INDOOR POLLUTANT CONCENTRATIONS AND EXPOSURES

Final Report
Contract No. A833-156

Prepared for:

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January 1992

DISCLAIMER

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

ABSTRACT

The California Health and Safety Code (HSC) Section 39660.5 requires that indoor exposures to candidate toxic air contaminants (TACs) be considered during risk assessments. The purpose of this study was to generate indoor and personal exposure data to be used by the California Air Resources Board (ARB) for its toxic air contaminants identification process. The overall study was designed to provide the maximum amount of information to the ARB for as many candidate TACs as possible. Personal monitoring, as well as indoor and outdoor microenvironmental monitoring, were performed. Target toxic air pollutants (TAPs) represent a broad range of very volatile organic chemicals (VVOCs), volatile organic chemicals (VOCs), and semivolatile organic chemicals (SOCs). For the main study, monitoring was conducted during a single season (June 1990) using a probability sample of 128 households and individuals from Woodland, California. Along with field monitoring, information on time/activity patterns and potential source usage within specific microenvironments was collected using questionnaires.

Prior to statistical analysis, sampling weights were developed and applied to the chemical concentration and questionnaire results. This approach allowed population estimates to be made for the resulting statistics. For the SOC and outdoor VVOC air concentration data, sample weights were not used due to limited sample size or overall uncertainty in the data. The data were then used to estimate indoor, outdoor and personal air concentrations for a range of volatile, very volatile, and semivolatile toxic air pollutants. They were also used to examine the relationship

among toxic air pollutants in various matrices and to investigate the association between air concentrations and potential pollutant sources. Finally, a comparison of activity patterns and pollutant concentrations to other areas in the state was made.

As with other air monitoring programs in California, the common volatile organic solvents (1,1,1-trichloroethane, benzene, and the xylenes) were found most often in all types of air samples. They were also found at the highest concentrations. Several other chemicals including perchloroethylene, styrene, p-dichlorobenzene, methylene chloride, acrolein, and di-ethylhexylphathlate were frequently or occasionally found in air samples with highest prevalence in indoor or personal air samples. Highest concentrations were reported for methylene chloride and p-dichlorobenzene. A number of other chemicals that had not been monitored on previous programs were included in this study. These were included because of their high priority in the ARB review process. With the exception of methylene chloride, acrolein and di-2-ethylhexylphthalate, these chemicals were rarely or never detected in air samples.

For all of the common solvent based TAPs, personal air samples showed the highest concentrations followed by indoor air and then outdoor air samples. Indoor/outdoor air concentration ratios for most of the TAPs were greater than one. Highest ratios were calculated for styrene and p-dichlorobenzene, suggesting strong indoor sources for these two chemicals.

Air concentrations for VOCs reported for this study were lower than those reported for other, similar studies in California. This trend was observed for indoor, outdoor, and personal air samples.

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF TABLES (continued)

GLOSSARY OF TERMS, ABBREVIATIONS, AND SYMBOLS

ARB	-	Air Resource Board
C	-	Centigrade
CAPI	-	Computer-Assisted Personal Interview
cm	-	Centimeter
ED	-	Enumeration Districts
EIQL	-	Estimated Instrumental Quantifiable Limit
EMQL	-	Estimated Method Quantitation Limit
FSU	-	First-stage Sampling Units
GC/ECD	-	Gas Chromatography/Electron Capture Detection
GC/FID	-	Gas Chromatography/Flame Ionization Detection
GC/MS	-	Gas Chromatography/Mass Spectrometry
HSC	-	Health and Safety Code
HU	-	Housing Units
i.d.	-	Internal Diameter
INT	-	large interference
L	-	Liter
m	-	meter
m^3	-	cubic meter
min	-	minute
mm	-	millimeter
mL	-	milliliter
MQL	-	Method Quantitation Limit
ND	-	no detector response
ng	-	nanogram
NQ	-	below the method quantification limit
NR	-	not reported
NS	-	not significantly >0 at 0.05 level
NT	-	not analyzed; monitoring not performed
o.d.	-	Outer Diameter
OU	-	Office Units
PTEAM	-	Particle TEAM
PCBs	-	Polychlorinated Biphenyls
PFB	-	Perfluorobenzene
PFT	-	Perfluorotoluene

GLOSSARY OF TERMS, ABBREVIATIONS, AND SYMBOLS (continued)

PPS	-	Probability Proportional to Size
QC	-	Quality Control
QL	-	Quantitation Limit
RAE	-	Record of Activities and Environments
RF	-	Response Factor
%RMD	-	Percent Relative Mean Deviation
RTI	-	Research Triangle Institute
SE	-	standard error
SL	-	method control lost for sample
SU	-	analysis of standards was unacceptable
SIM	-	Selected Ion Monitoring
SOC	-	Semivolatile Organic Chemical
SOP	-	Standard Operating Procedure
STP	-	Standard Temperature and Pressure
TAC	-	Toxic Air Contaminant
TAD	-	Time Activity Diary
TAP	-	Toxic Air Pollutant
TEAM	-	Total Exposure Assessment Methodology
μg	-	microgram
VVOC	-	Very Volatile Organic Chemical
VOC	-	Volatile Organic Chemical

ACKNOWLEDGMENTS

The success of this project was the product of the work and input of a number of people. The authors wish to thank all those who contributed to the design, implementation, analysis, and reporting of this study.

Overall project management was provided by Mr. Steve Hui of the California Air Resources Board with the assistance of Ms. Peggy Jenkins, Manager of Indoor Exposure Assessment Section.

We would like to thank the Research Triangle Institute staff members who participated in this study. They include James Beach, Linda Ellis, Brenda Fletcher, Michele Hoffman, Brenda Hodges, Celia Keller, Kevin McGowan, and Mike Roberds.

The authors would especially like to thank the study respondents, who graciously allowed us to enter their homes for collection of samples and information. Their participation has enabled us to conduct the study and obtain new information on indoor pollutant concentrations and exposures.

This report is submitted in fulfillment of California Air Resources Board Contract No. A833-156, "Indoor Pollutant Concentrations and Exposures", by Research Triangle Institute under the sponsorship of the California Air Resources Board. Work on this research project was completed as of September 1991.

SECTION 1

INTRODUCTION

The California Health and Safety Code (HSC) Section 39660.5 requires that indoor exposures to candidate toxic air contaminants (TACs) be considered during risk assessments. Unfortunately, very little data are available for this purpose. As a result, the Air Resources Board (ARB) now has the responsibility for generating the indoor air and personal exposure data, as well as the health effect information, that is needed for making realistic exposure assessments for pollutants generated indoors or present in the indoor air.

In February 1988, ARB developed an <u>Indoor Air Quality/Personal Exposure Study Plan</u> that outlined their approach for gathering the requisite risk assessment data. Six research objectives were set forth in this plan:

1. To obtain activity pattern data for Californians.
2. To obtain indoor air concentration data and exposure pattern data for indoor air pollutants.
3. To obtain data regarding the health effects of indoor air pollutants.
4. To assure the development of adequate indoor and personal air monitors and monitoring methodology for use in ARB studies.
5. To identify indoor sources of air pollutants and to obtain source emission estimates.
6. To develop and validate a comprehensive total exposure model that can be used in carrying out complex risk assessments.

This "Indoor Pollutant Concentration and Exposure Study" was intended to address research objective 2 with the overall goal of gathering data required for the ARB toxic air contaminants review and regulation process.

Prior to focussing our research design, we first considered that ARB needs for indoor concentration and exposure data are very far reaching. For example, exposure assessment data are required for all of the toxic air pollutants (TAPs) listed in Table 1-1. Secondly, diverse information is needed for each pollutant and must include concentration data for a variety of indoor microenvironments (i.e., homes, schools, offices, retail stores, hospitals, etc.), outdoor concentration data, and personal exposure measurements. Time/activity data are also needed to relate microenvironmental data to exposure measurements. Finally, exposure estimates and data for indoor air pollutant concentrations are needed for both the statewide population and for populations within several diverse areas of the state. A major goal of this study was to provide the maximum amount of information for meeting ARB data needs. In keeping with this goal, eight research objectives were defined as given in Table 1-2. This field monitoring study based on the Total Exposure Assessment Methodology (TEAM) model was then designed to meet these specific objectives.

For this study, personal and microenvironmental air concentration data were generated for a broad range of very volatile organic chemicals (VVOCs), volatile organic chemicals (VOCs), and semivolatile organic chemicals (SOCs). The study design used a probability sample of homes/individuals from one geographical area in California. The use of a probability sample is one of several basic elements in the TEAM model that was used here. This approach was considered essential since it provides a sample that is representative of the study area, and as such, allows concentration and exposure estimates to be made for the entire study area.

TABLE 1-1. TOXIC AIR POLLUTANTS OF CONCERN TO ARB (JANUARY, 1989)

	Contaminants				
ARB Status[a]	Very Volatile and Volatile Organics	Nitrosamines	Semivolatile Organics	Inorganics	Others
IIB	Acetaldehyde[b] Acrylonitrile[b] 1,3-Butadiene[b] p-Dichlorobenzene[b,c] 1,4-Dioxane[b,c] Propylene Oxide[b,c] Styrene[b,c]	Alkylnitrosamines N-Nitrosomorpholine	Di(2-ethylhexyl)-phthalate[d] Hexachlorobenzene[d] Polynuclear Aromatic Hydrocarbons (PAHs) Polychlorinated Biphenyls (PCBs)[d] 2,4,6-Trichlorophenol[d]	Beryllium Inorganic Lead Mercury	Coke-oven Emissions Environmental Tobacco Smoke Radionuclides
III	Acrolein[b] Allyl Chloride[b,c] Benzyl Chloride[b,c] Chlorobenzene[b,c] Cresols Methyl Bromide[b] 1,1,1-Trichloroethane[b,c] Phenol Vinylidene Chloride[b] Xylenes[b,c]		Chlorophenols[d] Chloroprene[d] Maleic Anhydride Nitrobenzene[d]	Manganese	
IIA	Formaldehyde Methylene Chloride[b] Vinyl Chloride[b,c] Perchloroethylene[b,c] Trichloroethylene[b,c] Chloroform[b]			Inorganic Arsenic Nickel	
I	Benzene[b,c] Ethylene Dibromide[b,c] Ethylene Dichloride[b,c] Carbon Tetrachloride[b,c] Ethylene Oxide[b,c]		Chlorinated Dioxins and Dibenzofurans	Asbestos Cadmium Chromium (VI)	

[a] As defined in the RFP; given in priority of ARB's interest.
[b] Proposed VVOCs.
[c] Proposed VOCs.
[d] Proposed SOCs.

TABLE 1-2. RESEARCH OBJECTIVES FOR THE PHASE I STUDY

- Provide residential indoor air concentrations for VOCs, SOCs, and VVOCs during a single season in the study area
- Provide personal exposure data for VOCs and SOCs during a single season in the study area
- Examine whether VOC, SOC, and VVOC exposures are principally from indoor or outdoor microenvironments for this single season study
- Examine whether exposures to VOCs and SOCs are primarily from residential or other indoor microenvironments for this single season study
- Examine whether residential indoor concentrations correlate to potential sources in the home for this single season study
- Examine whether personal exposure correlates to microenvironmental data, time/activity patterns, and potential indoor sources for this single season study
- Compare time/activity data for the study population to the rest of the state
- Compare selected volatiles data from the proposed study with previous TEAM data for California

Along with field monitoring, information on time/activity patterns and potential source usage within specific microenvironments was collected using questionnaires. Questionnaires were designed to be similar to those used by ARB on their statewide time/activity survey of California residents and on previous California TEAM studies. This approach allowed us to compare activity patterns for our study population to the statewide population. It was also intended to provide useful information for extrapolating monitoring data and exposure estimates to the statewide population.

During this study, indoor microenvironmental monitoring was restricted to residential units. Monitoring was NOT performed in other indoor microenvironments such as schools, offices, stores, or theaters. This decision was based on our belief that exposure assessment data should be generated using probability based sampling techniques. Our experience (1) has demonstrated that although a probability sample of commercial buildings can be located, it is difficult, and often impossible, to identify owners of these buildings and to garner participation for field monitoring (especially within a reasonable time frame).

Table 1-1 lists the toxic air pollutants of concern to ARB. The chemicals targeted for monitoring on this study are also noted in the table. The specific chemical classes were selected to provide data for the largest number of chemicals with the highest priority to ARB for making risk assessments. Chemicals are designated as very volatile organic chemicals, volatile organic chemicals, or semivolatile organic chemicals based on monitoring methods.

Methods for personal and fixed site monitoring of volatile organic compounds were developed at Research Triangle Institute (RTI) and have been used throughout our TEAM studies (2,3). Several of the chemicals in this group (p-dichlorobenzene, styrene, chlorobenzene, 1,1,1-trichloroethane, benzene, the xylenes, chloroform, and carbon tetrachloride) were monitored in California as part of past TEAM studies (4) and data generated here should extend the ARB database for these chemicals. Methods for VVOCs were adopted from standard methods used previously in our laboratory (5, 6).

Standard methods were not available for the SOCs targeted for this study. The method used was proposed based on reported literature methods (1,7,8,9), their applicability to project needs, their adaptability and simplicity for field monitoring, and overall method costs. The proposed method used a filter/XAD-2 resin cartridge to accumulate SOCs from air. Gas chromatography with electron capture detection (GC/ECD) was initially used for quantitative analysis of target SOCs extracted from exposed cartridge samples. However, because of high concentrations of background interferences in sample extracts, gas chromatography/mass spectrometry (GC/MS) was used to provide the requisite selectivity during analysis.

This project was divided into two phases. A pilot study was performed on 16 individuals in 12 homes during the week of November 10, 1989. The purpose of the pilot study was to field test both the sampling and analysis methods as well as the questionnaires and questionnaire administration procedures. The main study was performed on 128 individuals/homes during May and June 1990 with the purpose of generating pollutant concentration data. Both studies were performed in Woodland, California.

In order to monitor the broadest range of chemicals possible, we included as targets all those TAPs that we felt could be quantified using the proposed sampling and analysis methods. This resulted in the inclusion of targets that had not been previously validated. Methods for all proposed target chemicals were evaluated during the pilot test, then only those chemicals that showed good performance characteristics were actually included in the main study.

The remainder of this report summarizes the results of the pilot study, gives an overview of the study design for the main study, and describes in detail the methods that were used for field sampling and analysis. Monitoring results and statistical analysis of the data for the main study are then given. Most importantly, we have provided the conclusions drawn from this study and have made recommendations for method improvements, as well as additional information that should be collected for the ARB toxic air contaminants review process.

SECTION 2

SUMMARY AND CONCLUSIONS

The overall purpose of this study was to obtain information on air concentrations and exposure patterns for indoor air pollutants. This was accomplished by performing a field monitoring study on 128 homes in Woodland, California in June, 1990. Woodland was selected to represent a medium-size city in the central valley of California. A city in this predominantly agricultural region of California was intended to provide a population with a different socioeconomic mix, employment history and lifestyle pattern than populations in the state that had been studied previously. The study design followed the TEAM methodology and included:

- development of a probability sampling design,
- selection and enlistment of field participants,
- collection and analysis of indoor, outdoor, and personal air samples from study participants, and
- collection of questionnaire information on participant activities and potential contaminant sources in their homes.

Prior to statistical analysis, sampling weights were developed and applied to the chemical concentration and the questionnaire results. This approach allowed population estimates to be made for the resulting statistics. For the SOC and outdoor VVOC air concentration data, sample weights were not used due to limited sample size or overall uncertainty in the data. The data were then used to estimate indoor, outdoor and personal air concentrations for a range of volatile, very volatile, and semivolatile toxic air pollutants. They were also used to examine the relationships among toxic air pollutants in various matrices and to investigate the association between air concentrations and potential pollutant sources.

Finally, a comparison of activity patterns and pollutant concentrations to other areas in the state was made.

The remainder of this section summarizes performance information on the methods that were used to conduct the study. The results of data analysis and conclusions are then presented as they relate to specific study objectives.

2.1 Method Performance

2.1.1 Sample Selection and Participation

The overall response rate for environmental measurements programs is a combination of the response rate for screening and for household/participant monitoring. For this study, 69% of the households contacted completed the screening interview, and 74% of these agreed to participate in chemical monitoring for an overall response rate of 51%. Although this response rate is low, it is consistent with other environmental monitoring programs. The screening response rate was lower than most other studies, while the response rate for monitoring was higher.

Although the data collection ended with the required number of participants, this goal was difficult to achieve. Several problems impacted on the performance on the field monitoring and survey staff. These included the availability of interviewers, the training of interviewers, the complexity of the field effort, the length of questionnaires and other documents, and the ability to supervise interviewers on-site. Procedures to alleviate these problems should be addressed for future programs.

