SMSAs, five of which were double collection sites. Double collection sites are SMSAs whose populations are so large that their proper representation in the sample requires that they be sampled twice. In a double collection center, either one cooperator provides twice the number of specimens (80) or two cooperators each provide the standard quota of specimens (40). Sixteen hundred specimens were designated for collection. However, due to incomplete fulfillment of target quotas and no response from several medical examiners/ pathologists, only 827 specimens were collected, from 26 SMSAs.

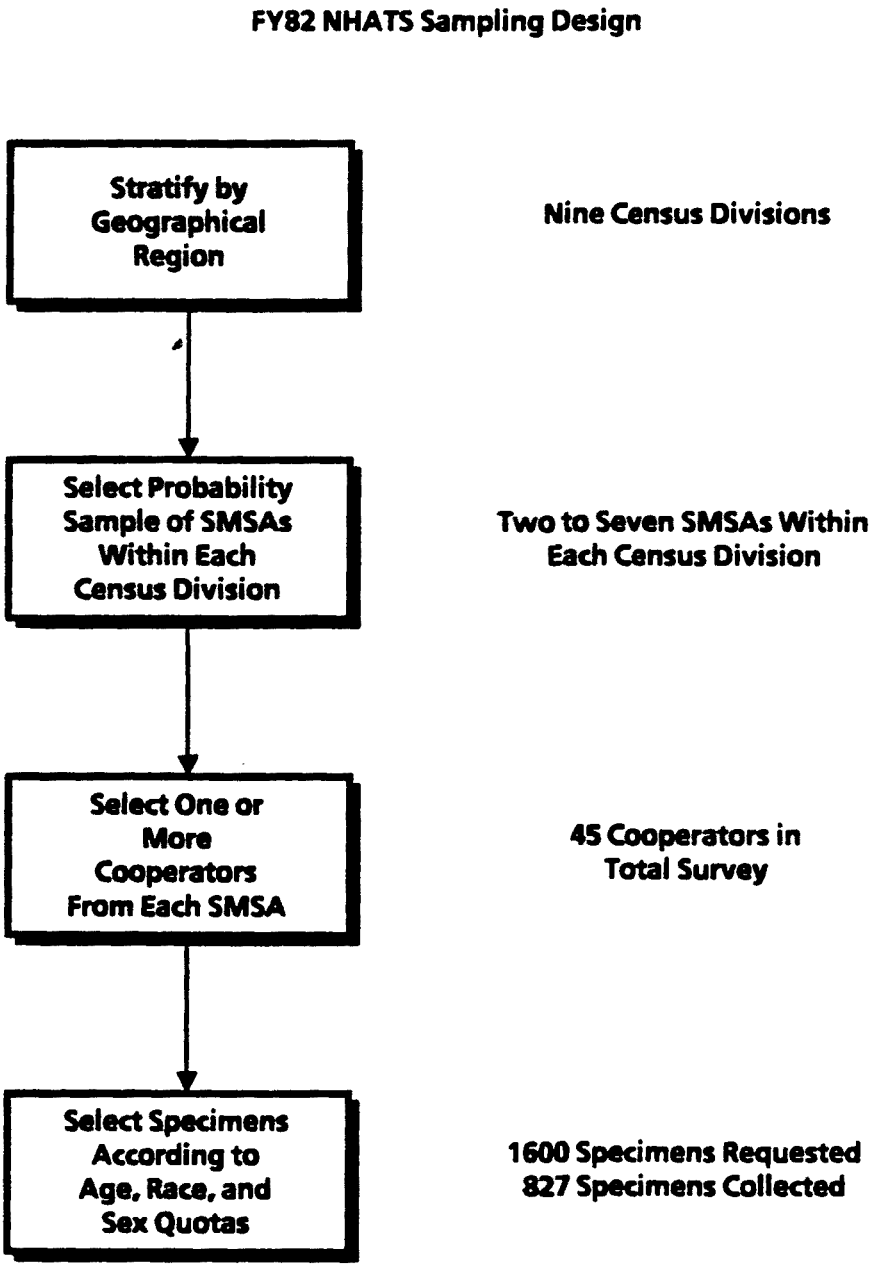


Figure 4-1. Overview of the FY82 NHATS Sampling Design

4.2 Compositing Design

The HRGC/MS analytical method and associated protocol required approximately 20 grams of tissue for each analysis sample. The amount of tissue available for each NHATS specimen ranged from two-tenths of a gram to thirty grams. Hence, it was necessary to composite individual specimens prior to chemical analysis. By requiring more tissue per analysis sample, the protocol also reduced the level of detection.

The variables Census division, age group, sex, and race group were selected as the design variables for the composite design. These four variables led to a structure of 108 cells (9 x 3 x 2 x 2 = 108). However, a design with 108 cells was not practical because of budgetary constraints and because of the target of twenty grams per sample. Census division and age group were chosen as the nesting variables. These variables created a structure of twenty-seven cells. The individual specimens were classified into these cells, and composites of specimens were created within this cell structure. The percentages of specimens in a composite from the sex and race groups were deliberately designed to vary over the set of composite samples. The variation in the sex and race percentages was designed to facilitate the estimation of the effect of sex and race on concentration levels.

The target for the composition of the composite samples was one gram apiece from twenty individual specimens. However, it was not possible to achieve the design in the preceding paragraph, to use all available FY82 specimens, and still meet the target of twenty specimens of one gram per composite. Moreover, as noted above, some specimens had weights as small as two-tenths of a gram. Therefore, the actual number of specimens in a composite, the weight of the composite, and the equality of individual specimen weights within a composite were allowed to vary over the set of composites.

A total of 763 specimens were assigned to the 46 composites dedicated to the semi-volatiles and dioxins and furans analyses. A total of 697 specimens were assigned to the 46 composites dedicated to the volatiles analysis. The geographic and demographic composition of the two specimen sets are shown in Table 4-1. The characteristics of the composite samples for the volatiles, semi-volatiles, and dioxins and furans analyses are listed in Appendix D.

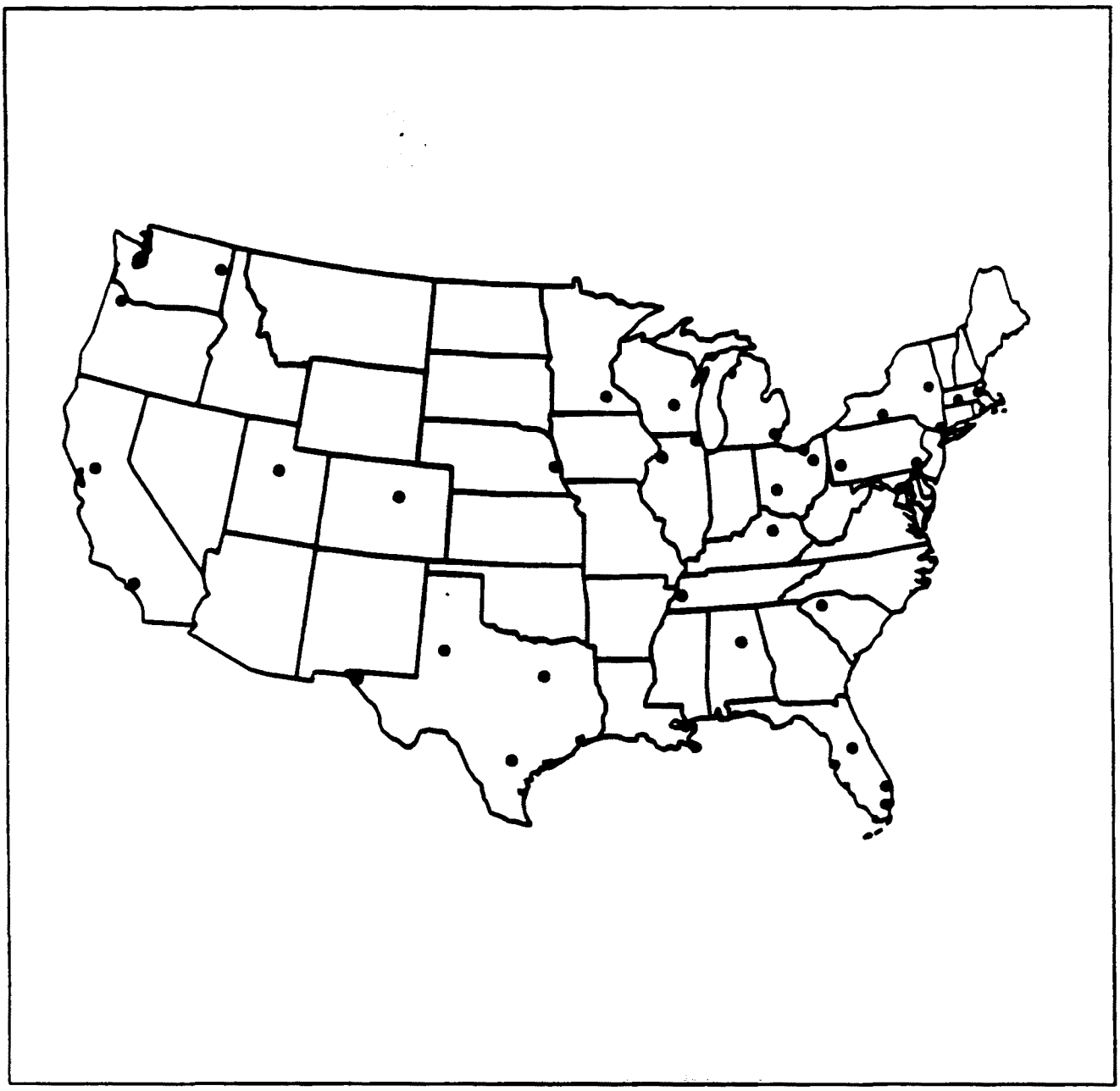


Figure 4-2. NHATS FY82 collection map.

