MRI REPORT

Determination of Body Burdens for Polychlorinated Dibenzo-*p*-dioxins (PCDDs) and Polychlorinated Dibenzofurans (PCDFs) in California Residents

Final Report

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The statements and conclusions in this report are those of the contractor and not necessarily those of the State of California Air Resources Board. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.

PREFACE

This final report is provided in fulfillment of the State of California's Air Resources Board (ARB) program to determine the current body burden levels for polychlorinated dibenzo-*p*-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) in California residents. This report covers work done under ARB Contract No. A6-195-33. This final report details in the survey design; identifies the sampling and analysis protocols that were necessary to determine background levels of PCDDs and PCDFs in the California population; and provides a review of the existing literature on body burden levels of PCDDs and PCDFs. This draft final report was prepared by Dr. John S. Stanley with assistance from Ms. Karin M. Bauer, Ms. Kathy E. Boggess, Ms. Kay Turman, and Mr. Paul H. Cramer.

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ABSTRACT

Determination of body burden levels of polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDDs and PCDFs) in residents of California was conducted based on a stratified survey design. Stratification factors included two geographical locations (San Francisco and Los Angeles), three age groups (12 to 34, 35 to 49, and 50 plus years), and sex. A total of 57 adipose tissue specimens were collected across the 12 specific strata. Analysis for the specific 2,3,7,8-substituted isomers was achieved based on high resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS). Detectable levels of PCDDs and PCDFs were measured in all samples with isomer patterns consistent with findings in other studies conducted within the United States, Canada, and Europe. The resulting data base demonstrates the prevalence of these compounds in the general California population. The factors (geographic location, age, and sex) considered in the survey design were not statistically significant at the 5% significance level. A questionnaire focused on the lifestyles of participants in the program was conducted to determine residual and occupational information and possible exposure routes to PCDDs and PCDFs. The data base provides a reference for comparison in future human monitoring programs.

SECTION 1.0

SUMMARY

The research program described in this report required the collection of human adipose tissue specimens via a stratified survey design. Stratification factors included two geographical locations within California (Los Angeles and San Francisco), three age groups (12 to 34, 35 to 49, and 50 plus years), and sex of donor. The resulting survey design covered 12 specific strata. The initial survey design specified a total of 60 fatty samples to be distributed among the 12 strata; the actual collection resulted in 57 adipose tissue specimens. Specimens were analyzed for polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) by high resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS). The PCDDs and PCDFs of interest were the 2,3,7,8-substituted compounds.

Detectable levels of the specific PCDDs and PCDFs were measured in the majority of samples analyzed. The PCDD and PCDF isomer patterns detected are consistent with the incidence of these compounds detected in other studies conducted within the continental United States, North America, and Europe. Although the sample collection did not meet the full requirements of the survey design, sufficient data were available to demonstrate the prevalence of these compounds in the general California population.

None of the factors considered in the survey design--geographic location, age and sex--were significant at the 5% significance level. There is no statistically significant difference in mean concentrations between cities, between sexes, or between age groups at the 95% confidence level, regardless of whether the data are analyzed at the highest level of detail or in any other combination.

The data presented herein provide a preliminary estimate of the body burden levels of PCDDS and PCDFs in the California population. In order to fully assess the impacts that specific contaminant sources might have on body burden levels of these compounds, it will be necessary to drastically increase the number of individual data points. This will be necessary in order to detect initial differences arising from exposure to these contaminants.

If ARB anticipates undertaking additional monitoring efforts, it is recommended that a rigorous and consistent sample collection and analysis program be initiated. Such a program must recognize the importance of long-term participation of a collection facility, development of the necessary quality control samples to demonstrate long-term accuracy and precision, and a detailed study design.

In the study reported in this document, the concentration data have been analyzed individually for each compound. Correlations between compounds may exist but have not been considered here. Relationships between geographic location, age groups or sex and the levels of all detected compounds should be investigated by means of a multivariate analysis approach. The results from a series of principal component analysis and cluster analyses could possibly indicate some clustering of samples when all compounds are considered simultaneously.

SECTION 2.0

INTRODUCTION

Midwest Research Institute (MRI) was contracted by the State of California Air Resources Board (ARB) to determine the current body burdens of polychlorinated dibenzo-p-dioxins and dibenzofurans in California residents. The results of this project will be used by the ARB as part of their assessment of the impact that major stationary combustion sources (municipal incinerators, hazardous waste incinerators, wire reclamation facilities, hospital incinerators, etc.) will have on the impact of air quality and human health.

Body burden levels of PCDDs and PCDFs in California residents have not been established prior to this study.

This final report provides:

- Details of the survey design considered for the collection of tissues from California residents and the analytical protocol required to provide accurate measurements of the 2,3,7,8-substituted PCDDs and PCDFs at low part-per-trillion (picograms/gram, pg/g) levels.
- The results of the high resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS) analyses of 57 human adipose tissue specimens and the results for 20 quality control samples analyzed along with the design specimens.
- The approach to the statistical analysis of the analytical data and the extrapolation of the data to upper and lower 95% confidence intervals of the average body burdens.
- A comparison of the results with other studies that focus specifically on body burden levels of the 2,3,7,8-substituted PCDDs and PCDFs.

2.1 Program Objectives

The objectives of this program were to provide the ARB with a preliminary estimate of the current body burden levels for PCDDs and PCDFs in a representative sample of the California population. This has been accomplished through a program of field sampling and laboratory analysis of human adipose tissue.

The chemical analysis of the adipose tissue were conducted for specific PCDD and PCDF congeners (tetra- through heptachloro congeners substituted in the

2,3,7,8-position). The specific PCDD and PCDF congeners of interest are identified in Table 2-1. These data may be used by the ARB to estimate health risks from the dioxins and furans designated as toxic air contaminants, and to compare them with source-specific isomers ("fingerprint" isomers) detected in future monitoring studies.

The data may also be used to determine if any correlation exists between body burden levels and lifestyle factors such as age, occupation, and residence history. For that purpose, a lifestyle questionnaire was developed and was administered to the donor group.

2.2 Report Organization

Section 3.0 presents the details on the experimental approach for this study. This section includes considerations for the survey design that was proposed at the outset of the program, describes considerations used in the development of the study questionnaire, presents the approaches for soliciting cooperation from the necessary medical facilities to collect samples, identifies the general sample handling considerations, describes the general analytical procedures used to conduct the analysis of the samples by HRGC/HRMS, and presents the approach to quality assurance/quality control.

Section 4.0 presents the results of the study to determine the body burden levels of PCDDs and PCDFs in the California population. Data presented in this section include the raw analytical data for each of the 57 adipose tissue samples that were collected, the results of repetitive analysis of a control lipid matrix and samples fortified with known levels of specific PCDDs and PCDFs, and the statistical analysis of the data.

Section 5.0 presents a synopsis of other human body burden study results to which the results from the ARB study of California residents can be compared. This section was prepared from a review of the existing literature on the levels of the 2,3,7,8-substituted PCDDs and PCDFs in humans. Section 5.0 summarizes the existing literature based on the data for the general United States population and from other countries, specific exposed populations, demographic factors that are correlated with PCDD and PCDF body burden, and distribution of PCDDs and PCDFs within the body.

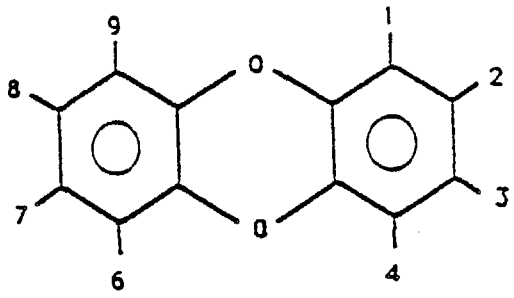
Section 6.0 contains the complete listing of pertinent references cited in this report.

Detailed descriptions of the sampling and analytical protocols and the QAPP are presented in Appendices A, B, and C, respectively. Appendix D presents information on the relationship between percent body fat and anthropometric data in humans.

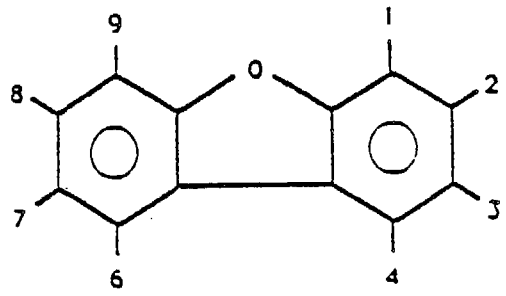
Table 2-1. Chlorinated Dioxins and Dibenzofurans of Interest

	Dioxins	Dibenzofurans
Tetrachloro	2,3,7,8	2,3,7,8
Pentachloro	1,2,3,7,8	1,2,3,7,8 2,3,4,7,8
Hexachloro	1,2,3,4,7,8 1,2,3,6,7,8 1,2,3,7,8,9	1,2,3,4,7,8 1,2,3,6,7,8 1,2,3,7,8,9 2,3,4,6,7,8
Heptachloro	1,2,3,4,6,7,8	1,2,3,4,6,7,8 1,2,3,4,7,8,9

NOTE: The numbers indicate the position of chlorine atoms on the dioxin or dibenzofuran molecule (see diagram below).



Dibenzo-*p*-dioxin



Dibenzo-*p*-furan

SECTION 3.0

EXPERIMENTAL APPROACH

This section describes the experimental procedures, including the survey design, the sample collection protocol, and the analytical method, that were required for completion of this program.

3.1 Survey Design

The development of the survey design required consideration of several factors. These included stratification factors (geographical strata, age categories, and sex of the donor), sample sizes and quotas, classification of individuals according to lifestyle factors, determination of the impact of the design on statistical influences, and determination of total body burden based on the residue levels. These factors and their relation to the initial survey design are addressed below.

3.1.1 Stratification Factors

Ideally, a random sampling from the whole California population, while considering relevant lifestyle factors as stratifying variables, would achieve the goals of establishing background body burden levels of PCDDs and PCDFs for the general California population. However, the scope of the study restricted such a sampling scheme.

Since one of ARB's overall objectives is to determine the impact of emissions from combustion and/or incineration sources on body burden levels of PCDDs and PCDFs, it would seem logical to have sampled at or near existing sources of airborne PCDDs and PCDFs. However, such an approach would have been biased towards higher PCDD and PCDF concentration levels in the sampled tissue should any correlation between airborne emissions and absorbed levels of these compounds be found significant. To establish baseline body burden levels, the selected population group should be representative of the whole California population. That is, one should aim at obtaining a sample which will reproduce the considered characteristics of the target population as closely as possible.

The collection of adipose tissue samples for this study was based on a stratified sampling design. The stratification factors that were considered for this survey design are:

- geographical location within California,
- age category, and
- sex of donor.

Geographical Strata

The ARB has also funded a study to evaluate the ambient airborne levels of PCDDs and PCDFs (ERT, 1987). This study focused on the air quality and the ambient air levels of PCDDs and PCDF in Los Angeles and San Francisco.

The adipose tissue samples were thus targeted for collection from these two major urban areas within California: Los Angeles and San Francisco. The ARB has suggested that the South Coast Air Basin should be considered the primary area of study. This air basin is one of many areas in which the State of California is subdivided for special air-monitoring purposes. It is a geographical area mainly defined by airflow patterns and natural barriers, and includes Los Angeles. Due to extensive air pollution problems in the highly populated Los Angeles area, this air basin might not be representative of the rest of the state. To minimize the bias towards higher polluted areas, San Francisco was included in the study as an urban control site.

Age Categories

Previous studies (Stanley, 1986b; Graham et al., 1986b; Patterson et al., 1986; Ryan, 1986) have shown a correlation of PCDD and PCDF levels with age. Thus a stratification by age is important to obtain independent concentration estimates within each age group. Even though levels of PCDDs and PCDFs have been found in children as young as or younger than 15 (Stanley, 1986), it was decided to consider only donors older than 12. Filling quotas for the age stratum of 0-12 years within each geographic strata was expected to be very difficult. Three age groups--12 to 34 years, 35 to 49 years, and 50 or older--were selected as the second stratifying variable. This stratification provides a good age distribution given the relatively small sample sizes available.

Sex of Donor Stratum

The literature (Graham et al., 1986a,1986b; Patterson et al., 1986b) has also shown a slight difference in PCDD and PCDF levels between males and females, the latter group showing higher body burden levels. Thus sex of donor was considered to be an important stratifying factor in this study.

3.1.2 Sample Size and Quotas

Based on the stratification factors described above, MRI proposed to analyze a total of 60 adipose tissue samples, plus the associated quality control samples (replicates, spikes, blanks, etc.). Hence the target sample size of donors was 60. From this figure, the quotas within the 12 strata (2 geographical areas x 3 age groups x 2 sex groups) were determined. The restrictions on the allocations of donors to strata were as follows:

- at least two donors per stratum,
- equal allocation to each age group,
- equal allocation to each sex, and
- 40 donors in Los Angeles and 20 donors in San Francisco.

These allocations and quotas are summarized in Table 3-1:

Table 3-1. Survey Design for the PCDD/PCDF Body Burden Study

	Los Angeles		San Francisco	
	Male	Female	Male	Female
12-34 years	6	6	2	2
35-49 years	7	7	4	4
50 and above	7	7	4	4
Total	20	20	10	10

3.1.3 Lifestyle Questionnaire

In collecting the adipose samples, MRI arranged with medical care institutions to obtain samples from patients who volunteered for the study after giving informed consent (Appendix A). These patients were selected from those undergoing surgery. During the surgery, a sample of at least 5 g of adipose tissue was removed and used as the tissue sample. Patients were interviewed prior to their surgery to obtain information on a set of lifestyle variables.

A questionnaire (Appendix A) was developed to collect the lifestyle information on all participants. Among the informational items to be collected were:

- age,
- sex,
- height/weight,
- residence history,
- military service in Southeast Asia between 1960 and 1971,
- any known exposure to PCDDs/PCDFs (for example, herbicides, pentachlorophenol, etc.), and
- occupational history.

3.1.4 Impact of Survey Design on Statistical Inference

The survey was designed to yield a total of 60 samples of adipose tissue for analysis. Although 60 is not a large number, it is sufficient to determine whether PCDDs and PCDFs are found in detectable quantities in California residents. The sample size should also allow for the determination of whether there are geographical differences among the samples, whether the age and concentration association reported elsewhere is also found in these residents, and investigation of other possible associations based on the lifestyle questionnaire data.

Overall, little information is available in the literature about the body burdens of PCDDs and PCDFs, but the study of residents of Missouri (Graham et al., 1986) not known to be exposed to PCDDs and PCDFs reported levels of specific 2,3,7,8-substituted congeners. Using this study as a rough guide to the variation expected among individuals, and assuming that approximately similar levels will be found in California residents, the approximate relative standard errors were estimated (Table 3-2).

Table 3-2 contains information on the mean concentration and standard deviation calculated from the individual sample values. The relative standard error of the mean was calculated by assuming a design effect of 2, which is reasonable for the design suggested.

As can be seen, the relative standard errors are reasonable and would provide useful information. However, of more concern than the precision of the estimates is any possible bias. With a sample of this size one must be particularly concerned about bias in representing the population.

3.1.5 Determination of Total PCDD and PCDF Body Burden Based on Adipose Tissue Levels

The human population studies conducted to date have focused primarily on the comparison of the adipose tissue levels of the PCDDs and PCDFs. Since most of these studies have been conducted using samples collected during autopsy, there has not been a good mechanism for assessing total

body fat and the relation of total body weight for extrapolating to the true body burden values. One of the approaches that can be taken to generate estimates of total body fat include conducting skinfold measurements of participants or to use the height, weight, and age of the participant and compare these values to reference tabulations.

Table 3-2. Estimate of Relative Standard Error of the Mean for PCDD and PCDF Congeners Measured in Adipose Tissue Samples from a Human Population[a]

PCDD/PCDF congener	Concentration (ppt)	Std. Dev. (ppt)	Relative Standard Error of Mean (%)[b]
2,3,7,8-TCDD	8.4	4.69	10.2
1,2,3,7,8-PeCDD	19.1	10.34	9.9
2,3,4,7,8-PeCDF	12	7.21	11.0
1,2,3,6,7,8-HxCDD	111	69.21	11.4
1,2,3,4,6,7,8-HpCDD	261	214.00	15.0
Octa	1273	606.00	8.7

Source: Graham, M., F. D. Hileman, R. G. Orth, J. M. Wedling, J. D. Wilson, "Chlorocarbons in Adipose Tissue from a Missouri Population," *Chemosphere*, 15, 1595-1600 (1986).

[a] Derived from individual data points from 60 adipose tissue samples.
[b] This statistic assumes a design effect of 2.

3.2 Sample Collection Protocols

The request for proposal indicated that both tissue and body fluid should be analyzed for estimating the baseline levels of PCDDs and PCDFs. Previous work by the Centers for Disease Control (Patterson et al., 1986b) demonstrated a strong correlation between blood serum and adipose tissue concentrations for 2,3,7,8-TCDD, although the actual concentrations in blood serum are roughly two orders of magnitude less than observed in the adipose tissue. These correlations were derived from the analysis of paired adipose and blood serum samples collected from Missouri residents with and without histories of exposure to 2,3,7,8-TCDD. The strong correlation of concentration between adipose and serum suggested that either matrix is suitable for monitoring body burden levels of 2,3,7,8-TCDD. However, as discussed earlier in the literature review section, the correlation of concentration between higher chlorinated PCDDs and PCDFs in adipose and blood serum may not be as high as shown for TCDD.

3.2.1 Selection of Biological Matrix for Analysis

Analysis of both sample matrices for the proposed study was not necessary. The work conducted by the Centers for Disease Control (Patterson et al., 1986b; Rappe et al., 1986a) has demonstrated that the lower level

of 2,3,7,8-TCDD in human blood serum approaches approximately 0.01 pg/g or 10 parts per quadrillion. When the concentration in blood serum is adjusted for lipid content, the reported concentration approaches the 1-10 pg/g (parts-per-trillion) range. The required level of detection for blood serum presents an extremely difficult and challenging problem in maintaining instrumental capability for analysis. Selection of blood as the matrix for establishing baseline estimates of PCDDs and PCDFs would require high resolution mass spectrometry instrumentation that is dedicated to these levels of analyses. Adipose tissue, on the other hand, has been shown to be a good indicator for PCDDs and PCDFs and offers the advantage that the PCDD and PCDF levels are more concentrated and hence the instrumental requirements although still stringent are less significant. For these reasons, MRI selected adipose tissue as the more desirable matrix for estimating body burden levels of PCDDs and PCDFs in the general California population.

3.2.2 Selection/Recruitment of Sample Collection Centers

Arrangements were made with at least two medical facilities within each of the geographic strata to recruit the patients and obtain the adipose samples. Among the criteria for selecting the participating institution were:

- the institution's willingness to cooperate,
- the elective surgery load, and
- the geographical area covered by the institution.

3.2.3 Sample Collection Protocols

Recruitment efforts were carried out by MRI staff and IWG Corporation staff beginning in January 1988.

A letter explaining the body burden study objectives and requesting contribution of adipose tissue specimens was the first contact with all facilities. The letter was sent to the head of surgery of the facility, whose name was obtained by telephone contacts. A follow-up call to determine level of interest was then made. If the surgeon expressed interest, a packet containing the survey design, the scope of work, the collection and shipping protocol, the medical exclusion form, the questionnaires, and the consent forms was provided. A sample supply kit was also sent to the surgeon. In several cases, the packets of information and the sample supply kits were presented to the internal review board of the facility as information pertinent to approval. Additional follow-up calls were made to answer questions and determine status of the approval process within the facility.

In all, 22 facilities and 3 plastic surgeons in private practice were contacted by MRI or IWG staff regarding participation in the study.

Three facilities in Los Angeles contributed adipose tissue specimens, and collection in San Francisco was conducted at two facilities.

The guidelines for sample collection were a key element in the sampling process. The guideline materials specific to the sample collection protocol are provided in Appendix A of this report. The materials in Appendix A include the sample collection procedure, the information and consent forms to be signed by the hospital participants (donors), and a medical exclusion screening form for use by the hospital coordinators. These were sent to each participating hospital at the start of the recruitment. Although the collection procedure is relatively simple, the guidelines give the cooperating physician a complete understanding of all aspects of the collection procedure. Items included are the requirement for age/sex quota distribution, the criteria for selecting patients to be sampled, legal consideration, forms completion, sample collection, and shipment. The signed consent forms have been retained by the collection facilities to maintain confidentiality of the participating individuals. All of these materials were submitted to MRI's Human Subjects Studies Review Committee for review and approval for this study.

3.2.4 Considerations for Exclusion of Donors from the Study Design

As indicated above, the hospital coordinators were requested to determine from review of the medical charts of the prospective donors, or through personal interviews with the patients or their physicians, if any of the following characteristics would exclude a potential subject from this study.

- pregnancy,
- malignancy, excluding nonmalignant melanoma skin cancers,
- insulin-dependent diabetes,
- immunosuppression caused by either a disease process or therapeutic medications,
- history of unintentional weight loss greater than 10 lb in preceding 6 months,
- bleeding disorder,
- infectious or serum hepatitis, active tuberculosis, or acquired immune deficiency syndrome, and
- children less than 12 years of age.

These procedures for exclusion are consistent with the approach taken by the Centers for Disease Control in their study of Missouri residents.

3.3 Selection of the Analytical Protocol

MRI has developed and validated an analytical method specifically for the analysis of PCDDs and PCDFs in biological tissue (Stanley et al., 1986d). The method performance has been documented to provide accurate quantitative data for the 2,3,7,8-TCDD to concentrations in the range of 1 to 10 pg/g. Method performance for this procedure has been demonstrated for each of the 2,3,7,8-substituted PCDD and PCDF congeners as well as the octachlorodibenzo-*p*-dioxin (OCDD) and octachlorodibenzofuran (OCDF).

The specific analytical procedures for the determination of PCDDs and PCDFs in adipose tissues are presented in detail in Appendix B of this report. However, there are several deviations to the analytical procedure that should be addressed. Specifically, some modifications of the chromatographic cleanup techniques were incorporated in this study. These modifications included the use of neutral alumina versus acidic alumina columns to fractionate sample extracts and the use of a carbon-based column which consisted of AX-21 charcoal (Anderson Development Company) on silica gel versus Carbopak C on Celite as described in the protocol in Appendix B. The AX-21/silica column was used only with the first batch of samples. The basis for these modifications resulted from the incorporation of these procedures in EPA's high resolution mass spectrometry (HRMS) procedure, Method 8290, for the determination of PCDDs and PCDFs in multimedia samples (Tondeur 1987; Stanley et al., 1989).

3.3.1 Laboratory Sample Preparation Procedures

A known amount of a series of ^{13}C-labeled internal quantitation standards was added (Table 3-3) to each adipose sample (5 to 10 g aliquots). The adipose samples were extracted with methylene chloride using a Tekmar Tissuemizer. The methylene chloride extract was dried by elution through sodium sulfate. The extraction procedure was repeated at least two additional times per tissue sample. The final extract was adjusted to known volume. A portion of the extract was removed to gravimetrically determine the lipid content and the remaining extract was solvent exchanged to hexane.

The hexane extract was subsequently subjected to an acidic silica gel slurry cleanup procedure. Specifically, 100 g of 40% sulfuric acid-impregnated silica gel was mixed with the hexane/milk fat mixture for 2 hr. Afterwards, the hexane was decanted through a funnel of sodium sulfate into a 4-g acid silica gel/1-g neutral silica gel column. The fraction was collected in a Kuderna-Danish (K-D) evaporating flask. The acidic silica gel was slurried an additional two times with 50 mL of hexane for 15 min each time and the rinses placed on the column. After all the solvent from the slurry had passed through the column, an additional 50 mL of hexane was placed on the column and combined with the other eluent in the K-D flask.

The extract was reduced in volume to approximately 2 mL and applied to the top of a chromatography column comprised of 4 g sodium sulfate, 4 g neutral alumina, and 4 g sodium sulfate. The column was eluted with 10 mL of 8% dichloromethane in hexane. This portion was archived. The PCDDs and PCDFs were eluted in 15 mL of 60% dichloromethane in hexane.

Table 3-3. Internal Standard Spiking Solutions for Determination of PCDDs and PCDFs in Human Adipose Tissue

Compound	Concentration (pg/μL)
Internal Quantitation Standards[a]	
$^{13}C_{12}$-2,3,7,8-TCDD	5
$^{13}C_{12}$-2,3,7,8-TCDF	5
$^{13}C_{12}$-1,2,3,7,8-PeCDD	5
$^{13}C_{12}$-1,2,3,7,8-PeCDF	5
$^{13}C_{12}$-1,2,3,6,7,8-HxCDD	12.5
$^{13}C_{12}$-1,2,3,6,7,8-HxCDF	12.5
$^{13}C_{12}$-1,2,3,4,6,7,8-HpCDD	12.5
$^{13}C_{12}$-1,2,3,4,6,7,8-HpCDF	12.5
$^{13}C_{12}$-OCDD	25
Internal Recovery Standard[b]	
$^{13}C_{12}$-1,2,3,4-TCDD	50
$^{13}C_{12}$-1,2,3,7,8,9-HxCDD	125

[a] Prepared in isooctane, 100 μL spiked.
[b] Prepared in tridecane, 10 μL spiked.