2.1.2 Field Monitoring

Field monitoring aspects of the pilot study proceeded very smoothly. Sufficient time was allocated at each home for all monitoring activities. All pumps and sample collection devices worked well and over 95% the scheduled samples were collected. Greatest losses occurred during collection of SOC samples. Losses for this sample type were primarily due to pump failures.

2.1.3 Monitoring Methods

VVOCs in indoor and outdoor air samples were collected in evacuated 6 L stainless steel canisters. For analysis, a 75 mL sample of the canister air was cryofocused, then injected for GC/MS analysis in the selected ion monitoring mode. VOCs in indoor, outdoor, and personal air samples were collected on Tenax sorbent cartridges. Samples were collected over 24 hours using low flow pumps. Collected samples were analyzed by thermal desorption/GC/MS. Particulate and vapor phase SOCs were collected on a quartz filter backed by an XAD-2 cartridge. Samples were collected over 24 hours using a medium flow pump. Sample cartridges were extracted with acidified methyl-*t*-butyl ether. Phenols in the sample extracts were derivatized using diazomethene. Extracts were first analyzed by GC/ECD using two columns with dissimilar stationary phases. Extracts were later analyzed by GC/MS in the selected ion monitoring mode to provide increased selectivity.

Quality control sample data for the VVOCs and VOCs are given in Tables 2-1 and 2-2. Ethylene oxide and propylene oxide were dropped from the VVOC target list since reproducible and stable calibration standards

TABLE 2-1. QUALITY CONTROL RESULTS FOR VVOC ANALYSIS

Compound	MQL[a] ($\mu g/m^3$)	Duplicate Samples Precision (mean RMD[b])	Mean Concentration in Field Blanks[c] (n = 4) ($\mu g/m^3$)	% Recovery on Field Controls[d] (n = 3)
Vinyl chloride	1.2	NQ[e]	0.09	100 ± 8.6
1,3-Butadiene	1.2	NQ	0.06	99 ± 13
Bromomethane	0.9	NQ	0.04	96 ± 8.0
Acrolein	2.0	NQ	0.63	102 ± 11
Vinlyidine chloride	0.78	NQ	0.02	103 ± 8.6
Allyl chloride	1.2	NQ	0.02	97 ± 13
Methylene chloride	2.8	NQ	2.70	106[f]
Acrylonitrile	2.1	NQ	0.06	111 ± 17
Chloroform	1.2	NQ	0.19	104 ± 6.1
1,1,1-Trichloroethane	0.9	0.13	0.16	94 ± 0.8
Carbon tetrachloride	0.6	0.05	0.02	100 ± 3.5
Benzene	1.6	0.21	0.00	108 ± 5.7
Ethylene dichloride	0.8	NQ	0.01	101 ± 3.2
Trichloroethylene	0.3	0.13	0.01	96 ± 6.7
1,4-Dioxane	0.6	NQ	0.02	57 ± 7.9
Perchloroethylene	0.7	0.20	0.10	95 ± 8.0
Ethylene dibromide	0.8	NQ	0.01	99 ± 20
Chlorobenzene	0.6	NQ	0.03	112 ± 25
m,p-Xylene	1.2	0.05	0.10	105 ± 23
o-Xylene	0.6	0.06	0.04	105 ± 22
Styrene	1.2	0.07	0.08	110 ± 25
p-Dichlorobenzene	0.5	0.14	0.12	106 ± 29
Benzyl chloride	0.6	NQ	0.02	111 ± 21

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[a] Method quantifiable limit.

[b] Relative mean deviation calculated as

$$\frac{|C - \bar{C}|}{\bar{C}}$$

where C is the concentration of one sample in the duplicate pair and $\bar{C}$ is the mean concentration.

[c] All values below the method quantifiable limits.

[d] Percent recovery as mean ± standard deviation.

[e] Below the method quantifiable limit.

[f] Single determination; other two field controls had high levels of contamination.

TABLE 2-2. QUALITY CONTROL RESULTS FOR VOC ANALYSIS

Compound	MQL[a] ($\mu g/m^3$)	Duplicate Sample Precision (mean RMD[b])	Mean Concentration in Field Blanks (n = 13) ($\mu g/m^3$)	% Recovery on Field Controls (n = 13)
Allyl chloride	0.25	NQ[c]	ND[d]	106 ± 18
1,1,1-Trichloroethane	0.12	0.18	0.45	70 ± 13
Benzene	0.38	0.21	2.0	102 ± 16
Carbon tetrachloride	0.15	0.21	0.31	83 ± 7
Trichloroethylene	0.31	0.23	0.02	101 ± 11
1,4-Dioxane	0.11	NQ	ND	94 ± 18
Ethylene dibromide	0.15	NQ	ND	93 ± 10
Perchloroethylene	0.26	0.21	ND	99 ± 13
Chlorobenzene	0.23	NQ	0.47	79 ± 9
m,p-Xylene	0.35	0.20	0.39	112 ± 15
Styrene	0.18	0.19	2.4	104 ± 11
o-Xylene	0.11	0.21	0.01	76 ± 9
Benzyl Chloride	0.22	NQ	ND	76 ± 39
p-Dichlorobenzene	0.26	0.19	1.7	109 ± 12

[a] Method quantifiable limit.

[b] Relative mean deviation calculated as

$$\frac{|C - \bar{C}|}{\bar{C}}$$

where C is the concentration of one sample in the duplicate pair and $\bar{C}$ is the mean concentration.

[c] Below the method quantifiable limit.

[d] No detector response.

could not be prepared. Results demonstrate that data of acceptable quality was generated for the other target VOCs and VVOCs using these two methods.

For the VVOCs, field blanks showed low contamination levels with only methylene chloride (2.7 $\mu g/m^3$) and acrolein (0.63 $\mu g/m^3$) giving mean concentrations greater than 0.2 $\mu g/m^3$. With the exception of 1,4-dioxane (57 ± 7.9%), mean recoveries of all target chemicals from field controls was greater than 90%. Precision evaluated as the mean percent relative mean deviation (RMD) of duplicate samples gave mean values of 0.05 to 0.21 indicating acceptable precision. Method quantifiable limits (MQLs) ranged from 0.3 $\mu g/m^3$ for trichloroethylene to 2.8 $\mu g/m^3$ for methylene chloride.

VOC analyses (Table 2-2) also showed low background contamination of field blanks and acceptable recovery from field controls (all values greater than 70%). Mean RMD values for VOCs were somewhat greater than for VVOCs and ranged from 0.18 for 1,1,1-trichloroethane to 0.23 for trichloroethylene. MQLs, ranging from 0.11 $\mu g/m^3$ for o-xylene and 1,4-dioxane to 0.38 $\mu g/m^3$ for benzene, were lower than those reported for VVOCs.

The monitoring method for the SOCs was a preliminary test method. During sample analysis, problems were encountered due to high and variable background interference in the GC/ECD chromatograms. Our first approach was to analyze extracts using two GC columns with dissimilar phases to provide greater selectivity. However, after multiple analyses of the sample extracts, it was determined that this approach still would not provide the required selectivity.

GC/MS analysis was then used to provide the requisite selectivity. Some problems were encountered, primarily due to the long storage time for sample extracts and the multiple manipulations that were performed in an effort to find a suitable analytical method. Thus, only semiquantitative data were reported. Although the overall objectives for the SOC analyses were not met, several useful outcomes resulted from this work. First, semiquantitative estimates have been made for SOC concentrations in air samples. These data should provide the ARB with a preliminary assessment of indoor and personal exposures to SOCs. Second, a method for SOC analysis was developed that should be capable of providing acceptable quality data for future indoor air and exposure assessment studies.

2.2 Concentrations and Exposures

Objective: Estimate Indoor, Outdoor, and Personal Air Occurrence and Concentrations

The first step in data analysis was to determine the prevalence of the target VOCs, VVOCs, and SOCs in each of the three sample matrices. Table 2-3 provides data for the percentage of samples with air concentrations above the method quantifiable limits (percent quantifiable) with target chemicals sorted according to prevalence. Chemicals with percent quantifiable values greater than 65% were termed ubiquitous; chemicals with percent quantifiable values between 20% and 65% were termed occasionally found. Finally, chemicals with percent quantifiable values less than 20% were termed rarely found.

1,1,1-Trichloroethane, benzene, carbon tetrachloride, and the xylenes were ubiquitous in all sample types. Several other chemicals including perchloroethylene, styrene, p-dichlorobenzene, methylene chloride, and acrolein were ubiquitous in indoor and/or personal air samples. Di-2-ethylhexylphthalate was ubiquitous in automobile samples. Percent

TABLE 2-3. PREVALENCE OF TAPs IN AIR SAMPLES

		Percent Quantifiable		
Compound[a,b]	Type	Outdoor	Personal	Indoor
Ubiquitous in personal, indoor, and outdoor air samples				
1,1,1-Trichloroethane	VVOC, VOC	98.6	100.0	99.2
Benzene	VVOC, VOC	100	100.0	98.3
Carbon Tetrachloride	VVOC, VOC	97.7	98.5	97.7
o-Xylene	VVOC, VOC	100.0	100.0	99.2
m,p-Xylene	VVOC, VOC	100.0	100.0	99.2
Ubiquitous in personal and indoor air samples				
Perchloroethylene	VVOC, VOC	31.5	71.7	55.3
Styrene	VVOC, VOC	34.8	100.0	97.6
p-Dichlorobenzene	VVOC, VOC	26.4	87.6	76.4
*Methylene Chloride	VVOC	30.8	NT[c]	66.8
*Acrolein	VVOC	38.5	NT	79.6
Occasionally quantifiable in indoor and/or personal air samples				
Chloroform	VVOC	NT	NT	NT
Trichloroethylene	VVOC, VOC	1.6	36.6	32.8
1,4-Dioxane	VVOC, VOC	0.0	20.2	21.2
*Pentachlorophenol	SOC	10.0	11.1	31.8
*Di-2-ethylhexylphthalate	SOC	13.3	33.3	31.8
Rarely or never quantifiable in air samples				
Chlorobenzene	VVOC, VOC	0.0	13.3	9.6
*Vinylidine Chloride	VVOC	0.0	NT	0.0
Ethylene Dichloride	VVOC	0.0	NT	1.3
Ethylene Dibromide	VVOC, VOC	0.0	0.0	0.0
*Vinyl Chloride	VVOC	0.0	NT	0.0
*Allyl Chloride	VVOC, VOC	0.0	0.0	0.0
*1,3-Butadiene	VVOC	0.0	NT	9.8
*Acrylonitrile	VVOC	0.0	NT	8.8
*Benzyl Chloride	VVOC, VOC	0.0	0.0	0.9
*Bromomethane	VVOC, VOC	0.0	NT	3.2
*Nitrobenzene	SOC	10.0	11.1	14.8
*2,4,5,6-Tetrachlorophenol	SOC	0.0	11.1	9.1
*Hexchlorobenzene	SOC	0.0	0.0	11.4

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[a] TAPs not monitored on other studies designated by an *.

[b] VOC results are presented for chemicals that were analyzed by both VVOC and VOC methods.

[c] Monitoring not performed.

quantifiable values for these chemicals in outdoor air samples was less than 40%. Several chemicals were occasionally found at quantifiable levels in indoor samples. These included chloroform, trichloroethylene, 1,4-dioxane, di-2-ethylhexylphthalate, and pentachlorophenol. Percent quantifiable values for these chemicals were greater for indoor and personal air samples than for outdoor air samples. The remaining TAPs were rarely or never found above the quantifiable limit.

For the chemicals that were monitored in this study and other monitoring studies in California (2,10), very similar patterns for compound prevalence (i.e., percent quantifiable or percent detectable) were found. A number of other chemicals were included on this study because they are TAPs of concern to ARB. Of these additional TAPs, only methylene chloride and acrolein had high percent quantifiable values. Di-2-ethylhexylphthalate was occasionally found in indoor and personal air samples. All three were quantifiable less often in outdoor air samples. The remainder of the added TAPs were quantifiable in very few collected air samples. This is an important finding since it shows little or no air pollution for these toxic air pollutants. It is probably not a surprising result, since sources for these additional chemicals are less prevalent than for some of the more common VOC solvents (i.e., 1,1,1-trichloroethane, xylenes, etc.).

Concentration distributions were then calculated for the most abundant compounds. Air concentration data by matrix are given in Table 2-4.

For indoor and personal VOC samples, m,p-xylene, 1,1,1-trichloroethane, benzene, and o-xylene gave the highest median air concentrations. On the other hand, p-dichlorobenzene had the highest VOC concentration for personal and indoor air at the 90th percentile. This compound showed a

TABLE 2-4. AIR CONCENTRATIONS FOR THE MOST ABUNDANT TAPs

		Air Concentration ($\mu g/m^3$)							
		Indoor		Personal		Outdoor		Automobile	
Compound	Type[a]	median	90th percentile	median	90th percentile	median	90th percentile	median	90th percentile
1,1,1-Trichloroethane	VVOC,VOC	3.0	11	4.2	36	1.3	1.9	NT[b]	NT
Benzene	VVOC,VOC	2.2	8.3	3.1	8.9	1.1	1.9	NT	NT
Carbon Tetrachloride	VVOC,VOC	0.49	0.99	0.45	0.83	0.49	0.66	NT	NT
Perchloroethylene	VVOC,VOC	0.28	2.3	0.36	3.4	NQ[c]	0.59	NT	NT
Styrene	VVOC,VOC	0.95	3.9	1.2	3.3	NQ	0.70	NT	NT
p-Dichlorobenzene	VVOC,VOC	1.1	36	1.5	88	NQ	0.94	NT	NT
o-Xylene	VVOC,VOC	1.9	6.5	3.0	9.4	0.77	1.5	NT	NT
m,p-Xylene	VVOC,VOC	3.8	13	5.9	1.8	1.5	2.9	NT	NT
Methylene Chloride	VVOC	15	160	NT	NT	NQ	110	NT	NT
Acrolein	VVOC	4.1	21	NT	NT	NQ	8.6	NT	NT
Di-2-ethylhexylphthalate	SOC	0.059	0.64[d]	0.086	0.32	NQ	0.14	0.19	0.64

[a] Where VOC and VVOC data are available, VOC results are given.
[b] Monitoring not performed.
[c] Not quantifiable.
[d] Maximum value reported.

skewed concentration distribution with a small portion of the air samples showing very high concentrations.

For outdoor VOC air samples, m,p-xylene, 1,1,1-trichloroethane, benzene, and o-xylene showed the highest concentrations in that order for all computed statistics. Outdoor air concentrations were generally lower than indoor or personal air concentrations. In addition, the range of measured concentrations was smaller for outdoor air samples compared to the other sample types.

Figure 2-1 graphically summarizes median concentration data for 1,1,1-trichloroethane, benzene, and the xylenes. As can be seen in the figure and in Table 2-4, personal air samples showed the highest median concentrations followed by indoor air, then outdoor air samples. This trend suggests that personal activity may provide a substantial contribution to both personal exposure and to indoor microenvironmental air concentrations. Alternately, high exposures in other indoor microenvironments could be responsible for the elevated VOC levels.

Two VVOCs, methylene chloride and acrolein, also showed high indoor air concentrations (Table 2-4). Like p-dichlorobenzene, methylene chloride showed a skewed distribution with very high measured concentrations at the 90th (160 $\mu g/m^3$) percentile.

Results for di-2-ethylhexylphthalate showed highest median concentrations in automobile air (0.19 $\mu g/m^3$), followed by personal air (0.086 $\mu g/m^3$), and indoor air (0.059 $\mu g/m^3$). Di-2-ethylhexylphthalate concentrations in outdoor air samples were generally below the estimated method quantifiable limit.