Table 4-1. Geographic and Demographic Counts for Specimens

Category	Volatiles Specimens	Semi-volatiles, Dioxins and Furans Specimens	Requested Specimens
Census Region			
Northeast	161	166	320
North Central	188	206	480
South	295	331	520
West	53	60	280
Total	697	763	1,600
Age Group			
0-14 years	134	178	463
15-44 years	301	312	662
45 + years	262	273	475
Total	697	763	1,600
Sex			
Male	364	412	788
Female	333	351	812
Total	697	763	1,600
Race Group			
White	590	632	1,420
Non-White	107	131	180
Total	697	763	1,600

Note: The number of individual specimens comprising the composite samples used in analysis of semi-volatiles, dioxins, and furans was larger than the number of specimens in composites samples used to analyze volatile organic compounds. Since the composite samples used for analysis of semi-volatiles were formed first, several of the volatile organic composite samples contained fewer specimens.

5.0 SPECIMEN COLLECTION AND STORAGE

The 827 individual specimens collected for the Broad Scan Analysis Study were obtained by medical examiners and pathologists either during regularly scheduled surgical procedures, that is, from tissue excised for therapeutic or elective purposes, or as part of routine postmortem examinations. If the specimen was collected postmortem, the tissue was obtained from an unembalmed cadaver which had been dead for less than twenty-four (24) hours and had been kept under refrigeration during that time. The death should have been caused by sudden traumatic injury, such as cardiac arrest, car accident, or gunshot wound.

The following groups were excluded from data collection:

institutionalized individuals;

persons known to be occupationally exposed to toxic chemicals;

persons who died of pesticide poisoning; and

persons suffering from cachexia.

These guidelines were stipulated so that the levels of the substances detected in the specimens were a result of environmental exposure.

All NHATS cooperators in the selected SMSAs were provided with target quotas for specimen collection from age, sex and race groups. The cooperators were asked to obtain at least five grams of adipose tissue from each donor. The cooperators were asked to guard against contamination through contact with disinfectants, paraffins, plastics, preservatives, and solvents. After collection, the adipose tissue specimens were placed in glass jars frozen to -20° centigrade. These jars were packed on dry ice in insulated containers for transport and delivery to the Toxicant Analysis Center at Bay St. Louis, Mississippi. In September, 1983, the frozen specimens were transferred to Midwest Research Institute (MRI) in Kansas City, Missouri. At MRI, the specimens were placed in freezers maintained at a temperature of

-20° centigrade. The adipose tissue specimens were kept frozen during the transfer from the Toxicant Analysis Center to the Midwest Research Institute (USEPA 1986b).

All tissue specimens remaining after the completion of the FY82 analytical effort are stored at the Midwest Research Institute in Kansas City, Missouri. All remaining NHATS tissue specimens from 1970 to the present are stored at the same location. The specimens are kept frozen at a temperature of approximately -20 degrees centigrade.

At the time the FY82 Broad Scan Analysis was conducted and since that time, there has not been a comprehensive study to evaluate the stability of volatile organics in fatty tissues. Following the completion of the FY82 analytical effort, there have been studies by EPA to assess the stability of organochlorine pesticides and dioxins and furans in human adipose tissue. The issue of storage and stability for the NHATS is not fully resolved at this time.

6.0 CHEMICAL ANALYSIS PROCEDURES

Midwest Research Institute (MRI) conducted the chemical analysis of the FY82 composites. For the volatiles analysis, MRI developed a "dynamic headspace purge and trap system" to extract the volatile target compounds from the composite samples. The target compounds were directed into a Finnigan 9610 gas chromatograph and a Finnigan 4000 quadruple mass spectrometer for analysis. Target volatile compounds were identified by the response time of the primary characteristic ion relative to either a deuterated analog of the target compound or to the internal standard, bromochloropropane. The complete mass spectra at the appropriate points in time were reviewed to confirm the identification. The quantitation of the volatile compounds was carried out by comparison of peak areas for the compounds to the peak area for the associated deuterated counterpart, if one were available, or to the peak area for bromochloropropane, the internal standard for this analysis. (USEPA 1986b)

The deuterated compounds and bromochloropropane were added to the system by a ten milliliter syringe. This syringe was first filled with three milliliters of water free of volatile organics. The deuterated compounds and bromochloropropane were inserted into the ten milliliter syringe from a five microliter syringe. An additional two milliliters of water and one milliliter of air were drawn into the ten milliliter syringe, and the syringe was inverted several times to allow mixing. Finally, the contents of the ten milliliter syringe were transferred to the sample vessel in the "purge and trap" system. The sample vessel was tightly capped and allowed to remain at room temperature for thirty minutes before initiating the analysis. Refer to Table 6-1 for the quantitation standard associated with each of the target volatile compounds.

Table 6-1. Pairing of Target Analytes Versus Internal Quantitation Standards for Volatile Organic Compounds Analysis

Target Analyte	Internal Quantitation Standard
Benzene	
Benzene	d_6-Benzene
Substituted Benzenes	
Styrene	Bromochloropropane
Ethylphenol	d_{10}-Ethylbenzene
Alkyl Benzenes	
Toluene	d_8-Toluene
Ethylbenzene	d_{10}-Ethylbenzene
Xylene	d_{10}-p-Xylene
Chlorinated Benzenes	
Chlorobenzene	d_5-Chlorobenzene
1,2-Dichlorobenzene	d_4-1,4-Dichlorobenzene
1,4-Dichlorobenzene	d_4-1,4-Dichlorobenzene
Trihalomethanes	
Chloroform	d-Chloroform
Bromodichloromethane	Bromochloropropane
Dibromochloromethane	Bromochloropropane
Bromoform	Bromochloropropane
Halocarbons	
1,1,1-Trichloroethane	Bromochloropropane
1,1,2-Trichloroethane	Bromochloropropane
1,1,2,2-Tetrachloroethane	d_2-1,1,2,2-Tetrachloroethane
Tetrachloroethene	Bromochloropropane

For the semi-volatiles analysis, the composites went through an initial extraction step (see Figure 6-1). One percent (1%) of this extract was set aside to determine the percentage of extractable lipid tissue in the composite sample. The ninety-nine percent (99%) of the extract left underwent a gel permeation chromatographic step to separate the lipid tissue from the target compounds. After the gel permeation step, ten percent (10%) of the resulting extract was reserved for the dioxins and furans analysis. The ninety percent (90%) aliquot of the extract was partitioned through Florisil fractionation to create "fractions", each with different sets of target semi-volatile compounds. A sample from the fractions was injected to a Finnigan MAT 311A double focusing magnetic sector mass spectrometer for analysis. Target semi-volatile compounds were identified by the response time of the primary characteristic ion relative to the internal standard, anthracene-d_{10}. The ratios of the peak areas of two secondary ions to the peak area for the primary ion were computed to further verify the identification. Review of mass spectra at appropriate points in time was carried out to confirm identification. Quantitation of the semi-volatile target compounds was carried out by comparison of peak areas for the compounds to the peak area for anthracene-d_{10}, the internal standard for this analysis. (USEPA 1986c)

For the dioxins and furans analysis, the fractions obtained in the semi-volatiles analysis were recombined. These fractions represented the ninety percent aliquot mentioned in the preceding paragraph. The recombined fractions went through a further "clean up" step. The ten percent aliquot was subject to separate and different "clean up" step. The ninety percent aliquot was earmarked for analysis for the tetra- and penta-chloro dioxins and furans. The ten percent aliquot was earmarked for analysis for the hexa-, hepta-, and octa- chloro dioxins and furans. Although a number of exceptions were necessary, in general the analysis was carried out according to the plan for