This fraction was collected and reduced in volume to approximately 2 mL and applied to the final column. Neutral alumina was used rather than acidic alumina specified in the analytical protocol to improve method recoveries.

The final cleanup column consisted of 1 g of Carbopak C on Celite 545. The column was prerinsed with 4 mL toluene, 2 mL dichloromethane/methanol/benzene (75:20:5), and 4 mL cyclohexane/dichloromethane (50:50). The fraction from the alumina column was transferred to a Carbopak C/Celite column with two 1-mL rinses of hexane. (Batch 1 samples were chromatographed in a carbon column consisting of AX-21 dispersed on silica gel.) The column was eluted with 10 mL of the cyclohexane/dichloromethane solution and 5 mL of the dichloromethane/ methanol/benzene solution. These fractions were combined and archived. The columns were then turned over and eluted with 20 mL of toluene. The toluene was reduced in volume to approximately 100 µL, the internal recovery standards in tridecane were then added (10 µL, Table 3-3), and the extract further evaporated to final volume (10 µL).

3.3.2 HRMS Analysis Procedures

The sample extracts were analyzed using either a Kratos MS-50TC or a VG 70 250S high resolution mass spectrometer (HRMS). Analytical parameters for the PCDD and PCDF determination are given in Table 3-4.

A typical analysis day started with the mass calibration of the mass spectrometer, followed by the analysis of a window defining mix. This solution contains the first and last eluting isomers of a homolog group and is used to determine the ion switching points needed to switch from monitoring one homolog series to the next. This was followed by the analysis of a low level standard (2.5 pg TCDD to 12.5 pg OCDD). Relative response factors (RRFs) were calculated based on this run and were compared to those RRFs established during the initial calibration. The initial calibration curve consisted of a series of up to eight standards ranging in concentration from 1 to 200 pg/µL 2,3,7,8-TCDD. All other 2,3,7,8-substituted PCDDs and PCDFs are included in the calibration standards.

The concentration of each isomer varies with the degree of chlorination. For example, the concentration range for the octachloro isomer is 5 to 1,000 pg/µL. Table 3-5 gives the concentration ranges for each of the isomers in the calibration standards.

Criteria for passing the daily calibration must be within ±20% deviation from the initial RRFs. Following the analysis of the low level standard, a solvent blank (tridecane) was analyzed, then field samples were analyzed in a random order. The day was completed with the analysis of an additional calibration standard to verify instrumental stability.

Table 3-4. HRGC/HRMS Operating Conditions for PCDD/PCDF Analysis

Mass Spectrometer	Kratos MS 50TC (Batch 1)	VG 70S 250 (Batches 2-5)
Accelerating voltage:	8,000 V	
Trap current:	500 µA	
Electron energy:	70 eV	70 eV
Electron multiplier voltage:	-1,800 V	
Source temperature:	280°C	
Resolution:	≥ 10,000 (10% valley definition)	> 10,000
Overall SIM cycle time:	1 s	1 s
Gas Chromatograph		
Column coating:	DB 5	
Film thickness:	0.25 µm	
Column dimensions:	60 m x 0.25 mm ID	
He linear velocity:	~ 25 cm/s	
He head pressure:	1.75 kg/cm² (25 psi)	
Injection type:	Splitless, 45 s	
Split flow:	30 mL/min	
Purge flow:	6 mL/min	
Injector temperature:	270°C	
Interface temperature:	300°C	
Injection size:	1-2 µL	
Initial temperature:	200°C	
Initial time:	2 min	
Temperature program:	200° to 270°C at 5°C/min	
Second hold time:	10 min	
Second temperature ramp:	270° to 330°C at 5°C/min	
Final hold time:	5 min	

Table 3-5. Concentration Calibration Solutions for PCDD/PCDF

Compound	Concentration in calibration solutions in pg/uL							
	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8
2,3,7,8-TCDD	200	100	50	25	10	5	2.5	1
2,3,7,8-TCDF	200	100	50	25	10	5	2.5	1
1,2,3,7,8-PeCDD	200	100	50	25	10	5	2.5	1
1,2,3,7,8-PeCDF	200	100	50	25	10	5	2.5	1
2,3,4,7,8-PeCDF	200	100	50	25	10	5	2.5	1
1,2,3,4,7,8-HxCDD	500	250	125	62.5	25	12.5	6.25	2.5
1,2,3,6,7,8-HxCDD	500	250	125	62.5	25	12.5	6.25	2.5
1,2,3,7,8,9-HxCDD	500	250	125	62.5	25	12.5	6.25	2.5
1,2,3,4,7,8-HxCDF	500	250	125	62.5	25	12.5	6.25	2.5
1,2,3,6,7,8-HxCDF	500	250	125	62.5	25	12.5	6.25	2.5
1,2,3,7,8,9-HxCDF	500	250	125	62.5	25	12.5	6.25	2.5
2,3,4,6,7,8-HxCDF	500	250	125	62.5	25	12.5	6.25	2.5
1,2,3,4,6,7,8-HpCDD	500	250	125	62.5	25	12.5	6.25	2.5
1,2,3,4,6,7,8-HpCDF	500	250	125	62.5	25	12.5	6.25	2.5
1,2,3,4,7,8,9-HpCDF	500	250	125	62.5	25	12.5	6.25	2.5
OCDD	1,000	500	250	125	50	25	12.5	5
OCDF	1,000	500	250	125	50	25	12.5	5
Internal Quantitation Standards								
$^{13}C_{12}$-2,3,7,8-TCDD	50	50	50	50	50	50	50	50
$^{13}C_{12}$-2,3,7,8-TCDF	50	50	50	50	50	50	50	50
$^{13}C_{12}$-1,2,3,7,8-PeCDD	50	50	50	50	50	50	50	50
$^{13}C_{12}$-1,2,3,7,8-PeCDF	50	50	50	50	50	50	50	50
$^{13}C_{12}$-1,2,3,6,7,8-HxCDD	125	125	125	125	125	125	125	125
$^{13}C_{12}$-1,2,3,4,7,8-HxCDF	125	125	125	125	125	125	125	125
$^{13}C_{12}$-1,2,3,4,6,7,8-HpCDD	125	125	125	125	125	125	125	125
$^{13}C_{12}$-1,2,3,4,6,7,8-HpCDF	125	125	125	125	125	125	125	125
$^{13}C_{12}$-OCDD	250	250	250	250	250	250	250	250
Internal Recovery Standard								
$^{13}C_{12}$-1,2,3,4-TCDD	50	50	50	50	50	50	50	50
$^{13}C_{12}$-1,2,3,7,8,9-HxCDD	125	125	125	125	125	125	125	125

3.3.3 Data Reduction Procedures

Data reduction procedures were primarily conducted using a basic computer program which receives a specially formatted data file as input and outputs an extract concentration. Then, the sample weight, percent lipid, dry weight, or other concentration or dilution factors were taken into account to arrive at a final sample concentration. Limits of detection were determined for each 2,3,7,8-substituted isomer in each sample by multiplying the median of nonmatching peaks in a retention time window by 2.5 or by reporting the concentration of a coeluting peak that did not match the qualitative ion ratio criteria for that isomer.

3.3.4 Calculation Theory

During the initial calibration, a series of up to eight standards are analyzed and relative response factors (RRFs) are determined for each native relative to the corresponding ^{13}C-labeled internal quantitation standard (IQS) and for each IQS relative to the recovery standards (RS). The average of the RRFs over all the standards is used in all succeeding calculations to determine sample amounts for a specific isomer.

In the data calculations, the response of the IQS, its known concentration, the response of the native, and the average RRF are used to calculate the concentration of the native isomers in the extract. Since the IQS are affected by the sample matrix and the overall extraction procedure, the calculation procedure adjusts for recovery from the sample matrix.

The recovery standards, which are added to the extract just prior to HRGC/HRMS analysis, are used to determine the absolute recovery of the IQS. The delivery of these two RS compounds in 10 µL of a high boiling solvent also assures the integrity of the small volume of the final extract.

SECTION 4.0

RESULTS

This section provides a summary of the sample collection efforts; the raw analytical data for the individual sample analysis; the supporting quality control data from replicates, spikes, and method blanks; a summary of the tabulated responses from the lifestyle questionnaires; and the results of the statistical analysis of the analytical data.

4.1 Sample Collection

A total of 57 adipose tissue samples were collected, which represented 95% of the collection goal of 60 individual specimens. Of the 57 specimens, 28 (49%) were from males and 29 (51%) were from females (31 of the targeted 40 samples were collected in Los Angeles, while 26 samples were obtained from San Francisco).

Table 4-1 provides a synopsis of the samples collected based on age group distribution. As noted in Table 4-1, most of the samples collected were taken from individuals in the 50+ age category, while the youngest age category, 12 to 34, provides the fewest number of specimens. Although the youngest age group was targeted at 18 to 34 years, a sample was available from an individual 12 years of age and hence was included in the study.

4.2 Chemical Analysis Results

The chemical analysis results for each of the individual adipose tissue samples are provided in Tables 4-2 through 4-6. These results correspond to the analysis of the samples as five separate batches. These tables provide the raw analytical data for each of the specific 2,3,7,8-substituted PCDD and PCDF analytes. Responses to PCDDs and PCDFs were limited to only the 2,3,7,8-substituted isomers.

Each data table indicates the sex and age of the individual and the city from which the sample was collected. All data are reported on the lipid extractable basis, rather than a wet tissue basis. Concentration data reported on a lipid basis is essential for comparing body burden levels with other existing data bases or for comparison in future program efforts.

Each table also includes a value termed the 2,3,7,8-TCDD toxic equivalents (TE) value. These values were generated from the TE formula developed by the California Department of Health Services. The TE values are based on the

assignment of relative toxicities of 2,3,7,8-substituted PCDDs and PCDFs to the 2,3,7,8-TCDD. Compilation of TE values allows a comparison of total PCDD and PCDF residue levels between samples. The TE formula for the 2,3,7,8-substituted PCDDs and PCDFs are given below. The OCDD and OCDF were not assigned TE values by the Department of Health Services Procedure.

TE Formula (TEF)

PCDD		PCDF	
Isomer	TE[a]	Isomer	TE[a]
2,3,7,8-TCDD	1	2,3,7,8-TCDF	1
1,2,3,7,8-PeCDD	1	1,2,3,7,8-PeCDF	1
1,2,3,6,7,8-HxCDD	0.03	2,3,4,7,8-PeCDF	1
1,2,3,7,8,9-HxCDD	0.03	1,2,3,6,7,8-HxCDF	0.03
1,2,3,4,7,8-HxCDD	0.03	1,2,3,7,8,9-HxCDF	0.03
1,2,3,4,6,7,8-HpCDD	0.03	1,2,3,4,7,8-HxCDF	0.03
		2,3,4,6,7,8-HxCDF	0.03
		1,2,3,4,6,7,8-HpCDF	0.03
		1,2,3,4,7,8,9-HpCDF	0.03

[a] California Department of Health Services, 1986, "Technical Support Document on Chlorinated Dioxins and Furans. Part B. Health Effects. Appendix B. Methods for Inferring Total Potency of a Mixture of PCDDs and PCDFs" (Tables B-1 and B-2).

Several considerations should be noted for further extrapolation of the data reported herein. All samples were analyzed as blinds in the laboratory and were decoded after reduction of the HRMS data. Each sample was assigned a unique identification (bar code) on receipt. The laboratory identification was used for reference throughout the analysis effort.

The data for the samples analyzed for the first sample batch (Table 4-2) were acquired under slightly different conditions than batches 2 through 5 (Tables 4-3 through 4-6). The difference in the sample analyses for batch 1 pertained to the use of final extract cleanup using a carbon column based on AX-21 on silica gel versus Carbopak C on Celite and HRMS analysis on a Kratos MS-50TC versus the VG 70 250S. As will be described in the statistical analysis section, the detection limits for specific compounds for batch 1 samples tended to be somewhat higher than for the other batches. In particular, this result was noted for the hexa- and heptachlorinated PCDF analytes. The detection limits for the HxCDF isomers were affected by the presence of coeluting interferences, potentially octachlorodiphenylethers. The use of Carbopak C/ Celite cleanup on the samples in batches 2 through 5 removed these interferences completely.

Table 4-2 (batch 1) presents the results for the 1,2,3,4,7,8-HxCDD and 1,2,3,6,7,8-HxCDD as a combined value because of the incomplete HRGC chromatographic separation. Sufficient separation of these isomers was achieved in the subsequent analyses of batches 2 through 5, and the data are reported as such. The data for these isomers were combined for batches 2 through 5 for consistency in dealing with the statistical analysis of the data.

Several of the samples were analyzed as duplicates within a batch. The data from the duplicate analyses were averaged, and the average value has been reported in the data tables. The samples that were analyzed as duplicates are designated as such in the specific data tables.

4.3 Results of Quality Control Samples

As part of the quality assurance program, several different quality control (QC) samples were analyzed along with the study samples. These QC samples included replicate determinations of more than 10% of all samples to assess method precision, samples fortified with known amounts of specific PCDDs and PCDFs to assess method accuracy, and laboratory method blanks to demonstrate that the laboratory procedures did not contribute to measured levels in the adipose tissue samples.

4.3.1 Replicate Analyses

Replicate analyses of samples included duplicate sample preparation and HRMS analyses of selected study samples and the repetitive analysis of one of the quality control samples identified as a control lipid matrix. The duplicate analyses of the individual samples provide a measure of within batch method precision, while the repetitive analysis of the control matrix provides a measure of between batch method precision.

Table 4-7 provides a summary of the precision for each PCDD and PCDF analyte from the duplicate analysis (within batch precision) for specific study samples. Precision for these analyses are reported as the range percent difference (high value-low value/average value * 100%). Table 4-8 provides a measure of precision from the repetitive analyses (between batch precision) for the control sample matrix. Prior to this study for ARB, this control matrix has been analyzed previously with five other sample sets as part of a study for EPA's Office of Toxic Substances. As noted in Tables 4-7 and 4-8, the precision of the measurements is good for the analytes that are normally detected in adipose tissues. Estimates of precision have not been calculated for the analytes that were reported as not detected.

4.3.2 Spiked Samples

Table 4-9 summarizes the results from the analysis of 10 spiked samples fortified with known levels of the specific PCDDs and PCDFs. Data reported in Table 4-9 are the calculated recoveries for each of the individual analytes. The spiked samples were generally prepared from the control sample matrix, although duplicate spiked samples were prepared

from an actual study sample of batch 1. The method recoveries (accuracies) were calculated for a specific compound as the difference of the value between the spiked sample and the control sample divided by the known spiked amount. As noted in Table 4-9, the method accuracies for all compounds are well documented. In some instances, the spiked level was not substantially greater than the level in the control to allow an effective measure of recovery.

4.3.3 Laboratory Method Blanks

The results of the analysis of the laboratory method blanks that were prepared and analyzed along with the study samples demonstrated that there was no contribution of PCDDs or PCDFs from the laboratory reagents or glassware. The results of the analyses of these method blanks are critical with respect to supporting the identification of compounds in the adipose tissues, particularly those with concentrations in the 1 to 10 pg/g level.

4.3.4 Recoveries of Internal Quantitation Standards

The method recoveries for the nine internal quantitation standards were monitored for each of the samples analyzed. Data for the individual recoveries in each sample are presented in Appendix E of this report. It should be noted that the concentrations of the PCDD and PCDF residue levels have been corrected for these method recoveries based on the calculation procedures used. As noted in Appendix E, the method recoveries are fairly consistent across all samples for a given internal quantitation standard.

4.4 Summary of the Lifestyle Questionnaire Results

Responses to the full lifestyle questionnaire were achieved from 44 of the 57 individuals included in this study (31 out of 41 Los Angeles residents and 13 out of 26 San Francisco residents). A copy of the blank questionnaire is included in Appendix A. For the remaining 13, only partial patient information provided by the hospital (i.e., first page of questionnaire) was available. The questionnaire results are presented in two parts. First, the answers to the questions completed by hospital personnel are summarized in a series of tables. Next, a summary of the answers to the questionnaire obtained from the 44 donors is presented. The question numbering is identical to that used in the questionnaire.

4.4.1 Patient Data Statistics (Questions 1 through 11)

Of the 11 questions completed by hospital personnel, statistics on a selected number of them are presented below in Table 4-10, anatomical origin of adipose tissue sample; Table 4-11, race of donor; Table 4-12, height of donor; Table 4-13, weight of donor; and Table 4-14, skinfold caliper measurements. The data in Tables 4-10 and 4-11 are shown in the design cells determined by city and sex; data in Tables 4-12 through 4-14 are shown by sex and age group.

4.4.2 Questionnaire Data Summary (Questions 12 through 32)

The donors were asked to fill out a set of questions structured into three categories. The following summarized the donors' answers within each set of questions.

Residential History Information (Questions 12 through 17)

Thirty-one Los Angeles donors presently live in 28 different zip codes. Slightly over half of them (17) have been living at their present zip code for at least 5 years. Of the 14 residents who have relocated within the last 5 years, 7 have relocated from within Los Angeles, 2 from out of state, and 5 could not remember their previous zip code.

Thirteen San Francisco donors presently live in 11 different zip codes. Most of them (83%) have been living at their present zip code for at least 5 years. Only two have relocated within the city limits in the last 5 years.

The donor's current residency or workplace with respect to the vicinity (within 5 miles) of various potential sources of PCDD and PCDF contamination is summarized in Table 4-15.

Similar information could be gathered for those residents (11 in Los Angeles and 2 in San Francisco) who have relocated within the last 5 years. The results are shown in Table 4-16.

Potential Chemical Exposure Information (Questions 18 through 25)

Information on potential chemical exposure on the job or in and around the home during the last 5 years or during service in Vietnam was obtained from most of the 44 respondents. The data are summarized in Table 4-17.

Occupational History Information (Questions 26 through 32)

Only data from answers to questions on types of occupations relevant to this study, that is, occupations that involve potential chemical exposure, were summarized here. Table 4-18 follows the outline of the questionnaire on pages 6 and 7.

4.5 Statistical Data Analysis

4.5.1 General Results

A total of 57 specimens were collected from both cities. The distribution of the specimens across the design cells is shown in Table 4-19. The 57 specimens were analyzed in 5 batches as follows:

Batch 1: 17 Los Angeles specimens
Batch 2: 10 Los Angeles and 6 San Francisco specimens
Batch 3: 7 San Francisco specimens
Batch 4: 2 Los Angeles and 7 San Francisco specimens
Batch 5: 2 Los Angeles and 6 San Francisco specimens

Ideally, the specimens would have all been collected first, then randomly assigned to the batches to circumvent a potential confounding effect of the batch and city factors. Because of collection difficulties, however, the samples were analyzed as they arrived, resulting in the above assignment. This potential problem has been investigated throughout the statistical analyses performed on the concentration data.

The 57 specimens were analyzed for the presence and levels (pg/g) of the 17 compounds listed below:

Ref. No.	Compound
1	2,3,7,8-TCDF
2	2,3,7,8-TCDD
3	1,2,3,7,8-PeCDF
4	2,3,4,7,8-PeCDF
5	1,2,3,7,8-PeCDD
6	1,2,3,4,7,8-HxCDF
7	1,2,3,6,7,8-HxCDF
8	2,3,4,6,7,8-HxCDF
9	1,2,3,7,8,9-HxCDF
10	1,2,3,4,7,8-1,2,3,6,7,8-HxCDD
11	1,2,3,7,8,9-HxCDD
12	1,2,3,4,6,7,8-HpCDF
13	1,2,3,4,7,8,9-HpCDF
14	1,2,3,4,6,7,8-HpCDD
15	OCDF
16	OCDD

Table 4-20 presents the overall results on the occurrences of compounds in the individual specimens. The distribution of nondetects and detects varies between cities as shown by the percentage figures for Los Angeles and San Francisco.

Figure 4-1 is a bar chart summary of the proportions of nondetects for each compound in the following five categories:

a. Batch 1, i.e., Los Angeles samples only (17 samples)
b. Batches 1+2+4+5, Los Angeles samples only (31 samples)
c. Batches 2+4+5, Los Angeles samples only (14 samples)

d. Batches 2+3+4+5, San Francisco samples only (26 samples)
e. All 57 samples

The higher occurrence of nondetects in the Los Angeles samples versus the San Francisco samples is mostly due to a high occurrence of nondetects in batch 1. The Los Angeles samples in batches 2, 4, and 5 show a similar pattern in percent nondetects as do the San Francisco samples.

The compounds, ordered by the percent of specimens with detectable (positive quantifiable, PQ) levels, correspond to the compounds that are most often cited in other studies related to human body burdens of PCDDs and PCDFs.

Compound	% PQ in 57 specimens
OCDD	100
1,2,3,4,6,7,8-HpCDD	100
1,2,3,4,7,8/1,2,3,6,7,8-HxCDD	100
1,2,3,7,8-PeCDD	95
2,3,7,8-TCDD	93
2,3,4,7,8-PeCDF	89
1,2,3,7,8,9-HxCDD	88
1,2,3,4,7,8-HxCDF	86
1,2,3,4,6,7,8-HpCDF	82
1,2,3,6,7,8-HxCDF	79
2,3,7,8-TCDF	77
2,3,4,6,7,8-HxCDF	70
OCDF	58
1,2,3,7,8-PeCDF	23
1,2,3,4,7,8,9-HpCDF	19
1,2,3,7,8,9-HxCDF	9

4.5.2 Statistical Analysis of the Concentration Levels

The objective of the statistical analysis of the levels of the compounds in the 57 specimens is twofold: first, to determine whether the levels between Los Angeles and San Francisco, between males and females, and among age groups are statistically different; and second, to calculate average concentration levels and their confidence intervals for the 12 design cells determined by the survey design. If some or all factors (i.e., city, sex, or age group) are found to be nonsignificant, then the cells can be collapsed and statistics computed across larger cells.

Data Transformation and Calculations

Prior to computing mean concentration levels in the design cells, the data were analyzed to examine the shape of their distribution. It was found that the concentrations followed approximately

a lognormal distribution, with most of the levels in the lower concentration range and a small proportion in the higher concentration range. Taking this fact into account, the concentration data were first log-transformed; the analyses performed on the log scale; and the results transformed back to the original scale by taking the antilog, that is, using the exponential function. Thus the average results are reported as the geometric mean rather than the arithmetic mean. (The antilog of the mean of the log concentrations is the geometric mean of the untransformed concentrations.)

For any cell defined by a given combination of the design factors, the geometric mean concentration and its lower and upper 95% confidence limits were calculated for each compound. The confidence limits were computed as follows.

In a given cell, let Y be the average of the log-transformed concentration levels and SE_Y be the standard error of the mean, Y. Then a 95% confidence interval for Y, $[LL_Y, UL_Y]$, is given by:

$$[LL_Y, UL_Y] = [Y - t_{0.025,(n-1)}*SE_Y,\ Y + t_{0.025,(n-1)}*SE_Y]$$

where $t_{0.025,(n-1)}$ is the 2.5th-percentile of the t-distribution with n-1 degrees of freedom, where n is the number of samples used to compute the mean, Y. This interval will be on the log scale.

Next, for that cell, the geometric mean, X, of the concentration levels is obtained by taking the antilog of the mean, Y,

$$X = \exp(Y)$$

To obtain a 95% confidence interval for X, $[LL_X, UL_X]$, simply take the antilog of LL_Y and UL_Y,

$$[LL_X, UL_X] = [\exp(Y - t_{0.025,(n-1)}*SE_Y),\ \exp(Y + t_{0.025,(n-1)}*SE_Y)]$$

These values will be on the original concentration scale. Note that the confidence interval for the geometric mean, X, will not be symmetrical around X.

Data Set Used for Computation of Average Levels

Based on the high occurrence of nondetects in batch 1 samples as compared to batches 2, 3, 4, and 5, only results above detection limits were included into the analyses. Also, since the detection limits obtained on batch 1 are generally higher than those obtained from the other four batches, using the limit of detections whenever the level of a compound is below detection limit would bias the average concentrations for Los Angeles towards the high side. On the other hand, substituting zero for those concentrations below detection limit would bias the average results for

Los Angeles towards the low side because of the high proportion of nondetect Los Angeles samples.

In summary, to eliminate the effect of batch 1 results on overall statistics, it was decided to only include detected concentrations (PQs) in the analysis. This approach resulted in a drastic reduction in the Los Angeles sample size for the majority of the compounds (see Table 4-20). In addition, interferences were frequently experienced for 1,2,3,4,7,8- and 1,2,3,6,7,8-HxCDF in batch 1. Therefore, for those two compounds, all batch 1 results were excluded from all subsequent analyses of variance. However, detected concentrations from batch 1 are included in all tabulated statistics (Tables 4-21 through 4-26).