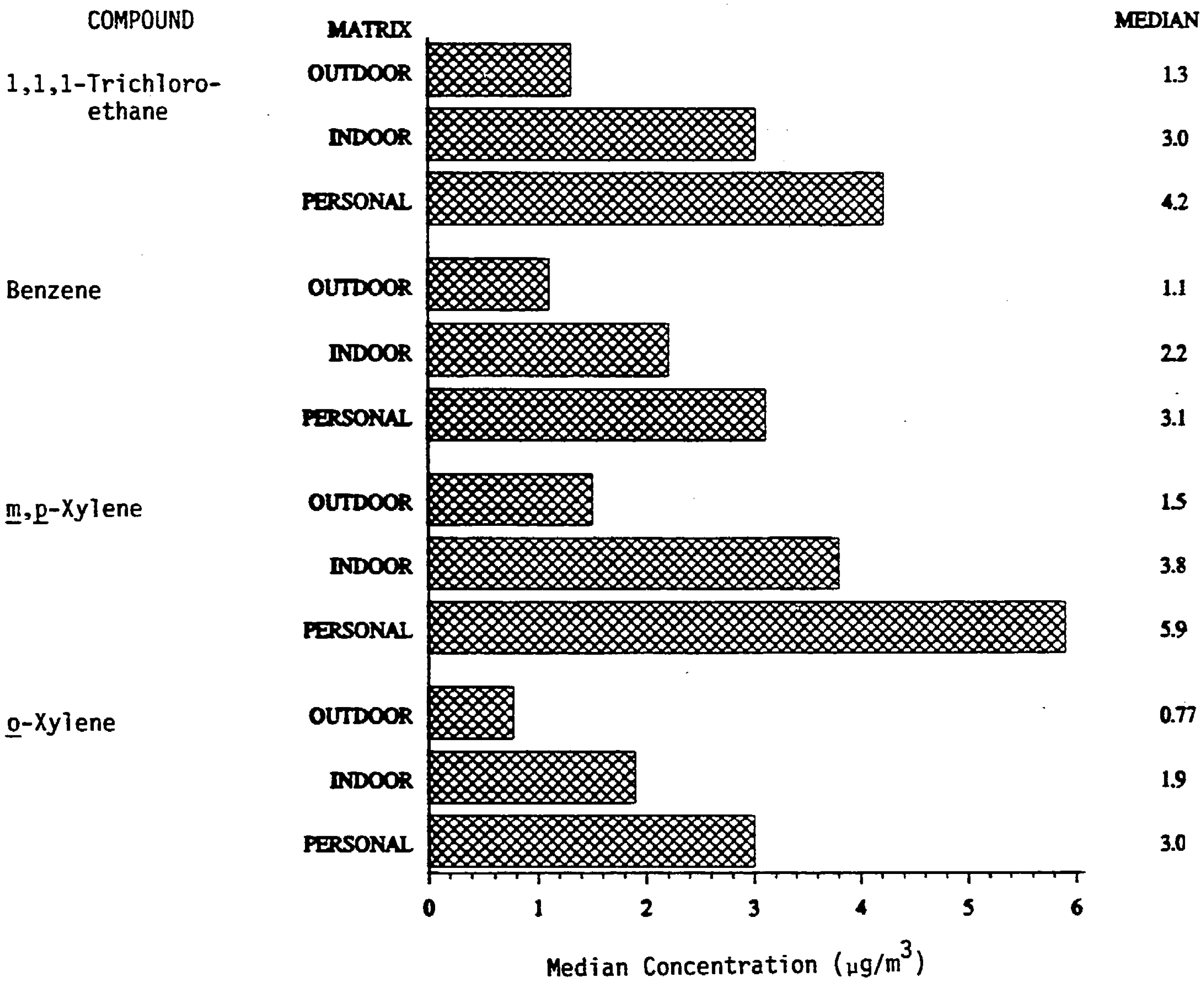

Figure 2-1. Comparison of Median VOC Concentrations ($\mu g/m^3$).

Objective: Examine the Relationship Between Select TAP Concentrations in Various Matrices

Correlation statistics were computed as a first step in studying the relationship between selected VOCs in various matrices. Other TAPs were not examined due to limited sample numbers. Spearman rank correlations were calculated between indoor, outdoor, and personal air samples using data where both air concentrations were above the quantifiable limits. Between personal and indoor air, all correlations were significantly greater than zero at the 0.05 level. In all but one case, the correlations between personal and indoor air concentrations were higher than correlations between indoor and outdoor concentrations. For p-dichlorobenzene, the indoor/outdoor correlation was slightly higher, but it was not significantly greater than zero (0.05 level). The highest correlations between indoor and personal air concentrations were computed for styrene (0.72), benzene (0.63), perchloroethylene (0.73), and 1,4-dioxane (0.71). These strong correlations between indoor and personal air samples suggest that sources for VOCs are the same for the two matrices and are most likely due to indoor sources and personal activities in the home.

The highest correlations between indoor and outdoor air concentrations that were significantly different than zero at the 0.05 level were for benzene and the xylenes. These correlations could possibly be due to the ubiquitous nature of the aromatic VOCs.

Spearman rank correlations between compounds within a matrix were also calculated and were high for certain chemicals in all media. For example, benzene and the xylene isomers showed correlations greater than 0.80 for microenvironmental samples (indoor and outdoor air), and correlations greater than 0.70 for personal air samples. Measured concentrations for styrene also showed some correlation (0.51 to 0.68) with benzene and the xylenes in indoor and personal air samples. The highest correlations were for indoor air samples. Finally, 1,1,1-trichloroethane and 1,4-dioxane gave a very high correlation coefficient (0.90) in personal air samples; some correlation (0.60) was also seen between the two chemicals in indoor air samples. High correlations may suggest a common source for different chemicals. This is presumably the case for benzene and the xylenes. The same may be true for these aromatic chemicals and styrene. 1,4-Dioxane is added to all grades of 1,1,1-trichloroethane as an antioxidant and may be the cause for the strong correlation between the two chemicals.

To further analyze the relationship between indoor and outdoor air concentrations, the ratio of indoor to outdoor air concentrations at each home was calculated. Table 2-5 gives the statistics summarizing these data. Ratios were calculated only if both indoor and outdoor concentrations were above quantifiable limit. With the exception of carbon tetrachloride, the indoor levels were usually higher than the outdoor levels. For carbon tetrachloride, all levels indoors and outdoors were near the MQL. Styrene and *p*-dichlorobenzene had the highest indoor/outdoor concentration ratios, suggesting that these chemicals are coming from primarily indoor sources.

Objective: Examine the Relationship Between Air Concentrations and Potential Sources

Selected questionnaire data were analyzed to determine if certain activities or sources were related to elevated indoor and/or personal air concentrations. For each question and matrix of interest, arithmetic and

TABLE 2-5. WEIGHTED MEAN RATIOS OF INDOOR TO OUTDOOR VOC AIR CONCENTRATIONS

	Indoor/Outdoor Ratio	
Compound	Geometric Mean	S.E.[a]
1,1,1-Trichloroethane	2.8	0.42
Benzene	2.1	0.38
Carbon Tetrachloride	1.0	0.11
Perchloroethylene	1.9	0.40
Styrene	8.5	2.4
p-Dichlorobenzene	7.8	3.1
o-Xylene	2.5	0.36
m,p-Xylene	2.5	0.43

[a] S.E. = Standard error.

geometric mean air concentrations and their standard errors were determined for two groups based on questionnaire data: exposed individuals or homes and non-exposed individuals or homes. Pairwise t-tests were then performed to test for group differences using geometric or arithmetic mean air concentrations. Since multiple activities were performed by each individual and in each environment, only very strong sources for a particular chemical would be expected to show significant differences between the exposed and non-exposed groups.

Several observations were made based on the data analysis.

- Many of the common VOCs have higher mean indoor and personal air concentrations for the exposed versus the non-exposed groups. Although the results are often not significant at the 0.05 level, an overall pattern can be observed that may suggest source/concentration relationships.
- The xylenes and styrene were the VOCs most often found at elevated concentrations for the exposed group. Benzene and 1,1,1-trichloroethane also showed elevated air concentrations for many of the exposed groups. Again, these results are often not significant at the 0.05 level, but they may suggest potential exposure sources.
- Air conditioning appeared to have the greatest effect on indoor VOC concentrations. 1,1,1-Trichloroethane, benzene, styrene, and the xylenes all had significantly higher indoor concentrations (at the 0.05 level) in homes that used air conditioning compared to those that did not. This may be a result of lower air exchange rates in air-conditioned homes.

- Use of petroleum-based products, exposure to vehicle exhausts, and exposure to gasoline appeared to have the greatest impact on personal air concentrations. The xylenes, benzene, and 1,1,1-trichloroethane often had significantly higher mean air concentrations for individuals in these exposure groups.
- For indoor and personal air samples, smoking appeared to elevate benzene concentrations (but not significantly) compared to not smoking; however, mean benzene personal air concentrations for heavy smokers (> 20 cigarettes/day) were no higher than for all smokers.
- p-Dichlorobenzene concentrations were not associated with the use of mothballs, air fresheners, or bathroom deodorizers. Since these are the most common sources for p-dichlorobenzene, the reason for elevated concentrations in personal and indoor air samples are unknown and may warrant further investigation.
- As found in other studies (10), individuals who worked away from home in a regular occupation showed significantly higher VOC concentrations compared to those who stayed at home during the monitoring period.

Objective: To Compare Activity Patterns and Pollutant Concentrations to Other Areas of the State

The Time Activity Diary used on this study was identical to that used on the ARB statistical survey of activity patterns (11). Results given in Table 2-6 compare the weighted mean percent of time Woodland residents spent in selected microenvironments to those estimated for the statewide population. The Woodland population showed slight differences from the

TABLE 2-6. PERCENTAGE OF TIME SPENT IN SELECTED MICROENVIRONMENTS

	Mean % of time	
Microenvironment	Woodland	Statewide
Indoor - Home	68.4	61.9
Indoor - Away from Home	17.6	24.6
Enclosed - Transit	3.5	7.6
Outdoor - Transit	1.0	0.7
Outdoors	8.4	5.1

statewide population with more time spent indoors-at-home and outdoors. Less time was spent indoors-away from home and in enclosed transit. These differences could be due to differences in the study population compared to the rest of the state, seasonal differences for the data collection activities, or changes in activity patterns caused by wearing the personal monitors.

Results of air measurements for VOCs generated during this study were compared to similar data generated during other TEAM studies in California (2). Included are results from field studies performed in Los Angeles in January 1984, May 1984, February 1987 and July 1987. Data from the Contra Costa county study (June 1984) and the Woodland pilot study (November 1988) (12) are also presented. Tables 2-7, 2-8, and 2-9 compare median concentration data for indoor, personal and outdoor air, respectively. Collection methods used on the different studies, although similar, were different (i.e., 12-hour versus 24-hour samples) and could effect the overall results; however, comparisons of data for personal overnight versus indoors studies shows several interesting trends. First, the air concentrations reported for this main study are lower than those reported for the other studies. This trend is observed for indoor, outdoor, and personal air samples. Air concentrations reported for this study are most similar to those reported for the 1984 Contra Costa county study, which was the only other study performed outside of the Los Angeles area. Styrene is the single contaminant that shows higher concentrations here than in the Contra Costa county study or the summer study in Los Angeles.

TABLE 2-7. COMPARISON OF INDOOR VOC AIR CONCENTRATIONS TO THOSE REPORTED IN OTHER STUDIES

	Median Concentration ($\mu g/m^3$)						
Compound	Woodland[a] Main (n=104) May-June 1990	Woodland[a] Pilot (n=8) Nov. 1989	LA[b,c] (n=112) Feb. 1984	LA[b] (n=50) May 1984	LA[e] (n=42) Feb. 1987	LA[e] (n=40) July 1987	CC[b,d] (n=71) June 1984
1,1,1-Trichlrooethane	3.0	6.9	26	7.2	19	9.1	4.3
Benzene	2.2	8.8	15	4.4	11	4.5	4.6
Carbon tetrachloride	0.5	0.7	0.7	0.7	0.9	0.8	0.7
Trichloroethylene	0.3	2.3	1.1	0.3	0.7	0.3	0.3
Perchloroethylene	0.3	1.6	8.3	1.9	4.8	1.5	1.8
Styrene	1.0	1.3	2.8	0.8	2.7	0.9	0.7
p-Dichlorobenzene	1.1	1.7	2.6[f]	0.8[f]	2.3	0.7	0.5[f]
o-Xylene	1.9	6.5	9.7	2.5	10	3.6	2.2
m,p-Xylene	3.8	16	22	8.7	30	10	6.1

[a] 24-hour sample.
[b] 12-hour overnight personal sample.
[c] Los Angeles.
[d] Contra Costa County..
[e] 12-hour overnight kitchen sample.
[f] Reported as m,p-dichlorobenzene.

TABLE 2-8. COMPARISON OF PERSONAL VOC AIR CONCENTRATIONS TO THOSE REPORTED IN OTHER STUDIES

	Median Concentration ($\mu g/m^3$)						
Compound	Woodland [a] Main (n=93) May-June 1990	Woodland [a] Pilot (n=8) Nov. 1989	LA [b,c] (n=110) Feb. 1984	LA [b] (n=50) May 1984	LA[b,c] (n=43) Feb. 1987	LA [b,c] (n=40) July 1987	CC[b,d] (n=76) June 1984
1,1,1-Trichloroethane	4.2	9.4	26	7.2	19	7.7	4.2
Benzene	3.1	9.3	15	4.5	12	5.2	4.6
Carbon tetrachloride	0.5	0.6	0.7	0.7	0.7	0.7	0.7
Trichloroethylene[e]	NQ[e]	6.3	1.1	0.3	0.7	0.3	0.3
Perchloroethylene	0.4	2.1	8.3	1.9	6.8	2.0	1.8
Styrene	1.2	1.5	2.8	0.8	3.0	1.0	0.7
p-Dichlorobenzene	22	5.4	2.6[f]	0.8[f]	1.9	1.4	0.5[f]
o-Xylene	3.0	6.0	9.7	2.5	12	3.3	2.2
m,p-Xylene	5.9	17	22	8.7	31	9.5	6.1

[a] 24-hour sample.
[b] 12-hour sample.
[c] Los Angeles.
[d] Contra Costa County.
[e] Below the MQL.
[f] Reported as m,p-dichlorobenzene.

TABLE 2-9. COMPARISON OF OUTDOOR VOC AIR CONCENTRATIONS TO THOSE REPORTED IN OTHER STUDIES

	Median Concentration ($\mu g/m^3$)						
Compound	Woodland [a] Main (n=48) May-June 1990	Woodland [a] Pilot (n=4) Nov. 1989	LA [b,c] (n=24) Feb. 1984	LA [b] (n=23) May 1984	LA [b] (n=46) Feb. 1987	LA[b] (n=40) July 1987	CC [b,d] (n=10) June 1984
1,1,1-Trichloroethane	1.4	2.6	29	4.0	12	4.3	2.1
Benzene	1.1	9.0	19	2.5	7.9	2.0	1.7
Carbon tetrachloride	0.5	0.7	0.7	0.7	0.7	0.8	0.3
Trichloroethylene	NQ[e]	NQ	0.7	NQ	0.3	NQ	NQ
Perchloroethylene	0.2	0.7	7.4	1.3	4.2	1.0	0.3
Styrene	0.1	1.3	4.2	0.6	1.9	0.3	0.2
p-Dichlorobenzene	0.1	0.9	1.7[f]	0.5[f]	1.8	0.3	0.5[f]
o-Xylene	0.8	5.8	13	1.9	5.7	2.4	0.4
m,p-Xylene	1.6	14.2	30	7.3	9.7	6.5	1.3

[a] 24-hour sample.
[b] 12-hour overnight sample.
[c] Los Angeles.
[d] Contra Costa County.
[e] Below the MQL or method detection limit.
[f] Reported as m,p-dichlorobenzene.

Comparison of winter and summer data for the Los Angeles studies, as well as the pilot and main study here, indicate seasonal trends in VOC air concentrations. In both cases, the highest VOC concentrations are found in the winter. Again, this trend is apparent for indoor, personal, and outdoor air samples. The observation of seasonal variability is important and may warrant further investigation.

SECTION 3

RECOMMENDATIONS

This study on "Indoor Pollutant Concentrations and Exposure" has provided important data that can be used by ARB in its exposure and risk assessment process. This study provides residential indoor, outdoor, and personal exposure air concentration data for homes and individuals in Woodland, California. The study focused on a group of TAPs that are of highest priority to the ARB. Additional work is recommended that would broaden the scope of the database generated during this study, as well as on previous TEAM studies performed in California. Recommendations are listed in order of overall priority.

- Additional monitoring should be performed in Woodland during a winter season. Both the Los Angeles TEAM data (2) and the main and pilot study results from this program show substantial differences in pollutant concentrations during winter and summer seasons. Highest air concentrations were measured during the winter season. It is important to determine if this trend is real for a central valley site such as Woodland. More importantly, if pollutant air concentrations are significantly higher in the winter, it is essential that these data are generated and used for the required exposure and risk assessments.
- Additional chemicals should be incorporated into the study. As a first priority, methods need to be optimized and tested for those chemicals that were proposed for this study but could not be analyzed due to problems with the monitoring methods. Table 3-1 lists these chemicals, the problems encountered and their potential

TABLE 3-1. TARGET CHEMICALS WITH METHOD DEFICIENCIES

Chemical	Problem	Solution
Acetaldehyde	Poor accuracy and precision for VVOC analysis	Alternate methods are available for aldehyde analysis and should be used.
Ethylene Oxide Propylene Oxide	Canister standards unstable	Further investigation required on standard preparation and stability at low ppb concentrations.
PCBs	Interferences in GC/ECD chromatograms	GC/MS method used here should provide selectivity required; alternately, sample cleanup with GC/ECD analysis could be used for better sensitivity.
SOCs	Poor selectivity by GC/ECD precluded component identification; alternate GC/MS method used but extracts had been stored for an extended period prior to this analysis. QC sample spike levels were too low.	Collection/extraction/GC/MS method finally used should be adequate for field monitoring. It should be tested, however, prior to additional field implementation.

solutions. As a second priority, additional chemicals that are on ARB candidate Toxic Air Contaminants Identification list could be incorporated into future studies. Table 3-2 shows those chemicals that could potentially be monitored using existing methods. Prior to incorporating any of these chemicals into a field monitoring study, several method evaluation steps should be performed. These include laboratory testing, method optimization, and field evaluations in a pilot study. All methods and chemicals should show adequate performance during pilot testing using real air samples under field conditions before being used to generate concentration data.