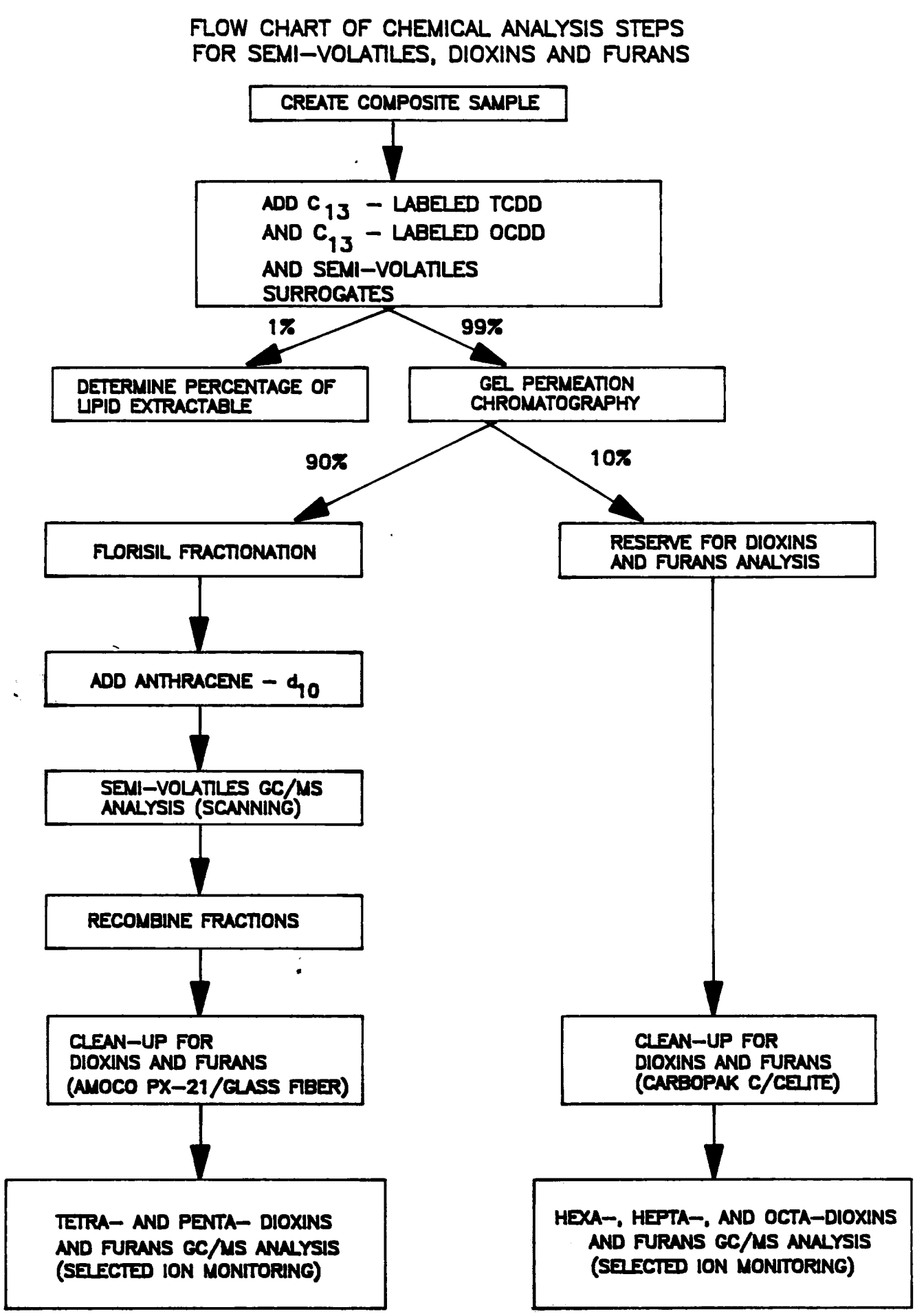


Figure 6–1. Chemical analysis steps for semi–volatiles, dioxins and furans.

the ninety and ten percent aliquots. Analysis was performed by a Kratos MS-50 double focusing mass spectrometer functioning in the Selected Ion Monitoring phase. Analysis of ash from an incinerator was used to determine the time frame during which dioxin and furan ions were likely to appear. If characteristic ions for dioxins and furans appeared in this time frame and theoretical ion ratios were achieved within certain limits, a dioxin or furan was identified. More specific identification of dioxin and furan chemicals was carried out through comparison of response times to selected internal standards. The quantitation of the tetra- and penta- chloro dioxins and furans was accomplished by comparison of peak areas of the target compounds to the peak area for carbon-13 labeled 2,3,7,8-TCDD. The quantitation of the hexa-, hepta-, and octa- compounds was accomplished through comparison of peak areas of the target compounds to the peak area for carbon-13 labeled OCDD. (USEPA 1986d)

7.0 DATA PREPARATION AND MANAGEMENT

Data were reported on 46 composite samples for the analysis of volatile organic compounds and 46 composite samples for the analysis of semi-volatile organic, dioxin, and furan compounds. Altogether, analyses were conducted on 57 compounds: 17 volatile organics, 30 semi-volatile organics, 5 dioxins and 5 furans.

Each concentration was reported in one of three categories:

- Not Detected (ND) if the analytical instrument response was below the limit of detection;
- Trace (TR) if the result was between the limit of detection and the limit of quantitation; and
- Positive Quantifiable (PQ) if results were above the limit of quantitation.

The limit of detection (LOD) is a threshold value below which the presence or absence of a compound cannot be determined. For this study the LOD was calculated as 2.5 times the estimated average background signal. The limit of quantitation (LOQ) is a threshold value below a detected compound cannot be accurately quantified. The LOQ was calculated as four (4) times the LOD. For positive quantifiable measurements, the actual concentration was reported. For readings that were either trace or not detected, the LOD was reported.

The reported concentrations were converted to the following concentrations:

actual concentration, if positive quantifiable;

$\frac{LOD + LOQ}{2}$, if trace; and

$\frac{LOD}{2}$, if not detected.

The data were stored in three Statistical Analysis System (SAS) data bases, one each for volatiles, semi-volatiles, and dioxins and furans on the National Computer Center IBM computer system in Research Triangle Park, North Carolina. Model fitting was performed using the Biomedical Statistical Software System, BMDP (Dixon 1981). The program BMDP3V, Mixed Model Analysis of Variance, was used to fit the model parameters. Output from BMDP was then entered into SAS to generate variance estimates.

8.0 STATISTICAL ANALYSIS APPROACH

8.1 Selection and Development of the Statistical Model

Since one of the objectives of the Broad Scan Analysis Study was to estimate average levels of toxic chemicals in the general, non-institutionalized U.S. population, it was necessary to derive information about population averages from the chemical analyses of the composite samples. This required an assumption relating the chemical level of a composite sample to the chemical levels of the individual specimens which comprised the composite sample. Average concentration levels for the demographic subpopulations, as well as for the nation, could then be estimated.

In developing the compositing design, it was first necessary to assume that the amount of a chemical in a composite sample was equal to the sum of the amounts contributed by each of the individual specimens that comprise the composite sample. This assumption is quite sound provided the compositing procedure does not result in any synergistic effect that chemically alters the specimens. Second, a review of the composites indicated that, in general, specimens in the same composite contributed approximately the same weight of tissue to that composite. Hence, it was assumed that the concentration of the composite sample equaled the average of the concentrations of the individual specimens that comprised it. Accordingly, the concentration level of the composite sample, calculated by simply dividing the total amount present by the total tissue mass of the composite sample, was assumed to equal the average of the concentrations of the individual specimens.

A statistical model was developed to permit data from the chemical analyses of composite samples to be used to estimate average chemical levels in the U.S. population and its various geographic and demographic subpopulations. The model postulates how the chemical level of a composite sample varies as a function of the geographic and demographic characteristics of the

individual specimens that comprise it. It assumes that the chemical level of any individual specimen is a function of the characteristics (i.e., Census region, age group, sex, and race) of the specimen donor. This implies that the chemical level of a composite sample is also a function of the geographic and demographic characteristics of the specimens that comprise it.

The model is a multiplicative one. It assumes that the effect of each geographic or demographic factor (e.g., Census region) is to proportionally increase or decrease the expected average concentration level of the composite sample. For example, if specimens from the North East Census region have an average concentration level that is ten percent higher than the overall average level, composite samples from the North East Census region will tend to have average concentration levels ten percent higher than composite samples from other regions of the country. The model further assumes that the standard deviation of the measured concentrations increases with the mean (Snedecor and Cochran 1967). This type of model is common for models used in the analysis of data on toxic pollutants, where the distribution of concentration levels is typically asymmetric or skewed (Gilbert 1987).

Since geography and age were the primary factors of interest to EPA, the composite design stipulated that individual specimens be composited within Census division and age group combinations. However, the effects of race and sex on average concentration levels were still a concern. The compositing design needed to provide information on these factors by purposefully mixing individual specimens of both race groups and sexes within a composite sample and varying the race and sex proportions across the composite samples. The race and sex makeups of the composite samples were either homogenous or mixed depending on the availability of individual specimens.

These concepts lead to the statistical model:

$$E(C_{ijk}) = M \quad CR_i \quad A_j \quad \exp(\beta_1 R_{ijk}) \exp(\beta_2 S_{ijk}) \qquad \text{(Equation 8-1)}$$

where

- $E(C_{ijk})$ is the expected average concentration level for the distribution of all composite samples formed from specimens collected from the ith Census region, jth age group, and having race and sex proportions given by R_{ijk} and S_{ijk}, respectively, with:

  R_{ijk} = proportion of white specimens minus the proportion of non-whites; and

  S_{ijk} = proportion of male specimens minus the proportion of females;

- M is the overall average effect of all demographic factors;

- CR_i is the effect of the ith Census region;

- A_j is the effect of the jth age group; and

- β_1 and β_2 are parameters which describe the relationship between the chemical level and the race and sex makeup of the composite sample.

The Census region, age group, sex, and race parameters of the model indicate how the average concentration levels differ across the various demographic subpopulations. The parameter estimates are interpreted as follows: if CR_i is greater than one, composite samples formed from specimens collected from the ith Census region will tend to have higher than average concentration levels. If CR_i is less than one, the concentration levels will tend to be lower than average. The age parameter A_j is interpreted similarly. For the race parameter, if β_1 is positive, the expected concentration level of the composite sample will increase as the proportion of white specimens increases. If β_1 is negative, the expected concentration level decreases as the proportion of whites decreases. The parameter

β_2 is interpreted similarly for sex. A positive value for β_2 indicates that higher expected concentration levels are associated with males. A negative value for β_2 indicates that lower concentration levels are associated with males or, conversely, that higher levels are associated with females.

It should be noted that variation in the number of specimens comprising the composites was not taken into account in estimating the model parameters; each composite was given equal weight in the computation. This does not create any bias in the estimated parameters or average concentrations, but may entail a loss of efficiency in the estimators. As a practical matter the increase in estimator variance due to not taking this into account is minimal, since the measurement error of a composite is independent of the number of its constituent specimens, and this is the dominant component of variance across composites.

Census region, rather than Census division, was used in the statistical estimation analysis procedures. Although Census division was used to specify the collection and compositing procedures, the nine Census divisions were collapsed into the four U.S. Census regions for statistical analysis purposes. This reduced the number of subpopulations and hence the number of model parameters that needed to be estimated. Originally 108 subpopulations (corresponding to the 9 Census divisions, 3 age groups, 2 sexes and 2 race groups) were defined. Collapsing resulted in a total of 48 target subpopulations. Only eight model parameters were then needed to estimate the 48 subpopulations, since the model estimated subpopulation averages without interaction effects. This was a reasonable number of model parameters given that 46 composite samples were available for each analysis set.