Analysis of Variance

Analysis of variance was performed on the log-transformed concentrations for each compound individually. The main factors considered were city (two levels), sex (two levels), and age group (three levels). All two-way interactions, i.e., city by sex, city by age group, and sex by age group, were introduced in the model, if permitted by sample sizes for a given compound. In a first pass-through analysis of variance, all three two-way interactions were included in the general linear model whenever adequate sample sizes allowed it. Appropriate two-way interactions were excluded in the case of empty design cells. The significance of main factors and interactions was based on the probability level associated with the partial sums of squares in each model. All analyses were performed using Type IV sums of squares from the PROC GLM in SAS (Statistical Analysis System).

In the case of a significant main effect but no other significant factors or interactions (this only occurred once), a second analysis of variance was performed using only that significant factor. In the case of a significant interaction but no other significant sources of variation, the analysis was performed again to evaluate the effect of one factor within each level of the second factor. (This situation only occurred once.) A 5% significance level was chosen a priori for all analyses.

An analysis of variance was performed for each of the following cases and concentration means, and their 95% confidence limits were calculated:

1. Within each cell defined by city, sex, and age group, that is, 12 cells for each compound. These results are shown in Table 4-21.

2. After collapsing the data across age groups, within each cell defined by city and sex, that is, four cells per compound. These results allow for comparisons of all male versus female

levels within a city, regardless of age group. These results are shown in Table 4-22.

3. After collapsing the cells further across sex, within each city, that is, two cells per compound. Mean differences in concentration levels can thus be compared between cities. The results are shown in Table 4-23.

4. After collapsing the first table (item 1) across cities, within each cell defined by sex and age group, that is, six cells per compound. These results allow for age group comparisons within each sex. The results are shown in Table 4-24.

5. After further collapsing across sex in the table from item 5, within each age group, that is, three cells per compound. These results allow for comparisons between age groups, across cities and sex. The results are shown in Table 4-25.

6. Across all design cells, that is, an overall mean concentration level for each compound. The results are shown in Table 4-26.

Discussion

Of all 16 analyses of variance (ANOVA) including main effects and two-way interactions, only one, for 1,2,3,4,7,8/1,2,3,6,7,8-HxCDD, was significant at the 95% confidence level. The second highest F-statistic was obtained for 1,2,3,7,8,9-HxCDF; however, detectable levels of this compound were obtained from only 5 specimens. The probability levels associated with the overall F-statistic for the remaining 14 analyses ranged from 0.31 to 0.88. Table 4-27 summarizes the ANOVA results.

The significant sex effect for 1,2,3,7,8-PeCDF was considered to be inconclusive for two reasons. First, the sample size of 13 (23% of total) specimens with detectable levels is relatively small. Second, the levels detected were close to the average detection limit (0.894 pg/g) for that compound. (The maximum detected level of 1,2,3,7,8-PeCDF is 1.93 pg/g, and the geometric mean of the 13 concentrations above LOD is 0.557 pg/g.)

Because of the very small sample size of 5 specimens, the significant age effect on 1,2,3,7,8,9-HxCDF was discounted as well.

A one-way analysis of variance to determine the effect of age group on 1,2,3,4,7,8/1,2,3,6,7,8-HxCDD concentration levels showed that concentration levels significantly increase with age, regardless of sex or city (p-value of 0.05). The means in the three age categories are 51.0, 60.7, and 79.0 pg/g, respectively. The means

from the youngest and oldest age groups are statistically different from each other; however, the remaining two pairwise comparisons (middle group vs. youngest or oldest) are not significant. Because of the small number (7) of young people, the specimens were grouped into two age categories, below and above 50 years. The analysis of variance provided again a significant age effect ($p = 0.02$), with an average concentration in the below 50 group (sample size of 27) of 58.1 pg/g as compared to an average of 79.0 pg/g for the older group (sample size of 30).

The only significant interaction, city by sex, was found for OCDD. In that case, average concentration levels were significantly higher ($p = 0.02$) for San Francisco women (634 pg/g, 17 specimens) than for Los Angeles women (407 pg/g, 11 specimens). However, average concentration levels in men did not vary between the two cities (377 pg/g from 9 specimens in San Francisco and 387 pg/g from 20 specimens in Los Angeles).

Comparing average female vs. male OCDD levels within each city provided no significant differences between sexes, neither in San Francisco ($p = 0.16$) nor in Los Angeles ($p = 0.26$).

> In San Francisco, women have higher OCDD levels than men, with average OCDD levels of 634 pg/g from 17 San Francisco women and 482 pg/g from 9 San Francisco men. The non-significant difference between these two results is due to the large variability in concentration levels and unequal sample sizes. A relative ratio of 1.48 of female to male results would be necessary to show a significant difference at the 95% confidence level. The ratio of the results here is 1.04.
>
> In Los Angeles, men have higher OCDD levels than women, with average OCDD levels of 518 pg/g from 20 men and 407 pg/g from 11 women. This difference is not statistically significant, however. A relative ratio of 1.53 of male to female OCDD levels would be necessary to find a significant difference. In this case, the ratio of male to female OCDD levels is 1.04, the exact inverse of the ratio from San Francisco specimens.

In summary, aside from a significant age effect for 1,2,3,4,7,8/1,2,3,6,7,8-HxCDD and a significant city by sex interaction for OCDD (all specimens had detectable levels in both cases), none of the factors considered in the survey design--city, sex, and age group--were statistically significant at the 5% level. Thus there is no statistical evidence that mean concentration levels differ between cities, sexes, age groups, or combinations thereof, for the majority of the compounds.

Data from other studies reported in the literature are presented in Section 5.0 for comparison of the data generated in the ARB-sponsored program. The statistical treatment of the data from the 57 samples has not demonstrated consistent significant effects across all compounds with respect to age, sex, or geographical region. Some of the studies report (in Section 5.0) "significant differences" based on age and/or sex. However, a correlation of the data from other studies with the data from this ARB program has not been conducted at this time.

Additional Considerations/Recommendations

The concentration data have been analyzed individually for each compound. However, correlations between compounds exist and have not been considered here. One could investigate possible relationships between age groups or sex, and the levels of all detected compounds by means of a multivariate analysis approach. The results from a series of principal component analyses and cluster analyses could possibly indicate some clustering of the specimens by their age or sex, or both, when considering all compounds simultaneously. Auxiliary variables, such as height and weight, or a derived measurement, such as body mass index, could also be considered to underline differences should they exist.

The questionnaires filled out by the patients who donated the specimens did not provide enough relevant information on most of the patients to include these results in the analysis.

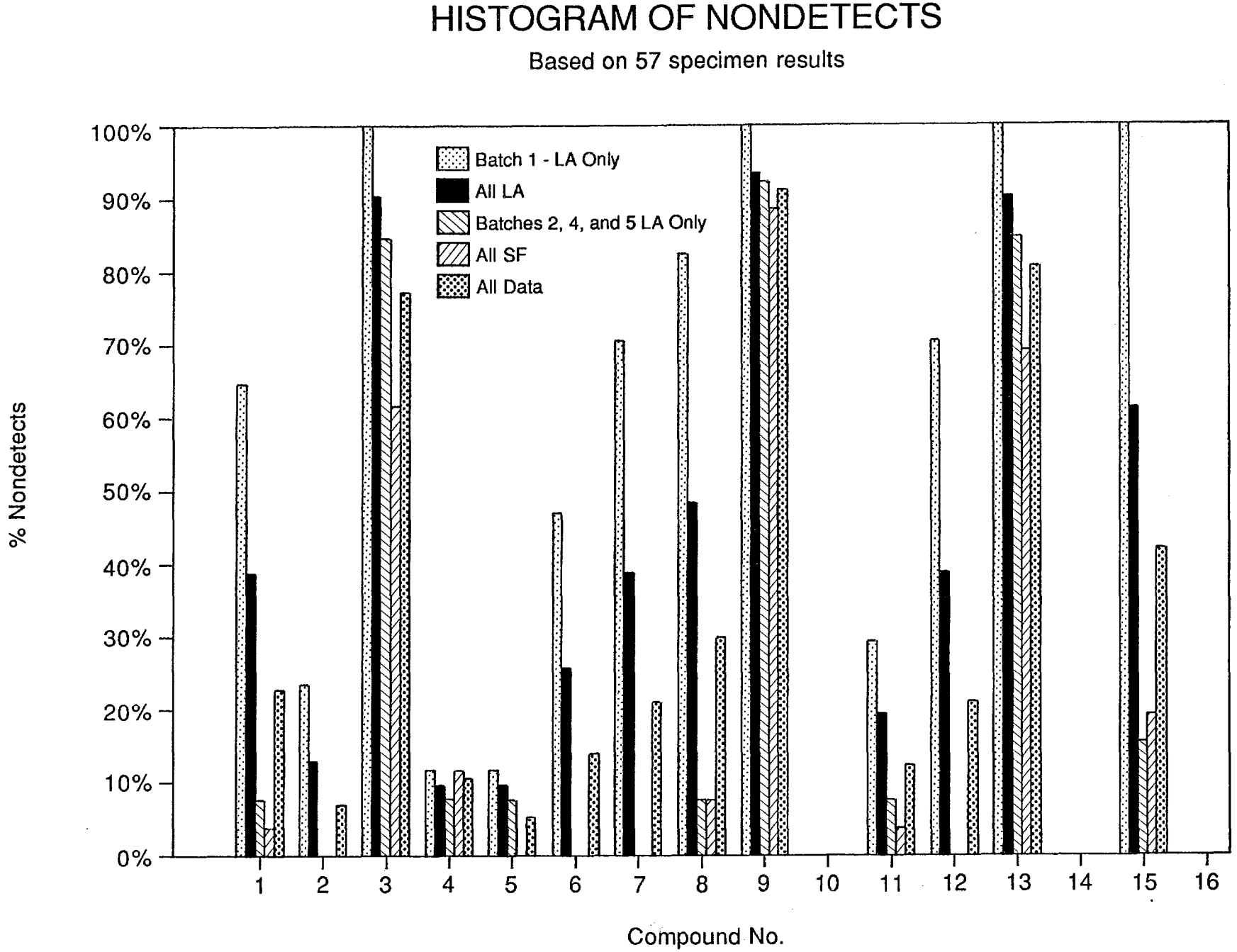


Figure 4-1. Incidence of nondetects for each PCDD and PCDF compound on a batch basis. The reference to compound number is given in Section 4.5.1 of the text.

Table 4-1. Age Group Distribution of Adipose Tissue Specimens

Age	San Francisco		Los Angeles		Overall	
	No. of specimens	% of goal	No. of specimens	% of goal	No. of specimens	% of goal
12-34	1	25	6	50	7	44
35-49	13	163	7	50	20	91
50+	12	150	18	129	30	136

Table 4-2. Lipid Adjusted Concentrations (pg/g) of PCDDs and PCDFs in Human Adipose Tissues--Batch 1

SEX	Female	Male	Female	Female	Female	Female	Male	Male	Female	Female
AGE	59	50	42	52	59	44	49	33	88	46
CITY	LA	LA	LA	LA	LA	LA	LA	LA	LA	LA
COMPOUND										
2378 TCDF	ND(1.12)	ND(0.71)	ND(1.83)	ND(1.74)	1.45	ND(2.27)	ND(1.89)	2.34	2.61	ND(0.60)
2378 TCDD	3.02	ND(1.30)	2.52	2.46	6.77	2.31	ND(1.21)	4.33	8.55	7.34
12378 PECDF	ND(2.22)	ND(2.92)	ND(2.32)	ND(0.70)	ND(0.74)	ND(0.75)	ND(0.31)	ND(2.32)	ND(3.31)	ND(0.46)
23478 PECDF	9.15	6.66	6.72	2.11	13.2	11.1	4.62	8.37	25.3	ND(0.42)
12378 PECDD	11.0	7.81	4.24	3.55	12.1	7.97	4.97	5.03	24.9	39.1
123478 HXCDF	ND(9.90)	ND(7.24)	3.55	ND(3.90)	1.69	7.20	ND(4.10)	ND(12.5)	ND(17.1)	5.64
123678HXCDF	ND(9.72)	ND(7.11)	ND(1.47)	ND(3.83)	1.83	2.02	ND(4.03)	ND(12.3)	ND(4.26)	ND(2.61)
234678 HXCDF	ND(11.6)	10.5	ND(1.61)	ND(4.55)	ND(1.32)	ND(1.29)	ND(4.79)	ND(14.6)	ND(5.06)	ND(3.11)
123789 HXCDF	ND(12.6)	ND(9.24)	ND(1.38)	ND(4.97)	ND(1.44)	ND(1.41)	ND(5.23)	ND(16.0)	ND(5.33)	ND(3.39)
123478 HXCDD/ 123678 HXCDD *	75.4	40.3	41.7	21.9	64.9	46.6	20.1	56.1	114	27.8
123789 HXCDD	11.0	ND(4.42)	4.93	22.5	8.63	6.41	15.7	ND(11.8)	12.2	ND(10.7)
1234678 HPCDF	4.48	ND(19.7)	ND(5.74)	6.37	ND(7.24)	ND(150)	ND(729.)	ND(7.30)	ND(7.31)	7.66
1234789 HPCDF	ND(2.30)	ND(28.1)	ND(3.29)	ND(1.53)	ND(10.3)	ND(6.90)	ND(4.96)	ND(7.00)	ND(5.38)	ND(3.75)
1234678 HPCDD	22.0	31.6	58.3	49.9	151	36.1	177	57.3	75.4	51.0
OCDF	ND(3.96)	ND(1.19)	ND(2.02)	ND(0.68)	ND(1.83)	ND(7.95)	ND(0.54)	ND(2.61)	ND(5.66)	ND(0.88)
OCDD	338	199	695	374	749	455	572	350	415	437
2378 TCDD Toxic Equivalent	26.6	16.9	16.7	11.1	40.4	24.3	16.0	23.5	67.4	49.2

* - Sum of 123478 and 123678 HXCDD isomers

Note: 2378-TCDD toxic equivalents based on the California Department of Health Services Procedure.

Table 4-2 (continued)

SEX	Female	Male	Female	Male	Female	Male	Male
AGE	66	12-34	53	33	30	27	33
CITY	LA	LA	LA	LA	LA	LA	LA
COMPOUND							
2378 TCDF	2.12	ND(1.12)	1.70	ND(0.82)	1.78	ND(1.05)	ND(0.68)
2378 TCDD	4.14	ND(1.24)	1.95	3.99	5.96	1.80	ND(2.57)
12378 PECDF	ND(1.04)	ND(5.76)	ND(0.57)	ND(1.63)	ND(1.43)	ND(0.52)	ND(0.50)
23478 PECDF	10.3	ND(5.26)	1.56	15.5	10.3	5.74	4.63
12378 PECDD	9.05	ND(5.00)	1.98	15.3	10.1	ND(15.1)	6.19
123478 HXCDF	6.27	3.76	1.98	12.0	8.28	ND(0.12)	ND(0.09)
123678HXCDF	3.42	ND(2.42)	ND(1.69)	3.43	8.13	ND(0.12)	ND(0.08)
234678 HXCDF	ND(2.11)	ND(2.87)	ND(2.01)	9.80	2.10	ND(0.14)	ND(0.10)
123789 HXCDF	ND(2.31)	ND(3.14)	ND(2.19)	ND(1.97)	ND(10.6)	ND(0.16)	ND(0.11)
123478 HXCDD/							4.64
123678 HXCDD *	63.0	15.6	26.2	103	62.0	49.8	36.3
123789 HXCDD	10.9	ND(9.34)	20.2	20.3	9.32	14.4	ND(5.35)
1234678 HPCDF	ND(9.60)]	ND(3.82)	12.2	15.8	ND(18.4)	ND(9.24)	ND(0.59)
1234789 HPCDF	ND(5.14)	ND(5.46)	ND(1.20)	ND(0.96)	ND(1.67)	ND(1.31)	ND(0.85)
1234678 HPCDD	70.9	88.3	43.2	89.1	104	72.6	31.2
OCDF	ND(0.50)	ND(0.37)	ND(4.00)	ND(1.66)	ND(1.13)	ND(0.94)	ND(2.01)
OCDD	345	152	178	1250	478	470	316
2378 TCDD Toxic Equivalent	30.2	3.23	10.3	42.4	34.0	11.6	13.0

* - Sum of 123478 and 123678 HXCDD isomers

Note: 2378-TCDD toxic equivalents based on the California Department of Health Services Procedure.

Table 4-3. Lipid Adjusted Concentrations (pg/g) of PCDDs and PCDFs in Human Adipose Tissue--Batch 2

SEX	Male	Male *	Male	Male	Male *	Male	Male	Male
AGE	50 +	50 +	50 +	50 +	50 +	50 +	12-34	35-49
CITY	LA	LA	LA	LA	LA	LA	LA	LA
COMPOUND								
2378 TCDF	1.22	6.49	1.76	1.15	0.976	1.1	0.634	0.961
2378 TCDD	3.62	4.46	6.07	2.65	1.98	5.99	2.46	3.78
12378 PECDF	ND(0.59)	ND(0.67)	ND(0.23)	ND(0.21)	ND(0.8l)	ND(0.20)	ND(0.73)	0.35
23478 PECDF	4.89	5.96	5.13	5.28	4.8	2.79	2.7	5.11
12378 PECDD	8.85	7.98	13.3	7.7	6.3	13.6	ND(5.95)	10.8
123478 HXCDF	6.95	5.4	16.7	4.16	5.17	7.13	4.82	7.55
123678 HXCDF	4.55	2.92	8.85	2.43	2.96	12.7	2.89	4.18
234678 HXCDF	0.772	0.715	3.15	0.885	0.733	ND(1.5)	1.37	2.08
123789 HXCDF	0.557	ND(0.74)	ND(0.40)	ND(0.24)	ND(1.17)	ND(1.5)	ND(1.83)	ND(0.46)
123478 HXCDD	13.1	7.25	21.4	7.65	6.4	* *	7.88	18.4
123678 HXCDD	77.1	57.2	116	57.8	63.7	154	44.5	69.4
123789 HXCDD	9.21	4.47	15	5.07	6.12	ND(1.50)	4.79	10.5
1234678 HPCDF	6.07	4.82	25.8	5.73	8.52	12.1	8.85	9.72
1234789 HPCDF	ND(0.36)	ND (0.32)	0.733	ND(0.45)	0.38	ND(2.97)	ND(0.16)	ND(0.57)
1234678 HPCDD	84.2	35.8	181	35.4	36.4	290	74.8	154
OCDF	0.668	0.836	1.37	ND(0.54)	0.911	0.891	0.946	0.988
OCDD	766	275	1320	237	880	885	304	1060
2378 TCDD Toxic Equivalent	24.7	28.4	37.9	20.4	18.0	37.8	10.3	29.3

* - mean of duplicate sample preparations and analyses
**- 123478 HXCDD summed with 123678 HXCDD

Note: 2378-TCDD toxic equivalents based on the California Department of Health Services Procedure.

Table 4-3 (continued)

SEX	Male	Male	Female	Male	Female	Male	Male	Male
AGE	42	42	51	50	52	58	76	55
CITY	LA	SF	SF	SF	SF	SF	SF	LA
COMPOUND								
2378 TCDF	0.868	0.898	2.58	ND(2.26)	0.97	2.28	3.18	ND(1.57)
2378 TCDD	3.87	3.49	3.94	3.8	4.35	9.33	5.6	4.38
12378 PECDF	ND(0.62)	ND(0.87)	ND(0.16)	ND(0.67)	ND(0.12)	ND(0.09)	ND(0.64)	ND(0.92)
23478 PECDF	15.3	6.61	3.48	ND(0.71)	2.99	0.726	6.83	4.41
12378 PECDD	9.05	12.3	7.71	12.6	11.8	25.2	15	9.52
123478 HXCDF	12.6	17.3	7.22	6.32	7.39	11.2	7.89	8.10
123678 HXCDF	4.24	5.53	4.06	4.13	4.02	7.42	5.41	4.08
234678 HXCDF	0.906	ND(1.13)	1.27	1.35	0.826	4.41	1.55	1.44
123789 HXCDF	ND(0.11)	ND(2.34)	ND(0.36)	ND(1.08)	0.643	ND(1.17)	ND(0.85)	ND(0.50)
123478 HXCDD	7.33	10.9	8.37	11.5	8.79	38.3	9.8	13.8
123678 HXCDD	47.7	68.8	52.2	71.6	74.2	126	88.5	80.3
123789 HXCDD	6.15	7.21	8.02	9.57	6.05	13.3	6.95	9.89
1234678 HPCDF	8.2	6.48	8.54	7.83	9.27	10.5	8.66	8.71
1234789 HPCDF	ND(0.25)	ND(0.55)	ND(0.27)	ND(0.24)	ND(0.33)	ND(0.23)	0.743	ND(0.12)
1234678 HPCDD	39.5	62.7	69	80.3	34.3	297	72	129
OCDF	0.857	ND(0.68)	0.78	ND(1.61)	1.00	0.838	ND(1.3)	0.942
OCDD	341	304	760	469	336	774	669	757
2378 TCDD Toxic Equivalent	32.9	28.7	22.5	22.2	24.5	52.8	36.7	26.0

Note: 2378-TCDD toxic equivalents based on the California Department of Health Services Procedure.

Table 4-4. Lipid Adjusted Concentrations (pg/g) of PCDDs and PCDFs in Human Adipose Tissue--Batch 3

SEX	Female	Male	Female	Female	Male	Male	Female *
AGE	37	39	43	43	65	65	65
CITY	SF	SF	SF	SF	SF	SF	SF
COMPOUND							
2378 TCDF	1.19	2.13	2.31	3.88	1.82	1.48	1.01
2378 TCDD	7.08	4.03	3.48	3.37	4.84	4.40	5.89
12378 PECDF	ND(0.45)	0.464	ND(0.37)	0.372	ND(0.19)	0.257	ND(0 .10)
23478 PECDF	3.41	2.74	2.68	2.6	ND(0.55)	1.12	3.95
12378 PECDD	15.1	8.85	8.24	8.51	9.59	9.56	13.0
123478 HXCDF	13.5	6.34	4.67	5.65	5.12	5.73	6.14
123678 HXCDF	6.72	3.89	2.82	3.5	3.51	3.04	3.61
234678 HXCDF	3.27	1.42	1.60	1.13	1.18	0.674	0.528
123789 HXCDF	ND(0.10)	ND(0.12)	ND(0.62)	ND(0.10)	ND(1.35)	ND(0.57)	0.742
123478 HXCDD	22.6	9.17	10.3	* *	7.46	11.0	10.5
123678 HXCDD	92.3	56.8	47.7	56.6	50.2	57.6	71.5
123789 HXCDD	15.2	7.17	6.61	5.00	4.90	6.20	7.40
1234678 HPCDF	20.2	11.5	5.03	4.84	7.55	7.35	5.28
1234789 HPCDF	ND(0.60)	0.443	0.341	0.236	ND(0.17)	ND(0.46)	0.34
1234678 HPCDD	334	83.2	120	42.2	60.6	65.9	44.0
OCDF	0.847	0.918	0.675	0.435	0.864	1.01	0.486
OCDD	1230	397	773	137	359	410	923
2378 TCDD Toxic Equivalent	42.0	23.6	22.7	22.3	20.5	21.5	28.4

* - mean of duplicate sample preparations and analyses

**- 123478 HXCDD summed with 123678 HXCDD

Note: 2378-TCDD toxic equivalents based on the California Department of Health Services Procedure.