- Non-residential buildings should be included in future studies. Other buildings should be prioritized for monitoring based on the amount of time Californians spend in these buildings, the exposed population, and the potential for elevated exposures in the buildings. Schools and daycare centers should be given highest priority since they represent a very important microenvironmental exposure for children. Likewise, office buildings should be considered as important microenvironments for pollutant exposure to adult populations.
- Specific populations should be considered for study. Children may be the most important subpopulation. Not only are they a susceptible group of individuals, but because of limitations in monitoring methods, studies focusing on personal exposures for children have not been performed. A microenvironmental modeling

TABLE 3-2. OTHER CHEMICALS ON ARB CANDIDATE TOXIC AIR CONTAMINANT IDENTIFICATION LIST THAT ARE POTENTIALLY AMENABLE TO FIELD MONITORING

(APRIL, 1991)

Category	VOC/VVOC[a]	SOC[b]	SOC/Acid[c]	Aldehyde[d]
I	Ethylene oxide	Benzo(a)pyrene		
IIA				Acetaldehyde Formaldehyde
IIB	Ethylacrylate Propylene oxide	PAHs		
IIIA	Acetone Acetonitrile Benzoyl chloride Butyl acrylate Carbon disulfide Chlorinated fluorocarbons Cyclohexane Epichlorohydrin 1,2-Expoxybutane Ethylbenzene Ethyl chloride Ethylene glycol Glycidyl ethers Isopropyl alcohol Methyl bromide Methyl chloride Methylethylketone Methylmethacrylate Methyl-*t*-butylether *n*-Butyl alcohol Propane Propylene dichloride sec-Butyl alcohol Toluene 1,2,4-Trimethylbenzene 2,2,4-Trimethylpentane Vinyl acetate	Di-2-ethylhexylphthalate Butylbenzylphthalate Carbaryl Hexachloroethane *n*-Hexane Parathion 2-Phenylphenol Propoxur	Dinitro-*o*-cresol	
IIIB	Acetophenone Bromoform Chroromethylmethyether 1,2-dibromo-3-propane Dichloroethylether Isophorone 1,1,2-Trichloroethane Vinyl bromide	Chlordane 2-Chloroacetophenone *p,p*'-DDE Dinitrotoluene Heptachlor Lindane Methoxychlor 4-Nitrobiphenyl Pentachloronitrobenzene Quinoline Toxaphene Trifluralin		Dinitrophenol 4-nitrophenol

[a] Monitored using the VOC or VVOC methods used on this study.
[b] Collected using a filter/XAD cartridge; exposed cartridges sonication extracted with methylene chloride; extracts concentrated then analyzed by GC/MS.
[c] Monitored using the SOC method used on this study.
[d] Collected on cartridges containing silica gel impregnated with dinitrophenylhydrazine, analysis by high performance liquid chromatography.

approach is probably required here and could be used if home, outdoor, and school or daycare environments were monitored.

- Finally, more detailed information should be obtained to evaluate sources and activities that affect pollutant exposure. This study measured higher personal air concentrations for most pollutants compared to residential indoor or outdoor concentrations. This effect may be due to either personal activities that are a source for pollutant exposure or higher exposures in other microenvironments. It is important to understand and quantify the sources for elevated personal exposure. This is especially important if a microenvironmental modeling approach is used for making exposure estimates.

SECTION 4

PILOT STUDY

Prior to initiating the main study, a pilot study was conducted to field test all of the monitoring and data collection activities associated with the proposed program. The pilot test was performed on 16 individuals in 12 homes in Woodland, California during the week of November 10, 1989.

Major emphasis for this pilot study was placed on evaluating the proposed sampling and analysis methods along with the questionnaires and questionnaire administration procedures. Testing during the pilot study was designed to estimate precision, accuracy, and method quantifiable limits for each sampling and analysis method. Field monitoring results were examined to determine potential interferences resulting from the sample matrix.

The pilot study allowed us to evaluate the level of effort associated with each monitoring method. It also provided information on the burden that each method placed on the study participants who volunteered to have monitoring performed in their homes. Only those chemicals/methods that showed adequate performance during the pilot study were included in the main study. The implementation and results of the pilot study are described in detail in a separate report (12). Conclusions relating to the major elements are summarized below.

4.1 Questionnaires and Data Collection Methodology

A Household Enumeration Questionnaire, a Study Questionnaire, a Record of Activities and Environments, and a 24-hour Time Activity Diary were developed, then used to gather information from each of the participants in the pilot study. All documents performed as expected. A computer-assisted personal interview (CAPI) technique was used for data collection. This worked in an acceptable fashion, although there were some problems with the computers that resulted in rather long (40 to 45 minutes) interview times. New software and changes in several default settings on the computers were recommended to overcome these problems. A shorter questionnaire (no longer than 25 minutes) was recommended. Pilot test results also indicated that additional training on questionnaire administration was required.

4.2 Field Monitoring

Field monitoring aspects of the pilot study proceeded very smoothly. Sufficient time was allocated at each home for all monitoring activities. All pumps and sample collection devices worked well and over 95% of the scheduled samples were collected. The DuPont P-2500 pumps used for SOC sample collection were noisy, especially for personal exposure monitoring. For the main study, DuPont P-4000 pumps were used to provide a higher flow rate with less strain on the pumps. In addition, a case was designed for the pumps that effectively reduced noise levels.

4.3 Very Volatile Organic Chemicals

Method performance data indicated the VVOC method should give results of acceptable quality during field monitoring. Field samples showed few interferences during quantitative or qualitative analysis. Acetaldehyde was the exception and was dropped from the target chemicals list based on its poor performance throughout pilot study testing. Also, some problems were seen for the most volatile chemicals with shifting chromatographic retention times that made identifications difficult. A volatile retention time standard was recommended, although a suitable standard was not identified for sample analysis during the main study.

4.4 Volatile Organic Chemicals

Method performance data indicated that the VOC method should give results of high quality. Field samples showed few interferences during either quantitative or qualitative analysis. Propylene oxide was the exception and was dropped from the target VOC list based on its poor performance throughout the pilot study.

4.5 Semivolatile Organic Chemicals

Results of field sample analysis showed that few of the target SOCs were above the estimated method quantifiable limits (EMQL) in any of the samples. An inspection of the chromatograms indicated that significant concentrations of other chemicals were present in the collected air samples, although the identities of these chemicals were unknown.

A chromatographic pattern for polychlorinated biphenyls (PCBs) was not found for any of the sample extracts. However, EMQLs were quite high, since large chromatographic peaks for other sample components obscured the PCB pattern.

There were several instrumental and procedural problems with the method used for monitoring SOCs during the pilot study. As a result, modifications were proposed and the modified method tested in the laboratory. Modifications included:

1. increasing the air sample volume collected and decreasing the extract volume in order to improve the overall method quantitation limits,
2. extracting the sample using sonication with acidified methyl-*t*-butyl ether to improve extraction efficiency for the phenolic compounds,
3. derivatizing phenolic compounds with diazomethane prior to GC/ECD analysis to improve chromatographic performance, and
4. deleting PCBs from the list of target compounds.

Laboratory tests on the modified SOC method demonstrated that the proposed modifications were effective in improving the chromatographic behavior of the phenols and providing improved method sensitivity. Additional testing indicated that recoveries of target chemicals from the sorbent material were acceptable and that the XAD-2 resin cartridge was an efficient collection medium. The method was recommended for use during the main study, although it was still considered a preliminary test method.

SECTION 5

MAIN STUDY DESIGN AND OVERVIEW

The main study was a single season (May and June, 1990) indoor air and personal exposure study for a probability sample of homes/individuals in Woodland, California. Monitoring was performed for the VOC, VVOC, and SOC toxic air pollutants shown in Table 5-1. This list is a modification of the original target list shown in Table 1-1. Acetaldehyde was eliminated as a VVOC, propylene oxide was eliminated as a VOC, and PCBs were eliminated as SOCs. These changes were made due to problems with method performance in the pilot test. 2,4,6-Trichlorophenol, 2,4,5,6-tetrachlorophenol, and pentachlorophenol were selected as the chlorinated phenols of concern.

A study design based on field monitoring of 130 homes was developed. The design was intended to provide as much information as possible for each TAC in indoor microenvironmental, outdoor microenvironmental, and personal air samples within the funding limitation. In keeping with this objective, not all sample types were collected in all homes. An overview of the proposed monitoring design is shown in Table 5-2. As shown in the table, indoor microenvironmental monitoring was emphasized. Indoor microenvironmental samples for SOCs were to be collected in all 130 homes. For the VOCs, this was also the objective, but a combination of monitoring methods was proposed. The VOC (Tenax) method was to be used exclusively in 70 homes, both VOC (Tenax) and VVOC (canister) methods were to be used in 40 homes, while the VVOC (canister) method was to be used exclusively in 20 homes.

TABLE 5-1. PROPOSED TARGET CHEMICALS AND METHODS FOR MAIN STUDY

Compound	Type of Monitoring Indoor microenvironmental	 Outdoor microenvironmental	 Personal exposure	Monitoring method[a]
Acrylonitrile	✓	✓		VVOC
1,3-Butadiene	✓	✓		VVOC
p-Dichlorobenzene	✓	✓	✓	VVOC, VOC
1,4-Dioxane	✓	✓	✓	VVOC, VOC
Propylene oxide	✓	✓		VVOC
Styrene	✓	✓	✓	VVOC, VOC
Acrolein	✓	✓		VVOC
Allyl chloride	✓	✓	✓	VVOC, VOC
Benzyl chloride	✓	✓	✓	VVOC, VOC
Chlorobenzene	✓	✓	✓	VVOC, VOC
Methyl bromide	✓	✓		VVOC
1,1,1-Trichloroethane	✓	✓	✓	VVOC, VOC
Vinylidene chloride	✓	✓		VVOC
Xylenes	✓	✓	✓	VVOC, VOC
Methylene chloride	✓	✓		VVOC
Vinyl chloride	✓	✓		VVOC
Perchloroethylene	✓	✓	✓	VVOC, VOC
Trichloroethylene	✓	✓	✓	VVOC, VOC
Chloroform	✓	✓		VVOC
Benzene	✓	✓	✓	VVOC, VOC
Ethylene dibromide	✓	✓	✓	VVOC, VOC
Ethylene dichloride	✓	✓	✓	VVOC
Carbon tetrachloride	✓	✓	✓	VVOC, VOC
Ethylene oxide	✓	✓		VVOC
Di-2-ethylhexylphthalate	✓	✓	✓	SOC
Hexachlorobenzene	✓	✓	✓	SOC
2,4,6-Trichlorophenol	✓	✓	✓	SOC
Pentachlorophenol	✓	✓	✓	SOC
2,4,5,6-Tetrachlorophenol	✓	✓	✓	SOC
Nitrobenzene	✓	✓	✓	SOC

[a] VVOC - monitored using collection in stainless steel canisters; analyzed by gas chromtography with mass spectrometry (GC/MS).

VOC - monitored using collection on Tenax GC; analyzed by GC/MS.

SOC - monitored using collection on filters backed by XAD-2; analyzed by GC/ECD and GC/MS.

TABLE 5-2. PROPOSED MONITORING SCHEME

Monitoring Type	Number of Field Samples		
	SOCs	VOCs	VVOCs
Indoor microenvironmental	130	110	60
Outdoor microenvironmental	50	50	15
Personal exposure	20	100	0
Automobiles	10	0	0

The rationale for this approach for VOCs was based on the fact that (as shown in Table 5-1) the targeted VOCs could be monitored using either method. The VVOC (canister) method has the advantage of providing data for more chemicals. However, it is not amenable to personal monitoring and the number of samples that could be collected in this study was limited by canister availability. As a consequence, most samples were collected using the VOC (Tenax) method. Our study design assumed that the two methods would provide comparable data for the VOCs and that results from the two methods could be combined for statistical analysis. Using both monitoring methods in 40 homes allowed us to test this assumption.

Personal monitoring for VOCs was proposed for 110 individuals in the same 110 homes where VOC monitoring methods were used. In the other 20 homes, personal monitoring for SOCs was to be performed. Outdoor samples for VOCs, VVOCs, and SOCs were proposed for a subset of homes as shown in Table 5-2. Figure 5-1 shows the design used for selecting the probability samples of homes/individuals outlined in Table 5-2. Along with the indoor air, outdoor air, and personal exposure monitoring originally proposed, SOC monitoring was to be performed in a purposely selected group of 10 cars. This was done as a preliminary evaluation of phthalate contamination in automobiles.

The study was performed in Woodland, California which was selected in consultation with the ARB to represent a medium-size city in the central valley of California. A city based in this predominantly agricultural region of California was intended to provide a population with a different socioeconomic mix, employment history, and lifestyle pattern than populations in Los Angeles or Contra Costa counties that had been studied

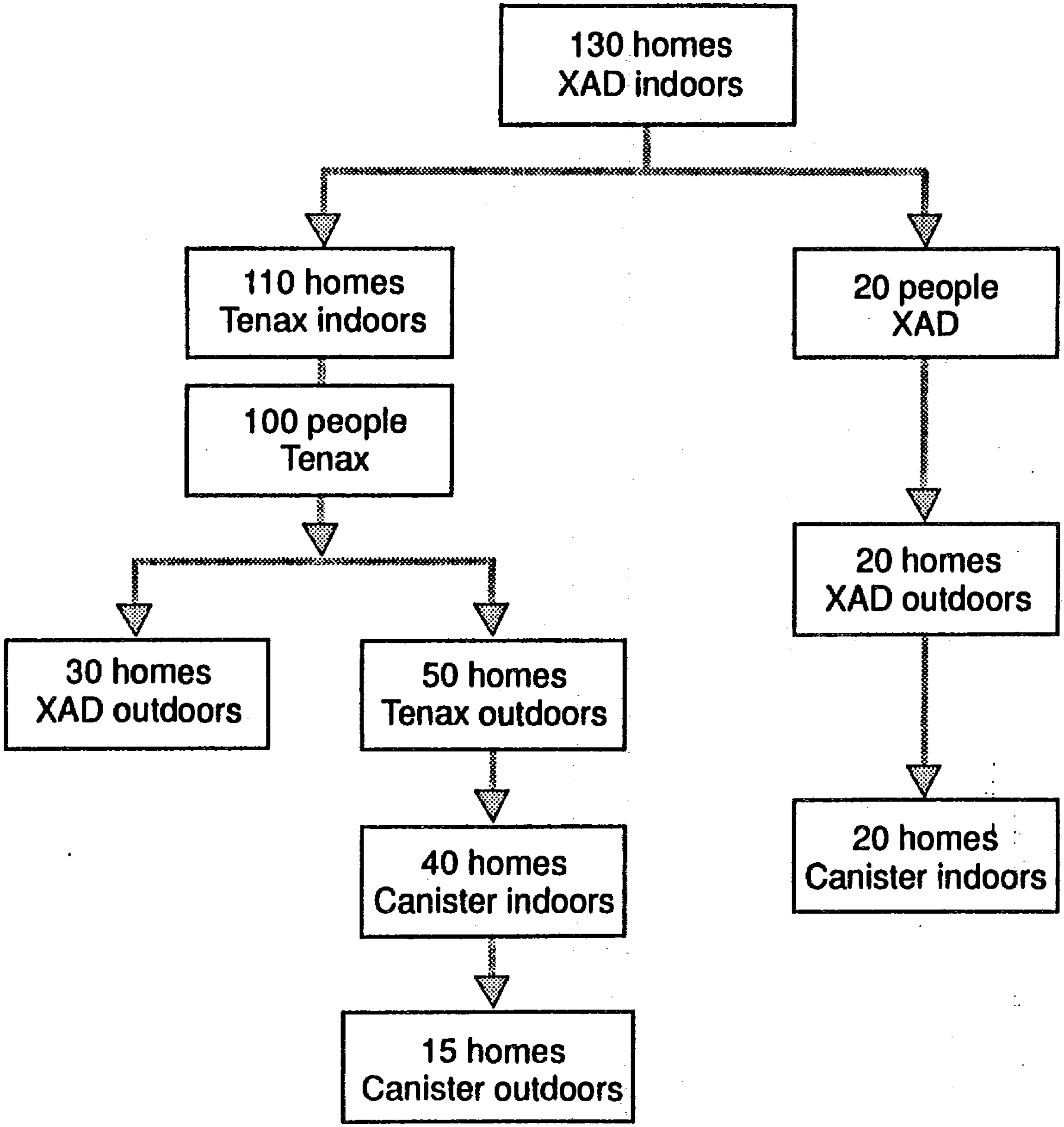

Figure 5-1. Proposed Sampling Design for Main Study.

previously (2). The meteorological conditions and ambient pollutant sources were also expected to be different for this community compared to other California sites.