8.2 Application of the Statistical Model

The expected value of the concentration level expressed as a function of the effects of Census region, age, race, and sex is given by Equation 8-1. The assumed error structure of this model is given in Equation F-1 of Appendix F, incorporating into the model terms that explicitly reflect the variance components attributable to the complex NHATS sample design as well as measurement error.

The statistical model given in Equations 8-1 and F-1 is called a mixed model since it includes several factors whose effects on the composite concentration levels are considered to be random in addition to factors whose effects are considered to be systematic rather than random. The BMDP program P3V (Dixon, 1981) can perform mixed model regression analysis and was used to fit the Broad Scan analysis data. P3V uses maximum likelihood estimation (MLE) techniques to fit linear models under the assumption that the random factors are normally distributed. MLE techniques were used in the Broad Scan analysis because they are more flexible for fitting mixed models with unbalanced data.

Because the model in Equation F-1 assumed that the composite concentration levels have a lognormal distribution, the parameters of the model were estimated by taking logarithms (base e) on both sides of Equation F-1 and then fitting the logarithms of the measured concentration levels to the transformed model. The log-concentration model met the assumptions of the P3V analysis because the model was linear in the unknown parameters and the assumptions of Equation F-1 implied that the log-concentrations are normally distributed.

Goodness-of-fit tests on the residuals from the fitted model confirmed that the assumption of normality on the log-concentrations was reasonable in 19 of 22 compounds analyzed. A Chi-square goodness-of-fit test rejected the hypothesis of lognormality at the .10 level for three compounds, xylene, 2,3,4,7,8-PECDF and OCDD. In tests of 22 compounds, by chance

alone, it is expected that two compounds would have been rejected at a .10 level. The distribution of values for 2,3,4,7,8-PECDF had a significantly lighter right tail than a lognormal distribution. The distributions of values for xylene and OCDD had significantly heavier right tails than a lognormal distribution. Since the mean estimates generated by the model are fairly robust in the face of variability in distributional form, the model was used with these compounds as well.

Results from the P3V analysis included maximum likelihood estimates of all the parameters of the log-concentration model including estimates of the variances for the random factors log SMSA and log E. The output also included standard errors for all estimated parameters and statistical tests of significance.

Because the composite concentration levels were assumed to be lognormally distributed, a maximum likelihood estimate of the expected concentration level of any composite sample can be calculated by

$$\hat{E}(C_{ijk}) = e^{\hat{\log} M+\hat{\log} CR_i+\hat{\log} A_j+\hat{\beta}_1 \cdot R_{ijk}+\hat{\beta}_2 \cdot S_{ijk}+\frac{1}{2}(\hat{\sigma}^2_{SMSA}+\hat{\sigma}^2_E)} \qquad (8\text{-}2)$$

where each ^ denotes an MLE for the corresponding parameter.

Equation 8-2 was used to calculate an MLE of the average concentration level for each of the 48 demographic subpopulations defined by the 4 Census regions, 3 age groups, 2 race groups, and 2 sexes. Each MLE was obtained by substituting into Equation 8-2 estimates for the corresponding Census region and age group effects and setting the race proportion, R_{ijk}, equal to either +1 (to indicate an all white subpopulation) or -1 (all non-white subpopulation), and setting the sex proportion, S_{ijk}, equal to either +1 (all male subpopulation) or -1 (all female subpopulation). Although these MLEs are explicitly estimates of average concentration levels of composite samples, the estimates are also MLEs for average concentration levels of

individual specimens. This is because the expected value of the average of random variables with identical means (in this case, the concentration level of a composite formed entirely from specimens from a single demographic subpopulation) is the same as the expected value of the individual random variables (in this case, the concentration levels of specimens from that demographic subpopulation).

8.3 Statistical Estimation of Average Concentration Levels for the Entire Nation and Various Subpopulations

The estimated average concentration levels for the 48 target subpopulations were used to construct estimates of average levels for other subpopulations of interest. Of particular interest were the estimates for each Census region, age group, race group, and sex, as well as estimates for the entire nation. These estimates were calculated as weighted averages of the individual 48 subpopulation estimates, where the weights were proportional to the population of each target subpopulation. For example, the estimated average concentration level for the ith Census region was calculated as:

$$\hat{\mu}_{i...} = \Sigma^{3}_{j=1} \quad \Sigma^{2}_{l=1} \quad \Sigma^{2}_{m=1} \quad W_{ijlm} \cdot \hat{\mu}_{ijlm}, \qquad \text{(Equation 8-3)}$$

where

W_{ijlm} is the population proportion for the jth age group, lth race group, and mth sex group relative to the total ith Census Region, and

$\hat{\mu}_{ijlm}$ is the estimated average concentration level from Section 8.2 for the respective subpopulation.

This procedure involves summing the weighted average concentration level estimates for each of the twelve subpopulations within the Census Region. The national estimate was obtained by summing the weighted estimates over all 48 target subpopulations.

8.4 Significance Testing of Differences Between Subpopulations

Significance testing was conducted to determine whether any significant differences existed among the levels of any of the geographic or demographic factors (i.e., Census region, age group, race group, or sex). The results of the model fitting and parameter estimation were used to test the following hypotheses concerning the parameters estimated in Equation 8-1:

Ho:	$CR_i=1$ for all i=1,2,3,4	versus Ha:	$CR_i \neq 1$, for some i
Ho:	$A_j=1$, for all j=1,2,3	versus Ha:	$A_j \neq 1$, for some j
Ho:	$\beta_1=0$	versus Ha:	$\beta_1 \neq 0$
Ho:	$\beta_2=0$	versus Ha:	$\beta_2 \neq 0$

Each of these tests was conducted on the model parameters to determine whether the corresponding factor had a significant effect on concentration levels. The results of the significance tests were presented in Table 2-4.

8.5 Detection and Exclusion of Outliers Among PECDD Measurements

The two largest measured values of PECDD in the sample of composites were determined to be outliers and excluded from the data used to estimate average concentration and test hypotheses. The decision to declare them outliers was based both on evidence of internal inconsistency with the rest of the distribution, and the implausibility of their magnitude when compared to external sources of PECDD concentration data.

First, the two largest PECDD concentration measurements of 5300 and 5200 pg/g were each more than six times the next highest value. For no other chemical detected in the study was there an interval as great between the maximum values and the rest of the distribution. The existence of such an extremely large gap in a measurement distribution is an indication of the probable presence of outliers.

Second, for the other chemicals the arithmetic averages of the composite measurements by age group were close to the model-based, maximum-likelihood estimates, a result which would be expected for large samples if the measurements were in fact identically, lognormally distributed within age group. However, approximate equality between the arithmetic averages and the model estimates of concentration was not observed for PECDD when the two largest values were included, but was when they were excluded. This is further indication that these large values were generated from a contaminant distribution, rather than the distribution associated with the other PECDD data.

Finally, other data sources have reported average concentrations of PECDD in the 20 pg/g range, with maximum concentrations that are almost two orders of magnitude less than the two suspect outliers. Since the Broad Scan composite measurements are themselves averages of the concentrations of their constituent specimens they should tend to cluster around population means, and it is therefore extremely implausible that they would have values as high as 5000 pg/g.

The effect on concentration estimates and hypothesis tests due to excluding the two outliers is shown in Table 8.1.

8.6 Concentration Estimates and Hypothesis Tests for Total Equivalent DDT

Levels of Total Equivalent DDT (TEDDT) can be estimated from the concentrations of the congeners in the DDE, DDT, and DDD families, through the following formula:

$$\text{TEDDT} = \text{p,p'-DDT} + \text{o,p'-DDT} + 1.114\ (\text{o,p'-DDE} + \text{p,p'-DDE} + \text{o,p'-DDD} + \text{p,p'-DDD})$$

Of the six chemicals appearing in the formula only p,p'-DDT and p,p'-DDE were found to have detectable levels in the analyzed

Table 8-1. Comparison of Average Concentration Estimates and Significance Test Results for 1,2,3,7,8-PECDD Including, and Excluding Outliers

	Estimate with Two Outliers[1]	
	Included	Excluded
	Average Concentration and Relative Standard Error[2]	
Nation	190 (43)	75 (23)
Census Region		
NE	420 (61)	120 (39)
NC	170 (54)	62 (34)
S	100 (50)	60 (30)
W	130 (70)	73 (42)
Age Group		
0-14 yrs	200 (53)	54 (30)
15-44	290 (48)	130 (27)
45+	44 (56)	11 (31)
Race Group		
White	210 (44)	83 (24)
Non-White	91 (78)	39 (46)
Sex		
Male	140 (55)	100 (34)
Female	240 (62)	49 (39)
	Significance Test p-Value	
Census region	.214	.464
Age	.001	.000
Race	.261	.102
Sex	.505	.230

[1] Outliers are composite IDs 82858 and 82851

[2] Concentration is in units of pg/g. Relative standard errors are shown in parentheses.

composites. If zero is substituted for the non-detected congeners the following approximate formula results:

TEDDT = p,p'-DDT + 1.114(p,p'-DDE).

There are two possible ways to apply this formula to the Broad Scan data to estimate the average concentration of Total Equivalent DDT for the nation and for demographic subgroups: (1) TEDDT is first estimated for each composite by substituting the values of p,p'-DDE and p,p'-DDT into the formula, and the resulting composite-level data are then analyzed by the multiplicative model to yield average concentration estimates for subgroups; (2) the average concentrations of p,p'-DDE and p,p'-DDT are first estimated for each subgroup by the multiplicative model, and these subgroup estimates are then substituted into the formula to yield average concentration estimates of TEDDT.