Table 4-5. Lipid Adjusted Concentrations (pg/g) of PCDDs and PCDFs in Human Adipose Tissue--Batch 4

SEX	Female *	Female	Female	Female	Female	Male	Male	Male	Male
AGE	35-49	44	35-49	35-49	63	50 +	35-49	50 +	50 +
CITY	SF	SF	SF	SF	SF	SF	SF	LA	LA
2378 TCDF	1.22	2.73	5.36	1.29	3.35	1.82	3.58	2.10	2.28
2378 TCDD	2.25	11.8	3.76	4.11	12.5	6.06	5.45	3.22	4.40
12378 PECDF	ND(0.39)	ND(0.49)	ND(0.58)	ND(0.62)	0.876	ND(0 .23)	0.305	ND(0.19)	0.278
23478 PECDF	3.13	15.0	ND(0.58)	2.83	24.1	13.7	11.3	6.02	7.74
12378 PECDD	4.36	21.4	5.60	13.0	24.9	12.9	8.63	5.63	9.28
123478 HXCDF	4.30	11.2	4.26	4.27	17.2	7.61	5.72	6.38	7.13
123678 HXCDF	2.42	6.50	2.79	2.30	11.9	5.23	3.78	3.64	4.64
234678 HXCDF	0.97	1.84	ND(1.46)	0.741	4.28	0.865	2.38	0.932	0.619
123789 HXCDF	ND (0.28)	ND(0.16)	ND(1.46)	ND(0.11)	ND(0.13)	ND(1.51)	ND(0.37)	0.942	ND(0.46)
123478 HXCDD	6.84	22.8	* *	10.0	25.1	11.0	10.7	6.07	9.80
123678 HXCDD	31.8	83.6	44.0	94.7	124	95.4	57.0	49.3	64.6
123789 HXCDD	6.02	17.7	ND(4.9)	31.7	22.2	11.8	6.76	6.97	9.13
1234678 HPCDF	12.4	11.2	8.50	4.08	20.2	6.12	5.94	9.38	6.26
1234789 HPCDF	ND(0.97)	ND(0.35)	ND(1.46)	ND(1.54)	0.633	ND(0.55)	ND(0.42)	ND(0.16)	ND(0.21)
1234678 HPCDD	79.4	158	92.2	203	317	51.3	109	53.0	33.0
OCDF	0.95	0.782	0.917	0.586	0.699	0.518	0.379	0.275	0.405
OCDD	548	915	728	376	949	676	481	458	521
2378 TCDD Toxic Equivalent	15.3	60.3	19.3	31.8	82.0	40.2	35.3	21.1	28.0

* - mean of duplicate sample preparations and analyses
**- 123478 HXCDD summed with 123678 HXCDD

Note: 2378-TCDD toxic equivalents based on the California Department of Health Services Procedure.

Table 4-6. Lipid Adjusted Concentrations (pg/g) of PCDDs and PCDFs in Human Adipose Tissue--Batch 5

SEX	Male	Male	Female	Female	Female	Female	Female	Female *
AGE	50+	50+	32	42	39	35-49	50 +	50 +
CITY	LA	LA	SF	SF	SF	SF	SF	SF
COMPOUND								
2378 TCDF	2.67	4.46	2.84	5.22	3.21	1.98	2.35	3.10
2378 TCDD	6.25	9.34	6.29	5.79	6.6	10.2	7.45	5.94
12378 PECDF	ND(0.48)	0.472	0.591	1.93	1.57	1.04	ND(0.22)	0.495
23478 PECDF	ND(2.85)	14.0	9.17	6.02	9.82	12.5	19.3	15.2
12378 PECDD	12.6	16.6	7.84	10.7	13.2	18.1	15.8	12.3
123478 HXCDF	9.53	15.7	10.1	9.73	11.7	11.6	12.9	7.92
123678HXCDF	6.29	10.7	5.63	6.53	6.56	7.31	8.93	5.61
234678 HXCDF	2.70	1.86	1.96	2.46	1.22	1.37	2.28	2.39
123789 HXCDF	ND(0.13)	ND(1.69)	0.155	ND(1.65)	ND(0.26)	ND(1.67)	ND(0 .21)	ND(0.94)
123478 HXCDD	22.6	19.6	9.69	10.9	14.4	21.5	15.1	12.8
123678 HXCDD	88.6	134	52.1	57.0	93.1	95.4	87.2	65.1
123789 HXCDD	15.9	20.0	10.0	11.5	16.5	15.4	14.3	10.8
1234678 HPCDF	10.5	13.7	10.8	13.3	11.4	13.5	18.6	9.97
1234789 HPCDF	ND(0.54)	0.643	ND(0.42)	0.561	ND(0.20)	ND(0.21)	0.579	ND(.30)
1234678 HPCDD	176	133	111	97.5	70.7	108	116	125
OCDF	0.917	ND(0.96)	ND(1.01)	0.444	0.983	ND(1.25)	4.55	3.62
OCDD	621	845	467	799	859	823	623	666
2378 TCDD Toxic Equivalent	31.5	55.3	33.1	35.9	41.2	52.0	53.2	44.1

*-mean of duplicate sample preparations and analyses

Note: 2378-TCDD toxic equivalents based on the California Department of Health Services Procedure.

Table 4-7. Precision of Duplicate Sample Preparations (Relative Percent Difference %)

	Batch 1[a]	Batch 2	Batch 2	Batch 3	Batch 4	Batch 5
Sex	Female	Male	Male	Female	Female	Female
Age	53	50 +	50 +	65	35-49	50 +
City	LA	LA	LA	SF	SF	SF
Compound						
2378 TCDF	13	81	1.8	9.3	24	6.1
2378 TCDD	13	13	19	6.1	55	3.5
12378 PECDF	1.7	NC b	NC	NC	NC	NC
23478 PECDF	4.0	24	1.5	48	160	28
12378 PECDD	12	3.9	8.6	14	9.4	14
123478 HXCDF	0.2	7.2	9.7	6.3	9.3	2.6
123678 HXCDF	7.2	4.8	3.4	5.6	0.4	7.1
234678 HXCDF	13	21	9.7	10	9.1	2.5
123789 HXCDF	13	NC	NC	NC	16	NC
123478 HXCDD	25	8.1	3.2	5.7	18	0.8
123678 HXCDD	35	9.4	4.1	7.0	4.7	0.5
123789 HXCDD	6.1	1.3	14	6.8	8.6	1.8
1234678 HPCDF	14	15	4.4	1.0	4.8	0.6
1234789 HPCDF	0.7	NC	NC	7.4	NC	0.7
1234678 HPCDD	25	2.5	6.9	16.1	8.4	7.3
OCDF	14	18	20	2.7	12	30
OCDD	7.2	3.6	0.0	6.5	4.2	7.4

a- Precision measurement from duplicate native spike sample preparations

b- NC: not calculated, compound not detected

Table 4-8. Control QC Sample Results (pg/g) CARB, 1989

Compound	Batch 2	Batch 3	Batch 4	Batch 5
2378 TCDF	1.02	0.96	1.17	1.34
2378 TCDD	9.35	9.51	10.10	10.30
12378 PECDF	0.44	ND(0.39)	ND(0.36)	ND(0.55)
23478 PECDF	12.0	9.69	18.9	24.3
12378 PECDD	21.7	18.1	32.2	20.4
123478 HXCDF	29.0	30.1	28.4	30.9
123678 HXCDF	11.6	11.5	12.0	15.6
234678 HXCDF	2.27	2.33	2.47	2.85
123789 HXCDF	ND(0.10)	ND(0.22)	ND(0.10)	ND(0.17)
123478 HXCDD	18.5	21.4	19.7	16.6
123678 HXCDD	133	136	133	137
123789 HXCDD	17.4	17.8	19.2	22.1
1234678 HPCDF	28.6	28.2	28.0	30.4
1234789 HPCDF	ND(1.12)	ND(1.26)	ND(1.32)	ND(1.34)
1234678 HPCDD	156	159	163	167
OCDF	1.41	1.50	1.88	2.83
OCDD	1,250	1,220	1,230	1,200

Table 4-8 (continued). Control QC Sample Results (pg/g) From Previous Analysis of NHATS FY 1987

Compound					
2378TCDF	1.24	0.999	ND(0.89) (a)	ND(0.74) (a)	ND(0.81) (a)
2378TCDD	10.60	9.13	9.73	8.66	8.34
12378PeCDF	ND (0.1)	ND (0.08)	0.48	ND(0.54)	ND(0.41)
23478PeCDF	28.2	24.5	24.6	24.9	23.1
12378PeCDD	19.5	21.9	20.9	20.2	21.5
123478HxCDF	ND(42.9) (b)	ND(29.2) (b)	18.7	ND(37.2) (b)	ND(33.6) (b)
123678HxCDF	12.5	12.2	7.56	9.21	12.7
234678HxCDF	ND (1.96)(c)	ND(1.93)(c)	ND(14.7) (b)	ND(15.8) (b)	ND(14.8) (b)
123789HxCDF	ND (0.5)	ND (0.5)	ND(0.64)	ND(0.92)	ND(0.73)
123478/123678HxCDD	134	140	151	126	133
123789HxCDD	19.6	23.0	ND(20.8) (a)	19.5	22.1
1234678HpCDF	31.8	27.0	29.1	30.1	31.1
1234789HpCDF	1.64	ND (0.9)	1.21	ND(1.36)	ND(0.97)
1234678HpCDD	151	144	125	140	138
12346789OCDF	ND (2.65)	2.37	ND(0.83)	7.30	2.39
12346789OCDD	1130	1250	1170	1180	1190

(a) - Ion ratios for these compounds were outside the ratio criteria for these compounds
(b) - The results for this compound include response for a diphenyl ether interference.
(c) - Diphenyl interferences in these samples were separated from the 234678HxCDF isomer.

Table 4-9. Method Accuracy (Recovery %) for PCDDs and PCDFs Spiked Into Human Adipose Tissue

Compound	Spike level (pg/g)	Batch 1 Rep 1	Batch 1 Rep 2
2378 TCDF	20	105	91
2378 TCDD	10	79	92
12378 PECDF	20	105	104
23478 PECDF	20	95	91
12378 PECDD	10	112	98
123478 HXCDF	50	85	85
123678 HXCDF	50	73	78
234678 HXCDF	50	96	85
123789 HXCDF	50	74	64
123478 HXCDD/	20		
123678 HXCDD	20	56	96
123789 HXCDD	20	111	105
1234678 HPCDF	50	111	131
1234789 HPCDF	50	96	97
1234678 HPCDD	20	32	96
OCDF	50	106	93
OCDD	400	92	82

Table 4-9 (continued)

Compound	Spike level (pg/g)	Batch 2	Batch 3	Batch 4	Batch 5
2378 TCDF	10	104	114	107	114
2378 TCDD	10	97	117	108	104
12378 PECDF	10	98	118	98	124
23478 PECDF	10	NC*	138	155	124
12378 PECDD	10	NC	126	99	105
123478 HXCDF	25	104	109	97	95
123678 HXCDF	25	108	112	93	118
234678 HXCDF	25	94	97	88	98
123789 HXCDF	25	89	91	92	121
123478 HXCDD	25	109	112	100	91
123678 HXCDD	25	105	119	99	143
123789 HXCDD	25	101	107	97	117
1234678 HPCDF	25	112	120	110	122
1234789 HPCDF	25	105	122	107	129
1234678 HPCDD	25	37	174	85	108
OCDF	50	96	99	89	110
OCDD	50	NC	126	49	NC

* - NC; Not Calculated due to high concentrations in control lipid

Table 4-9 (continued)

Compound	Spike level (pg/g)	Batch 2	Batch 3	Batch 4	Batch 5
2378 TCDF	25	106	117	115	128
2378 TCDD	25	107	114	113	105
12378 PECDF	25	107	121	101	122
23478 PECDF	25	58	23	92	122
12378 PECDD	25	109	147	102	103
123478 HXCDF	63	104	114	98	96
123678 HXCDF	63	108	125	98	113
234678 HXCDF	63	102	112	92	105
123789 HXCDF	63	95	107	95	112
123478 HXCDD	63	102	117	98	94
123678 HXCDD	63	104	120	107	134
123789 HXCDD	63	100	113	107	108
1234678 HPCDF	63	115	123	113	120
1234789 HPCDF	63	109	115	111	117
1234678 HPCDD	63	103	147	101	118
OCDF	125	96	100	97	118
OCDD	125	89	145	91	135

Table 4-10. Questionnaire Summary--Anatomical Origin of Adipose Tissue Sample

	CITY					
	LOS ANGELES		SAN FRANCISCO		BOTH CITIES	
	SEX		SEX		SEX	
	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE
	N	N	N	N	N	N
ANATOMICAL ORIGIN OF SAMPLE						
ABDOMEN	14	4	6	10	20	14
AXILLA	0	1	0	1	0	2
BACK	2	0	0	0	2	0
BREAST	0	5	0	5	0	10
CHEST	1	0	0	0	1	0
INGUINAL REGION	3	1	0	0	3	1
LEG	0	0	2	0	2	0
THIGH	0	0	0	1	0	1
UNKNOWN	0	0	1	0	1	0

Table 4-11. Questionnaire Summary--Race of Donor

	CITY					
	LOS ANGELES		SAN FRANCISCO		BOTH CITIES	
	SEX		SEX		SEX	
	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE
	N	N	N	N	N	N
RACE						
WHITE (NON-HISPANIC)	16	4	7	16	23	20
BLACK (NON-HISPANIC)	1	1	2	1	3	2
HISPANIC	3	4	0	0	3	4
ASIAN OR PACIFIC ISLANDER	0	2	0	0	0	2

Table 4-12. Questionnaire Summary--Height (in) of Donors

HEIGHT STATISTICS BY SEX AND AGE GROUP ACROSS CITIES		HEIGHT (INCHES)				
		N	MIN	MEAN	MAX	STD
SEX	AGE GROUP					
MALE	12-34 YEARS	5	65	68	71	2.2
	35-49 YEARS	6	65	71	76	4.2
	50 AND ABOVE	18	67	71	79	3.7
FEMALE	12-34 YEARS	2	65	65	65	0.4
	35-49 YEARS	14	59	65	71	3.3
	50 AND ABOVE	12	61	65	69	2.1

Table 4-13. Questionnaire Summary--Weight (lb) of Donor

WEIGHT STATISTICS BY SEX AND AGE GROUP ACROSS CITIES		WEIGHT (LBS)				
		N	MIN	MEAN	MAX	STD
SEX	AGE GROUP					
MALE	12-34 YEARS	5	130	182	250	44.0
	35-49 YEARS	6	140	190	230	35.8
	50 AND ABOVE	18	140	182	225	27.4
FEMALE	12-34 YEARS	2	148	179	210	43.8
	35-49 YEARS	14	120	178	243	38.6
	50 AND ABOVE	12	105	160	220	39.7

Table 4-14. Questionnaire Summary--Skinfold Caliper (mm) Measurements of Donors

CALIPER STATISTICS BY SEX AND AGE GROUP ACROSS CITIES		CALIPER (MM)				
		N	MIN	MEAN	MAX	STD
SEX	AGE GROUP					
MALE	12-34 YEARS	1	6.0	6.0	6.0	
	35-49 YEARS	2	7.0	7.5	8.0	0.71
	50 AND ABOVE	2	6.0	8.0	10.0	2.83
FEMALE	12-34 YEARS	1	26.0	26.0	26.0	
	35-49 YEARS	10	10.0	22.6	38.0	8.11
	50 AND ABOVE	7	2.0	15.0	32.0	10.91

Table 4-15. Number of Respondents Presently Living or Working Within 5 Miles of Potential Sources of PCDD and PCDF Contamination, by City

	Los Angeles		San Francisco	
	Live near	Work near	Live near	Work near
Municipal waste incinerator	1	1	1	0
Sewage sludge incinerator	1	0	1	0
Hospital	19	3	9	3
Wire reclamation incinerator	0	0	0	0
Hazardous waste site	0	0	0	2
Wood treatment facility	0	0	1	0

Table 4-16. Number of Respondents Who Have Relocated Within the Last 5 Years and Have Previously Lived or Worked Within 5 Miles of Potential Sources of PCDD and PCDF Contamination, by City

	Los Angeles		San Francisco	
	Lived near	Worked near	Lived near	Worked near
Municipal waste incinerator	0	0	0	0
Sewage sludge incinerator	0	0	0	0
Hospital	5	1	2	1
Wire reclamation incinerator	0	0	0	0
Hazardous waste site	0	0	0	0
Wood treatment facility	0	0	0	0

Table 4-17. Number of Respondents With Potential Chemical Exposure at Work, at Home During the Last 5 Years, or From Vietnam, by City

	Los Angeles	San Francisco
Job involving handling of chemicals (Q # 18)	6	2
Job involving handling of electrical equipment (Q # 19)	4	0
Job involving incineration of plastic or wood materials (Q # 20)	1	1
Service in Vietnam (Q # 21)	1 (from March 1968-February 1969 and involved in use of defoliant)	0
Use of pest control services in/or outside residence (Q # 22)	8	6
Use of lawn and garden spraying services at residence (Q # 23)	10	3
General use of wood preservatives (Q # 24)	3	1
Use of herbicides during leisure activities (Q # 25)	3	4
Use of pesticides during leisure activities (Q # 25)	9	5
Use of wood preservatives during leisure activities (Q # 25)	2	2

Table 4-18. Number of Respondents in Various Relevant Occupational Categories, by City

	Los Angeles	San Francisco
Professional with chemical exposure (Q # 29 b))	3	3
Laborer with chemical exposure (Q # 31b))	7	0
Nonprofessional or unskilled laborer with chemical exposure (Q # 32b)	2	1

Table 4-19. Distribution of Adipose Tissue Specimens Across Design Cells

Age	San Francisco		Los Angeles		Total
	Female	Male	Female	Male	
12-34	1	0	1	5	7
35-49	10	3	4	3	20
50+	6	6	6	12	30
Total	17	9	11	20	57

Table 4-20. Overall Results on Occurrences of Compounds in 57 Samples by City and Across Both Cities

		LOS ANGELES (31 samples)				SAN FRANCISCO (26 samples)				BOTH CITIES (57 samples)			
Compound	No.	ND	PQ	%ND	%PQ	ND	PQ	%ND	%PQ	ND	PQ	%ND	%PQ
2378-TCDF	1	12	19	39%	61%	1	25	4%	96%	13	44	23%	77%
2378-TCDD	2	4	27	13%	87%		26		100%	4	53	7%	93%
12378-PeCDF	3	28	3	90%	10%	16	10	62%	38%	44	13	77%	23%
23478-PeCDF	4	3	28	10%	90%	3	23	12%	88%	6	51	11%	89%
12378-PeCDD	5	3	28	10%	90%		26		100%	3	54	5%	95%
123478-HxCDF	6	8	23	26%	74%		26		100%	8	49	14%	86%
123678-HxCDF	7	12	19	39%	61%		26		100%	12	45	21%	79%
234678-HxCDF	8	15	16	48%	52%	2	24	8%	92%	17	40	30%	70%
123789-HxCDF	9	29	2	94%	6%	23	3	88%	12%	52	5	91%	9%
123478/123678-HxCDD	10		31		100%		26		100%		57		100%
123789-HxCDD	11	6	25	19%	81%	1	25	4%	96%	7	50	12%	88%
1234678-HpCDF *1	12	10	19	34%	66%		26		100%	10	45	18%	82%
1234789-HpCDF	13	28	3	90%	10%	18	8	69%	31%	46	11	81%	19%
1234678-HpCDD	14		31		100%		26		100%		57		100%
OCDF	15	19	12	61%	39%	5	21	19%	81%	24	33	42%	58%
OCDD	16		31		100%		26		100%		57		100%

*1: Interference in analysis could not be removed for two Los Angeles samples

ND = Not detected; PQ = Positive quantifiable.

Table 4-21. Concentration Statistics by Compound, City, Sex, and Age Group

Compound (No.)	City	Sex	Age group	Number of detects/ number of specimens	Minimum detected level (pg/g)	Lower 95% limit of geometric mean (pg/g)	Geometric mean of detected levels (pg/g)	Upper 95% limit of geometric mean (pg/g)	Maximum detected level (pg/g)
2378-TCDF (1)	Los Angeles	Female	12-34 years	1 of 1	1.78		1.78		1.78
			35-49 years	0 of 4					
			50 and above	4 of 6	1.45	1.28	1.92	2.89	2.61
		Male	12-34 years	2 of 5	0.634		1.22		2.34
			35-49 years	2 of 3	0.868		0.913		0.961
			50 and above	10 of 12	0.976	1.27	1.99	3.12	6.49
	San Francisco	Female	12-34 years	1 of 1	2.84		2.84		2.84
			35-49 years	10 of 10	1.19	1.63	2.46	3.70	5.36
			50 and above	6 of 6	0.970	1.11	1.99	3.56	3.35
		Male	12-34 years	0 of 0					
			35-49 years	3 of 3	0.898	0.335	1.90	10.8	3.58
			50 and above	5 of 6	1.48	1.42	2.04	2.93	3.18
2378-TCDD (2)	Los Angeles	Female	12-34 years	1 of 1	5.96		5.96		5.96
			35-49 years	3 of 4	2.31	0.707	3.50	17.3	7.34
			50 and above	6 of 6	1.95	2.12	3.89	7.15	8.55
		Male	12-34 years	4 of 5	1.80	1.53	2.96	5.72	4.33
			35-49 years	2 of 3	3.78		3.82		3.87
			50 and above	11 of 12	1.98	3.26	4.37	5.87	9.34
	San Francisco	Female	12-34 years	1 of 1	6.29		6.29		6.29
			35-49 years	10 of 10	2.25	3.54	5.16	7.51	11.8
			50 and above	6 of 6	3.94	4.00	6.18	9.56	12.5
		Male	12-34 years	0 of 0					
			35-49 years	3 of 3	3.49	2.41	4.25	7.47	5.45
			50 and above	6 of 6	3.80	3.91	5.43	7.54	9.33

Note: Upper and lower confidence limits are not computed for less than 3 samples per cell
Significant figures for each compound are limited to 3

Table 4-21 (continued)

Compound (No.)	City	Sex	Age group	Number of detects/ number of specimens	Minimum detected level (pg/g)	Lower 95% limit of geometric mean (pg/g)	Geometric mean of detected levels (pg/g)	Upper 95% limit of geometric mean (pg/g)	Maximum detected level (pg/g)
12378-PeCDF (3)	Los Angeles	Female	12-34 years	0 of 1					
			35-49 years	0 of 4					
			50 and above	0 of 6					
		Male	12-34 years	0 of 5	0.524		0.524		0.524
			35-49 years	1 of 3	0.350		0.35		0.350
			50 and above	2 of 12	0.278		0.3622		0.472
	San Francisco	Female	12-34 years	1 of 1	0.591		0.591		0.591
			35-49 years	4 of 10	0.370	0.323	1.04	3.34	1.93
			50 and above	2 of 6	0.495		0.6585		0.876
		Male	12-34 years	0 of 0					
			35-49 years	2 of 3	0.305		0.3762		0.464
			50 and above	1 of 6	0.257		0.257		0.257
23478-PeCDF (4)	Los Angeles	Female	12-34 years	1 of 1	10.3		10.3		10.3
			35-49 years	3 of 4	4.63	2.22	7.02	22.2	11.1
			50 and above	6 of 6	1.56	2.18	6.85	21.6	25.3
		Male	12-34 years	4 of 5	2.70	2.09	6.70	21.4	15.5
			35-49 years	3 of 3	4.62	1.25	7.12	40.6	15.3
			50 and above	11 of 12	2.79	4.36	5.69	7.43	14.0
	San Francisco	Female	12-34 years	1 of 1	9.17		9.17		9.17
			35-49 years	9 of 10	2.60	2.95	5.10	8.81	15.0
			50 and above	6 of 6	2.99	2.99	8.14	22.2	24.1
		Male	12-34 years	0 of 0					
			35-49 years	3 of 3	2.74	0.904	5.89	38.4	11.3
			50 and above	4 of 6	0.726	0.314	2.95	27.8	13.7

Note: Upper and lower confidence limits are not computed for less than 3 samples per cell
Significant figures for each compound are limited to 3

Table 4-21 (continued)

Compound (No.)	City	Sex	Age group	Number of detects/ number of specimens	Minimum detected level (pg/g)	Lower 95% limit of geometric mean (pg/g)	Geometric mean of detected levels (pg/g)	Upper 95% limit of geometric mean (pg/g)	Maximum detected level (pg/g)
12378-PeCDD (5)	Los Angeles	Female	12-34 years	1 of 1	10.1		10.1		10.1
			35-49 years	4 of 4	4.24	2.01	9.51	45.0	39.1
			50 and above	6 of 6	1.98	2.96	7.71	20.1	24.9
		Male	12-34 years	2 of 5	5.03		8.77		15.3
			35-49 years	3 of 3	4.97	2.71	7.86	22.8	10.8
			50 and above	12 of 12	5.63	7.66	9.44	11.6	16.6
	San Francisco	Female	12-34 years	1 of 1	7.84		7.84		7.84
			35-49 years	10 of 10	4.36	7.40	10.6	15.3	21.4
			50 and above	6 of 6	7.71	8.93	13.4	20.0	24.9
		Male	12-34 years	0 of 0					
			35-49 years	3 of 3	8.63	5.83	9.79	16.4	12.3
			50 and above	6 of 6	9.56	9.16	13.3	19.4	25.2
123478-HxCDF (6)	Los Angeles	Female	12-34 years	1 of 1	8.28		8.28		8.28
			35-49 years	3 of 4	3.55	2.05	5.24	13.4	7.20
			50 and above	3 of 6	1.69	0.423	2.76	18.0	6.27
		Male	12-34 years	3 of 5	3.76	1.21	6.01	29.8	12.0
			35-49 years	2 of 3	7.55		9.75		12.6
			50 and above	11 of 12	4.16	5.72	7.66	10.2	16.7
	San Francisco	Female	12-34 years	1 of 1	10.1		10.1		10.1
			35-49 years	10 of 10	4.26	5.10	7.27	10.4	13.5
			50 and above	6 of 6	6.14	6.00	9.12	13.9	17.2
		Male	12-34 years	0 of 0					
			35-49 years	3 of 3	5.72	1.72	8.56	42.5	17.3
			50 and above	6 of 6	5.12	5.27	7.07	9.47	11.2