Homes and individuals for the main study were selected using a three stage sampling design. First, a frame was constructed of small areas throughout Woodland using U.S. Census materials. Next, field staff compiled a list of all housing units in the sample areas and 299 of these homes were then selected from the sample areas. Finally, the selected housing units were visited to complete a short screening interview and a subset was selected in the field for environmental monitoring.

Sample collection/field monitoring activities were to be performed as soon as possible after participants were identified. Sample collection from each household was scheduled for a 24-hour period. At the end of the monitoring period, a 24-hour recall questionnaire and its supplements were to be administered to the respondents using a computer assisted personal interviewing approach. All collected samples were to be shipped to RTI for subsequent analysis. Sampling and analysis procedures are summarized in Table 5-3.

Strict chain-of-custody and quality assurance/quality control procedures were proposed. Several types of quality control (QC) samples were to be used throughout the study. Sampling cartridges or canisters equivalent to ~5% of the field samples were to be set aside as field blanks in order to assess contamination and/or interferences on field samples. These samples travel to the field site, then are returned to the laboratory and analyzed along with the field samples. Field controls were to be used to assess analyte recovery. Here, cartridges or canisters equivalent to

TABLE 5-3. PROPOSED SAMPLING AND ANALYSIS METHODS

Compound Type	Sampling Method	Analysis Method
VVOCs	Collection of vapor phase analytes in evacuated 6 L stainless steel canisters.	75 mL sample is concentrated via cryofocusing, concentrated sample analyzed by high resolution gas chromatography with electron ionization mass spectrometry using selected ion monitoring for increased sensitivity.
VOCs	Collection of vapor phase analytes on sorbent traps containing Tenax. ~18 L samples collected over 24 hours using low flow pumps.	Sample analyzed by thermal desorption/high resolution gas chromatography with electron ionization mass spectrometry.
SOCs	Collection of particulate and vapor phase analytes using a quartz filter backed with an XAD-2 cartridge. ~ 4.3 m^3 sample collected over 24 hours using a medium flow pump.	Sample cartridges extracted with acidified methyl-t-butyl ether; phenols in sample derivatized using diazomethane; concentrated extract analyzed by high resolution gas chromatography with electron ionization mass spectrometry using selected ion monitoring for increased sensitivity.

~5% of the field samples are spiked with known amounts of the target analytes. As with the field blanks, these samples are shipped to the field, then returned and analyzed along with the field samples. Ten percent of the samples were to be collected and analyzed in duplicate to evaluate precision. Finally, several cartridges or canisters were to be spiked with low levels of the target chemicals, travel to the field, and be analyzed with field samples. These were term quantifiable limit (QL) samples and were to be used to establish method quantifiable limits (MQLs). The total numbers of samples including QC samples scheduled for collection are summarized in Table 5-4.

TABLE 5-4. PROPOSED SAMPLES FOR MAIN STUDY[a]

I. Semivolatile Organic Chemicals

1. Field Samples
   130 indoor MEM + 50 outdoor MEM + 20 PEM + 10 automobile = 210 samples
2. Quality Control Samples
   20 duplicates + 10 field controls + 10 blanks + 7 QL samples = 47 samples
3. Total
   210 field samples + 47 QC samples = 257 samples

II. Volatile Organic Chemicals

1. Field Samples
   110 Indoor MEM + 50 outdoor MEM + 100 PEM = 260 samples
2. Quality Control Samples
   26 duplicates + 13 field controls + 13 field blanks + 7 QL samples = 59 samples
3. Total
   260 field samples + 59 QC samples = 319 samples

III. Very Volatile Organic Chemicals

1. Field Samples
   60 indoor MEM + 15 outdoor MEM = 75 samples
2. Quality Control Samples
   7 duplicates + 3 field controls + 3 field blanks + 7 QL samples = 20 samples
3. Total
   75 field samples + 20 QC samples = 95 samples

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[a] MEM-microenvironmental monitoring.
PEM-personal exposure monitoring.

SECTION 6

MAIN STUDY SAMPLING DESIGN

6.1 Introduction

A sample of household residents in Woodland, California was selected for personal exposure monitoring and associated monitoring of the indoor and outdoor air at their residences. Study participants were selected using a probability sampling design where every member of the defined population has a known, positive probability of being included in the sample. Because of this feature, sample results can be used to make statistical inferences about the target population. Samples obtained by non-probability methods would not allow results to be generalized beyond the homes/individuals included in the study.

Implementing a probability sampling design requires constructing a sampling frame, or list, containing all elements of the target population and assigning probabilities of selection to the listed units. For some populations, it is possible to compile a sampling frame of the population elements directly. However, for household populations this is rarely possible. Usually, no complete listing of the household population exists or can be easily constructed. Therefore, alternative multistage procedures that rely on area probability sampling techniques have been developed for selecting samples of household populations. The samples for the exposure monitoring study were obtained using such procedures.

Probability sampling methods were used to identify the selected elements at each stage of sampling (Census areas, household screening, and household monitoring). Because each population member was uniquely associated with the geographic area containing the person's residence, every member of the defined population had a positive probability of selection that can be expressed as the product of the probabilities of selection at each stage of the sampling. The procedures used to construct the frames and obtain the samples for the exposure monitoring study are described below.

6.2 Target Area and Population

The incorporated city of Woodland, California (approximately 38,950 population in 1989) was chosen as the study site in collaboration with the ARB. Precisely, the target area was defined as delineated by the corporate city limits shown on a 1989 Chamber of Commerce map, excluding a small area east of Yolo County Highway E8 (Road 102).

The target population was defined as the household residents who were 12 years old or older and whose permanent residence was in the target area. Limiting the study to the household population was deemed appropriate since (a) the data collection protocols would be difficult or impossible to implement in non-household settings (i.e. in institutions and other group quarters) and (b) in 1980, only 2.4 percent of the city's population did not reside in households. A lower age limit was necessary for defining the study population because young children have difficulty wearing personal exposure monitors and accurately completing questionnaires. The choice of "12 years old or older" as the limiting age criterion was made to be compatible with the ARB statewide time/activity survey.

6.3 First-Stage Sample of Geographic Areas

First-stage sampling units (FSUs) were constructed from 1980 Census blocks and enumeration districts (EDs). Because blocks and EDs are the smallest Census-defined geographic entities and completely partition the land area of the county, they are ideal for construction of area sampling frames.

As described previously, the target area for the survey was defined using 1989 Woodland city limits. Because of annexation since 1980, the 1989 city limits did not necessarily follow recognized 1980 Census block and ED boundaries and a requisite first step was to depict the target area on Census maps and ascertain the Census units comprising the area to be surveyed. Development of the first-stage sampling frame began by accessing the 1980 Census Summary Tape files and extracting a unit record for each of the blocks and EDs having area within the 1989 Woodland city limits. The information obtained for each unit consisted of geographic identifiers and counts of housing units for use as size measures for the first stage of sampling.

To facilitate equal overall probabilities of selection for all housing units in Woodland, FSUs were selected with probabilities proportional to their size measures (estimates of housing unit counts). Inaccurate size measures for sampling units can reduce the effectiveness of PPS (probability proportional to size) sampling. Because the Census housing unit data were considerably out-of-date, procedures were implemented to update these size measures before selecting the first-stage sample. A database that reported current counts of residences for each block group (an aggregation of blocks within a Census tract) and enumeration district in the target area was obtained from a commercial firm that regularly compiles such information (R.L. Polk & Co.). The data were compared with the Census counts to identify areas that experienced substantial growth since 1980. A trained staff member visited each of these high-growth areas and prepared a sketch map showing the approximate count of housing units along each street and road segment in the area. These field counts were used in lieu of the Census data as block/ED size measures. Because Census counts were not available for the ED-parts annexed by Woodland after 1980, current housing unit counts were similarly compiled for each of these areas.

Review of the compiled field counts disclosed that many of the 1980 blocks and EDs contained far more housing units than required to constitute a first-stage sampling unit (20 housing units). Therefore, to minimize the number of housing units that would have to be listed to form the second-stage sampling frame, these blocks/EDs were subdivided whenever possible using the field count information. The sub-block/ED units thus formed were termed Office Units (OUs) and each contained a minimum of 20 counted housing units. A record for each of the OUs was added to the frame file; the record representing the original block/ED was deleted. In all subsequent frame development activities, the OUs had the same status as Census blocks and EDs.

Many of the 1980 Census blocks, EDs, and ED-parts in the target area contained fewer than the 20 housing units required to constitute a first-stage sampling unit (FSU). Therefore, such units were combined with other adjacent or nearby units to form an FSU of the minimum required size. Combinations were always made within the geographic strata discussed subsequently in this section. The frame database contained 470 distinct geographic entities (blocks, EDs, ED-parts, and OUs). After combining the units to meet the minimum size requirement, the frame contained 309 FSUs.

Geographic stratification of the sampling frame was considered important to ensure that each major area within Woodland would be appropriately represented in the sample. Five geographic strata were defined for selection of the first-stage sample as follows:

Stratum 1:	Area north of East Main Street (State Highway 16, Road 22) and east of College Street.
Stratum 2:	Area south of East Main Street, east of College Street, and north of Gibson Road (Road 24).
Stratum 3:	Area south of Gibson Road.
Stratum 4:	Area north of Gibson Road, west of College Street, and south of West Main Street (State Highway 16, Road 22).
Stratum 5:	Area north of West Main Street and west of College Street.

Consideration was given to additional stratification based on other Census variables possibly correlated with levels of personal exposure or indoor pollutant measurements. Such stratification can increase the precision of population estimates made from sample data if measurements are more homogeneous within strata than across the whole population, and rarely does the technique decrease precision when equal sampling rates are used in all strata. After deliberation, additional stratification was not utilized, however. The two primary reasons for the decision were: (a) the Census data available for defining additional strata were out-of-date, and (b) the target area was a relatively small geographic area, making it likely that the various characteristic domains would be adequately represented without further stratification.

The planned sample of 30 first-stage units was allocated to the five geographic strata approximately proportional to their housing unit counts (1980 occupied HUs or updated field counts) so that the sampling rate would be approximately the same in all strata. The resulting allocation is presented in Table 6-1.

Finally, the FSUs within each stratum were randomly ordered and a sample of the prescribed size was selected with probabilities proportional to the units' sizes (1980 occupied HUs or updated HU count) using a probability-minimum-replacement, sequential sampling algorithm (13). The expected frequency of selection of the i-th FSU in stratum r is given by

$$\pi_1(r,i) = [n_1(r) * S(r,i)] / S(r,+)$$

where $n_1(r)$ is the number of sample FSUs to be selected from stratum r, S(r,i) is the size of the i-th FSU in stratum r (1980 occupied HUs or updated HU count), and S(r,+) is the total size of stratum r.

For three of the sample FSUs, called sample segments, the number of apparent housing units was too great (over 200) to efficiently develop a complete list for selecting sample housing units. These three segments were subdivided into smaller areas, called subsegments, and one subsegment was selected from each with probability proportional to the count of apparent housing units in the subsegment. The conditional probability of selecting the j-th subsegment, given that the (r,i)-th segment had been selected, is given by

$$\pi_{2|1}(j|r,i) = M_2(r,i,j) / M_2(r,i,+) ,$$

where $M_2(r,i,j)$ is the number of apparent housing units counted for the j-th subsegment and $M_2(r,i,+)$ is the number counted for the entire segment. Therefore, the unconditional expected frequency of selection for the j-th subsegment in the (r,i)-th segment is

$$\begin{aligned}\pi_2(r,i,j) &= \pi_1(r,i) * \pi_{2|1}(j|r,i)\\ &= [n_1(r) * S(r,i) * M_2(r,i,j)] / [S(r,+) * M_2(r,i,+)].\end{aligned}$$

TABLE 6-1. ALLOCATION OF SAMPLING STRATA

Stratum	No. of FSUs	No. of Housing Units	Unrounded Sample Allocation	Rounded Sample Allocation
1	26	961	2.18	2
2	64	3,375	7.67	8
3	61	2,527	5.74	6
4	80	3,254	7.40	7
5	78	3,083	7.01	7
TOTAL	309	13,200	30.00	30

6.4 Second-Stage Sample of Housing Units for Screening

The total number of sample lines that we expected to be necessary so that the field sampling procedure would result in 130 study participants was 278. Thus, 278 sample lines were allocated to the sample segments (or subsegments) proportional to the ratio of the number of apparent housing units listed for the segment divided by the unconditional probability of selection for the segment. This allocation procedure achieves virtually equal probabilities of selection for the sample housing units. Two additional sample lines were selected from every segment as a reserve sample to be used if necessary. The initial sample of 278 lines had used all the available lines in one segment. Therefore, the total number of sample lines selected from the 30 sample segments was 336. The sample lines were chosen as a simple random sample selected without replacement from all apparent housing units that had been listed for each sample segment.

Shortly after field sampling had begun, the ARB project staff decided that multi-family housing units were only of limited interest for this study. Therefore, on May 31, 1990, a decision was made to include no more multi-family housing units in the sample beyond that date. For the purpose of this decision, multi-family units were defined to be structures with three or more connected housing units.

Partly as a result of this decision, and partly as a result of lower sample yield than expected, the entire reserve sample of housing units was fielded in June 1990. The number of sample lines determined to be out-of-sample because of being located in multi-family dwellings was 37.

Therefore, the total number of sample lines actually worked was 299 (336 - 37) which was sufficient to produce 128 participating housing units.

Letting $n_3(r,i,j)$ denote the number of sample lines fielded from the (r,i,j)-th segment (or subsegment), the conditional probability of selecting the k-th sample line given that this segment was selected is given by

$$\pi_{3|2}(k|r,i,j) = n_3(r,i,j) \; / \; M_3(r,i,j) \; ,$$

where $M_3(r,i,j)$ is the number of apparent housing units actually listed for the (r,i,j)-th segment. The unconditional probability of selecting the k-th sample line is then given by:

$$\pi_3(r,i,j,k) = \pi_2(r,i,j) * \pi_{3|2}(k|r,i,j).$$

For this sample design, these overall probabilities of selection are virtually identical for all housing units in the sample.

6.5 Third-Stage Sample of Households and Persons for Monitoring

The precision of survey estimates is generally maximized by selecting a sample of population units for observation with equal overall probabilities of selection. However, the present study collects environmental measurements both at the household level and at the person level. If the probabilities of selection are equal for one, they are necessarily unequal for the other. Therefore, we adopted the compromise position of selecting both samples with unequal probabilities of selection. In consultation with ARB, we determined that the household-level inferences were more important for this study than the person-level inferences. Therefore, the study was designed to yield slightly more uniform probabilities of selection for the household-level sample than for the person-level sample.

This was accomplished by selecting households for monitoring at different rates depending upon the number of age-eligible household members (age 12 or older). All households with two or more age-eligible members were selected for monitoring, but only half of the households with only one age-eligible member were randomly selected for monitoring. An indicator of whether or not the household was selected for monitoring was printed on a sample selection label by household size (number of age-eligible household members) for each of the 336 sample lines.

In order to collect the required number of samples from each category, the sample allocation scheme shown in Table 6-2 was developed. This scheme defined six different monitoring regimes as well as the number of targeted homes for each regime. A monitoring regime from one to seven was associated with each of the 336 sample lines using random permutations of the target distribution. Thus, the sample type was assigned at random to each sample line in such a way that the sample distribution was as close as possible to the target distribution. The sample type was then printed on the sample selection label for each of the 336 sample lines.

All but one of the sample types (Type 2) included selecting a household member for personal exposure monitoring. Whenever a home was selected for monitoring and the sample type included personal exposure monitoring, the person to be monitored was selected at random from all age-eligible household members. This selection was implemented by assigning roster line numbers only to age-eligible household members and printing randomly selected roster line numbers on the sample selection label by household size.