Although the defining equation implies that the population concentration of TEDDT must be greater than or equal to the concentrations of p,p'-DDT and p,p'-DDE, the estimated values produced by approach (1) may not satisfy this constraint because the multiplicative model is a nonlinear function of the composite measurements. Approach (2) has the desirable property of producing estimates that always satisfy the constraint, and for this reason was used to generate the average concentration estimates of TEDDT shown in this report. The associated standard error (SE) for the estimated average concentration of TEDDT was estimated as:

SE(TEDDT) = SE(p,p'-DDT) + 1.114 SE(p,p'-DDE).

To test hypotheses on the significance of effects due to census region, age group, sex, or race group on TEDDT levels, an analysis of composite-level data was necessary, and for this purpose individual composite estimates of TEDDT were computed by substituting the concentrations of p,p'-DDT and p,p'-DDE into the

formula for TEDDT. Hypothesis testing was then carried out for the derived values of TEDDT in the same manner as was done for the chemicals that were measured directly.

When TEDDT is estimated for composites, the problem arises of what values to substitute in the formula when one or both of the components p,p'-DDE and p,p'-DDT are not detected. A comparison was made of the results obtained from the following two alternative approaches: (a) if for a given composite either compound is not detected, a value of zero is substituted into the formula, and if the derived concentration of TEDDT is zero after this substitution, it is replaced with an LOD/2 value of .005; (b) if one or both of the components are not detected in a given composite, the LOD/2 values associated with the non-detected compounds are substituted into the formula. Since very little difference was observed between these two approaches, method (b) was adopted for this study because it was consistent with the statistical treatment of the directly measured compounds.

Table 8.2 compares estimation and hypothesis test results for the alternative ways of computing TEDDT.

Table 8-2. Comparison of Average Concentration Estimates and Significance Test Results for Alternative Ways of Computing Total Equivalent DDT (TEDDT)

	TEDDT Formula Applied at:		
	Composite Level Using Method[1]:		Subgroup Level
	(a)	(b)	
	Average Concentration and Relative Standard Error[2]		
Nation	1.4 (19)	1.4 (19)	1.6 (26)
Census Region			
NE	1.2 (29)	1.2 (29)	1.4 (37)
NC	0.74 (29)	0.75 (29)	0.87 (33)
S	1.9 (27)	1.9 (27)	2.4 (33)
W	1.4 (38)	1.4 (38)	1.7 (47)
Age Group			
0-14 yrs	0.7 (27)	0.7 (27)	0.98 (36)
15-44	1.2 (27)	1.2 (27)	1.7 (32)
45+	2.0 (25)	2.0 (25)	2.1 (30)
Race Group			
White	1.5 (21)	1.5 (21)	1.7 (27)
Non-White	0.85 (39)	0.85 (39)	1.1 (52)
Sex			
Male	1.9 (30)	1.9 (30)	2.4 (33)
Female	0.87 (36)	0.86 (36)	0.93 (46)
	Significance Test p-Value		
Census	0.159	0.166	-
Age	0.010	0.010	-
Race	0.256	0.254	-
Sex	0.152	0.141	-

[1] Method (a) replaces non-detected p,p'-DDE or p,p'-DDT with zero in the formula for TEDDT; if the resulting value of TEDDT is zero it is replaced with the value .005. Method (b) replaces non-detected p,p'-DDE and p,p'-DDT with their LOD/2 values.

[2] Lipid-adjusted weight in parts per million (μg/g). Relative standard errors are shown in parenthesis.

8.7 Considerations in the Use of the Broad Scan Analysis Study Statistical Analysis Approach

There are two general classes of assumptions that have been made in the statistical estimation approach used in the Broad Scan Study: assumptions about the form of the statistical model used in the analysis, and assumptions about the characteristics of the sample of specimens and composites.

The first set of assumptions is embodied in Equations 8-1 and F-1, which describe the relationship between the concentration level of a composite sample and the demographic characteristics of the individual specimens which comprise it. The model assumes the effect of each demographic factor was multiplicative, rather than additive, that the factors acted independently without interactions, and that the composite concentration levels have a lognormal distribution. Orders of magnitude differences between some of the composite concentration levels suggested the use of such a model and normal probability plots and goodness-of-fit tests on the log-concentration data confirmed the reasonableness of this assumption. A model which assumes that the composite concentration levels have a normal distribution might have seemed appropriate since each composite concentration level was essentially an average of concentration levels of individual specimens. However, the measurement error, which was likely a substantial component of the distribution of measured concentration levels, was not averaged since each composite was analyzed only once. Measurement error distributions often tend to be skewed and could have accounted for the fact that a lognormal model fit the composite concentration level data better than a normal model. Note that the standard procedure of replacing non-detects by LOD/2 and trace observations by (LOD+LOQ)/2 (LOD is the analytical procedure's limit of detection and LOQ is the limit of quantitation), may create artificial non-lognormal distributions of concentrations, if for example, all the LODs were

approximately equal. However, this seems not to have occurred, and the statistical tests that were performed on the model residuals did not reject the hypothesis of lognormality for 19 of the 22 chemicals.

The model used in this report is a main effects model with eight parameters. The model did not include interaction effects because of budget limitations, because of the need to make inferences for a large number of chemicals, and because the number of model parameters would have exceeded the number of observations. The discussion in Section 2.1.4 suggests consideration be given to a model which includes two-way interactions. Including all two-way interactions would increase the number of model parameters to twenty-five. The problem of interactions is one that would require funding for development and testing.

Several important assumptions have been made about the sample of tissue specimens constituting the NHATS data. First, because practical considerations dictated that tissue sampling had to be limited to surgical patients and autopsied cadavers, it was assumed that the average concentration levels in this sampling population would be approximately equal to the average concentration levels in the U.S. population. Second, it was assumed that nonresponse due to incomplete fulfillment of planned quotas by participating medical examiners and pathologists would not significantly bias the results. Finally, it was assumed that the concentration of a compound in a composite would be equal to the average of the concentrations of the constituent specimens; that is, the compounds retain their identities, and synergistic effects do not occur between chemicals as a result of the compositing. This assumption was necessary to justify equating the estimated average concentration level of a homogeneous composite population to the average concentration level of the individual specimen population.

It should be noted that if it were feasible to carry out a probability sample survey to collect adipose tissue from the general population EPA would prefer that approach. The NHATS approach is a practical solution to the problem of obtaining tissue samples. Its potential biases are mitigated by: 1) selection of areas of the country by a probability mechanism; 2) use of quotas based on population statistics for donor selection; 3) program preference for specimens from donors whose death was sudden and unexpected; 4) use of population statistics to weight average concentrations; and 5) emphasis on comparisons across years, which of course is not possible in this report.

Several projects are currently underway to improve the chemical and statistical approaches employed in the NHATS program. An alternative statistical model has been developed that represents a composite concentration as a linear function of the demographic and geographic descriptors of the constituent specimens. This additive model has been evaluated in comparison to the multiplicative model and found to perform well. The ultimate objective is to replace the multiplicative with the additive model so that prevalence as well as average concentration levels can be estimated from the composited NHATS data. The results and status of this project are described in the draft EPA report, "Statistical Methods for Analyzing NHATS Composite Sample Data--Evaluation of Multiplicative and Additive Model Methodologies."

Significant changes continue to be made in the chemical analysis approach, especially in the methods of calibration, quantitative procedures, qualitative identification, internal standards, and use of spiked and unspiked samples. These modifications have been implemented in the FY87 and FY86 surveys, and are expected to provide demonstrated improvements in data quality.

Work is also underway to determine what effect the change in chemical analysis methods had on the NHATS estimates of average concentration levels. Composite samples from the FY84 NHATS survey were analyzed by both the old chemical analysis method--packed column gas chromatography/electron capture detector (PGC/ECD)--and the new method--high resolution gas chromatography/mass spectrometry (HRGC/MS)--to determine their comparability. A report on this project is expected by the end of the year.

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APPENDIX A

STATISTICAL ESTIMATES

Table A-1. Weighted Estimates (and Their Associated Standard Errors) of the Average Concentration Levels for the Entire Nation and for Each Census Region, Age Group, Race Group, and Sex

Compound	Entire Nation	Census Region[1]				Age Groups			Race Groups		Sex	
		NE	NC	S	W	6-14 yrs	15-44 yrs	45+ yrs	White	Non-White	Male	Female
Population Percentages		22	26	33	19	23	46	31	83	17	49	51
VOLATILE ORGANICS[2]												
Benzene												
Benzene	0.014 (0.0016)[3]	0.018 (0.0038)	0.010 (0.0020)	0.010 (0.0017)	0.019 (0.0050)	0.016 (0.0029)	0.014 (0.0024)	0.012 (0.0020)	0.015 (0.0018)	0.0096 (0.0026)	0.017 (0.0035)	0.010 (0.0022)
Substituted Benzenes												
Styrene	0.096 (0.019)	0.095 (0.036)	0.059 (0.022)	0.10 (0.032)	0.18 (0.054)	0.12 (0.028)	0.10 (0.028)	0.075 (0.017)	0.095 (0.020)	0.10 (0.033)	0.14 (0.035)	0.050 (0.013)
Ethylphenol	0.085 (0.022)	0.13 (0.061)	0.029 (0.013)	0.090 (0.034)	0.10 (0.053)	0.17 (0.058)	0.065 (0.020)	0.050 (0.016)	0.079 (0.021)	0.12 (0.055)	0.096 (0.033)	0.076 (0.028)
Alkyl Benzenes												
Toluene	0.046 (0.017)	0.023 (0.012)	0.062 (0.029)	0.046 (0.022)	0.051 (0.030)	0.036 (0.017)	0.056 (0.024)	0.038 (0.017)	0.053 (0.020)	0.013 (0.003)	0.080 (0.036)	0.014 (0.0065)
Ethylbenzene	0.077 (0.032)	0.072 (0.052)	0.076 (0.054)	0.10 (0.061)	0.039 (0.029)	0.063 (0.029)	0.090 (0.040)	0.068 (0.030)	0.078 (0.033)	0.070 (0.040)	0.11 (0.051)	0.048 (0.023)
Xylene	0.30 (0.12)	0.20 (0.14)	0.25 (0.18)	0.49 (0.29)	0.12 (0.084)	0.27 (0.12)	0.33 (0.14)	0.26 (0.11)	0.31 (0.13)	0.23 (0.12)	0.43 (0.19)	0.17 (0.077)
Chlorinated Benzenes												
Chlorobenzene	0.0044 (0.0007)	0.0033 (0.0010)	0.0025 (0.0006)	0.0072 (0.0017)	0.0030 (0.0010)	0.0038 (0.0009)	0.0051 (0.0010)	0.0037 (0.0008)	0.0048 (0.0008)	0.0018 (0.0005)	0.0057 (0.0013)	0.0032 (0.0008)
1,4-Dichlorobenzene	0.12 (0.021)	0.076 (0.024)	0.11 (0.032)	0.20 (0.047)	0.052 (0.020)	0.12 (0.033)	0.13 (0.031)	0.11 (0.027)	0.11 (0.021)	0.19 (0.072)	0.13 (0.039)	0.11 (0.035)