Note: Upper and lower confidence limits are not computed for less than 3 samples per cell
Significant figures for each compound are limited to 3

Table 4-21 (continued)

Compound (No.)	City	Sex	Age group	Number of detects/ number of specimens	Minimum detected level (pg/g)	Lower 95% limit of geometric mean (pg/g)	Geometric mean of detected levels (pg/g)	Upper 95% limit of geometric mean (pg/g)	Maximum detected level (pg/g)
123678-HxCDF (7)	Los Angeles	Female	12-34 years	1 of 1	8.13		8.13		8.13
			35-49 years	1 of 4	2.02		2.02		2.02
			50 and above	2 of 6	1.83		2.50		3.42
		Male	12-34 years	2 of 5	2.89		3.15		3.43
			35-49 years	2 of 3	4.18		4.21		4.24
			50 and above	11 of 12	2.43	3.45	5.01	7.27	12.7
	San Francisco	Female	12-34 years	1 of 1	5.63		5.63		5.63
			35-49 years	10 of 10	2.30	3.03	4.29	6.07	7.31
			50 and above	6 of 6	3.61	3.43	5.72	9.55	11.9
		Male	12-34 years	0 of 0					
			35-49 years	3 of 3	3.78	2.49	4.33	7.55	5.53
			50 and above	6 of 6	3.04	3.26	4.58	6.44	7.42
234678-HxCDF (8)	Los Angeles	Female	12-34 years	1 of 1	2.10		2.10		2.10
			35-49 years	0 of 4					
			50 and above	0 of 6					
		Male	12-34 years	2 of 5	1.37		3.66		9.80
			35-49 years	2 of 3	0.906		1.37		2.08
			50 and above	11 of 12	0.619	0.797	1.43	2.55	10.5
	San Francisco	Female	12-34 years	1 of 1	1.96		1.96		1.96
			35-49 years	9 of 10	0.741	1.03	1.47	2.10	3.27
			50 and above	6 of 6	0.528	0.683	1.53	3.44	4.28
		Male	12-34 years	0 of 0					
			35-49 years	2 of 3	1.42		1.84		2.38
			50 and above	6 of 6	0.674	0.687	1.36	2.69	4.41

Note: Upper and lower confidence limits are not computed for less than 3 samples per cell
Significant figures for each compound are limited to 3

Table 4-21 (continued)

Compound (No.)	City	Sex	Age group	Number of detects/ number of specimens	Minimum detected level (pg/g)	Lower 95% limit of geometric mean (pg/g)	Geometric mean of detected levels (pg/g)	Upper 95% limit of geometric mean (pg/g)	Maximum detected level (pg/g)
123789-HxCDF (9)	Los Angeles	Female	12-34 years	0 of 1					
			35-49 years	0 of 4					
			50 and above	0 of 6					
		Male	12-34 years	0 of 5					
			35-49 years	0 of 3					
			50 and above	2 of 12	0.557		0.724		0.942
	San Francisco	Female	12-34 years	1 of 1	0.155		0.155		0.155
			35-49 years	0 of 10	0.275		0.275		0.275
			50 and above	2 of 6	0.643		0.6907		0.742
		Male	12-34 years	0 of 0					
			35-49 years	0 of 3					
			50 and above	0 of 6					
123478/ 123678-HxCDD (10)	Los Angeles	Female	12-34 years	1 of 1	62.0		62.0		62.0
			35-49 years	4 of 4	27.8	26.9	38.6	55.2	46.6
			50 and above	6 of 6	21.9	26.6	52.2	102	114
		Male	12-34 years	5 of 5	15.6	20.2	47.2	111	103
			35-49 years	3 of 3	20.1	6.38	46.0	331	87.8
			50 and above	12 of 12	40.3	65.3	85.4	112	154
	San Francisco	Female	12-34 years	1 of 1	61.8		61.8		61.8
			35-49 years	10 of 10	38.7	55.8	75.6	102	117
			50 and above	6 of 6	60.6	64.5	88.8	122	149
		Male	12-34 years	0 of 0					
			35-49 years	3 of 3	66.0	54.2	70.9	92.7	79.7
			50 and above	6 of 6	57.7	61.8	90.9	134	164

Note: Upper and lower confidence limits are not computed for less than 3 samples per cell
Significant figures for each compound are limited to 3

Table 4-21 (continued)

Compound (No.)	City	Sex	Age group	Number of detects/ number of specimens	Minimum detected level (pg/g)	Lower 95% limit of geometric mean (pg/g)	Geometric mean of detected levels (pg/g)	Upper 95% limit of geometric mean (pg/g)	Maximum detected level (pg/g)
123789-HxCDD (11)	Los Angeles	Female	12-34 years	1 of 1	9.32		9.32		9.32
			35-49 years	2 of 4	4.93		5.62		6.41
			50 and above	6 of 6	8.63	8.98	13.4	19.9	22.5
		Male	12-34 years	3 of 5	4.79	1.55	11.2	80.8	20.3
			35-49 years	3 of 3	6.15	2.93	10.0	34.5	15.7
			50 and above	10 of 12	4.47	6.35	9.09	13.0	20.0
	San Francisco	Female	12-34 years	1 of 1	10.0		10.0		10.0
			35-49 years	9 of 10	5.00	7.51	11.9	19.0	31.7
			50 and above	6 of 6	6.05	6.25	10.4	17.1	22.2
		Male	12-34 years	0 of 0					
			35-49 years	3 of 3	6.76	6.41	7.04	7.73	7.21
			50 and above	6 of 6	4.90	5.48	8.26	12.4	13.3
1234678-HpCDF (12)	Los Angeles	Female	12-34 years	0 of 1					
			35-49 years	1 of 4	7.66		7.66		7.66
			50 and above	3 of 6	4.48	1.86	7.04	26.7	12.2
		Male	12-34 years	2 of 5	8.85		11.8		15.8
			35-49 years	2 of 3	8.20		8.93		9.72
			50 and above	11 of 12	4.82	6.55	9.04	12.5	25.8
	San Francisco	Female	12-34 years	1 of 1	10.8		10.8		10.8
			35-49 years	10 of 10	4.08	6.37	9.30	13.6	20.2
			50 and above	6 of 6	5.28	6.33	10.8	18.3	20.2
		Male	12-34 years	0 of 0					
			35-49 years	3 of 3	5.94	2.97	7.62	19.5	11.5
			50 and above	6 of 6	6.12	6.54	7.89	9.53	10.5

Note: Upper and lower confidence limits are not computed for less than 3 samples per cell
Significant figures for each compound are limited to 3

Table 4-21 (continued)

Compound (No.)	City	Sex	Age group	Number of detects/ number of specimens	Minimum detected level (pg/g)	Lower 95% limit of geometric mean (pg/g)	Geometric mean of detected levels (pg/g)	Upper 95% limit of geometric mean (pg/g)	Maximum detected level (pg/g)
1234789-HpCDF (13)	Los Angeles	Female	12-34 years	0 of 1					
			35-49 years	0 of 4					
			50 and above	0 of 6					
		Male	12-34 years	0 of 5					
			35-49 years	0 of 3					
			50 and above	3 of 12	0.380	0.227	0.564	1.40	0.733
	San Francisco	Female	12-34 years	0 of 1					
			35-49 years	3 of 10	0.236	0.114	0.356	1.11	0.561
			50 and above	3 of 6	0.340	0.207	0.499	1.21	0.633
		Male	12-34 years	0 of 0					
			35-49 years	1 of 3	0.443		0.443		0.443
			50 and above	1 of 6	0.743		0.743		0.743
1234678-HpCDD (14)	Los Angeles	Female	12-34 years	1 of 1	104		104		104
			35-49 years	4 of 4	31.2	26.9	42.8	68.0	58.3
			50 and above	6 of 6	22.0	29.5	58.1	114	151
		Male	12-34 years	5 of 5	57.3	60.3	75.5	94.4	89.1
			35-49 years	3 of 3	39.5	11.7	102	900	177
			50 and above	12 of 12	31.6	45.2	75.4	126	290
	San Francisco	Female	12-34 years	1 of 1	111		111		111
			35-49 years	10 of 10	42.2	73.7	111	169	334
			50 and above	6 of 6	34.3	37.9	88.4	207	317
		Male	12-34 years	0 of 0					
			35-49 years	3 of 3	62.7	40.1	82.8	171	109
			50 and above	6 of 6	51.3	43.1	84.0	164	297

Note: Upper and lower confidence limits are not computed for less than 3 samples per cell
Significant figures for each compound are limited to 3

Table 4-21 (continued)

Compound (No.)	City	Sex	Age group	Number of detects/ number of specimens	Minimum detected level (pg/g)	Lower 95% limit of geometric mean (pg/g)	Geometric mean of detected levels (pg/g)	Upper 95% limit of geometric mean (pg/g)	Maximum detected level (pg/g)
OCDF (15)	Los Angeles	Female	12-34 years	0 of 1					
			35-49 years	0 of 4					
			50 and above	0 of 6					
		Male	12-34 years	1 of 5	0.946		0.946		0.946
			35-49 years	2 of 3	0.857		0.920		0.988
			50 and above	9 of 12	0.275	0.501	0.731	1.07	1.37
	San Francisco	Female	12-34 years	0 of 1					
			35-49 years	9 of 10	0.435	0.553	0.706	0.900	0.983
			50 and above	6 of 6	0.486	0.483	1.28	3.38	4.55
		Male	12-34 years	0 of 0					
			35-49 years	2 of 3	0.379		0.59		0.918
			50 and above	4 of 6	0.518	0.496	0.785	1.24	1.01
OCDD (16)	Los Angeles	Female	12-34 years	1 of 1	478		478		478
			35-49 years	4 of 4	316	273	457	765	695
			50 and above	6 of 6	178	226	366	594	749
		Male	12-34 years	5 of 5	152	152	394	1022	1250
			35-49 years	3 of 3	341	133	591	2619	1060
			50 and above	12 of 12	199	385	561	818	1320
	San Francisco	Female	12-34 years	1 of 1	467		467		467
			35-49 years	10 of 10	137	405	632	985	1230
			50 and above	6 of 6	336	452	673	1002	949
		Male	12-34 years	0 of 0					
			35-49 years	3 of 3	304	212	387	708	481
			50 and above	6 of 6	359	387	538	746	774

Note: Upper and lower confidence limits are not computed for less than 3 samples per cell
Significant figures for each compound are limited to 3

Table 4-22. Concentration Statistics by Compound, City, and Sex

Compound (No.)	City	Sex	Number of detects/ number of specimens	Minimum detected level (pg/g)	Lower 95% limit of geometric mean (pg/g)	Geometric mean of detected levels (pg/g)	Upper 95% limit of geometric mean (pg/g)	Maximum detected level (pg/g)
2378-TCDF (1)	Los Angeles	Female	5 of 11	1.45	1.43	1.89	2.50	2.61
		Male	14 of 20	0.634	1.13	1.66	2.43	6.49
	San Francisco	Female	17 of 17	0.970	1.74	2.30	3.04	5.36
		Male	8 of 9	0.898	1.38	1.99	2.86	3.58
2378-TCDD (2)	Los Angeles	Female	10 of 11	1.95	2.65	3.93	5.83	8.55
		Male	17 of 20	1.80	3.16	3.93	4.88	9.34
	San Francisco	Female	17 of 17	2.25	4.37	5.56	7.07	12.5
		Male	9 of 9	3.49	3.97	5.00	6.30	9.33
12378-PeCDF (3)	Los Angeles	Female	0 of 11					
		Male	3 of 20	0.278	0.185	0.358	0.692	0.472
	San Francisco	Female	7 of 17	0.370	0.480	0.842	1.48	1.93
		Male	3 of 9	0.257	0.156	0.331	0.705	0.464
23478-PeCDF (4)	Los Angeles	Female	10 of 11	1.56	3.92	7.19	13.2	25.3
		Male	18 of 20	2.70	4.78	6.13	7.85	15.5
	San Francisco	Female	16 of 17	2.60	4.12	6.30	9.64	24.1
		Male	7 of 9	0.726	1.38	3.97	11.4	13.7
12378-PeCDD (5)	Los Angeles	Female	11 of 11	1.98	4.83	8.53	15.1	39.1
		Male	17 of 20	4.97	7.48	9.06	11.0	16.6
	San Francisco	Female	17 of 17	4.36	8.94	11.3	14.3	24.9
		Male	9 of 9	8.63	9.28	12.0	15.6	25.2

Note: Upper and lower confidence limits are not computed for less than 3 samples per cell
Significant figures for each compound are limited to 3

Table 4-22 (continued)

Compound (No.)	City	Sex	Number of detects/ number of specimens	Minimum detected level (pg/g)	Lower 95% limit of geometric mean (pg/g)	Geometric mean of detected levels (pg/g)	Upper 95% limit of geometric mean (pg/g)	Maximum detected level (pg/g)
123478-HxCDF (6)	Los Angeles	Female	7 of 11	1.69	2.36	4.25	7.65	8.28
		Male	16 of 20	3.76	5.93	7.54	9.59	16.7
	San Francisco	Female	17 of 17	4.26	6.37	8.03	10.1	17.2
		Male	9 of 9	5.12	5.58	7.53	10.2	17.3
123678-HxCDF (7)	Los Angeles	Female	4 of 11	1.83	1.08	3.18	9.43	8.13
		Male	15 of 20	2.43	3.49	4.60	6.06	12.7
	San Francisco	Female	17 of 17	2.30	3.77	4.82	6.17	11.9
		Male	9 of 9	3.04	3.63	4.50	5.58	7.42
234678-HxCDF (8)	Los Angeles	Female	1 of 11	2.10		2.10		2.10
		Male	15 of 20	0.619	0.978	1.61	2.65	10.5
	San Francisco	Female	16 of 17	0.528	1.13	1.52	2.05	4.28
		Male	8 of 9	0.674	0.901	1.47	2.39	4.41
123789-HxCDF (9)	Los Angeles	Female	0 of 11					
		Male	2 of 20	0.557		0.724		0.942
	San Francisco	Female	3 of 17	0.155	0.049	0.420	3.60	0.742
		Male	0 of 9					
123478/ 123678-HxCDD (10)	Los Angeles	Female	11 of 11	21.9	33.9	47.5	66.5	114
		Male	20 of 20	15.6	50.8	67.1	88.6	154
	San Francisco	Female	17 of 17	38.7	65.2	79.1	95.9	149
		Male	9 of 9	57.7	65.4	83.7	107	164
123789-HxCDD (11)	Los Angeles	Female	9 of 11	4.93	7.28	10.6	15.4	22.5
		Male	16 of 20	4.47	7.33	9.63	12.7	20.3
	San Francisco	Female	16 of 17	5.00	8.46	11.2	14.8	31.7
		Male	9 of 9	4.90	6.13	7.83	10.0	13.3

Note: Upper and lower confidence limits are not computed for less than 3 samples per cell
Significant figures for each compound are limited to 3

Table 4-22 (continued)

Compound (No.)	City	Sex	Number of detects/ number of specimens	Minimum detected level (pg/g)	Lower 95% limit of geometric mean (pg/g)	Geometric mean of detected levels (pg/g)	Upper 95% limit of geometric mean (pg/g)	Maximum detected level (pg/g)
1234678-HpCDF (12)	Los Angeles	Female	4 of 11	4.48	3.70	7.19	13.9	12.2
		Male	15 of 20	4.82	7.37	9.35	11.9	25.8
	San Francisco	Female	17 of 17	4.08	7.67	9.88	12.7	20.2
		Male	9 of 9	5.94	6.54	7.80	9.31	11.5
1234789-HpCDF (13)	Los Angeles	Female	0 of 11					
		Male	3 of 20	0.380	0.238	0.564	1.34	0.733
	San Francisco	Female	6 of 17	0.236	0.279	0.422	0.637	0.633
		Male	2 of 9	0.443		0.574		0.743
1234678-HpCDD (14)	Los Angeles	Female	11 of 11	22.0	37.9	54.8	79.2	151
		Male	20 of 20	31.6	57.4	79.0	109	290
	San Francisco	Female	17 of 17	34.3	74.0	103	142	334
		Male	9 of 9	51.3	55.9	83.6	125	297
OCDF (15)	Los Angeles	Female	0 of 11					
		Male	12 of 20	0.275	0.589	0.776	1.02	1.37
	San Francisco	Female	15 of 17	0.435	0.617	0.895	1.30	4.55
		Male	6 of 9	0.379	0.475	0.713	1.07	1.01
OCDD (16)	Los Angeles	Female	11 of 11	178	313	407	529	749
		Male	20 of 20	152	387	518	693	1320
	San Francisco	Female	17 of 17	137	486	634	829	1230
		Male	9 of 9	304	377	482	616	774

Note: Upper and lower confidence limits are not computed for less than 3 samples per cell
Significant figures for each compound are limited to 3

Shaded compound: Significant City by Sex interaction (p=0.04)

Table 4-23. Concentration Statistics by Compound and City

Compound (No.)	City	Number of detects/ number of specimens	Minimum detected level (pg/g)	Lower 95% limit of geometric mean (pg/g)	Geometric mean of detected levels (pg/g)	Upper 95% limit of geometric mean (pg/g)	Maximum detected level (pg/g)
2378-TCDF (1)	Los Angeles	19 of 31	0.634	1.30	1.72	2.27	6.49
	San Francisco	25 of 26	0.898	1.78	2.20	2.71	5.36
2378-TCDD (2)	Los Angeles	27 of 31	1.80	3.27	3.93	4.72	9.34
	San Francisco	26 of 26	2.25	4.54	5.36	6.34	12.5
12378-PeCDF (3)	Los Angeles	3 of 31	0.278	0.185	0.358	0.692	0.472
	San Francisco	10 of 26	0.257	0.390	0.636	1.04	1.93
23478-PeCDF (4)	Los Angeles	28 of 31	1.56	5.07	6.49	8.29	25.3
	San Francisco	23 of 26	0.726	3.69	5.48	8.13	24.1
12378-PeCDD (5)	Los Angeles	28 of 31	1.98	7.04	8.85	11.1	39.1
	San Francisco	26 of 26	4.36	9.78	11.6	13.7	25.2

Note: Upper and lower confidence limits are not computed for less than 3 samples per cell
Significant figures for each compound are limited to 3

Table 4-23 (continued)

Compound (No.)	City	Number of detects/ number of specimens	Minimum detected level (pg/g)	Lower 95% limit of geometric mean (pg/g)	Geometric mean of detected levels (pg/g)	Upper 95% limit of geometric mean (pg/g)	Maximum detected level (pg/g)
123478-HxCDF (6)	Los Angeles	23 of 31	1.69	4.96	6.33	8.09	16.7
	San Francisco	26 of 26	4.26	6.62	7.85	9.32	17.3
123678-HxCDF (7)	Los Angeles	19 of 31	1.83	3.28	4.26	5.53	12.7
	San Francisco	26 of 26	2.30	3.98	4.71	5.57	11.9
234678-HxCDF (8)	Los Angeles	16 of 31	0.619	1.03	1.64	2.60	10.5
	San Francisco	24 of 26	0.528	1.19	1.50	1.90	4.41
123789-HxCDF (9)	Los Angeles	2 of 31	0.557		0.724		0.942
	San Francisco	3 of 26	0.155	0.049	0.420	3.60	0.742
123478/	Los Angeles	31 of 31	15.6	48.0	59.4	73.4	154
123678-HxCDD (10)	San Francisco	26 of 26	38.7	70.0	80.6	92.9	164
123789-HxCDD (11)	Los Angeles	25 of 31	4.47	8.12	9.97	12.2	22.5
	San Francisco	25 of 26	4.90	8.05	9.85	12.0	31.7
1234678-HpCDF (12)	Los Angeles	19 of 31	4.48	7.19	8.85	10.9	25.8
	San Francisco	26 of 26	4.08	7.65	9.11	10.8	20.2
1234789-HpCDF (13)	Los Angeles	3 of 31	0.380	0.238	0.564	1.34	0.733
	San Francisco	8 of 26	0.236	0.330	0.455	0.629	0.743
1234678-HpCDD (14)	Los Angeles	31 of 31	22.0	54.6	69.4	88.2	290
	San Francisco	26 of 26	34.3	75.1	95.6	122	334
OCDF (15)	Los Angeles	12 of 31	0.275	0.589	0.776	1.02	1.37
	San Francisco	21 of 26	0.379	0.636	0.839	1.11	4.55
OCDD (16)	Los Angeles	31 of 31	152	387	475	583	1320
	San Francisco	26 of 26	137	477	577	698	1230

Note: Upper and lower confidence limits are not computed for less than 3 samples per cell
Significant figures for each compound are limited to 3

Table 4-24. Concentration Statistics by Compound, Sex, and Age Group

Compound (No.)	Sex	Age group	Number of detects/ number of specimens	Minimum detected level (pg/g)	Lower 95% limit of geometric mean (pg/g)	Geometric mean of detected levels (pg/g)	Upper 95% limit of geometric mean (pg/g)	Maximum detected level (pg/g)
2378-TCDF (1)	Female	12-34	2 of 2	1.78		2.25		2.84
		35-49	10 of 14	1.19	1.63	2.46	3.70	5.36
		50 and above	10 of 12	0.970	1.43	1.96	2.68	3.35
	Male	12-34	2 of 5	0.634		1.22		2.34
		35-49	5 of 6	0.868	0.642	1.42	3.13	3.58
		50 and above	15 of 18	0.976	1.50	2.01	2.69	6.49
2378-TCDD (2)	Female	12-34	2 of 2	5.96		6.12		6.29
		35-49	13 of 14	2.25	3.37	4.71	6.59	11.8
		50 and above	12 of 12	1.95	3.48	4.90	6.90	12.5
	Male	12-34	4 of 5	1.80	1.53	2.96	5.72	4.33
		35-49	5 of 6	3.49	3.29	4.07	5.04	5.45
		50 and above	17 of 18	1.98	3.84	4.72	5.80	9.34
12378-PeCDF (3)	Female	12-34	1 of 2	0.591		0.591		0.591
		35-49	4 of 14	0.370	0.323	1.04	3.34	1.93
		50 and above	2 of 12	0.495		0.659		0.876
	Male	12-34	0 of 5	0.524		0.524		0.524
		35-49	3 of 6	0.305	0.216	0.367	0.625	0.464
		50 and above	3 of 18	0.257	0.142	0.323	0.734	0.472
23478-PeCDF (4)	Female	12-34	2 of 2	9.17		9.72		10.3
		35-49	12 of 14	2.60	3.65	5.52	8.35	15.0
		50 and above	12 of 12	1.56	4.00	7.47	13.9	25.3
	Male	12-34	4 of 5	2.70	2.09	6.70	21.4	15.5
		35-49	6 of 6	2.74	3.36	6.48	12.5	15.3
		50 and above	15 of 18	0.726	3.08	4.78	7.40	14.0

Note: Upper and lower confidence limits are not calculated for less than 3 samples per cell
Significant figures for each compound are limited to 3

Table 4-24 (continued)

Compound (No.)	Sex	Age group	Number of detects/ number of specimens	Minimum detected level (pg/g)	Lower 95% limit of geometric mean (pg/g)	Geometric mean of detected levels (pg/g)	Upper 95% limit of geometric mean (pg/g)	Maximum detected level (pg/g)
12378-PeCDD (5)	Female	12-34	2 of 2	7.84		8.90		10.1
		35-49	14 of 14	4.24	7.15	10.3	14.8	39.1
		50 and above	12 of 12	1.98	6.40	10.2	16.1	24.9
	Male	12-34	2 of 5	5.03		8.77		15.3
		35-49	6 of 6	4.97	6.34	8.77	12.2	12.3
		50 and above	18 of 18	5.63	8.82	10.6	12.7	25.2
123478-HxCDF (6)	Female	12-34	2 of 2	8.28		9.14		10.1
		35-49	13 of 14	3.55	5.06	6.74	8.98	13.5
		50 and above	9 of 12	1.69	3.40	6.12	11.0	17.2
	Male	12-34	3 of 5	3.76	1.32	6.01	27.4	12.0
		35-49	5 of 6	5.72	5.00	9.02	16.3	17.3
		50 and above	17 of 18	4.16	6.13	7.44	9.04	16.7
123678-HxCDF (7)	Female	12-34	2 of 2	5.63		6.77		8.13
		35-49	11 of 14	2.02	2.83	4.00	5.66	7.31
		50 and above	8 of 12	1.83	2.85	4.65	7.59	11.9
	Male	12-34	2 of 5	2.89		3.15		3.43
		35-49	5 of 6	3.78	3.55	4.28	5.17	5.53
		50 and above	17 of 18	2.43	3.80	4.85	6.20	12.7
234678-HxCDF (8)	Female	12-34	2 of 2	1.96		2.03		2.10
		35-49	9 of 14	0.741	1.030	1.47	2.10	3.27
		50 and above	6 of 12	0.528	0.683	1.53	3.44	4.28
	Male	12-34	2 of 5	1.37		3.66		9.80
		35-49	4 of 6	0.906	0.797	1.59	3.17	2.38
		50 and above	17 of 18	0.619	0.941	1.40	2.09	10.5