TABLE 6-2. MONITORING REGIMES WITH TARGET SAMPLE SIZES

	Type 1			Type 2			Type 3			Type 4			Type 5			Type 6		
Sample Type	VOC	SOC	VVOC	VOC	SOC	VVOC	VOC	SOC	VVOC	VOC	SOC	VVOC	VOC	SOC	VVOC	VOC	SOC	VVOC
Indoor Air	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes
Outdoor Air	No	Yes	No	No	No	No	No	No	No	No	Yes	No	Yes	No	No	Yes	No	No
Personal Air	No	Yes	No	No	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes	No	No
Number of Homes		20			10			20			30			10			25	

SECTION 7

MAIN STUDY SAMPLE SELECTION AND SURVEY ACTIVITIES

7.1 Methods

7.1.1 Documents

A series of questionnaires and related forms were developed for this study. Table 7-1 lists the forms and the type of information collected on each. Copies of all documents are found in Appendix A. All questionnaires were developed at RTI and reviewed by ARB in an iterative process.

The Record of Activities and Environments (RAE) was modeled after previous TEAM documents. At the outset of the study, household and personal activity information required for final data analysis were listed. A draft questionnaire that incorporated all required information was then prepared in a paper and pencil format. The draft questionnaire was reviewed at RTI and ARB. After all requested revisions were made, a final version was prepared and submitted to ARB for approval. For use in the field, the approved questionnaire was converted from a paper and pencil format to a CAPI mode. The conversion required some formating changes and subsequent programming in CASES, the software language used for the CAPI system on this project.

The Time Activity Diary (TAD) was identical to that used by ARB on their statewide time/activity survey of California residents. Some programming changes were performed on the electronic copy of the document to assure compatibility with the computer program. After the programming was completed, a hard copy form of the TAD was developed. The hard copy form was used by interviewers if a problem developed with the portable computer during administration.

TABLE 7-1. STUDY DOCUMENTS

Document	Purpose
Household Enumeration Questionnaire	List households for sample selection
Participant Consent Form	Obtain informed consent from participants
Participant Incentive Receipt	Show participant receipt of incentive
Study Questionnaire	Obtain information on household characteristics
Record of Activities and Environments	Obtain pollutant source information about the home, obtain potential exposure information
Time Activity Diary	Collect time activity data for the 24-hour monitoring period
Motor Vehicle Questionnaire	Obtain information on cars monitored for SOCs

7.1.2 Recruiting, Hiring, and Training Field Staff

Recruitment of local interviewers is crucial to the effective completion of data collection in the field. Recruitment was initiated by checking our National Interviewer File for experienced staff in the Woodland and Sacramento areas. Contacts with our supervisory staff in California were also made. Potential interviewers identified by this process were contacted and the study explained. They were then asked if they would be interested in participating. Each interviewer who was contacted was also asked to identify other potential interviewers. We asked specifically for interviewers who could conduct interviews in Spanish. A staff of three interviewers, including one bilingual interviewer, were identified to recruit participants, schedule field monitoring, and administer questionnaires.

Plans were made to train the interviewers over a two-day period, and all required training materials were developed. An interviewers' manual was prepared for use during training and as a reference during the data collection period. All documents were reviewed by ARB staff, and revisions were made as requested. Plans for training included active participation by ARB staff during both the presentation of material and the final review of procedures.

Training for the field interviewers was conducted by RTI staff. Training consisted of a review of the study design and objectives and a presentation of the data collection plan. The interviewers then reviewed each of the data collection documents and supplemental forms. The trainers presented the mechanics of sample location, enumeration, and respondent selection, as well as the details of appointment scheduling. Mock interviews were conducted and each interviewer demonstrated proficiency with each document. The trainers demonstrated the use of the lap-top computers and provided detailed instructions on the use of the CAPI system.

After interviewers were given their assignments, a member of the RTI training staff accompanied them to the field as they worked on the first housing units. The RTI staff trainer remained in the car and activities were discussed after each case was completed. Training staff remained in Woodland for several days after training was completed and met with each interviewer to review assignments and conduct of the interview.

Two of the three interviewers worked throughout the entire study. The third interviewer was replaced shortly after the study began and required additional training. Training for the third interviewer was accomplished by several hours of field training by a field supervisor, telephone training by RTI staff, and training by the ARB staff.

7.1.3 Field Data Collection

After training, interviewers began work including rostering households and enlisting participation in their assigned segments. Interviewers received assignments consisting of a number of segments, each containing multiple selected housing units. The interviewer contacted each housing unit and determined if it was eligible. A roster of the residents in each eligible housing unit was created and the respondents were selected.

If the respondent was available, he/she was interviewed immediately. If the respondent was not available, the interviewer established an appointment to return to interview the respondent. Before beginning the interview, the interviewer provided detailed information about the study and what the respondent would be required to do. The interviewer then asked the respondent if he/she had any questions about the study. After the interviewer answered these questions and all the components of informed consent were addressed, the respondent signed the Participant Consent Form. The interviewer then administered the Study Questionnaire. This questionnaire was completed using the CAPI system for most respondents, although a paper and pencil mode was used in cases where equipment problems occurred.

After the Study Questionnaire was completed, appointments for field monitoring were made. Appointments were established for the set-up of the equipment, and 24 hours later, for the recovery of the monitors. At the end of the 24-hour field monitoring period, the Record of Activities and Environments and the Time Activity Diary were administered to the respondent using the CAPI system. At the conclusion of this interview, monitoring personnel paid a cash incentive, obtained a receipt for the money, and answered any final questions that the respondent asked.

7.1.4 Data Processing

All data collection documents used in the field were returned to RTI for processing. Electronic data were saved on floppy disks and returned to RTI regularly during the data collection phase of the study. This provided backup for the data set and allowed a preliminary evaluation of the data being collected. At the completion of field monitoring, all data sets were downloaded onto computers at RTI where the data were edited. The steps included entering any field data that had been collected on paper questionnaires, checking the numbers assigned to all documents, determining that all documents were present for each respondent, and deleting data for respondents who completed the initial interview but did not participate in the rest of the study. Several edit steps including checks on internal consistency and allowable ranges for responses were also performed. Data in the TADs were reviewed for completeness and logical time entries. Data were edited only when the corrections were obvious from other information available from the respondent.

After all edit steps were completed, the files were transformed, then transferred for statistical analysis. Weight files were created based on final result codes assigned to all the housing units assigned to the field. These files were merged with questionnaire and chemical monitoring files.

7.2 Performance

The overall response rate for environmental measurements program is a combination of the response rate for screening and for household/participant monitoring. For this study, 69% of the household contacted completed the screening interview and 74% of these agreed to participate in the monitoring for an overall response rate of 51%. As shown in Table 7-2, this response rate is low but consistent with other environmental monitoring programs. It is interesting to note, however, that the screening response rate was lower than most other studies, while the response rate for monitoring was higher. Procedures used here attempted to count and list households and enlist participants during a single time period that was coincident with monitoring. This was proposed as a less expensive approach. However, recent experiences with this study and the Particle TEAM (PTEAM) study suggest that lower response rates are achieved using this approach (14). In both cases, low screening response

TABLE 7-2. RESPONSE RATES ACHIEVED IN COMPARABLE EXPOSURE MONITORING STUDIES

Description of Study	Location	Date	Screening Response Rate	Number Monitored	Monitoring Response Rate	Overall Response Rate
Total Exposure Assessment for VOCs	Bayonne, NJ	Fall '81	87%	154	55%	48%
Total Exposure Assessment for VOCs	Elizabeth, NJ	Fall '81	84%	201	51%	43%
Total Exposure Assessment for VOCs	Greensboro, NC	Spring '82	95%	24	80%	76%
Total Exposure Assessment for VOCs	Devils Lake, ND	Fall '82	96%	24	67%	64%
Total Exposure Assessment for VOCs	Los Angeles, CA	Winter '84	87%	117	64%	56%
Total Exposure Assessment for VOCs	Antioch/Pittsburg, CA	Summer '84	89%	71	64%	57%
Total Exposure Assessment for VOCs	Baltimore, MD	Spring '87	95%	155	62%	59%
CO Exposure Monitoring Study	Washington, DC	Winter '83	70%	1,161	58%	41%
CO Exposure Monitoring Study	Denver, CO	Winter '83	76%	485	43%	33%
Nonoccupational Pesticide Exposure Study	Jacksonville, FL	Summer '86	74%	65	54%	40%
Nonoccupational Pesticide Exposure Study	Jacksonville, FL	Spring '87	66%	53	73%	48%
Nonoccupational Pesticide Exposure Study	Jacksonville, FL	Winter '88	81%	55	61%	49%
Nonoccupational Pesticide Exposure Study	Springfield/Chicopee, MA	Spring '87	70%	49	55%	39%
Nonoccupational Pesticide Exposure Study	Springfield/Chicopee, MA	Winter '88	84%	37	51%	43%
VOC, VVOC, SVOC Exposure Study	Woodland, CA	Spring '90	69%	128	74%	51%

rates were achieved. This suggests that interviewers may be giving priority to scheduling field monitoring at the expense of completing the screening interviews for all potential participants. If a higher response rate is required for future studies, then an approach that separates the two steps should be taken.

Although the data collection ended with the required number of respondents participating, this goal was difficult to achieve. Several problems impacted on the performance of the field monitoring and survey staff. These included the availability of interviewers, the training of interviewers, the complexity of the field effort, and supervision of interviewers on-site.

The availability of local interviewers to work on a field data collection effort is determined by the type of study being conducted, the hours required, and the number of studies being conducted in the same area by other companies. Special interviewer skills and language abilities further limited the available pool of potential interviewers. At the time this study was conducted, other efforts were being undertaken in the same area, and the hours required for this effort limited the interest and availability of local interviewers. The loss of staff due to illness and family emergencies further constrained the ability to complete the work efficiently. In addition, the study design required a large number of interviewer hours during a short data collection period. To effectively address these constraints, more interviewers should have been identified, hired, and trained at the outset of this study. By using this approach, trained staff would have been available as interviewers quit or were unavailable to work. It would also have reduced the work burden placed on each interviewer.

Interviewers should have received better and more training prior to field work. More detailed information should have been provided in the training manual to fully explain the purpose of the study, the purpose of all items on the questionnaire, and the proper execution of the survey logistics. In addition, training should have been scheduled so that all interviewers attended a formal training session.

Interviewers were required to perform a number of complex tasks. These included enrolling respondents, setting appointments, and administering the RAE and TAD. This approach was taken since the questionnaires were complex and would require a trained interviewer rather than a chemist. In retrospect, it is clear that a technical and sufficiently trained person who understands the purpose of the study and each question can do a more effective job administering questionnaires. This should be the recommended approach for future studies.

The overall design of the questionnaire was long and rather cumbersome. The Study Questionnaire, RAE, and TAD all asked the same types of questions but with slightly different emphasis; this made much of the information redundant. In addition, the TAD was designed for telephone interviews and as a result, a number of questions were incorporated to verify the information provided. The approach taken here was to use questionnaires in the same format used previously in order to provide comparable data with other studies. To maintain comparability with a shorter questionnaire, it is recommended that the questions remain the same, but fewer questions be asked.

In addition to the above problems, the complexity of the survey activities and the supervision required for field interviewers to complete these activities were underestimated. Supervision by telephone contact was proposed but was ineffective. Trips to the site by survey staff were ultimately required to complete the field effort successfully. In addition to requiring extra resources, this lack of good field supervision may have impacted the screening and, hence, the overall response rate for the study. Provision for more supervision and communication are recommended for future studies.

SECTION 8

CHEMICAL SAMPLING AND ANALYSIS

8.1 Field Monitoring

Field monitoring for the main study was performed over a four-week period from May 25 to June 25, 1990. Indoor, outdoor, and personal air samples for the VOCs, VVOCs and SOCs were collected from 128 homes and their residents using the sample allocation scheme delineated by the probability sample design (Table 6-2). Each home and the participating residents in the home were monitored for a single 24-hour time period. Field monitoring activities for the 24-hour period are shown in Table 8-1. Four or five homes were monitored each day. Starting and ending appointments were scheduled at 3:00, 4:15, 5:30, 6:45, and 8:00 pm, allowing one hour and fifteen minutes for each visit. Two RTI chemists were responsible for placing monitoring equipment, explaining sampling procedures to the participants, and collecting samples. A field interviewer was responsible for administering the RAE and TAD.

Indoor air samples were collected from the primary living area. The primary living area was defined as the nonbedroom area in which the resident spent the majority of his/her time. Outdoor air samples were collected near the participants' homes using the sample placement rules given in Table 8-2. Both indoor and outdoor samples were collected at a height of 1 to 1.5 meters above the ground.

For personal exposure samples, the pumps were secured on the participant's hip or waist; the sampling cartridge was attached to the participant's lapel or collar to collect air from the breathing zone. At

TABLE 8-1. FIELD MONITORING SCHEDULE AT EACH HOME

Day	Time	Activity
1	3:30 - 8:30 pm	• Sample collection locations determined • Equipment setup and sample collection begun • Appointment times confirmed with participant
2	3:30 - 8:30 pm	• Remove sample cartridges and equipment • Enter sample collection data in computer • Adminster Record of Activities and Environments and Time Activity Diary

TABLE 8-2. RULES FOR OUTDOOR SAMPLE PLACEMENT

1. Place samplers on the house side away from the roadway when possible; when not possible place at least 15 ft. from roadway.
2. Place samplers a distance equal to two building heights away from the house when possible; when not possible, place at least 8 ft. from the house.
3. Place samplers in locations away from obvious sources such as vents and combustion sources.
4. When apartments are sampled, place samplers at ground level (not on balconies) at least 15 ft. from parking lots.

night or during rest, participants were told they could remove the monitors and place them on a table or nightstand nearby.

Table 8-3 presents information on the number of field samples scheduled, collected, and analyzed. Table 8-4 provides similar information for the quality control (QC) samples. An explanation for sample losses is given in Appendix B.

All samples were collected following the procedures described in the next section. All pertinent information such as sampling times, pump flows, sample volumes, maximum/minimum temperatures, dates, etc. were recorded on a lap-top computer that was taken into the home. A back-up handwritten data sheet was also filled out in order to allow reconstruction of the files in the event of a computer failure. The data in the computer were later used to generate a sampling protocol/chain of custody sheet for each sample collected.

8.2 Sample Collection Procedures

8.2.1 Very Volatile Organic Chemicals

8.2.1.1 Collection Method--

Air samples were collected in evacuated 6 L passivated stainless steel canisters using a restrictive orifice attached directly to the canister valve. Each orifice was designed to provide a total air volume of approximately 4 L over the 24-hour sampling period. Each orifice was tested and the 24-hour sampling volume accurately determined prior to use in the field. Initial flows were approximately 3.3 mL/min dropping to approximately 1.9 mL/min at the end of the 24-hour sampling period. The drop in flow was due to the change in pressure differential as the evacuated canister filled during sample collection. Indoor canisters were

TABLE 8-3. FINAL STATUS OF FIELD SAMPLES

Sample Type	Number Scheduled	 Collected	 Analyzed
VVOC			
Indoors	63	62	62
Outdoors	15	13	13
VOC			
Indoors	108	108	104
Outdoors	51	49	48
Personal	103	98	92
SOC			
Indoors	128	121	88[a] (107)[b]
Outdoors	51	49	30 (38)
Personal	20	15	9 (13)
Automobiles	10	10	8 (10)

[a] Analyzed by GC/MS.
[b] Analyzed by GC/ECD.

TABLE 8-4. FINAL STATUS OF QUALITY CONTROL SAMPLES

Sample Type	Number Scheduled	Number Collected	Number Analyzed
VVOC			
Field controls	3	4	3
Field blanks	3	4	4
Duplicates	7	7	7
QL[a]	7	8	8
VOC			
Field controls	13	13	13
Filed blanks	13	13	13
Duplicates	26	26	25
QL	7	8	8
SOC			
Field controls	15	15	7[b] (14)[c]
Field blanks	10	10	4 (10)
Duplicates	20	20	10 (15)
QL	7	8	8 (8)

[a] Samples spiked at low level used to calculate method quantifiable limits.
[b] Analyzed by GC/MS.
[c] Analyzed by GC/ECD.

placed on stands approximately 1 meter above the floor. Outdoor canisters were hung from hooks on metal posts driven into the ground. Sampling height was approximately 1.5 meters. Sample canisters were stored at ambient temperature until analyzed.

8.2.1.2 Preparation of Sampling Materials--

Prior to use, all canisters were cleaned and evacuated. To accomplish this, the canisters were evacuated to 0.05 mm Hg at 130°C for 4 hours. The canister shut off valves were closed and the system allowed to cool to room temperature. Canisters were then removed, capped, and stored until use.