[1]NE = North East S = South
NC = North Central W = West

[2]Volatile average concentrations are expressed in wet weight in parts per million (μg/g).

[3]Standard error expressed in the same units as the average concentration.

Table A-1. (continued)

Compound	Entire Nation	Census Region				Age Groups			Race Groups		Sex	
		NE	NC	S	W	0-14 yrs	15-44 yrs	45+ yrs	White	Non-White	Male	Female
Population Percentages		22	26	33	19	23	46	31	83	17	49	51
VOLATILE ORGANICS[2]												
Trihalomethanes												
Chloroform	0.047 (0.020)	0.021 (0.014)	0.041 (0.026)	0.049 (0.027)	0.081 (0.058)	0.053 (0.027)	0.053 (0.028)	0.033 (0.016)	0.046 (0.020)	0.052 (0.036)	0.081 (0.039)	0.014 (0.0075)
Halocarbons												
Tetrachloroethene	0.027 (0.0079)	0.041 (0.019)	0.044 (0.019)	0.016 (0.0058)	0.0086 (0.0045)	0.017 (0.0064)	0.030 (0.011)	0.031 (0.011)	0.029 (0.0087)	0.019 (0.0098)	0.044 (0.016)	0.011 (0.0044)
SEMI-VOLATILE ORGANICS[4]												
PCBs												
Total PCBs	0.33 (0.078)	0.31 (0.13)	0.23 (0.085)	0.51 (0.17)	0.20 (0.11)	0.071 (0.024)	0.30 (0.093)	0.57 (0.17)	0.32 (0.084)	0.41 (0.19)	0.35 (0.12)	0.32 (0.13)
Organochlorine Pesticides												
Beta-BHC	0.19 (0.029)	0.19 (0.047)	0.11 (0.023)	0.31 (0.068)	0.097 (0.032)	0.071 (0.016)	0.17 (0.033)	0.31 (0.065)	0.21 (0.036)	0.068 (0.026)	0.19 (0.044)	0.19 (0.058)
p,p'-DDE	1.3 (0.30)	1.1 (0.38)	0.73 (0.23)	1.9 (0.60)	1.3 (0.60)	0.75 (0.24)	1.3 (0.39)	1.8 (0.52)	1.4 (0.35)	0.73 (0.32)	2.0 (0.65)	0.64 (0.26)
Total DDT	1.6 (0.41)	1.4 (0.52)	0.87 (0.29)	2.4 (0.79)	1.7 (0.80)	0.98 (0.35)	1.7 (0.54)	2.1 (0.64)	1.7 (0.46)	1.1 (0.57)	2.4 (0.79)	0.93 (0.43)
Phthalates												
Butyl benzyl phthalate	0.39 (0.19)	0.11 (0.083)	0.45 (0.31)	0.62 (0.41)	0.21 (0.18)	0.46 (0.31)	0.31 (0.16)	0.46 (0.28)	0.45 (0.23)	0.095 (0.080)	0.54 (0.36)	0.24 (0.17)

[2]Volatile average concentrations are expressed in wet weight inparts per million (μg/g).

[4]Semi-volatile average concentrations are lipid adjusted weights expressed in parts per million (μg/g).

Table A-1. (continued)

Compound	Entire Nation	Census Region				Age Groups			Race Groups		Sex	
		NE	NC	S	W	0-14 yrs	15-44 yrs	45+ yrs	White	Non-White	Male	Female
Population Percentages		22	28	33	19	28	46	31	83	17	49	51
DIOXINS[5]												
2,3,7,8-TCDD	6.1 (0.76)	6.6 (1.6)	7.1 (1.6)	6.1 (1.2)	4.1 (1.2)	4.1 (0.80)	7.8 (1.3)	5.0 (0.96)	6.4 (0.90)	4.3 (1.3)	6.7 (1.4)	5.5 (1.3)
1,2,3,7,8-PECDD	75 (17)	120 (45)	62 (21)	60 (18)	73 (30)	54 (16)	130 (34)	11 (3.4)	83 (20)	39 (18)	100 (35)	49 (19)
HXCDD	120 (24)	160 (50)	110 (30)	100 (26)	120 (47)	92 (27)	120 (32)	130 (33)	120 (25)	110 (47)	70 (19)	160 (50)
1,2,3,4,7,8,9-HPCDD	140 (27)	160 (52)	180 (51)	110 (27)	100 (41)	89 (26)	150 (38)	150 (39)	140 (28)	140 (60)	89 (24)	180 (56)
OCDD	820 (100)	750 (180)	920 (190)	780 (140)	850 (250)	410 (85)	920 (170)	990 (180)	810 (110)	880 (280)	760 (160)	880 (210)
FURANS[5]												
2,3,4,7,8-PECDF	40 (8.7)	49 (15)	38 (9.8)	30 (7.1)	52 (18)	38 (8.9)	53 (12)	25 (6.0)	44 (7.8)	22 (8.5)	51 (14)	30 (9.3)
HXCDF	24 (3.7)	20 (5.0)	29 (6.3)	24 (4.7)	23 (6.8)	18 (4.1)	27 (5.1)	26 (5.0)	26 (4.1)	18 (5.6)	13 (2.7)	35 (7.9)
1,2,3,4,6,7,8-HPCDF	21 (2.6)	18 (4.3)	26 (5.4)	22 (3.8)	15 (4.3)	19 (4.0)	22 (4.0)	20 (3.5)	20 (2.8)	25 (7.6)	16 (3.3)	25 (5.8)

[5]Dioxin and furan average concentrations are lipid adjusted weights expressed in parts per trillion (pg/g).

APPENDIX B

PERCENTAGE DETECTED DATA

Table B-1. Volatile Organic Chemicals Identified in the Broad Scan Analysis Study

Class	Chemical	CAS Number	Number of Composite Sample Measurements*	Percentage Detected
Benzene	Benzene	71-43-2	46	96
Substituted Benzenes	Styrene	100-42-5	46	100
	Ethylphenol	25429-37-2	46	100
Alkyl Benzenes	Toluene	108-88-3	46	93
	Ethylbenzene	100-41-4	46	96
	Xylene	1330-20-7	46	100
Chlorinated Benzenes	Chlorobenzene	108-90-7	46	96
	1,2-Dichlorobenzene	95-50-1	46	63
	1,4-Dichlorobenzene	106-46-7	46	100
Trihalomethanes	Chloroform	67-66-3	46	78
	Bromodichloromethane	75-27-4	46	0
	Dibromochloromethane	124-48-1	46	0
	Bromoform	75-25-2	46	0
Halocarbons	1,1,1-Trichloroethane	71-55-6	46	46
	1,1,2-Trichloroethane	79-00-5	46	0
	1,1,2,2-Tetrachloroethane	79-34-5	46	9
	Tetrachloroethene	127-18-4	46	61

* The number of composite samples measurements (out of a possible 46) may vary per compound due to chemical problems in retrieving or summarizing the data.

Table B-2. Semi-Volatile Organic Chemicals Identified in the Broad Scan Analysis Study

Class	Chemical	CAS Number	Number of Composite Sample Measurements*	Percentage Detected
PCBs	PCBs	1336-36-3	44	86
	Trichlorobiphenyl	25323-68-6	44	23
	Tetrachlorobiphenyl	26914-33-8	44	55
	Pentachlorobiphenyl	25429-29-2	44	73
	Hexachlorobiphenyl	26601-64-9	44	75
	Heptachlorobiphenyl	28655-71-2	44	52
	Octachlorobiphenyl	31472-83-8	44	41
	Nonachlorobiphenyl	53742-07-7	44	14
	Decachlorobiphenyl	2051-24-3	44	7
Organochlorine Pesticides	Beta-BHC	319-85-7	43	93
	p,p'-DDE	72-55-9	45	100
	p,p'-DDT	50-29-3	37	68
	Mirex	2385-85-5	43	14
	trans-Nonachlor	39765-80-5	42	57
	Heptachlor Epoxide	1024-57-3	43	70
	Dieldrin	60-57-1	43	33
Aromatics	Naphthalene	91-20-3	43	42
	Phenanthrene	85-01-8	43	14
	Pyrene	129-00-0	43	9
Chlorinated Benzenes	1,2-Dichlorobenzene	95-50-1	43	12
	1,2,4-Trichlorobenzene	120-82-1	45	4
	Pentachlorobenzene	608-93-5	44	9
	Hexachlorobenzene	118-74-1	43	79
Phthalates	Diethyl Phthalate	84-66-2	42	48
	Di-n-butyl Phthalate	84-74-2	42	50
	Diethyl Hexyl Phthalate	117-81-7	42	33
	Butyl Benzyl Phthalate	85-68-7	42	74
Phosphates	Triphenyl Phosphate	115-86-6	42	38
	Tributyl Phosphate	126-73-8	43	2
	Tris (2-Chloroethyl) Phosphate	115-96-8	46	2

* The number of composite samples measurements (out of a possible 46) may vary per compound due to chemical problems in retrieving or summarizing the data. Several composite samples were not analyzed due to the unavailability of sufficient tissue mass.