Note: Upper and lower confidence limits are not calculated for less than 3 samples per cell
Significant figures for each compound are limited to 3

Table 4-24 (continued)

Compound (No.)	Sex	Age group	Number of detects/ number of specimens	Minimum detected level (pg/g)	Lower 95% limit of geometric mean (pg/g)	Geometric mean of detected levels (pg/g)	Upper 95% limit of geometric mean (pg/g)	Maximum detected level (pg/g)
123789-HxCDF (9)	Female	12-34	1 of 2	0.155		0.155		0.155
		35-49	0 of 14	0.276		0.276		0.276
		50 and above	2 of 12	0.643		0.691		0.742
	Male	12-34	0 of 5					
		35-49	0 of 6					
		50 and above	2 of 18	0.557		0.724		0.942
123478/ 123678-HxCDD (10)	Female	12-34	2 of 2	61.8		61.9		62.0
		35-49	14 of 14	27.8	47.1	62.4	82.6	117
		50 and above	12 of 12	21.9	47.9	68.1	96.7	149
	Male	12-34	5 of 5	15.6	20.2	47.2	110.7	103
		35-49	6 of 6	20.1	32.5	57.1	100.2	87.8
		50 and above	18 of 18	40.3	71.6	87.2	106	164
123789-HxCDD (11)	Female	12-34	2 of 2	9.32		9.65		10.0
		35-49	11 of 14	4.93	6.85	10.4	15.8	31.7
		50 and above	12 of 12	6.05	8.93	11.8	15.5	22.5
	Male	12-34	3 of 5	4.79	1.72	11.2	72.8	20.3
		35-49	6 of 6	6.15	5.79	8.41	12.2	15.7
		50 and above	16 of 18	4.47	6.89	8.77	11.1	20.0
1234678-HpCDF (12)	Female	12-34	1 of 2	10.8		10.8		10.8
		35-49	11 of 14	4.08	6.51	9.14	12.8	20.2
		50 and above	9 of 12	4.48	6.26	9.35	14.0	20.2
	Male	12-34	2 of 5	8.85		11.8		15.8
		35-49	5 of 6	5.94	5.77	8.12	11.4	11.5
		50 and above	17 of 18	4.82	7.03	8.62	10.6	25.8

Note: Upper and lower confidence limits are not calculated for less than 3 samples per cell
Significant figures for each compound are limited to 3

Table 4-24 (continued)

Compound (No.)	Sex	Age group	Number of detects/ number of specimens	Minimum detected level (pg/g)	Lower 95% limit of geometric mean (pg/g)	Geometric mean of detected levels (pg/g)	Upper 95% limit of geometric mean (pg/g)	Maximum detected level (pg/g)
1234789-HpCDF (13)	Female	12-34	0 of 2					
		35-49	3 of 14	0.236	0.121	0.356	1.05	0.561
		50 and above	3 of 12	0.340	0.217	0.499	1.15	0.633
	Male	12-34	0 of 5					
		35-49	1 of 6	0.443		0.443		0.443
		50 and above	4 of 18	0.380	0.366	0.604	1.00	0.743
1234678-HpCDD (14)	Female	12-34	2 of 2	104		107		111
		35-49	14 of 14	31.2	57.5	84.8	125	334
		50 and above	12 of 12	22.0	45.1	71.7	114	317
	Male	12-34	5 of 5	57.3	60.3	75.5	94.4	89.1
		35-49	6 of 6	39.5	51.0	92.1	167	177
		50 and above	18 of 18	31.6	54.2	78.2	113	297
OCDF (15)	Female	12-34	0 of 2					
		35-49	9 of 14	0.435	0.553	0.706	0.90	0.983
		50 and above	6 of 12	0.486	0.483	1.28	3.38	4.55
	Male	12-34	1 of 5	0.946		0.946		0.946
		35-49	4 of 6	0.379	0.362	0.737	1.50	0.988
		50 and above	13 of 18	0.275	0.577	0.747	0.97	1.37
OCDD (16)	Female	12-34	2 of 2	467		472		478
		35-49	14 of 14	137	416	576	796	1230
		50 and above	12 of 12	178	358	496	687	949
	Male	12-34	5 of 5	152	152	394	1022	1250
		35-49	6 of 6	304	298	478	769	1060
		50 and above	18 of 18	199	430	553	712	1320

Note: Upper and lower confidence limits are not calculated for less than 3 samples per cell
Significant figures for each compound are limited to 3

Table 4-25. Concentration Statistics by Compound and Age Group

Compound (No.)	Age group	Number of detects/ number of specimens	Minimum detected level (pg/g)	Lower 95% limit of geometric mean (pg/g)	Geometric mean of detected levels (pg/g)	Upper 95% limit of geometric mean (pg/g)	Maximum detected level (pg/g)
2378-TCDF (1)	12-34 years	4 of 7	0.634	0.572	1.66	4.78	2.84
	35-49 years	15 of 20	0.868	1.44	2.05	2.90	5.36
	50 and above	25 of 30	0.970	1.63	1.99	2.43	6.49
2378-TCDD (2)	12-34 years	6 of 7	1.80	2.24	3.77	6.33	6.29
	35-49 years	18 of 20	2.25	3.57	4.53	5.74	11.8
	50 and above	29 of 30	1.95	4.03	4.80	5.70	12.5
12378-PeCDF (3)	12-34 years	1 of 7	0.591		0.591		0.591
	35-49 years	7 of 20	0.305	0.326	0.665	1.36	1.93
	50 and above	5 of 30	0.257	0.231	0.430	0.797	0.876
23478-PeCDF (4)	12-34 years	6 of 7	2.70	4.04	7.58	14.2	15.5
	35-49 years	18 of 20	2.60	4.26	5.83	7.96	15.3
	50 and above	27 of 30	0.726	4.09	5.83	8.30	25.3
12378-PeCDD (5)	12-34 years	4 of 7	5.03	4.21	8.84	18.5	15.3
	35-49 years	20 of 20	4.24	7.58	9.81	12.7	39.1
	50 and above	30 of 30	1.98	8.55	10.4	12.7	25.2
123478-HxCDF (6)	12-34 years	5 of 7	3.76	3.85	7.11	13.1	12.0
	35-49 years	18 of 20	3.55	5.76	7.31	9.28	17.3
	50 and above	26 of 30	1.69	5.60	6.96	8.64	17.2
123678-HxCDF (7)	12-34 years	4 of 7	2.89	2.18	4.62	9.77	8.13
	35-49 years	16 of 20	2.02	3.25	4.09	5.14	7.31
	50 and above	25 of 30	1.83	3.89	4.79	5.89	12.7

Note: Upper and lower confidence limits are not calculated for less than 3 samples per cell
Significant figures for each compound are limited to 3

Table 4-25 (continued)

Compound (No.)	Age group	Number of detects/ number of specimens	Minimum detected level (pg/g)	Lower 95% limit of geometric mean (pg/g)	Geometric mean of detected levels (pg/g)	Upper 95% limit of geometric mean (pg/g)	Maximum detected level (pg/g)
234678-HxCDF (8)	12-34 years	4 of 7	1.37	0.680	2.73	10.9	9.80
	35-49 years	13 of 20	0.741	1.16	1.51	1.96	3.27
	50 and above	23 of 30	0.528	1.03	1.44	1.99	10.5
123789-HxCDF (9)	12-34 years	1 of 7	0.155		0.155		0.155
	35-49 years	0 of 20	0.276		0.276		0.280
	50 and above	4 of 30	0.557	0.495	0.707	1.01	0.942
123478/ 123678-HxCDD (10)	12-34 years	7 of 7	15.6	30.0	51.0	86.9	103
	35-49 years	20 of 20	20.1	48.3	60.7	76.3	117
	50 and above	30 of 30	21.9	66.2	79.0	94.2	164
123789-HxCDD (11)	12-34 years	5 of 7	4.79	5.39	10.5	20.6	20.3
	35-49 years	17 of 20	4.93	7.31	9.66	12.8	31.7
	50 and above	28 of 30	4.47	8.32	9.95	11.9	22.5
1234678-HpCDF (12)	12-34 years	3 of 7	8.85	5.52	11.5	23.8	15.8
	35-49 years	16 of 20	4.08	6.97	8.81	11.1	20.2
	50 and above	26 of 30	4.48	7.44	8.86	10.6	25.8
1234678-HpCDD (13)	12-34 years	0 of 7					
	35-49 years	4 of 20	0.236	0.208	0.376	0.679	0.561
	50 and above	7 of 30	0.340	0.417	0.557	0.744	0.743
1234678-HpCDD (14)	12-34 years	7 of 7	57.3	67.6	83.5	103	111
	35-49 years	20 of 20	31.2	64.8	86.9	117	334
	50 and above	30 of 30	22.0	57.7	75.5	98.8	317
OCDF (15)	12-34 years	1 of 7	0.946		0.946		0.946
	35-49 years	13 of 20	0.379	0.582	0.715	0.879	0.988
	50 and above	19 of 30	0.275	0.646	0.885	1.21	4.55
OCDD (16)	12-34 years	7 of 7	152	231	415	745	1250
	35-49 years	20 of 20	137	426	545	697	1230
	50 and above	30 of 30	178	439	530	639	1320

Note: Upper and lower confidence limits are not calculated for less than 3 samples per cell
Significant figures for each compound are limited to 3

Shaded compound: Significant Age Effect (p=0.05)

Table 4-26. Concentration Statistics by Compound

Compound (No.)	Number of detects/ number of specimens	Minimum detected level (pg/g)	Lower 95% limit of geometric mean (pg/g)	Geometric mean of detected levels (pg/g)	Upper 95% limit of geometric mean (pg/g)	Maximum detected level (pg/g)
2378-TCDF (1)	44 of 57	0.634	1.68	1.98	2.32	6.49
2378-TCDD (2)	53 of 57	1.80	4.04	4.58	5.18	12.5
12378-PeCDF (3)	13 of 57	0.257	0.375	0.557	0.827	1.93
23478-PeCDF (4)	51 of 57	0.726	4.86	6.01	7.42	25.3
12378-PeCDD (5)	54 of 57	1.98	8.75	10.1	11.6	39.1
123478-HxCDF (6)	49 of 57	1.69	6.17	7.10	8.17	17.3
123678-HxCDF (7)	45 of 57	1.83	3.93	4.51	5.18	12.7
234678-HxCDF (8)	40 of 57	0.528	1.25	1.55	1.93	10.5
123789-HxCDF (9)	5 of 57	0.155	0.217	0.522	1.26	0.942
123478/123678 HxCDD (10)	57 of 57	15.6	59.8	68.3	77.9	164
123789-HxCDD (11)	50 of 57	4.47	8.66	9.91	11.3	31.7
1234678-HpCDF (12)	45 of 57	4.08	7.94	9.00	10.2	25.8
1234789-HpCDF (13)	11 of 57	0.236	0.376	0.483	0.620	0.743
1234678-HpCDD (14)	57 of 57	22.0	68.0	80.3	94.9	334
OCDF (15)	33 of 57	0.275	0.677	0.815	0.982	4.55
OCDD (16)	57 of 57	137	453	519	595	1320

Note: Significant figures for each compound are limited to 3

Table 4-27. Overall Analysis of Variance Results

No.	Compound	Sample size	Significance level of F-statistic	Comments
1	2,3,7,8-TCDF	44	0.59	
2	2,3,7,8-TCDD	53	0.31	
3	1,2,3,7,8-PeCDF	13	0.31	Significant sex effect (p = 0.07)
4	2,3,4,7,8-PeCDF	51	0.84	
5	1,2,3,7,8-PeCDD	54	0.76	
6	1,2,3,4,7,8-HxCDF	40	0.82	Batch 1 results not included
7	1,2,3,6,7,8-HxCDF	40	0.87	Batch 1 results not included
8	2,3,4,6,7,8-HxCDF	40	0.88	
9	1,2,3,7,8,9-HxCDF	5	0.07	Significant age effect (p = 0.05)
10	1,2,3,4,7,8/1,2,3,6,7,8-HxCDD	57	0.03	Significant age effect (p = 0.04)
11	1,2,3,7,8,9-HxCDD	50	0.81	
12	1,2,3,4,6,7,8-HpCDF	45	0.86	
13	1,2,3,4,7,8,9-HpCDF	11	0.49	
14	1,2,3,4,6,7,8-HpCDD	57	0.56	
15	OCDF	33	0.44	
16	OCDD	57	0.50	Significant city by sex interaction (p = 0.04)

SECTION 5.0

REVIEW OF EXISTING INFORMATION ON HUMAN BODY BURDEN LEVELS OF PCDDs AND PCDFs

This section reports on studies of PCDD and PCDF residue levels in human tissues. Data from U.S. as well as international studies are included. Efforts are included to determine whether persons exposed to environmental or occupational levels of PCDDs and PCDFs can be identified through body burden measurements are discussed. Data are also presented on the distribution of PCDDs and PCDFs in specific tissues. Studies of other factors (such as age and sex) that are apparently correlated with body burden levels are also reviewed.

5.1 Literature Search

A literature search was conducted to review the state-of-the-art methods of analysis, to compile body burden data from other specific population studies, and to review potential exposure based on geographic area. The literature search was conducted via automated computer compilation of citations from chemical abstracts from ca. 1980 through 1987. MRI had prepared a review of the literature on the analysis of biological samples for PCDDs and PCDFs in 1983 (Stanley, 1984; Stanley et al., 1985) which provided a valuable source of information. Much of the current information on the body burden levels of PCDDs and PCDFs is not readily found in the open literature.

The most useful references are found in the Proceedings of the national American Chemical Society symposium on dioxins in the environment and from the Proceedings of the 5th International Dioxin Conference held in 1985 (Bayreuth, F.R.G.). The 6th and 7th international dioxin conferences were held in 1986 (Fukuoka, Japan) and in 1987 (Las Vegas, Nevada).

Additional data on human body burden levels were presented at the 8th International Dioxin Conference (Umea, Sweden). The data on human body burden levels from the studies presented at these conferences have not yet been published, but some information has been gleaned from reviewing the extended abstracts from the international conference program listings.

The literature search on analytical methods proved to be more successful due to the fact that the state-of-the-art techniques have matured and specific procedures have been extensively validated and reported to the scientific community for review.

5.2 General Population Studies

Several studies have been reported that describe the results of the efforts to determine body burden levels of PCDDs and PCDFs in the general population. These studies were based on the analysis of adipose tissue samples from distinct areas of the continental United States as well as from various other parts of the world.

5.2.1 Body Burden Data from the Continental United States

Figure 5-1 presents an overview of locations in the continental United States where studies on body burden levels of PCDDs and PCDFs have been conducted. More specifically, these studies have focused on a limited number of individuals from Binghamton, New York (Schecter et al., 1986), Atlanta, Georgia (Patterson et al., 1986), Salt Lake City, Utah (Patterson et al., 1986), St. Louis, Missouri (Graham et al., 1986a,1986b), and the State of Missouri (Patterson et al., 1986c). The studies that were conducted using samples from Binghamton, New York, and St. Louis, Missouri, were focused on the determination of total PCDDs and PCDFs. The studies conducted with the samples from the states of Missouri, Georgia, and Utah, however, focused solely on the levels of 2,3,7,8-TCDD (Patterson et al., 1986,1986c,1986d).

Only one study has been reported that provides estimates of the general U.S. population body burden levels of the tetra- through octachloro PCDD and PCDF congeners. These estimates were determined from samples composited from the U.S. Environmental Protection Agency's National Human Adipose Tissue Survey, NHATS (Stanley et al., 1986b; Stanley 1986c). Forty-six composite tissue samples of approximately 20 g each were prepared from approximately 900 adipose specimens from the NHATS fiscal year 1982 repository. The composite samples were stratified by age (0-14, 15-44, and 45 plus years) and nine census regions (Figure 5-2). This study is unique in that the lower age groups (specifically the 0-14 years) were included in the study design and that certain composites were statistically weighted such that relevant information could be obtained on potential sex and race differences.

Table 5-1 presents the mean concentrations of the PCDD and PCDF congeners in the FY82 NHATS composites. The data for the tetra- through octachloro PCDD and PCDF congeners from the FY82 NHATS composites are compared with the results from the analysis of samples from St. Louis, Missouri (Graham et al., 1986a,1986b) and Binghamton, New York (Schecter et al., 1986a) in Figure 5-3. Also included in Figure 5-3 are the results of the analysis of up to 46 adipose tissue specimens collected in Canada (Ryan et al., 1986b).

The data in Figure 5-3 are reported as mean wet weight concentration in picograms per gram (pg/g or 10^{-12} g/g or parts per trillion). The figure reflects that the most predominant compounds were detected in all studies, provided sufficiently sensitive instrumentation was available for the measurement. This illustration also shows that the levels of the compounds tend to follow the same relative patterns of concentration from study to study.

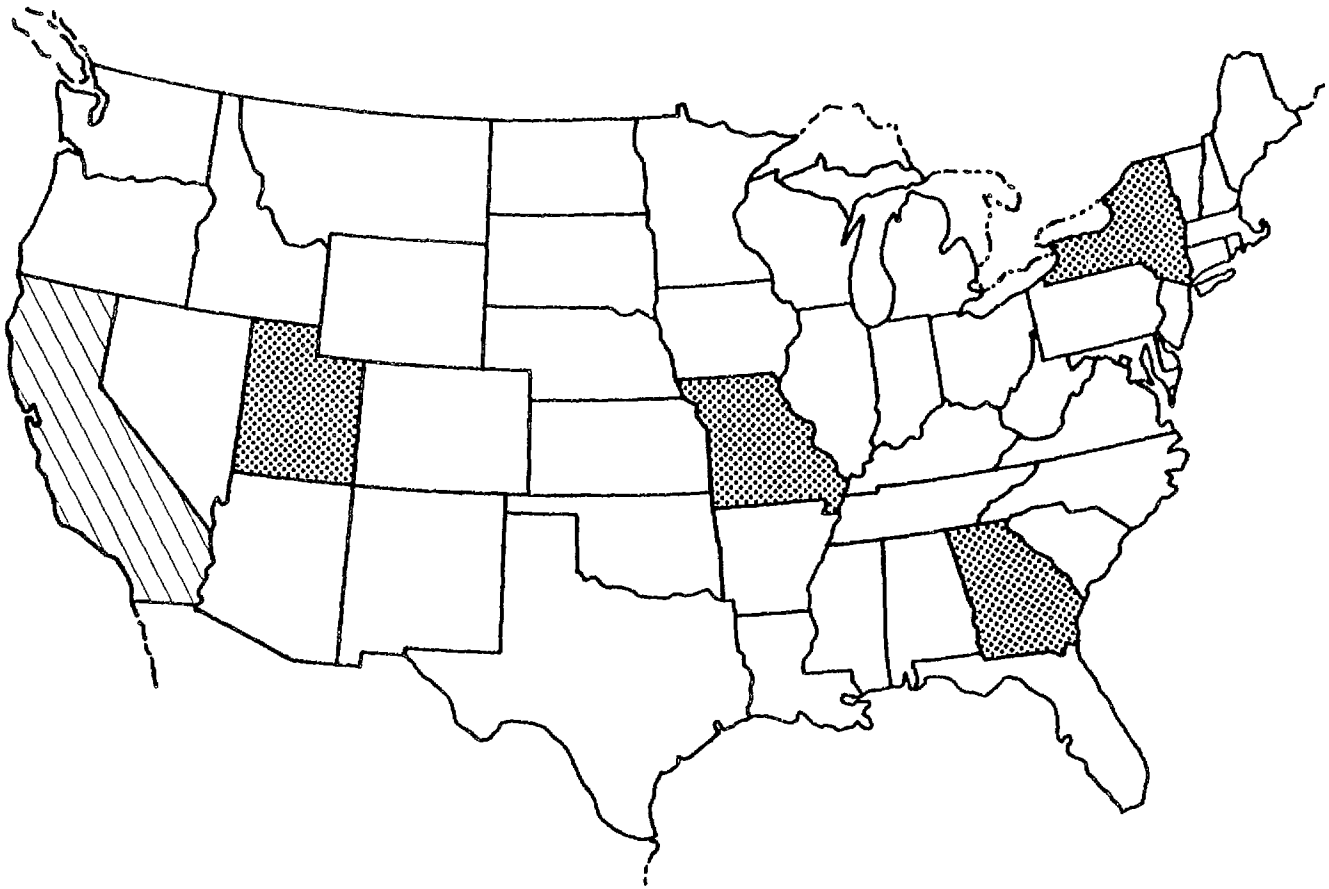


Figure 5-1. U.S. geographic regions where studies on body burden levels of PCDDs and PCDFs have been or will be conducted.

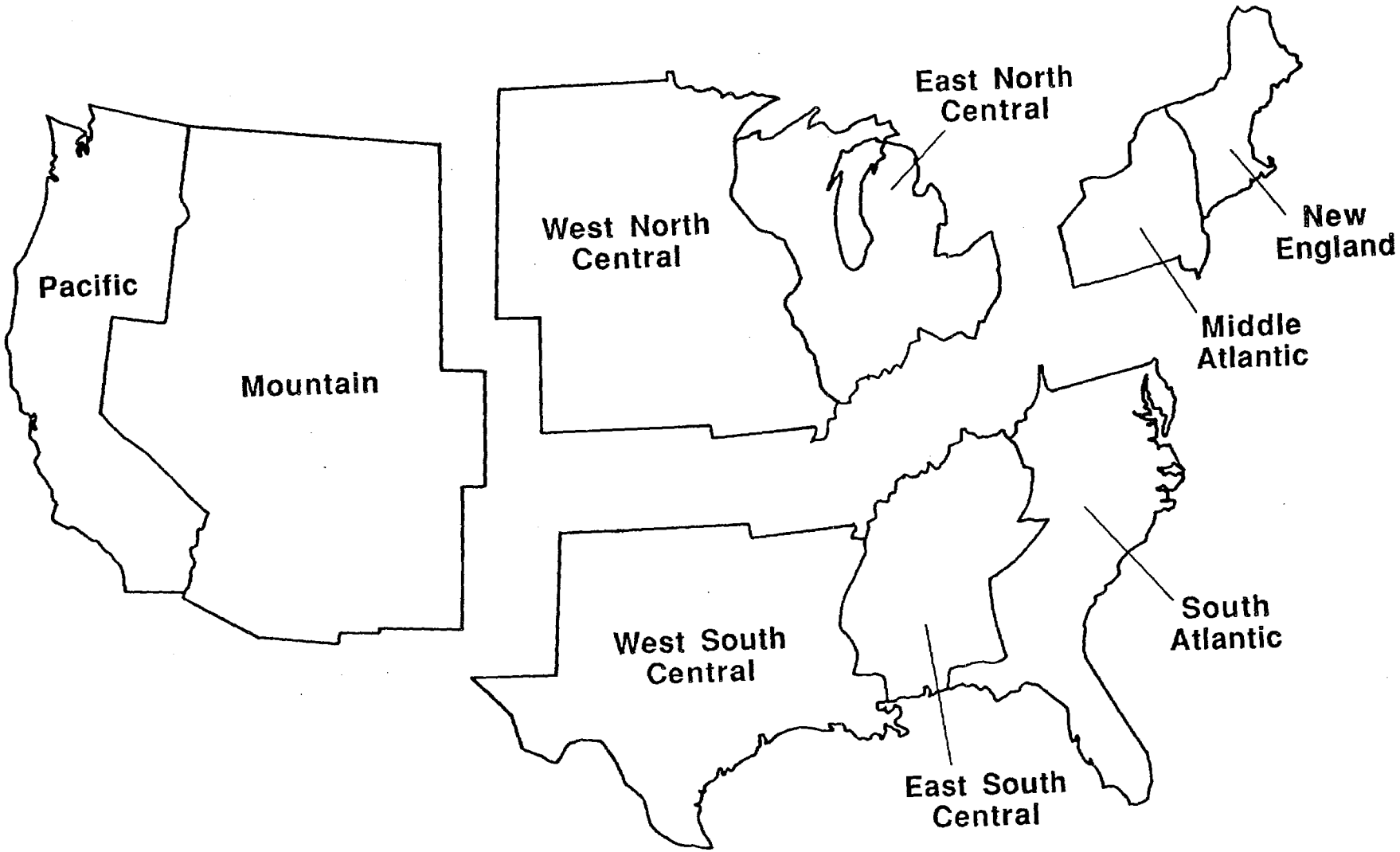


Figure 5-2. U.S. geographic strata considered in the FY82 NHATS study.