8.2.1.3 Preparation of Quality Control Samples--

Three sets of quality control samples, each consisting of one field blank and one spiked field control, were prepared. The field blanks were used to assess contamination during sampling and analysis. The field controls were used to assess compound recovery. Field blanks were prepared by loading cleaned canisters with 4.0 L (at STP) of humidified nitrogen. Spiked field controls were prepared by dilution of a primary canister standard. A primary liquid standard was first prepared by mixing the neat target VVOCs together in a single liquid solution. Gaseous compounds (1,3-butadiene, vinyl chloride, and methyl bromide) were not added to this mixture, but were added directly to the primary canister. A portion of the liquid mixture was loaded into the primary standard canister by flash evaporation injection. Spiked controls and gas chromatography/ mass spectrometry (GC/MS) calibration standards were prepared by diluting the primary canister standard with humidified nitrogen in a second canister. Samples for determining method quantifiable limits were prepared as described for field controls, but were loaded at lower concentrations (~ 1 $\mu g/m^3$).

8.2.2 Volatile Organic Chemicals

8.2.2.1 Collection Method--

Volatile organic compounds in personal and fixed site air samples were collected by pulling air through a 6.0 x 1.4 cm i.d. bed of Tenax contained in a glass tube using a constant flow pump. Glass fiber filters (Gelman, 25 mm) were attached to the inlet end of the Tenax cartridge to remove particulates from the sampled air. Collection of personal and fixed-site air samples on Tenax was accomplished as described in SOP numbers RTI-ACS-SOP-331-001, Revision 2 and RTI-ACS-SOP-331-002, Revision 2. Tenax cartridges were stored under helium purge at room temperature in sealed paint cans, except during actual sample collection.

Pumps used for the collection of the Tenax samples were DuPont P125 and P125-A constant flow personal monitors modified with low flow cams and alkaline battery packs to allow 24-hour sampling at flow rates of 12 to 15 mL/min. A total volume of 16 to 20 L was collected on each Tenax cartridge over the 24-hour sampling period.

For personal air sampling, the pump and cartridge were carried by the participant with the inlet of the sample cartridge located in his/her breathing zone. Fixed-site samples were collected indoors in the primary living area. Metal boxes containing the pumps, sampling trains, and sampling cartridges were generally placed on a wooden sampling stand or a piece of furniture such as a table or stand in the central part of the room, when possible. Care was taken not to place the samplers close to ash trays or other possible sources that might provide nonrepresentative results. All sampling equipment was placed away from family traffic patterns and out of reach of pets or children. Outdoor fixed-site samplers were placed in the front, side, or backyard of the house. The samplers were placed in weather-resistant metal boxes, supported by a sturdy post. The height of the sampler was approximately 1.5 meters above the ground. The distance from the house varied among homes, but samplers were generally placed equidistant from the house, driveways, streets, and/or fences.

8.2.2.2 Preparation of Sampling Materials--

Preparation of sampling cartridges followed an extremely rigorous procedure, described in detail in SOP number RTI-ACS-SOP-310-001, to ensure minimal background from the sampling device(s). Tenax used on previous field monitoring studies was recycled for use on this project. Prior to use, the Tenax was extracted in a Soxhlet apparatus for 48 hours with methanol, then 48 hours with n-pentane. After extraction, the Tenax was dried under a nitrogen atmosphere for 24 hours, and then in a vacuum oven at 160°C for 24 hours at 28 inches of water vacuum. The Tenax was sieved to provide a 40/60 particle size range and packed into glass sampling cartridges. After packing, each cartridge was desorbed at 270°C with a purified helium purge for 16 hours.

Twenty-four hours (minimum) after the final desorption step, 10% of the Tenax cartridges were analyzed by thermal desorption/gas chromatography with flame ionization detection (GC/FID) to determine background contamination. If the background contamination exceeded specified limits, the entire batch of cartridges was redesorbed and tested for contamination again. Only when cleanliness criteria were met were the cartridges designated for field sampling.

8.2.2.3 Preparation of Quality Control Samples--

Thirteen sets of quality control samples, each consisting of one field blank and one spiked field control, were prepared. The field blanks were used to assess contamination during sampling and analysis. The field controls were used to assess compound recovery.

Field controls were prepared by spiking Tenax cartridges with 50 to 100 ng of each of the target compounds prior to shipment to the field. The spiked controls were loaded using both a flash evaporation system and a permeation system (15). QL samples were prepared by loading Tenax cartridges with low levels (~5 ng) of each target compound. Samples for MQL determinations were also shipped to the field.

8.2.3 Semivolatile Organic Chemicals

8.2.3.1 Collection Method--

Vapor and particulate phase semivolatile organic compounds were collected by pulling air through a sampling head containing XAD-2 and a quartz fiber filter. DuPont P-4000 constant flow sampling pumps modified with alkaline battery packs were used for continuous 24-hour sample collection. The sampling cartridge consisted of a 17 mm quartz filter supported by a stainless steel wire mesh screen backed by a 5.0 g bed of XAD-2 resin. The filter and XAD-2 resin were contained in a modified screw cap glass tube. The glass tube was 6 cm in length, 2.5 cm o.d., with a screw cap on one end and reduced to 6 mm o.d. glass on the other end. A 25 cm long, 1/4 inch i.d. Tygon tube attached the sampling train to the pump. The nominal flow rate was 3 L/min over the 24-hour sampling period to provide an ~4 m^3 sample volume. The collected samples were stored under helium purge at room temperature in the field, then stored at -20°C in the laboratory until extraction.

For personal air sampling, the pump and cartridge were carried by the participant with the inlet of the sample cartridge located in his/her breathing zone. Pumps were enclosed in padded cases to provide reduced noise levels for the participants' comfort. Fixed-site samples were collected indoors in the primary living area of each home. Metal boxes containing the pumps, sampling trains, and sampling cartridges were generally placed on a piece of furniture such as a table or stand in the central part of the room, when possible. The SOC samplers were placed in the same metal boxes as the VOC samplers. Care was taken not to place the samplers close to ash trays or other possible sources that might provide nonrepresentative results. All sampling equipment was placed away from family traffic patterns and out of reach of children or pets. Outdoor fixed-site samplers were placed in the front, side, or backyard of the house. The samplers were placed in a weather-resistant metal box supported by a sturdy metal post. The height of the samplers was approximately 1.5 meters above the ground. Distances from the house varied among homes but samplers were generally placed equidistant from the house, driveway, streets, and/or fences.

8.2.3.2 Preparation of Sampling Materials--

Prior to packing the XAD-2 cartridges, the resin was Soxhlet-extracted for three days with methanol, three days with methylene chloride, and three days with methyl-t-butyl ether, then vacuum oven dried at ambient temperature for 16 hours. Glass sampling cartridge tubes were filled with ~5 g of the cleaned XAD-2. The sorbent bed was held in place by a fine mesh stainless steel wire screen, the quartz fiber filter, and "C" rings. The filters were cut from 8 by 10 inch sheets of quartz fiber filter material using a 17 mm punch. They were then placed in a muffle furnace and heated to 400°C for four hours to remove any organic impurities.

Prior to packing any cartridges, portions of the cleaned XAD were extracted and analyzed by GC/ECD to assure cleanliness. Assembled cartridge materials were also extracted and checked for background contamination by GC/ECD.

8.2.3.3 Preparation of Quality Control Samples--

Field blanks to assess background contamination and field controls to assess compound recovery were prepared just prior to the monitoring trip. A total of ten field blanks and fifteen field controls were prepared. The controls consisted of spiked XAD-2 cartridges and unspiked filters. Unexposed XAD-2 cartridges and filters served as blanks. Field blanks and controls were transported to the field with the sampling cartridges. The blanks and controls were extracted and treated exactly as sample cartridges.

Field controls were prepared by directly spiking the XAD-2 material in the cartridges with 1 μL of a methanol solution containing the target SOCs at known levels. Eight cartridges for MQL determinations were prepared in a similar manner but with a lower level of target chemicals.

8.3 Sample Analysis

8.3.1 Very Volatile Organic Compounds

8.3.1.1 Analytical Method--

The analysis of VVOCs from canister samples was performed using a gas chromatograph/mass spectrometer (GC/MS) in the electron ionization mode. Selected ion monitoring (SIM) was used for compound identification and quantitation. An external standard technique was used for component quantitation throughout. The system used for this analysis is diagrammed in Figure 8-1. The major components of the system include:

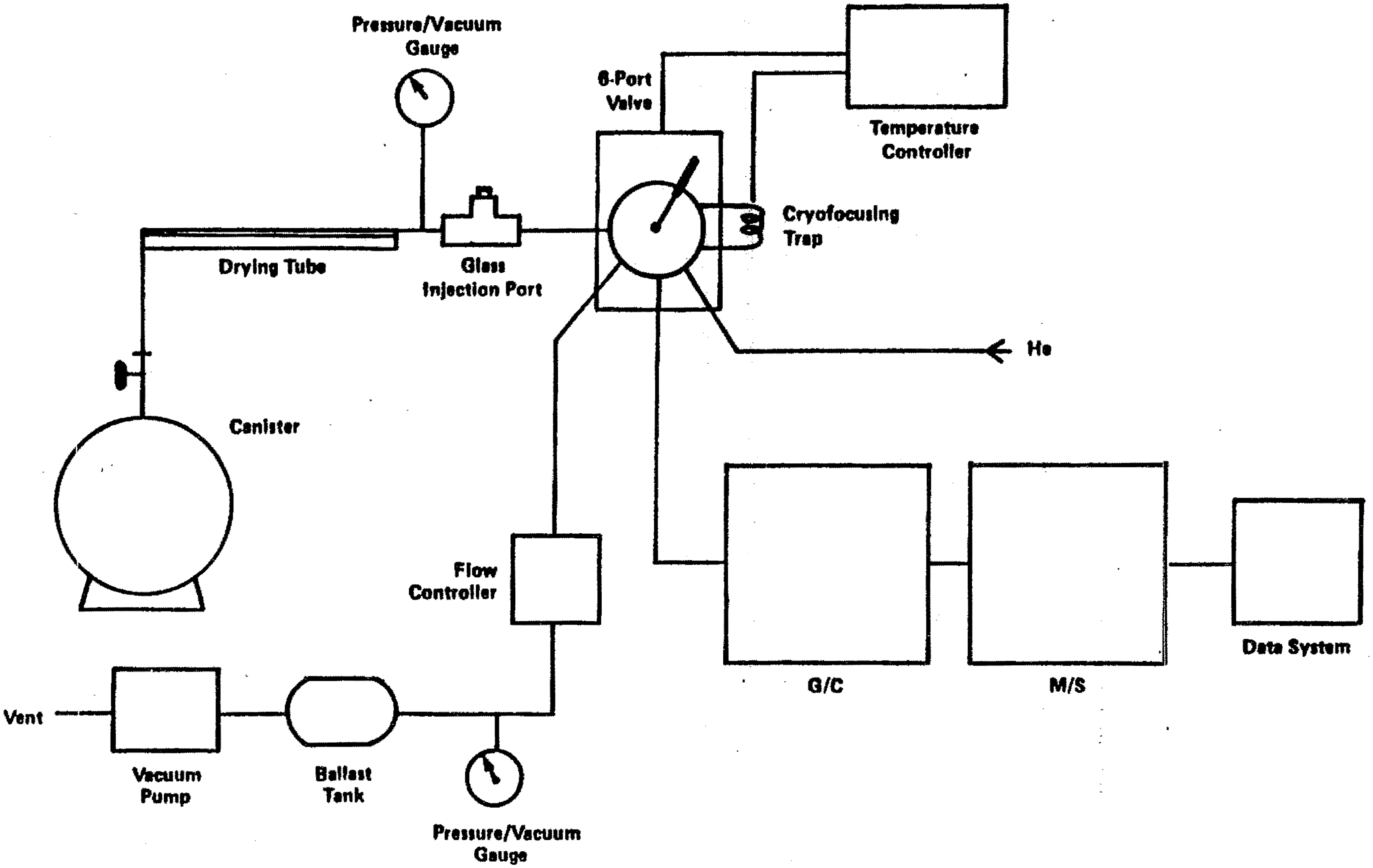
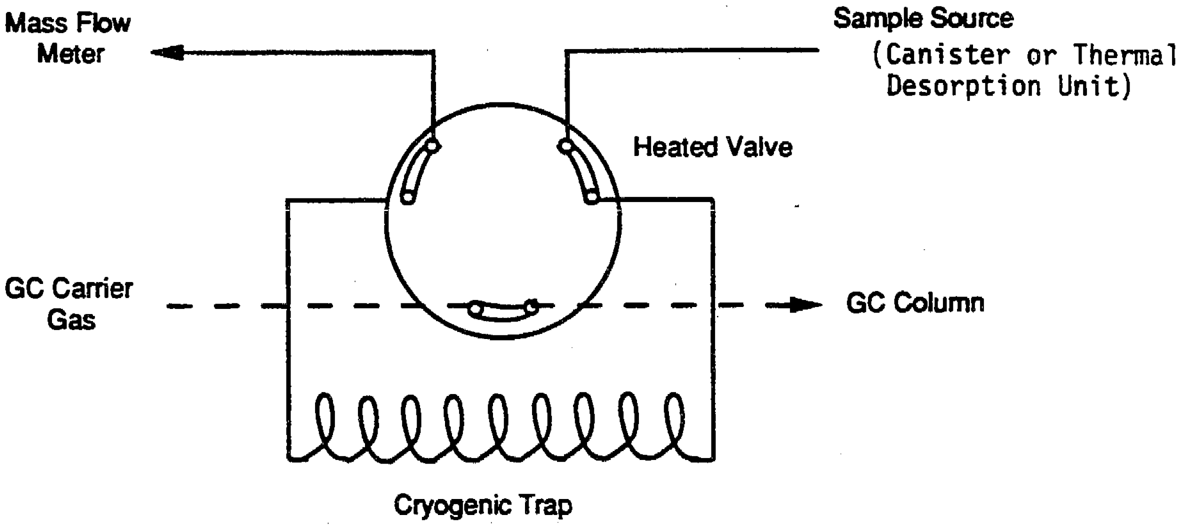


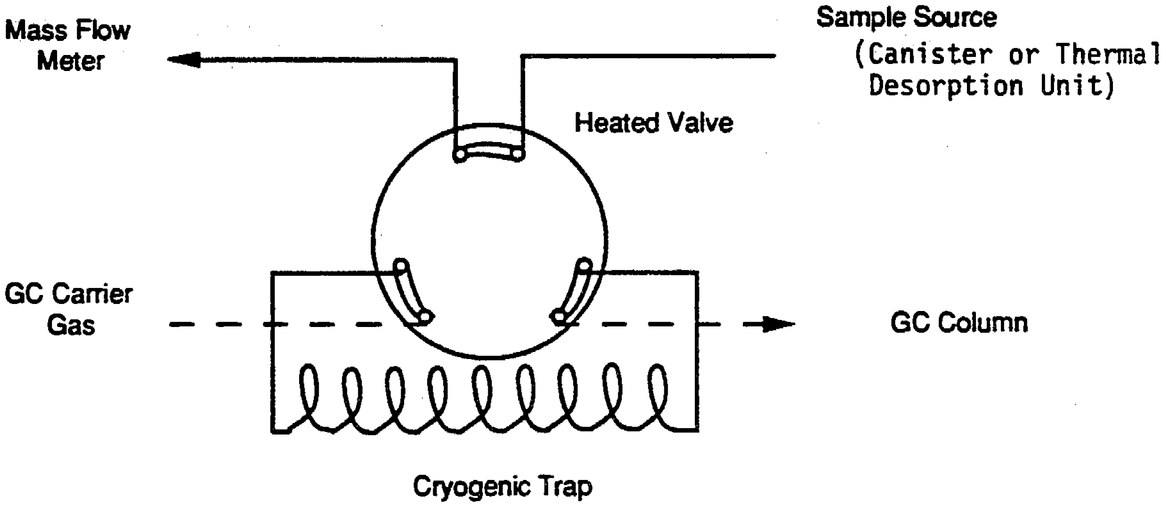
Figure 8-1. Instrumental System for VVOC Analysis

- a custom-built cryofocusing interface to concentrate and inject the canister samples and the external standards,
- a high resolution gas chromatograph, and
- a quadrupole mass spectrometer/data system.

Instrumental conditions for the analysis of VVOCs from canister samples are shown in Table 8-5. During a typical cryogenic injection cycle, the six-port valve in the cryofocusing inlet was placed in the inject position indicated in Figure 8-2. The canister containing the external standards (perfluorobenzene (PFB), perfluorotoluene (PFT), and benzene-d_6), was connected to the sample source inlet. The temperature of the cryogenic trap was cooled to -150°C, the vacuum pump turned on, and the canister valve opened. The transfer line was purged for one minute with the external standards. The six-port valve was then rotated to the fill position and a measured volume of external standard gas passed through the cold trap. While maintaining a trap temperature of -150°C, the valve was again rotated to the inject position, the canister containing the external standards was closed and removed, and the sample canister installed. The transfer line was purged for one minute with sample, the six-port valve rotated to the fill position and a measured volume of sample passed through the cold trap. To avoid losses for the more polar VVOCs, the experimental apparatus used for this project did not dry the sample gas. However, sample volumes were limited to 75 mL to minimize problems associated with water vapor in the air sample. When 75 mL of sample had passed through the cold trap, the valve was rotated to the inject position and the trap rapidly heated to 200°C. The carrier gas then swept the vapors onto the high resolution GC column for subsequent analysis.