Table B-3. Dioxins and Furans Identified in the Broad Scan Analysis Study

Class	Chemical	CAS Number	Number of Composite Sample Measurements*	Percentage Detected
Dioxins	2,3,7,8-TCDD	1746-01-6	43	74
	1,2,3,7,8-PECDD	40321-76-4	43	93
	HXCDD	34465-46-8	45	98
	1,2,3,4,7,8,9-HPCDD	35822-46-9	45	98
	OCDD	3268-87-9	45	100
Furans	2,3,7,8-TCDF	51207-31-9	43	26
	2,3,4,7,8-PECDF	57117-31-4	43	88
	HXCDF	55684-94-1	45	71
	1,2,3,4,6,7,8-HPCDF	67562-39-4	45	93
	OCDF	39001-02-0	45	40

* The number of composite samples measurements (out of a possible 46) may vary per compound due to chemical problems in retrieving or summarizing the data. Several composite samples were not analyzed due to the unavailability of sufficient tissue mass. Additionally, a measurement for several composite samples could not be calculated for some dioxins and furans due to low response observed for the internal standard used in the analysis procedures.

APPENDIX C

FY82 NHATS SAMPLING DESIGN SMSAs

Table C-1. SMSAs Selected for the FY82 NHATS Sample

Census Division	SMSA
New England	Springfield, MA
	Boston, MA
Middle Atlantic	Albany, NY
	New York, NY (2)
	Binghamton, NY
	Philadelphia, PA
	Pittsburgh, PA
South Atlantic	Washington, DC
	Norfolk, VA
	Orlando,FL
	Ft. Lauderdale, FL
	Greenville, SC
	Miami, FL
East South Central	Memphis, TN
	Lexington, KY
	Birmingham, AL
East North Central	Detroit, MI (2)
	Cleveland, OH
	Dayton, OH
	Akron, OH
	Chicago, IL (2)
	Madison, WI
	Moline, IL
West North Central	Rochester, MN
	Omaha, NE (2)
West South Central	Lubbock, TX
	El Paso, TX
	San Antonio, TX
	Dallas, TX
Mountain	Salt Lake City, UT
	Denver, CO

Table C-1. (Continued)

Census Division	SMSA
Pacific	Sacramento, CA Los Angeles, CA (2) Portland, OR Spokane, WA

(2) Indicates a double collection site. A double collection site is an SMSA whose population relative to its Census Division population is so large that its proper representation in the sample required it to be selected twice.

APPENDIX D

BROAD SCAN ANALYSIS STUDY COMPOSITING DESIGN

Table D-1. Demographic Characteristics for Each Broad Scan Analysis Study Composite Sample - Volatile Analysis

Census Regions	Census Divisions	Age Groups***	Composite Number	Number of Specimens	Percent White	Percent Male	Tissue Mass (g)
NC	ENC	1	1	12	83.3	100.0	12.7
NC	ENC	1	2	16	75.0	0.0	17.3
NC	ENC	2	1	19	94.7	47.4	20.8
NC	ENC	2	2	19	89.5	42.1	21.1
NC	ENC	3	1	18	94.4	55.6	18.6
NC	ENC	3	2	16	93.8	62.5	22.6
NC	ENC	3	3	13	100.0	46.2	21.4
NC	WNC	1	1	10	90.0	50.0	18.9
NC	WNC	2	1	17	100.0	64.7	21.6
NC	WNC	3	1	15	93.3	66.0	21.6
NC	WNC	3	2	15	93.3	53.3	18.3
NE	MA	1	1	7	100.0	71.4	20.3
NE	MA	1	2	12	83.3	58.3	18.1
NE	MA	2	1	24	83.3	50.0	25.0
NE	MA	2	2	22	86.4	54.5	25.3
NE	MA	3	1	20	95.0	50.0	16.3
NE	MA	3	2	20	85.0	40.0	17.8
NE	NE	1	1	16	87.5	56.3	20.0
NE	NE	2	1	21	95.2	57.1	23.6
NE	NE	3	1	19	100.0	47.4	25.5
S	ESC	1	1	25	88.0	52.0	25.6
S	ESC	2	1	16	87.5	100.0	19.0
S	ESC	2	2	17	94.1	0.0	24.3
S	ESC	3	1	17	100.0	52.9	20.5
S	ESC	3	2	9	0.0	55.6	19.3
S	SA	1	1	12	100.0	50.0	12.6
S	SA	1	2	11	0.0	63.6	16.7
S	SA	2	1	24	100.0	100.0	22.0
S	SA	2	2	22	100.0	0.0	18.7
S	SA	2	3	13	0.0	100.0	16.1
S	SA	2	4	12	0.0	8.3	17.0
S	SA	3	1	21	100.0	100.0	15.4
S	SA	3	2	21	100.0	0.0	23.2
S	SA	3	3	7	0.0	100.0	13.0
S	SA	3	4	3	0.0	0.0	11.0
S	WSC	1	1	5	100.0	40.0	6.0
S	WSC	2	1	19	78.9	52.0	22.4
S	WSC	2	2	18	83.3	50.0	21.9
S	WSC	3	1	23	87.0	43.5	22.0
W	MO	1	1	2	100.0	50.0	5.1
W	MO	2	1	12	100.0	50.3	18.0
W	MO	3	1	10	100.0	70.0	22.4
W	PA	1	1	6	83.3	66.7	15.0
W	PA	2	1	0	100.0	50.0	17.4
W	PA	3	1	15	80.0	46.7	20.7

* NC = North Central
NE = North East
S = South
W = West

** ENC = North Central
WNC = West North Central
MA = Middle Atlantic
NE = New England
ESC = East South Central
SA = South Atlantic
WSC = West South Central
MO = Mountain
PA = Pacific

*** 1 = 0-14 years
2 = 15-44 years
3 = 45- years

[1] Census Division, Age Group and Composite Number uniquely identify each composite.

Table D-2. Demographic Characteristics for Each Broad Scan Analysis Study Composite Sample - Semi-Volatile and Dioxin and Furan Analyses

Census Regions	Census Divisions	Age Groups	Composite Number	Number of Specimens	Percent White	Percent Male	Tissue Mass (g)
NC	ENC	1	1	18	77.8	100.0	18.1
NC	ENC	1	2	20	80.0	0.0	21.2
NC	ENC	2	1	20	90.0	50.0	21.6
NC	ENC	2	2	19	89.5	42.61	21.4
NC	ENC	2	3	19	89.5	52.6	25.2
NC	ENC	3	1	18	94.4	55.6	19.8
NC	ENC	3	2	18	88.9	55.6	26.2
NC	ENC	3	3	14	100.0	50.0	23.2
NC	WNC	1	1	13	92.3	53.8	23.4
NC	WNC	2	1	17	100.0	64.7	29.6
NC	WNC	3	1	15	93.3	66.0	22.5
NC	WNC	3	2	15	93.3	53.3	21.4
NE	MA	1	1	11	90.9	81.8	23.0
NE	MA	1	2	13	76.9	61.5	20.2
NE	MA	2	1	24	83.3	50.0	25.2
NE	MA	2	2	22	86.4	54.5	26.1
NE	MA	3	1	20	95.0	50.0	16.2
NE	MA	3	2	20	85.0	40.0	18.0
NE	NE	1	1	16	87.5	50.3	19.1
NE	NE	2	1	21	95.2	57.1	21.9
NE	NE	3	1	19	100.0	47.4	26.7
S	ESC	1	1	20	80.5	53.0	20.1
S	ESC	2	1	16	87.5	100.0	19.9
S	ESC	2	2	17	94.1	0.0	25.7
S	ESC	3	1	17	100.0	52.9	20.7
S	ESC	3	2	9	0.0	55.6	21.1
S	SA	1	1	20	100.0	45.0	20.7
S	SA	1	2	14	0.0	64.3	19.1
S	SA	2	1	20	100.0	100.0	20.4
S	SA	2	2	22	100.0	0.0	19.5
S	SA	2	3	19	0.0	100.0	17.9
S	SA	2	4	12	0.0	0.0	18.2
S	SA	3	1	25	100.0	100.0	20.0
S	SA	3	2	21	100.0	0.0	20.1
S	SA	3	3	9	0.0	100.0	18.0
S	SA	3	4	5	0.0	0.0	17.6
S	WSC	1	1	13	69.2	53.8	11.1
S	WSC	2	1	19	78.9	52.6	22.7
S	WSC	2	2	18	83.3	50.0	21.9
S	WSC	3	1	23	87.0	43.5	22.4
W	MO	1	1	7	85.7	71.4	9.0
W	MO	2	1	12	100.0	58.3	18.3
W	MO	3	1	10	100.0	70.0	21.0
W	PA	1	1	7	85.7	71.4	19.7
W	PA	2	1	9	88.9	55.6	21.6
W	PA	3	1	15	80.0	46.7	22.0

* NC = North Central
NE = North East
S = South
W = West

** ENC = North Central
WNC = West North Central
MA = Middle Atlantic
NE = New England
ESC = East South Central
SA = South Atlantic
WSC = West South Central
MO = Mountain
PA = Pacific

*** 1 = 6-14 years
2 = 15-44 years
3 = 45- years

[1] Census Division, Age Group and Composite Number uniquely identify each composite.