Table 5-1. PCDDs and PCDFs in NHATS FY82 Composite Specimens

Homolog	Mean concentration (pg/g)	Range (pg/g)
2,3,7,8-TCDD	5.0 ± 2.8	ND (1.0) - 10
1,2,3,7,8-PeCDD	32 ± 38	ND (1.0) - 180
HxCDD[a]	72 ± 70	7.9 - 330
1,2,3,4,7,8,9-HpCDD	87 ± 78	ND (23) - 390
1,2,3,4,6,7,8,9-OCDD	560 ± 290	64 - 1250
2,3,7,8-TCDF	9.1 ± 9.6	ND (2.0) - 32
2,3,4,7,8-PeCDF	27 ± 16	ND (1.8) - 77
HxCDF[a]	18 ± 8.3	2.9 - 35
1,2,3,4,6,7,8-HpCDF	18 ± 12	ND (10) - 55
1,2,3,4,6,7,8,9-OCDF	60 ± 110	ND (2.0) - 360

Source: Stanley, J. S., K. Boggess, J. Onstot, T. Sack, J. Remmers, J. Breen, F. W. Kutz, P. Robinson, and G. Mack. 1986b. *Chemosphere*, **15**, 1605-1612.

[a] Reference compounds were not available to specify isomers.

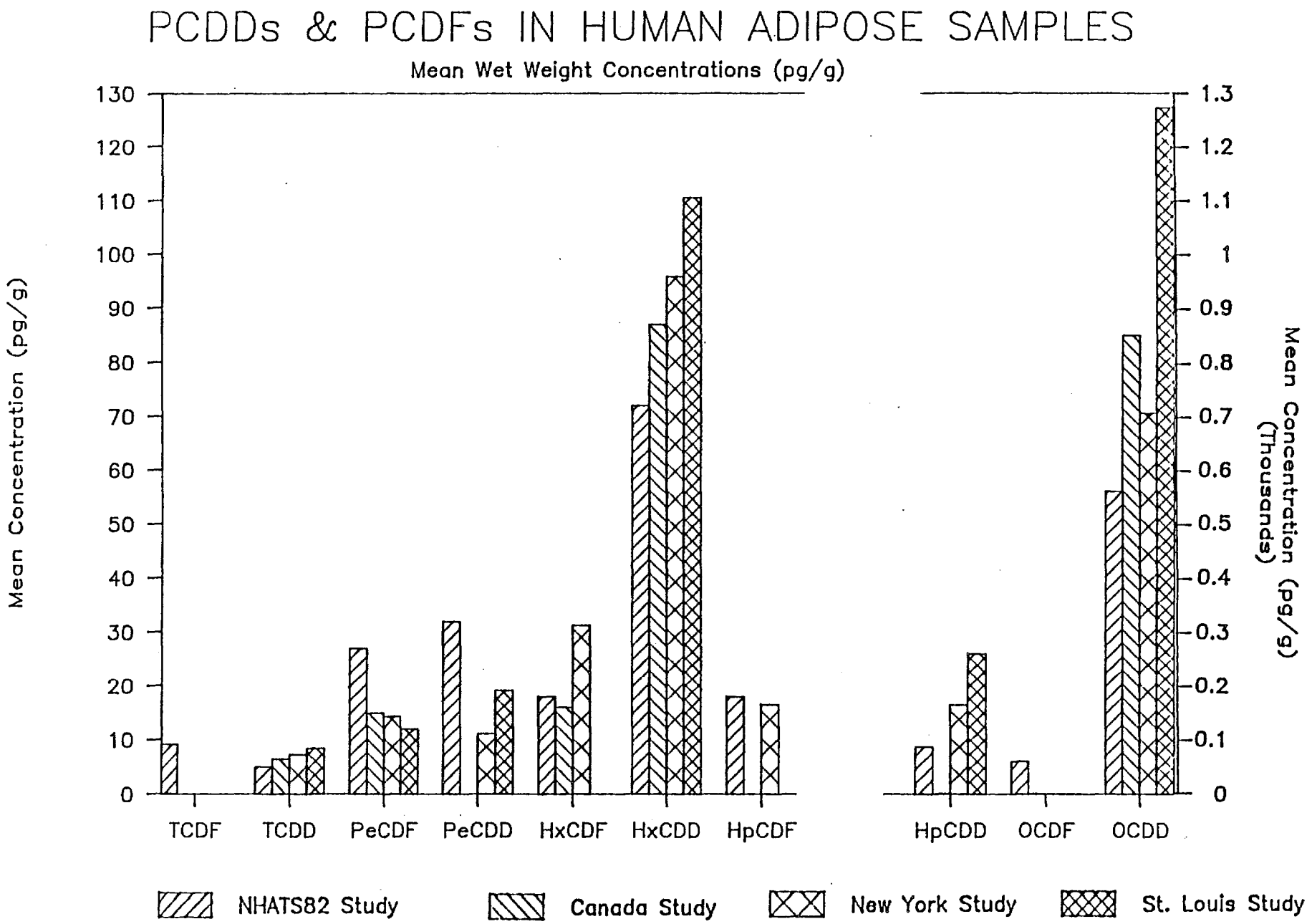


Figure 5-3. Average wet weight tissue concentration of PCDDs and PCDFs in human adipose tissue from the continental United States and Canada.

The results of the analysis for 2,3,7,8-TCDD for the FY82 NHATS composites are presented in Figure 5-4 in greater detail along with the results of the analysis of the specimens from Atlanta, Georgia, Salt Lake City, Utah, and St. Louis, Missouri. This figure plots the percentage of samples in each study detected in specific concentration intervals. The concentrations are reported in picograms per gram based on wet tissue weight. This figure demonstrates that the 2,3,7,8-TCDD was detected in each study at levels ranging from less than 1 pg/g to approximately 20 pg/g. Most of the samples, however, fall within the 2 to 12 pg/g concentration range.

In addition to these studies, the Centers for Disease Control (Anon, 1987) have reported on the results of a study to determine the levels of 2,3,7,8-TCDD in Vietnam veterans who served as ground troops as well as in a control population. Preliminary study results based on blood serum levels (adjusted for lipid content) are shown in Figure 5-5. This figure shows that the mean concentrations of 2,3,7,8-TCDD for both the control group and the Vietnam veterans are within the same range of 0 to 10 pg/g as determined in the general U.S. population studies discussed above.

Several studies have been undertaken within the last two years to assess the body burdens of PCDDs and PCDFs in the general population as well as specific exposed groups. These studies include the analysis of additional composite samples from the NHATS 1987 collection; the completion of a collaborative effort between the Veterans Administration and EPA's Office of Toxic Substances; a study of chemical workers by NIOSH and CDC; a continuation of the Vietnam Veterans Study conducted by CDC and two studies undertaken by the California Department of Health Services to address specific exposure instances (residents from Oroville, California, and individuals consuming contaminated fish). Unfortunately, the data from these studies are not available for review or comparison at this time.

5.2.2 Body Burden Data from International Studies

Body burden measurements of PCDDs and PCDFs have also been conducted on samples from various global regions including Canada (Ryan et al., 1985,1986), Sweden (Nygren et al., 1986), Germany (Thoma et al., 1987; Beck et al, 1987), Japan (Ryan et al., 1986a; Ono et al., 1986), and the north and south of Vietnam (Schecter et al., 1986b, Dai et al., 1987).

Canada: Ryan et al. (1985,1986) reported the results of the analysis of 46 adipose tissue samples that were collected during autopsies. The mean concentration values for each of the PCDDs and PCDFs are presented in Figure 5-3 and are compared to the results for the FY82 NHATS composites and the data generated from samples collected in Binghamton, New York (Schecter et al., 1985a) and St. Louis, Missouri (Graham et al., 1986a,1986b). The data in this figure indicate that the concentration levels and the relative ratio of the PCDDs and PCDFs are fairly consistent for North America (United States and Canada).

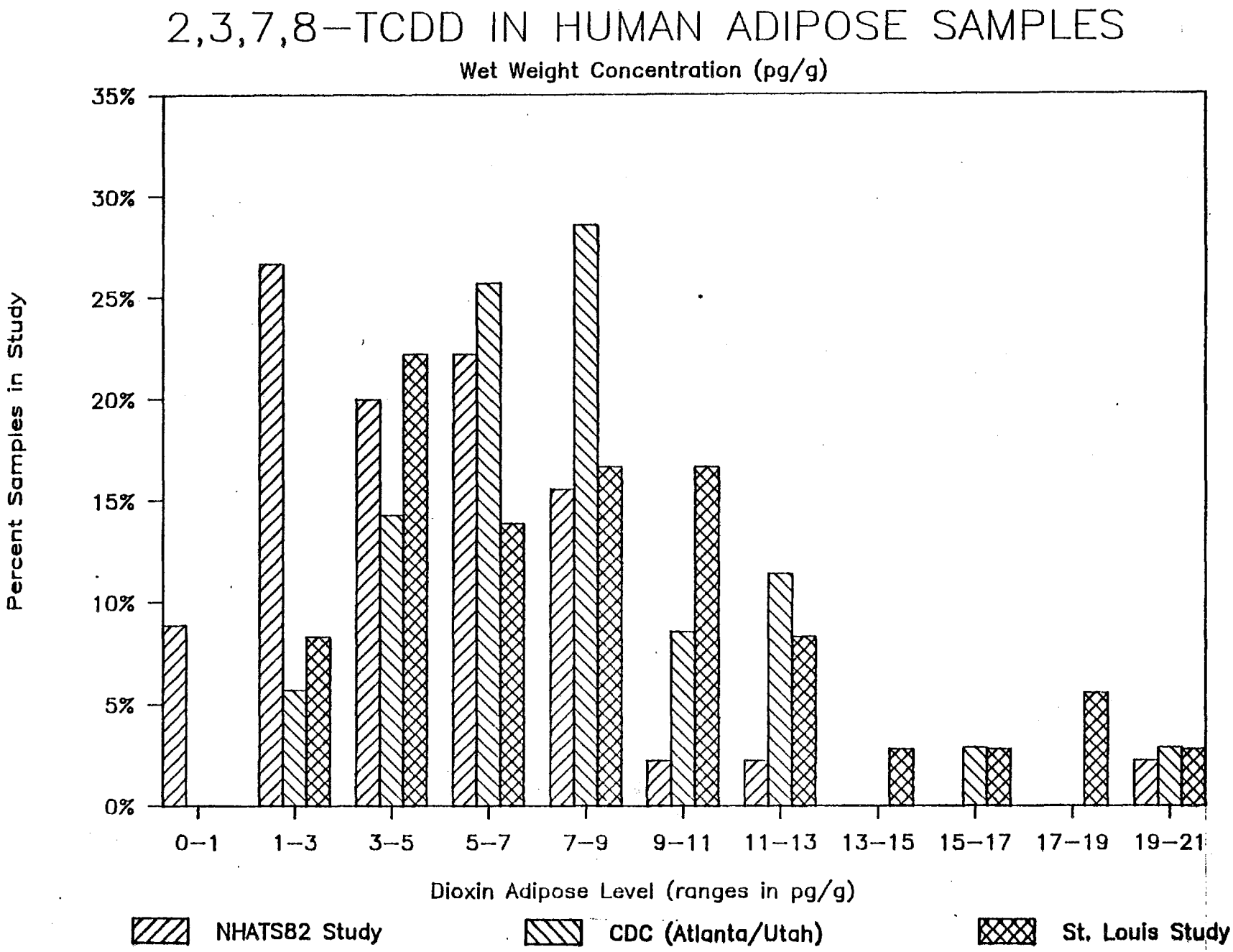


Figure 5-4. Distribution of the frequency of detection of 2,3,7,8-TCDD from specific human adipose tissue studies.

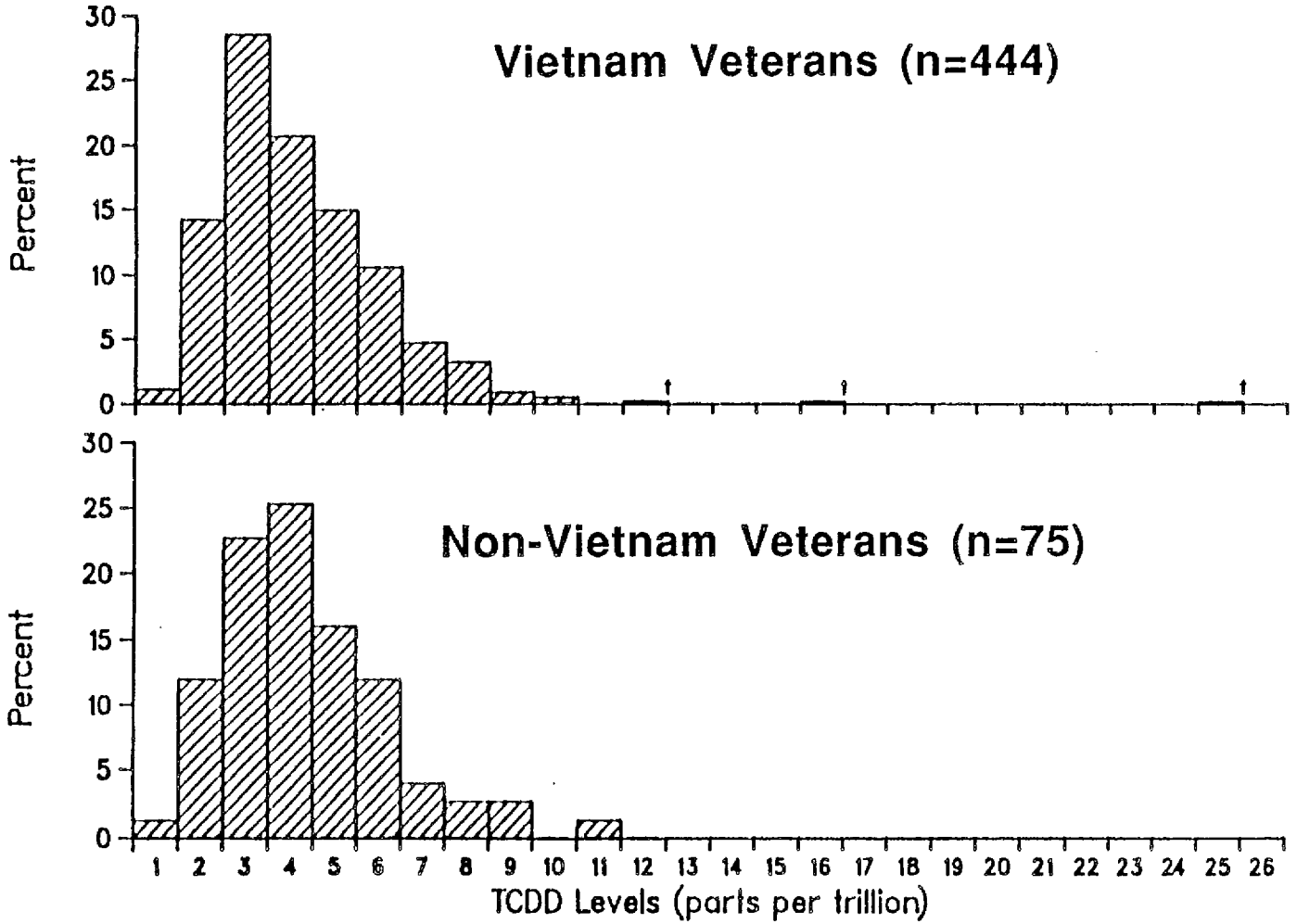


Figure 5-5. Serum 2,3,7,8-TCDD levels of Vietnam and non-Vietnam veterans participating in the Agent Orange validation studies--preliminary data 1987.

Source: Anon. 1987. *Morbidity and Mortality Weekly Report*, 36(26), 470-475.

Sweden: Nygren et al. (1986) reported the PCDD and PCDF levels for 31 adipose tissue samples collected in Sweden. The adipose tissue samples for this study were collected from 13 persons who were reportedly exposed to phenoxy herbicides and 18 nonexposed controls. A total of 17 of the 31 persons from whom adipose tissues were collected were classified as cancer patients. The data from this study are presented in Table 5-2. Mean concentration values and the range of measured concentrations are provided for the total sample set and the respective subclassification of exposed versus nonexposed and cancer patient versus noncancer patient. The data generated in this study are comparable with the data generated from the various studies conducted within the United States. The PCDDs and PCDFs detected are limited to the 2,3,7,8-substituted compounds.

The general trends of the concentrations of the individual congeners are similar to those reported in the other studies cited previously in this interim report. Nygren et al. (1986) indicate a slight difference in concentration of the PCDDs and PCDFs in exposed patients versus non-exposed patients, especially for the 2,3,4,7,8-PeCDF. However, no statistical confirmation is provided with the data to indicate the significance of this observation. Also, the data from that study were reported such that additional information on age or sex of the patients is not available to the reader.

Federal Republic of Germany: Two studies that are currently being conducted in the Federal Republic of Germany were reported at the 7th International Dioxin Conference, Las Vegas, Nevada, October 1987. These studies are focused on the levels of PCDDs and PCDFs in both the general population and occupationally exposed workers. Thoma et al. (1987) reported on the PCDD and PCDF levels in 19 samples of human fat from persons from the Munich area. The subjects were of different ages and health conditions. As noted in the other studies summarized in this report, only compounds with a 2,3,7,8-substitution pattern could be detected. The minimum and maximum concentrations of PCDD and PCDF found in adipose tissue in this study are listed below:

	min.	max.
TCDD	< 1.0	18.2
PCDD	3.5	54.4
H_6CDD	52.3	298.0
H_7CDD	49.4	220.0
OCDD	327.2	973.0
TCDF	1.0	12.4
PCDF	13.0	77.7
H_6CDF	18.9	78.8
H_7CDF	9.7	55.3
OCDF	< 2.0	24.0

The levels of PCDDs and PCDFs in adipose tissue of occupationally exposed workers were reported by Beck et al. (1987). These data were reported as part of a comprehensive study on the health risks for TCDD-exposed

Table 5-2. Levels of PCDDs and PCDFs Found in Human Adipose Tissue from the Swedish Population[a]

Compound	Mean value n=31	Range n=31	Mean value exposed n=13	Range n=13	Mean value nonexposed n=18	Range n=18	Mean value cancer pat. n=17	Range n=17	Mean value noncancer n=14	Range n=14
2,3,7,8-TCDD	3	0-9	2	0-9	3	2-6	3	2-9	3	2-6
1,2,3,7,8-PeCDD	10	3-24	6	3-24	9	4-18	9	4-24	9	3-18
1,2,3,6,7,8-HxCDD	15	3-55	19	8-55	12	3-18	18	3-55	12	8-18
1,2,3,7,8,9-HxCDD	4	3-5	5	3-13	4	3-5	4	3-13	4	3-5
1,2,3,4,6,7,8-HpCDD	97	12-380	104	20-380	85	12-176	100	12-380	85	20-168
OCDD	414	90-763	398	90-763	421	98-679	408	90-620	421	182-763
2,3,7,8-TCDF	3.9	0.3-11	3.7	0-7.2	4.2	0.3-11	3.4	0.3-7.2	4.6	0-11
2,3,4,7,8-PeCDF	54	9-87	50	15-87	32	9-54	45	9-87	33	11-65
1,2,3,4,7,8/ 1,2,3,4,7,9-HxCDF	6	1-15	7	2-15	5	1-6	6	1-15	5	2-7
1,2,3,6,7,8-HxCDF	5	1-13	5	2-13	4	1-5	5	1-13	4	2-7
2,3,4,6,7,8-HxCDF	2	1-7	2	1-7	2	1-4	2	1-7	2	1-4
1,2,3,4,6,7,8-HpCDF	11	1-49	14	5-49	10	1-18	13	1-49	10	5-16
OCDF	4									

Source: Nygren et al. 1986. In *Chlorinated Dioxins and Dibenzofurans in Perspective*.

[a] Values given in pg/g on a wet weight basis.

workers of the Boehringer Company in Ingelheim and Hamburg. Adipose tissue was collected from 45 volunteers and analyzed for PCDD, PCDF, and some organochlorine compounds, specifically HCB and β-HCH. The data reported by Beck et al. have not been published to this date. However, the results presented at the 7th International Dioxin Conference indicated that the range of concentration for the PCDDs and PCDFs was greater than the values reported for occupationally exposed chemical workers in Missouri (Patterson et al., 1987).

Japan: Ryan et al. (1986a) and Ono et al. (1986) reported PCDD and PCDF data for adipose tissue samples collected in Japan. The data reported by Ryan et al. (1986a) focused on samples collected during autopsy from six individuals not known to be exposed to these compounds. The study conducted by Ono et al. (1986) included 13 adipose tissue samples collected from cancer patients. The results of the two studies on levels in the Japanese residents are summarized in Table 5-3. The data are comparable between the two studies and demonstrate the same general trends in the relative PCDD and PCDF concentrations as noted for the other studies cited. The exception is the data reported by Ono et al. (1986) for the mean concentration of OCDD. In reviewing the data for this compound, it should be noted that the actual concentration of OCDD may have been affected by the use of an alcoholic potassium hydroxide digestion procedure at the outset of the sample preparation. This strong base may have resulted in the inadvertent dechlorination of OCDD.

Table 5-3. Wet Tissue Concentration of PCDDs and PCDFs in Adipose Tissue Samples Collected in Japan

	Ryan et al. (1986a) Concentration (pg/g)		Ono et al. (1986) Concentration (pg/g)	
	Mean (n = 6)	Range	Mean (n = 13)	Range
2,3,7,8-TCDD	3.9	ND-5.7	9	ND-18
2,3,4,7,8-PeCDF	19	7.3-23.2	25	4-71
HxCDF	40	ND-94	37	ND-68
HxCDD	51	30-60	90	ND-278
OCDD	802	240-1920	230[a]	25-1100[a]

[a] The OCDD levels in this study are suspect since samples were digested in the presence of strong base, which is known to cause dechlorination of the OCDD.

Vietnam: Schecter et al. (1986b) reported the results of the analyses of 20 adipose tissue samples collected from Vietnam. Thirteen of the samples were collected in Ho Chi Minh City, and seven were obtained in Hanoi. The results of this study are provided in Table 5-4. The average levels of the PCDDs and PCDFs in the samples collected in Ho Chi Minh City are obviously higher than from samples collected in Hanoi. The authors of this study suggest that the differences in concentration from the samples collected in the North and South of Vietnam are a measure of the differences in industrialization. Additional data on levels of PCDDs and PCDFs in human tissues from Vietnam were presented at the 7th International Dioxin Conference (Dai et al., 1987). These data have not been published.

Table 5-4. Mean PCDD and PCDF Levels (pg/g) in Adipose Tissues from Vietnam (Wet Weight Basis)

Analyte	North Vietnam, 1984 n = 7	South Vietnam, 1984 n = 13
2,3,7,8-TCDD	ND[a] (2)[b]	22.1
1,2,3,7,8-PeCDD	ND (2)	9.9
1,2,3,6,7,8-HxCDD	4.6	46.7
1,2,3,4,6,7,8-HpCDD	19.0	105
OCDD	36.1	514
2,3,4,7,8-PeCDF	9.7	13.0
1,2,3,4,7,8/1,2,3,6,7,8-HxCDF	9.3	31.7
1,2,3,4,6,7,8-HpCDF	4.2	17.0

[a] ND = not detected.
[b] Number in parentheses is detection level in parts per trillion.

5.3 Distribution of PCDD and PCDF Congeners in Body Tissues and Fluids

A primary concern in conducting studies to determine exposure to hazardous compounds is the selection of the appropriate biological medium for analysis. Adipose tissue is recognized as the biological tissue that contains the highest concentrations of most environmentally persistent contaminants that are difficult to metabolize. At least two studies have been conducted to demonstrate the appropriateness of adipose tissue as the biological tissue of choice for monitoring exposure to PCDDs and PCDFs (Ryan et al., 1986b; Alley et al., 1987).

These studies focused on the analysis of several different tissue types taken during autopsies. The tissues analyzed by Ryan et al. (1986b) included fat (subcutaneous, either abdominal or gluteal, mesenteric abdominal, and perirenal), adrenal, bone marrow, liver, muscle, spleen, kidney, and lung. The

tissues were selected on the basis of their known accumulation of lipid-soluble compounds or due to their importance in metabolism of xenobiotics. Samples were collected from three different autopsies. The data were reported based on tissue levels for each specific autopsy.

The PCDD and PCDF levels varied widely based on tissue type when the data were reported based on the initial wet tissue weight. For example, a factor of approximately 36 was noted for the ratio of wet tissue concentration of total PCDDs in subcutaneous fat to lung tissue from a particular autopsy. However, when the tissue concentrations were calculated based on the amount of extractable lipid, these values resulted in approximately a 1:1 ratio. Calculations of all tissue concentrations based on extractable lipid significantly reduced the variability on reported concentrations.

The study conducted by Alley et al. (1987) focused more specifically on the distribution of PCDDs and PCDFs in adipose tissues collected from up to five anatomical sites for two individuals (one male and one female). The adipose tissue samples analyzed were collected from the breast (female only), buttock, abdomen, omentum, kidney, and heart. An example of the results of the analyses is presented in Figure 5-6. Only results for the hexa- through octachloro congeners are shown, although the data for the tetra- and pentachloro congeners are within the precision noted for the higher chlorinated compounds.