APPENDIX E

GLOSSARY OF TERMS

BMDP	Biomedical Statistical Software System
ECD	Electron Capture Detection
EED	Exposure Evaluation Division
FY82	Fiscal Year 1982
GPC	Gel Permeation Chromatography
HPCDD	Heptachlorodibenzo-para-dioxin
HPCDF	Heptachlorodibenzofuran
HRCG	High Resolution Gas Chromatography
HXCDD	Hexachlorodibenzo-para-dioxin
HXCDF	Hexachlorodibenzofuran
LOD	Limit of Detection
LOQ	Limit of Quantification
MS	Mass Spectrometry
NCC	National Computer Center
NHATS	National Human Adipose Tissue Survey
NHMP	National Human Monitoring Program
OCDD	Octachlorodibenzo-para-dioxin
OCDF	Octachlorodibenzofuran
OTS	Office of Toxic Substances
PCB	Polychlorinated Biphenyls
PCDD	Polychlorinated dibenzo-para-dioxin
PCDF	Polychlorinated dibenzofuran
PECDD	Pentachlorodibenzo-para-dioxin
PECDF	Pentachlorodibenzofuran
PGC	Packed Column Gas Chromatography
SAS	Statistical Analysis System
SIM	Selected Ion Monitoring
SMSA	Standard Metropolitan Statistical Area
TCDD	Tectrachlorodibenzo-para-dioxin
TCDF	Tetrachlorodibenzofuran
TSCA	Toxic Substances Control Act

APPENDIX F

STATISTICAL ANALYSIS METHODOLOGY

Statistical Model

The statistical analysis assumed that the chemical concentration level of each composite can be expressed as

$$C_{ijk} = M \cdot CR_i \cdot A_j \cdot \exp(\beta_1 R_{ijk}) \cdot \exp(\beta_2 S_{ijk}) \cdot SMSA_{ijk} \cdot E_{ijk} \quad (F-1)$$

where

- C_{ijk} is the concentration level for the kth composite from the jth age group and ith census region;
- M is a constant;
- CR_i is the effect of the ith Census Region
- A_j is the effect of the jth age group;
- R_{ijk} equals the proportion of white specimens in the composite minus the proportion of non-whites;
- S_{ijk} equals the proportion of male specimens in the composite minus the proportion of females;
- β_1 and β_2 are parameters which describe the relationship between the chemical level and the race and sex makeup of the composite sample;
- $SMSA_{ijk}$ is a random variable representing the random effect due to the cluster of SMSAs which contributed specimens to the composite. SMSA was assumed to have a lognormal distribution where

$$\ln SMSA_{ijk} \sim N(0, \sigma^2_{SMSA});$$

- E_{ijk} is a random variable representing the random effect of all exposure factors unique to the individual specimens included in the composite. E_{ijk} is also assumed to include the random effect due to measurement error since this component of variance could not be separately estimated. E_{ijk} was assumed to have a lognormal distribution where

$$\ln E_{ijk} \sim N(0, \sigma^2_E);$$

$SMSA_{ijk}$ and E_{ijk} were assumed to be independent.

The model assumes that a composite's concentration level is systematically affected by the demographic characteristics of the donors which contributed specimens to the composite. The model further assumes that the concentration level is also randomly affected by unknown exposure factors unique to the SMSAs and individuals which contributed to the composite.

Estimation Approach

Let μ_{ijlm} be the population average concentration level for the ith census region, jth age group, lth race and mth sex. Our goal was to estimate the average concentration levels for the entire nation and various subpopulations, respectively defined by

$$\mu_{...} = \sum_{i=1}^{4}\sum_{j=1}^{3}\sum_{l=1}^{2}\sum_{m=1}^{2} W_{ijlm} \cdot \mu_{ijlm} \qquad \text{(entire nation)}$$

$$\mu_{i...} = \sum_{j=1}^{3}\sum_{l=1}^{2}\sum_{m=1}^{2} W_{ijlm} \cdot \mu_{ijlm} \qquad \text{(ith census region)}$$

$$\mu_{.j..} = \sum_{i=1}^{4}\sum_{l=1}^{2}\sum_{m=1}^{2} W_{ijlm} \cdot \mu_{ijlm} \qquad \text{(jth age group)}$$

$$\mu_{..l.} = \sum_{i=1}^{4}\sum_{j=1}^{3}\sum_{m=1}^{2} W_{ijlm} \cdot \mu_{ijlm} \qquad \text{(lth race group)}$$

$$\mu_{...m} = \sum_{i=1}^{4}\sum_{j=1}^{3}\sum_{l=1}^{2} W_{ijlm} \cdot \mu_{ijlm} \qquad \text{(mth sex group)}$$

where each W_{ijlm} is a weight proportional to the population census count for the (i,j,l,m) subpopulation.

Estimates of the national and means estimates were obtained by substituting estimated values of μ_{ijlm}'s into each of the equations. The approach used to estimate each μ_{ijlm} is as follows.

The statistical model in (F-1) implies that

$$\log C_{ijk} \sim N(\log M+\log CR_i+\log A_j+\beta_1 \cdot R_{ijk}+\beta_2 \cdot S_{ijk}, \sigma^2_{SMSA}+\sigma^2_E) \qquad (F-2)$$

and therefore,

$$E(C_{ijk}) = e^{\log M+\log CR_i+\log A_j+\beta_1 \cdot R_{ijk}+\beta_2 \cdot S_{ijk}+\frac{1}{2}(\sigma^2_{SMSA}+\sigma^2_E)}. \qquad (F-3)$$

When a composite consists only of specimens from the same subpopulation (i,j,l,m), the expected concentration level of the composite is equivalent to the expected concentration level of an individual specimen. That is

$$\mu_{ijlm} = E(C_{ijk}).$$

This follows from the statistical result that when $X_1, \cdots, X_n$ are random variables with identical means,

$$E(X_i) = E\left(\frac{X_1 + \cdots + X_n}{n}\right).$$

A maximum likelihood estimate for each μ_{ijlm} was therefore obtained from (F-3) by the equation

$$\hat{E}(C_{ijk}) = e^{\log \hat{M}+\log \hat{CR}_i+\log \hat{A}_j+\hat{\beta}_1 s(\pm 1)+\hat{\beta}_2 s(\pm 1)+\frac{1}{2}(\hat{\sigma}^2_{SMSA}+\hat{\sigma}^2_E)}, \qquad (F-4)$$

where the $\hat{}$ denotes an MLE and the $\pm$ 1 indicates that R_{ijk} and

S_{ijk} were set equal to either +1 or -1 to correspond to a pure race (all white or all non-white) and pure sex (all male or all female) composite.

The BMDP program P3V was used to obtain the MLEs given in (F-4) by fitting the linear model in Equation F-2 to log-concentrations of the composites. P3V also yielded the variance-covariance matrix of the estimated parameters in Equation F-4. The standard error of $\hat{E}(C_{ijk})$ was obtained by substituting the elements of the variance-covariance matrix into a Taylor Series linearization of (F-4), as described below.

Define the random variables X and Y for a fixed set of i, j, and k, as follows

$$X = \log \hat{M} + \log \hat{CR}_i + \log \hat{A}_j + \hat{\beta}_1(\pm 1) + \hat{\beta}_2(\pm 1)$$
$$Y = \tfrac{1}{2}(\hat{\sigma}^2_{SMSA} + \hat{\sigma}^2_E)$$

Then the estimator $\hat{E}(C_{ijk})$ in (F-4) can be written as

$$\hat{E}(C_{ijk}) = e^X e^Y. \qquad \text{(F-5)}$$

Expand e^X and e^Y in Taylor Series about the means Xo=EX and Yo=EY, respectively, giving the linear approximations

$$e^X = e^{Xo} + e^{Xo}(X-Xo)$$
$$e^Y = e^{Yo} + e^{Yo}(Y-Yo)$$

Substitute these formulas into equation (F-5) to give the following approximation to $\hat{E}(C_{ijk})$

$$\hat{E}(C_{ijk}) = e^{Xo}e^{Yo}[1+(X-Xo)+(Y-Yo)+(X-Xo)(Y-Yo)]$$

which can be written as

$$\hat{E}(C_{ijk}) - e^{Xo}e^{Yo} = e^{Xo}e^{Yo}[(X-Xo)+(Y-Yo)+(X-Xo)(Y-Yo)] \qquad (F-6)$$

Square both sides of (F-6) and take expectations, noting that because the MLEs of X and Y are independent, the expectation of the cross-product terms on the right-hand side is zero. This yields the following approximation to the variance of E(Cijk)

$$Var(\hat{E}(C_{ijk})) = e^{2Xo}e^{2Yo}(Var(X)+Var(Y)+Var(X)Var(Y)) \qquad (F-7)$$

Finally, substitute estimates generated from the BMDP program P3V for the unknown means, Xo and Yo, and variances, Var(X) and Var(Y), to give a numerical approximation for the variance and standard error of the estimated average concentration $\hat{E}(C_{ijk})$.

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Human adipose specimens were collected for the fiscal year 1982 National Human Adipose Tissue Survey (NHATS). The specimens were combined into composite samples, which were chemically analyzed for the presence and level of a number of potentially toxic chemicals. The chemical classes monitored were: volatile organic compounds, semi-volatile organic compounds, and dioxins and furans. Average concentrations of chemicals in the human adipose tissue of the general U.S. population are estimated. The estimation technique is maximum likelihood. Comparisons are made between Census regions, age groups, sex groups, and two race groups.

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