As noted in Figure 5-6, little to no difference in residue levels was detected between the various adipose tissues. This study and also that conducted by Ryan et al. (1986b) imply that results of adipose tissue studies should be comparable if corrections are made for the percent extractable lipid for each tissue type. More importantly, the normalization of residue levels based on the extractable lipid should allow latitude in collection of samples for population studies.

Additional studies have been conducted to determine the feasibility of using human blood serum rather than adipose tissues to determine PCDD and PCDF body burden levels. The impetus for pursuing blood serum over adipose tissue is an issue of the ease of collection via the relatively noninvasive procedure of blood collection and of separation of serum.

As part of the study on the residents of Times Beach, Missouri, the Centers for Disease Control (Patterson et al., 1986b) collected up to 200 g of blood serum in addition to adipose tissue from the study participants. Each matrix was analyzed for 2,3,7,8-TCDD following similar analytical protocols. The results of that study demonstrated a strong correlation ($R = 0.98$) between the residue levels of 2,3,7,8-TCDD in adipose tissue and the serum concentration based on an extractable lipid basis.

Figure 5-7 illustrates this high adipose tissue/blood serum correlation. As noted in the figure, the blood serum concentration is plotted as parts per trillion (pg/g) based on a lipid weight basis vs. the adipose tissue concentration adjusted for extractable lipid. If the concentration of PCDDs and PCDFs in serum is based on the total mass of the sample rather than the lipid content, the concentration values would be equivalent to parts per quadrillion (10^{-15} g/g).

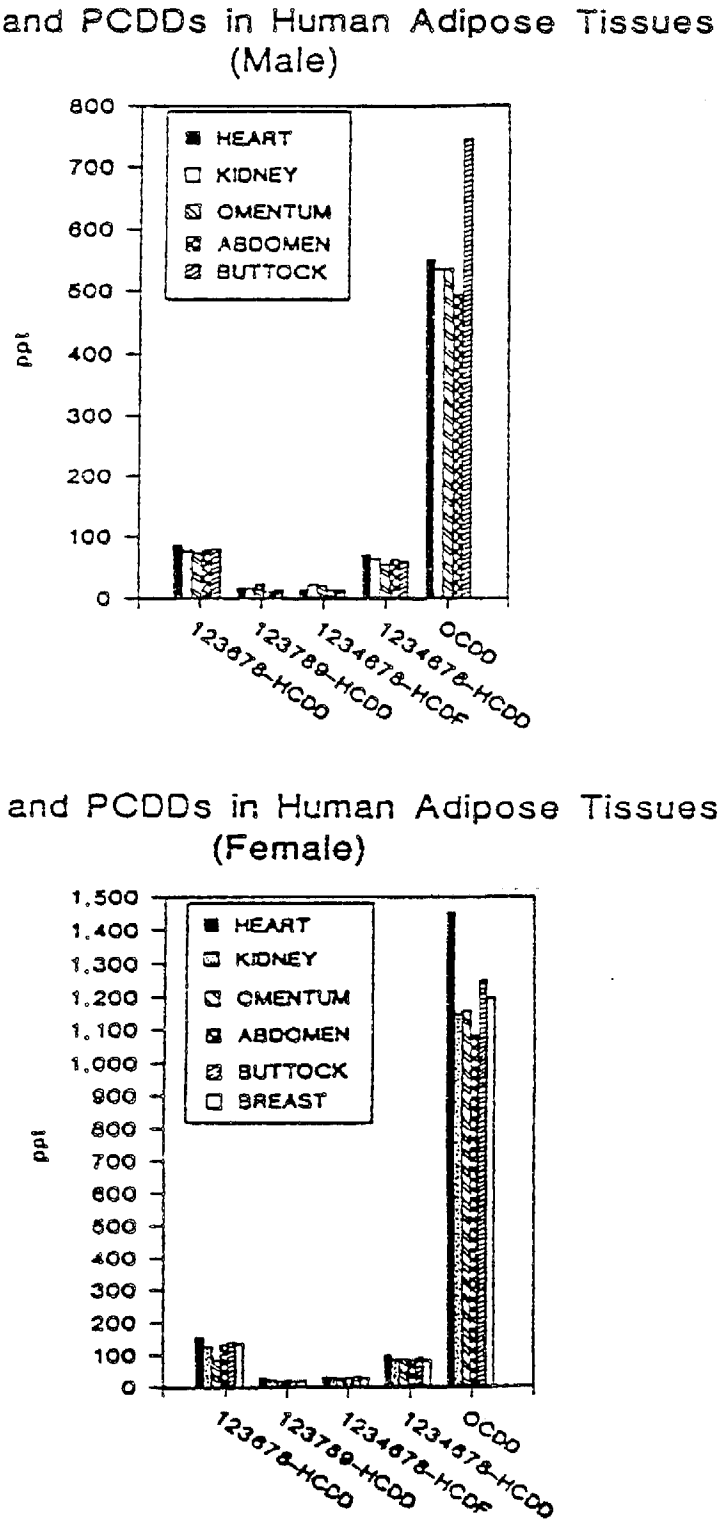


Figure 5-6. Distribution of PCDDs and PCDFs in various adipose tissues.

Source: Alley et al. 1987. 35th ASMS Conference.

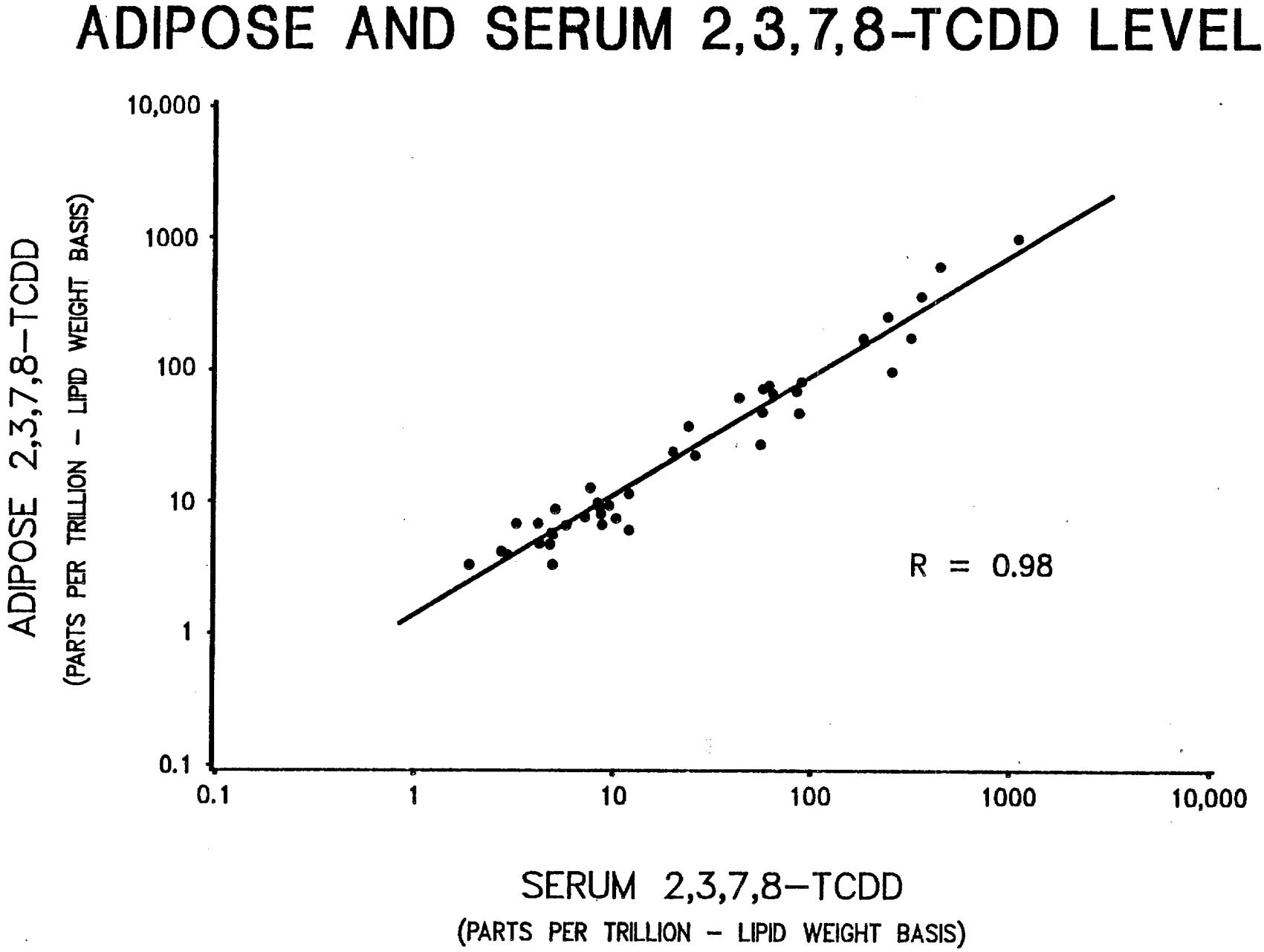


Figure 5-7. Correlation of serum 2,3,7,8-TCDD concentration vs. adipose tissue 2,3,7,8-TCDD concentration.
Source: Sampson et al. 1986. 6th International Dioxin Conference, Fukuoka, Japan.

The results of CDC's adipose tissue/blood serum correlation study successfully demonstrated that serum can be used to monitor body burden levels of 2,3,7,8-TCDD. As a result, blood serum has been used extensively as the biological matrix of choice for CDC's additional efforts in the Vietnam veterans study. Although the analysis of blood serum is effective for monitoring 2,3,7,8-TCDD body burdens, the feasibility of using this matrix for the other 2,3,7,8-substituted PCDDs and PCDFs has not been determined. Preliminary data presented at a recent international conference indicated that the adipose tissue/blood serum correlations for the higher chlorinated congeners are not as high as noted for the 2,3,7,8-TCDD (Nygren et al., 1987).

5.4 Body Burden Versus Lifestyle Factors

The most significant efforts to date to correlate lifestyle factors with body burden levels of PCDDs and PCDFs have been conducted by the Centers for Disease Control (Andrews et al., 1987; Patterson et al., 1987a). These studies have focused on residents of Times Beach, Missouri, and several employees of a chemical production facility (specifically, those exposed to trichlorophenol).

The study of the Times Beach, Missouri, residents consisted of 57 individuals classified as controls and 39 exposed individuals. The criteria for classification as exposed individuals consisted of residence within the Times Beach area. Exposure indices for the Times Beach residents were based on residence history, potential for occupational exposure (for example, job function within the chemical production facility), and recreational activities. Recreational activities of interest included gardening and participation in horse shows conducted in arenas treated with oil contaminated with 2,3,7,8-TCDD.

The results of this study are summarized in Figure 5-8. The data are presented separately for the control and the exposed populations. As noted in Figure 5-8, all control samples had concentrations of 2,3,7,8-TCDD below 20 pg/g with a median concentration of about 6 pg/g. The adipose tissue levels of 2,3,7,8-TCDD for the exposed individuals ranged from 2 to over 700 pg/g with a median concentration of about 20 pg/g. Of the 39 samples, 6 had levels above 100 pg/g. The potential exposure for those with 2,3,7,8-TCDD levels greater than 20 pg/g resulted from residential, occupational, and recreational parameters.

The second study conducted by CDC was a follow-up on the individuals with the high 2,3,7,8-TCDD residue levels from apparent exposure through occupational activities (Patterson et al., 1987a). This study focused on 19 workers who had reported occupational exposure to 2,3,7,8-TCDD during the Times Beach study. A review of the employment and chemical production plant records was used to explain the wide diversity of adipose tissue levels. Of the 19 individuals, nine were production workers who made products contaminated with 2,3,7,8-TCDD; seven worked at the same chemical company but not in the dioxin-contaminated process; and three were employees at trucking facilities contaminated with dioxin-containing waste oils. The average concentrations of 2,3,7,8-TCDD in the three groups were 326, 11.6, and 18.6 pg/g, respectively.

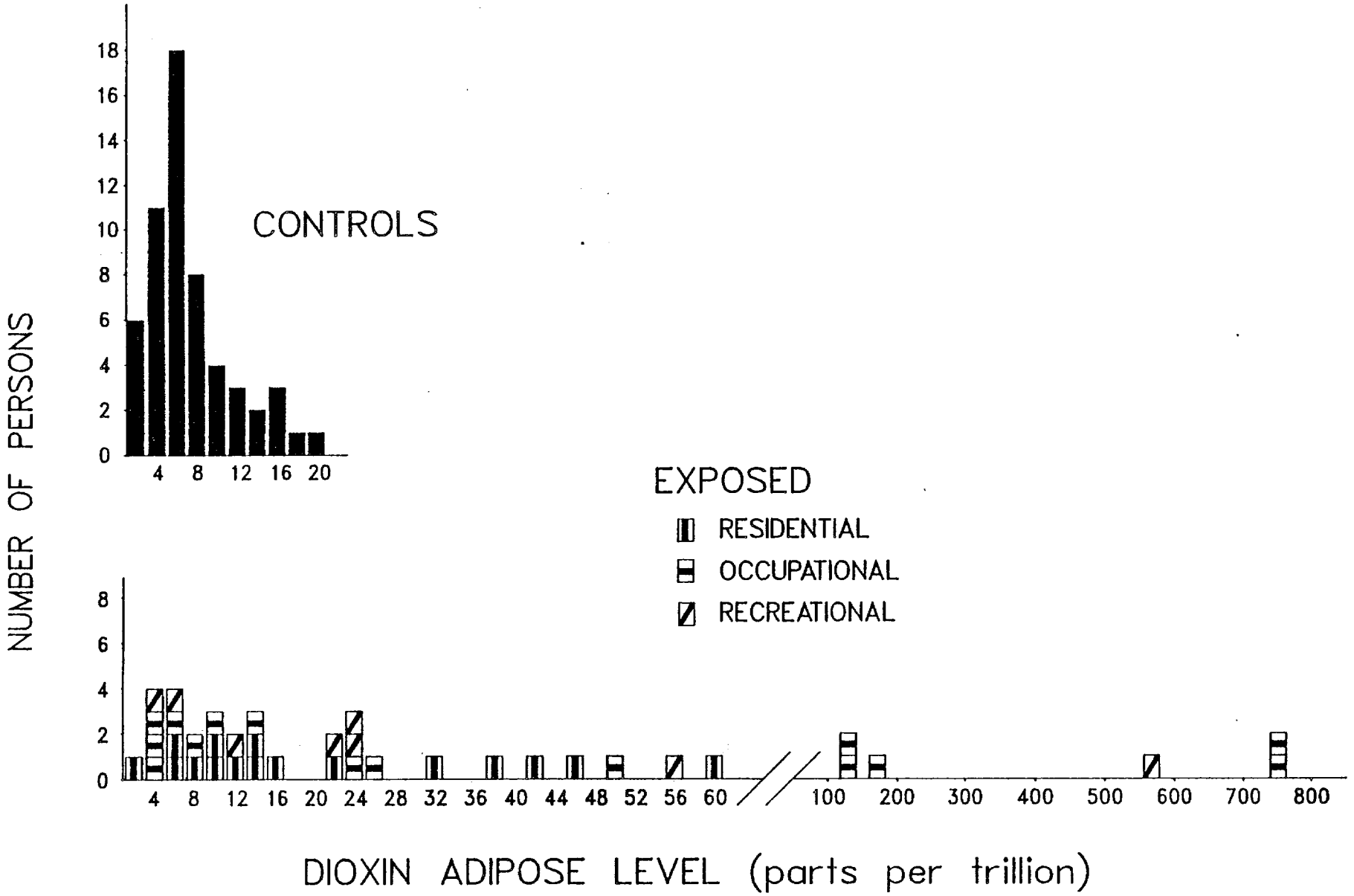


Figure 5-8. 2,3,7,8-TCDD adipose tissue concentration from persons classified as exposed at Times Beach, Missouri, vs. the adipose tissue concentration of controls.
Source: Sampson et al. 1986. 6th International Dioxin Conference, Fukuoka, Japan.

5.5 Body Burden Versus Age and Sex

Age and sex are other factors that have been considered with respect to the measured body burden levels of PCDDs and PCDFs. It has been generally noted that the concentrations of PCDDs and PCDFs tend to increase with age. Figure 5-9 is a summary of PCDD data from the analysis of the FY82 NHATS specimens. This figure shows clearly that the concentrations of the PCDDs tend to increase with increases in age. The correlation with age is not quite as apparent for the TCDD. This may be a result of the fact that the measured concentrations are generally below 10 pg/g and the possibility that the concentration in the 45 plus age group has been affected by the compositing of multiple samples. The trend noted for the 1,2,3,7,8-PeCDD is an exception to the observation that concentration is strongly correlated with age. The data from other studies presented in the literature dealing with the analysis of PCDDs and PCDFs in adipose tissues are not presented in enough detail to determine if this trend observed for PeCDD is consistent.

The studies conducted by CDC (Patterson et al., 1986,1986d) on Georgia and Utah residents and by Graham et al. (1986a,1986b) on St. Louis residents have provided additional information on the correlation of the 2,3,7,8-TCDD concentration with age. Figure 5-10 presents the results from these two studies. The data generated from the analysis of the samples from the CDC study indicated an overall significant correlation between age and concentration. However, when sex was considered as a factor, it is noted that age is a significant factor for females but not for males in their level of 2,3,7,8-TCDD.

The study conducted by Graham et al. (1986a,1986b), on the other hand, indicates that concentrations of 2,3,7,8-TCDD are correlated with age regardless of whether the samples were collected from males or females, with a slightly higher correlation for females than males. In both studies, average concentrations for females were higher than for males.

The more recent efforts by the CDC on the analysis of samples from Missouri residents have demonstrated that there is a correlation based on sex (females tend to have higher tissue concentrations of 2,3,7,8-TCDD) (Anderson et al., 1987). Further, the studies on the tissue concentrations of Vietnam veterans have indicated that the concentration of 2,3,7,8-TCDD tends to increase by approximately 1.3 pg/g per decade (Patterson et al., 1987a).

The correlation of sex with PCDD and PCDF concentration levels has also been statistically evaluated for the data from the analysis of the FY82 NHATS composites. These data have not provided significant correlations between sex and TCDD or PeCDD concentrations but have indicated that the concentrations of the hexa- through octachloro PCDDs and PCDFs are expected to be higher for females than for males.

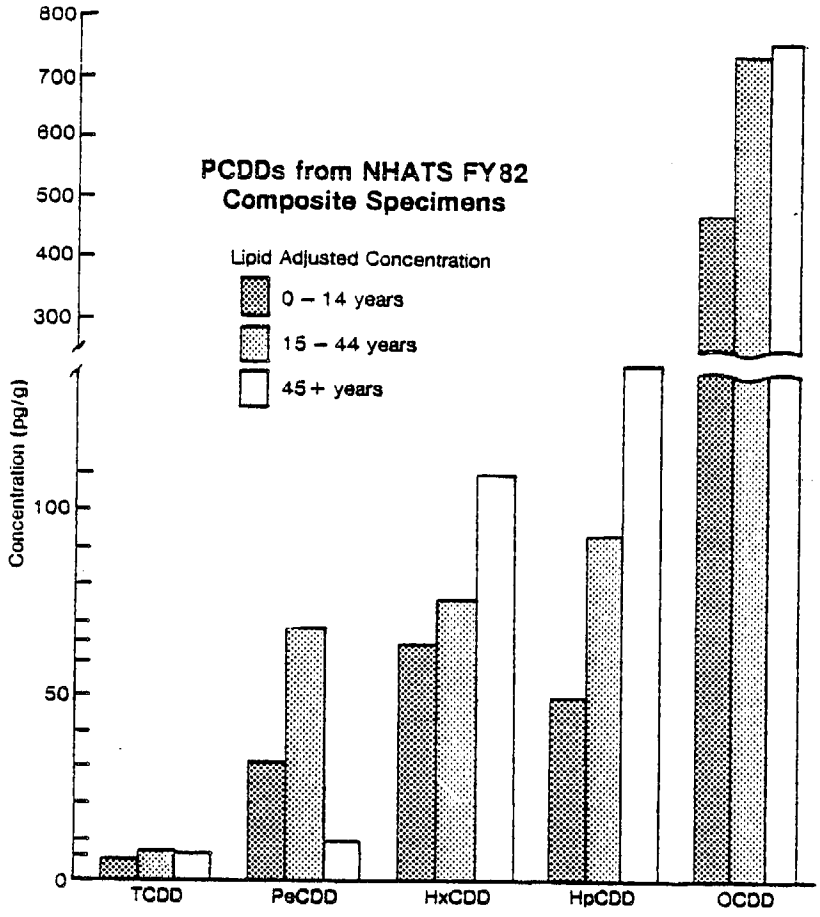


Figure 5-9. Correlation of PCDD concentration vs. age for the FY82 NHATS composite samples.

Source: Stanley et al. 1986b. *Chemosphere*, 15, 1605-1612.

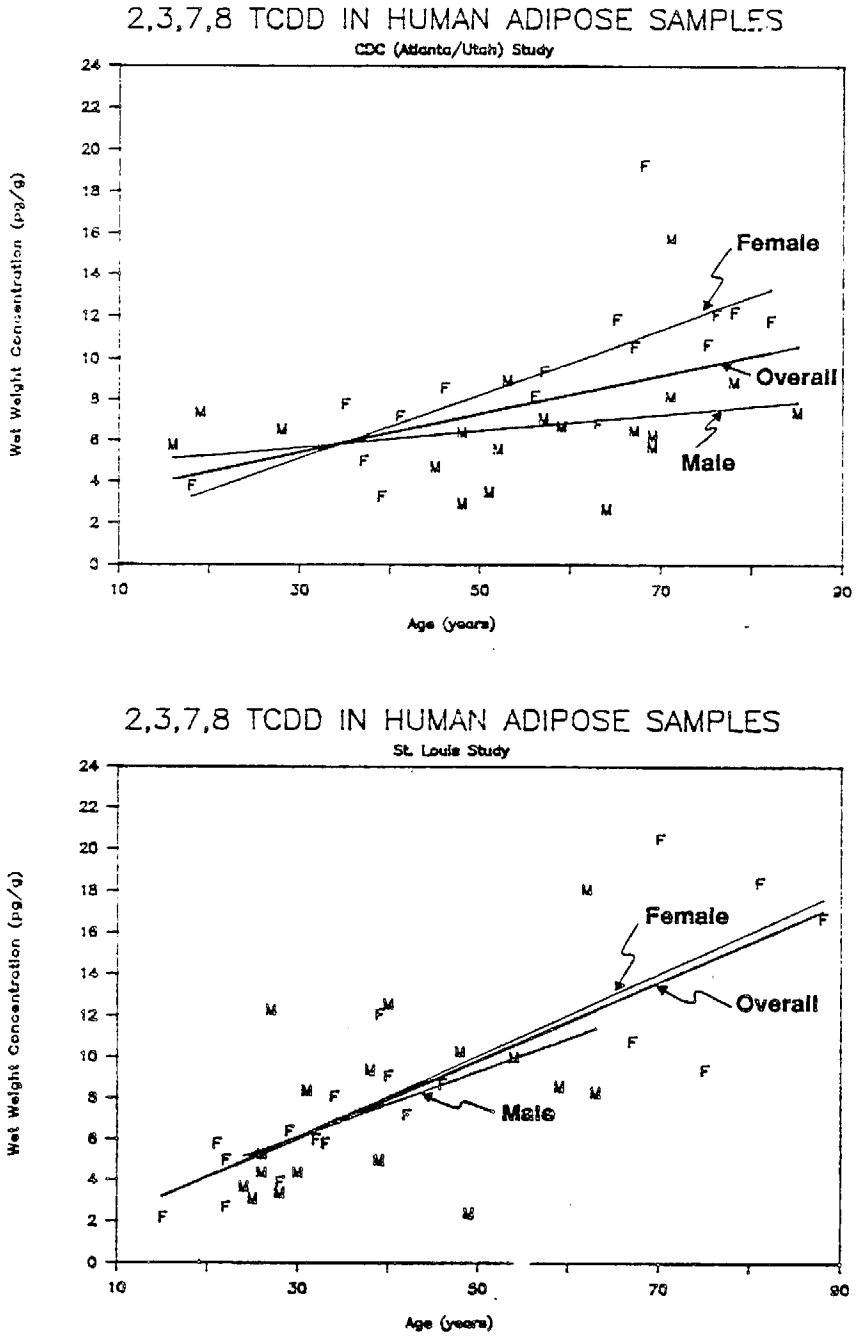


Figure 5-10. Correlation of 2,3,7,8-TCDD concentration vs. age and sex from analysis of samples from different geographic regions.

SECTION 6.0

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