A. Fill Position



B. Inject Position

Figure 8-2. Cryofocusing Inlet for VVOC and VOC Analysis

TABLE 8-5. INSTRUMENTAL OPERATING PARAMETERS FOR VVOC ANALYSIS

Parameter	Setting
Inlet-manifold	
Valve and fitting temperature	200°C
Capillary trap temperature	
- minimum	-150°C
- maximum	200°C
Transfer line temperature	180°C
He transfer flow	20 mL/min
Gas Chromatograph	
Column	30 m x 0.32 mm DB-624 fused silica capillary column
Temperature program	-20°C to 140°C, 4°C/min then 8°C/min to 180°C
Carrier gas (He) flow	2.6 mL/min
Mass Spectrometer	
Instrument	Hewlett Packard, Model 5988A
Ionization mode	Electron Ionization Selected Ion Monitoring
Scan range	45 - 350 m/z
Emission current	0.3 mA
Electron multiplier	2400 volts[a]
GC/MS interface Temperature:	250°C

[a] Typical value.

At the outset of the project, full scan electron impact mass spectra were generated for each target chemical by analyzing a high level canister standard (100 ng/injection for each component). For each target VVOC, fragment ions from the resulting mass spectrum were selected for monitoring. Generally, ions were selected that represented major fragment ions in the mass spectrum and that were unique to the target chemical. This latter criterion was important both to provide a method for positively identifying the target chemical and to minimize interferences from other sample components during quantitation. Selected ions are given in Table 8-6.

VVOC identifications were based on chromatographic retention times relative to the external standards and relative abundances of the selected ion fragments. The quantitation of VVOCs in canister air samples was performed using chromatographic peak areas derived from the selected ion profiles. Specifically, response factors (RFs), or first order linear regressions, for each target compound were generated from duplicate injections of the canister standards at three different concentrations, (Table 8-7). For each injection, the RFs were calculated as:

$$RF_T = \frac{A_T \bullet C_{QS}(\text{ng/L})}{A_{QS} \bullet C_T(\text{ng/L})}$$

where A_T is the peak area of the quantitation ion for the target compound and A_{QS} the peak area for the 186 ion of the external quantitation standard, PFB. C_T is the concentration of the target compound in the standard canister and C_{QS} is the concentration of PFB loaded from the external standard canister.

TABLE 8-6. MASS SPECTRAL FRAGMENT IONS SELECTED FOR VVOC ANALYSIS

	Ions[a]	
Compound	Primary	Secondary
Vinyl chloride	62	64
1,3-Butadiene	54	53,39
Bromomethane	94	96
Acrolein	56	55
Vinylidine chloride	96	98
Allyl chloride	76	78
Methylene chloride	84	86
Acrylonitrile	53	50
Chloroform	83	85
1,1,1-Trichloroethane	97	61
Carbon tetrachloride	117	121
Benzene	78	74
Ethylene dichloride	62	49,98
Trichloroethylene	130	95
1,4-Dioxane	88	58
Perchloroethylene	94	133,166
Ethylene dibromide	107	109
Chlorobenzene	112	114
m,p-xylene	91	106
o-xylene	91	106
Styrene	104	78
p-Dichlorobenzene	146	148
Benzyl chloride	91	126

[a] Primary ion is used for quantitation, secondary ion used to confirm compound identification.

TABLE 8-7. CANISTER STANDARDS FOR VVOC CALIBRATION

Compound	Concentration ($\mu g/m^3$)		
	Low Standard	Medium Standard	High Standard
Vinyl Chloride	2.0	5.0	15
1,3-Butadiene	1.7	4.4	13
Bromomethane	3.1	7.7	23
Acrolein	1.9	4.8	14
Vinylidine chloride	2.1	5.2	15
Allyl chloride	2.1	5.3	16
Methylene chloride	2.2	5.6	17
Acrylonitrile	1.8	4.6	14
Chloroform	2.0	5.1	15
1,1,1-Trichloroethane	2.3	5.7	17
Carbon tetrachloride	1.8	4.5	14
Benzene	2.0	5.0	15
Ethylene dichloride	2.1	5.3	16
Trichloroethylene	2.0	5.0	15
1,4-Dioxane	2.1	5.3	16
Perchloroethylene	1.8	4.6	14
Ethylene dibromide	2.5	6.2	19
Chlorobenzene	1.9	4.7	14
m,p-Xylene	3.9	9.8	29
Styrene	2.1	5.2	15
p-Dichlorobenzene	2.1	5.3	16
Benzyl chloride	1.9	4.7	14
o-Xylene	2.0	4.9	15

Mean values and standard deviations of the RFs were then calculated for each target analyte. The calibration curve was considered acceptable if the standard deviation for each response factor was less than 30%. During each day of analysis, an additional medium level standard was analyzed. If the RF values for this standard were within ± 30% of the average RF value of the medium level calibration standards from the calibration data set, the GC/MS system was considered "in control" and the mean RFs were used to calculate the concentration of the target VVOCs in a sample (C_{TS}):

$$C_{TS}(\text{ng/L or } \mu\text{g/m}^3) = \frac{A_T \cdot C_{QS}(\text{ng/L})}{A_{QS} \cdot RF_T}$$

The average concentration found in the field blanks (C_{TB}) was then subtracted from the concentration found in each sample (C_{TS}) to give the final sample concentration (C_S):

$$C_S(\text{ng/L or } \mu\text{g/m}^3) = C_{TS}(\text{ng/L}) - C_{TB}(\text{ng/L})$$

Ethylene and propylene oxides were not detected during the initial analysis of calibration standards. Additional standards were prepared several times. Analysis of these canister standards showed a highly variable response for both compounds, although analysis of neat solutions gave a reproducible response. These two compounds were subsequently dropped from the target list, since it appeared that reliable quantitation standards could not be prepared in canisters. Similar problems have been reported during the preparation of cylinder reference standards for these two compounds (16).

8.3.1.2 Quality Control Sample Analysis--

Several types of QC samples were prepared and analyzed.

- Field controls were canisters spiked with target analytes at known concentrations as shown in Table 8-8. These samples were taken to the field and treated exactly as field samples, but were not exposed.

TABLE 8-8. SPIKING LEVELS FOR FIELD CONTROLS AND QL SAMPLES FOR VVOC DETERMINATIONS

Compound	Spiking Level ($\mu g/m^3$)	
	Field Controls	QL Samples
Vinyl chloride	5.0	1.0
1,3-Butadiene	4.4	0.87
Bromomethane	7.7	1.5
Acrolein	4.8	0.95
Vinylidine chloride	5.2	1.1
Allyl chloride	5.3	1.1
Methylene chloride	5.6	1.1
Acrylonitrile	4.6	0.91
Chloroform	5.1	1.0
1,1,1-Trichloroethane	5.7	1.1
Carbon tetrachloride	4.5	0.90
Benzene	5.0	1.0
Ethylene dichloride	5.3	1.1
Trichloroethylene	5.0	1.0
1,4-Dioxane	5.3	1.1
Perchloroethylene	4.6	0.92
Ethylene dibromide	6.2	1.2
Chlorobenzene	4.7	0.94
m,p-Xylene	9.8	2.0
o-Xylene	4.9	1.0
Styrene	5.2	1.0
p-Dichlorobenzene	5.3	1.1
Benzyl chloride	4.7	0.93

- Field blanks were unspiked canisters filled with purified, humidified nitrogen. These samples were taken to the field and treated exactly as field samples, but were not exposed.
- Duplicates were field samples collected at the same time and location, then processed and analyzed separately to assess precision.
- QL samples were canisters spiked with low levels of target analytes (Table 8-8). These samples were taken to the field and treated exactly as field samples but were not exposed.

Field controls were intended to assess accuracy of the overall method. Field blanks were intended to provide information on background contamination and its variability. Duplicate samples were used to assess precision. QL samples were used to calculate method quantifiable limits.

Percent recovery for control samples was calculated as:

$$\% \text{ Recovery} = \frac{C_C - C_B}{C_S} \text{ X } 100\%$$

where C_C is the concentration of target found in the spiked controls, C_B is the concentration of target found in the blanks, and C_S is the concentration of target spiked onto controls.

Results of the analysis of canister blanks are summarized in Table 8-9. Data show low levels of contamination except for methylene chloride. Results for the analysis of the control samples are given in Table 8-10. The control samples generally showed good recovery and acceptable reproducibility with two exceptions. For methylene chloride, interferences prevented accurate quantitation in two of the three field controls. Since the same very high levels of interferences were not found in the field blanks, it is hypothesized that they resulted from the control loading process. 1,4-Dioxane gave rather low recoveries (57 ± 7.9%). Although field controls show good recovery for target compounds, it should be kept in mind that these controls were prepared using "clean" air as the

TABLE 8-9. VVOC CONCENTRATIONS FOUND IN FIELD BLANKS

	Mean Concentration ± S.D. ($\mu g/m^3$)[a] (n = 4)
Vinyl chloride	0.09 ± 0.02
1,3-Butadiene	0.06 ± 0.11
Bromomethane	0.04 ± 0.06
Acrolein	0.63 ± 0.46
Vinlyidine chloride	0.02 ± 0.01
Allyl chloride	0.02 ± 0.02
Methylene chloride	2.70 ± 1.85[b]
Acrylonitrile	0.06 ± 0.10
Chloroform	0.19 ± 0.10
1,1,1-Trichloroethane	0.16 ± 0.08
Carbon tetrachloride	0.02 ± 0.03
Benzene	0.00 ± 0.00[b]
Ethylene dichloride	0.01 ± 0.01
Trichloroethylene	0.01 ± 0.01
1,4-Dioxane	0.02 ± 0.04
Perchloroethylene	0.10 ± 0.06
Ethylene dibromide	0.01 ± 0.01
Chlorobenzene	0.03 ± 0.02
m,p-Xylene	0.10 ± 0.02
o-Xylene	0.04 ± 0.03
Styrene	0.08 ± 0.02
p-Dichlorobenzene	0.12 ± 0.03
Benzyl chloride	0.02 ± 0.01

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[a] All values are below the method quantifiable limits.
[b] Calculated using a linear regression equation.

TABLE 8-10. PERCENT RECOVERY OF VVOCs FROM FIELD CONTROLS

	Mean % Recovery ± S.D. (n=3)
Vinyl chloride	100 ± 8.6
1,3-Butadiene	99 ± 13
Bromomethane	96 ± 8.0
Acrolein	102 ± 11
Vinylidine chloride	103 ± 8.6
Allyl chloride	97 ± 13
Methylene chloride	106[a]
Acrylonitrile	111 ± 17
Chloroform	104 ± 6.1
1,1,1-Trichloroethane	94 ± 0.8
Carbon tetrachloride	100 ± 3.5
Benzene	108 ± 5.7
Ethylene dichloride	101 ± 3.2
Trichloroethylene	96 ± 6.7
1,4-Dioxane	57 ± 7.9
Perchloroethylene	95 ± 8.0
Ethylene dibromide	99 ± 20
Chlorobenzene	112 ± 25
m,p-Xylene	105 ± 23
o-Xylene	105 ± 22
Styrene	110 ± 25
p-Dichlorobenzene	106 ± 29
Benzyl chloride	111 ± 21

[a] Single value due to interference in controls.

sample matrix. Very reactive compounds such as vinyl chloride and 1,3-butadiene may not show comparable recovery in field samples where high levels of ozone or other reactants may be present. Spiked field samples should be used in future studies to evaluate this effect.

Results of analysis for duplicate samples are given in Table 8-11. Data are presented as relative mean deviations (RMD) for duplicate sample pairs. RMD was calculated as:

$$\text{RMD} = \frac{|C - \bar{C}|}{\bar{C}}$$

where C is the concentration of one sample of the duplicate pair and $\bar{C}$ is the mean concentration. Data show reasonable agreement between duplicate field samples.

Method quantifiable limits (MQL) were determined from the analysis of eight QL samples. These parameters were calculated as:

$$\text{MQL} = 3 \times \text{S.D.}$$

where S.D. is the standard deviation of the concentration of each target analyte found on the spiked QL samples. MQLs for target VVOCs are presented in Table 8-12.

For comparison, estimated method quantifiable limits (EMQLs) from the pilot study are also given in the table. During the pilot study, EMQLs were calculated from the variability of target chemicals found in the field blanks. Where target chemicals were not found on the field blanks, EMQLs were calculated based on instrumental response of the calibration standards. For the main study, MQLs were based on the variability of calculated concentrations for low concentrations of targets and reflect performance of the entire method. As seen in the table, MQLs tend to be

TABLE 8-11. RESULTS OF DUPLICATE SAMPLE ANALYSIS FOR VVOC COMPOUNDS[a]

		Relative Mean Deviation (RMD)			
Compound	N[b]	Mean	Median	Min	Max
1,1,1-Trichloroethane	5	0.13	0.04	0.00	0.54
Benzene	3	0.21	0.23	0.13	0.28
Carbon tetrachloride	6	0.05	0.04	0.02	0.09
m,p-Xylene	7	0.05	0.05	0.00	0.08
o-Xylene	7	0.06	0.07	0.00	0.10
p-Dichlorobenzene	4	0.14	0.12	0.09	0.24
Perchloroethylene	1	0.20	0.20	0.20	0.20
Styrene	1	0.07	0.07	0.07	0.07
Trichloroethylene	3	0.13	0.10	0.04	0.25

[a] For VVOC compounds for which measurable data was available.
[b] N = Number of duplicate pairs.

TABLE 8-12. CALCULATED METHOD QUANTIFIABLE LIMITS (MQL) FOR VVOCs

	Mean Concentration Found in Samples[a,b] ± S.D. ($\mu g/m^3$)	MQL[b] ($\mu g/m^3$)	EMQL[b,c] ($\mu g/m^3$)
Vinyl chloride	1.6 ± 0.4	1.2	0.2[d]
1,3-Butadiene	1.5 ± 0.4	1.2	0.1[d]
Bromomethane	1.8 ± 0.3	0.9	0.2[d]
Acrolein	1.5 ± 0.5	2.0	2.9
Vinylidine chloride	1.4 ± 0.2	0.7	0.2[d]
Allyl chloride	1.2 ± 0.4	1.2	0.6[d]
Methylene chloride	2.3 ± 0.9	2.8	0.7
Acrylonitrile	1.2 ± 0.7	2.1	0.9[d]
Chloroform	1.5 ± 0.4	1.2	0.1
1,1,1-Trichloroethane	1.8 ± 0.3	0.9	0.1
Carbon tetrachloride	1.2 ± 0.3	0.6	0.6[d]
Benzene	0.6 ± 0.5	1.6	3.8
Ethylene dichloride	1.5 ± 0.2	0.8	0.8[d]
Trichloroethylene	1.0 ± 0.1	0.3	0.2
1,4-Dioxane	0.8 ± 0.2	0.6	1.6
Perchloroethylene	1.1 ± 0.2	0.7	0.3
Ethylene dibromide	1.3 ± 0.3	0.8	0.2
Chlorobenzene	1.0 ± 0.2	0.6	0.3
_m_,_p_-Xylene	2.2 ± 0.4	1.2	0.5
_o_-Xylene	1.1 ± 0.2	0.6	0.2
Styrene	1.1 ± 0.4	1.2	0.4
_p_-Dichlorobenzene	1.0 ± 0.2	0.5	1.2
Benzyl chloride	0.9 ± 0.2	0.6	0.6

[a] N = 8.

[b] Values were rounded to one decimal place after MQL calculations were made.

[c] From pilot study.

[d] Estimated from instrumental response only.

higher than the EMQLs especially when the EMQLs were calculated based on instrumental response alone. The higher MQLs reported here are not a reflection of changing method performance; rather, they are a result of using a more rigorous and realistic procedure for calculating MQLs.

8.3.2 Volatile Organic Compounds (VOCs)

8.3.2.1 Analytical Method--

The analysis of VOCs collected on Tenax cartridges was performed using a high resolution GC/MS technique. Electron ionization mass spectrometry in the full scan mode was applied for all analyses. The analytical system here was similar to that used for the canister analysis except that a thermal desorption unit was used to thermally strip adsorbed analytes from the Tenax cartridge, then cryofocus them for introduction onto the capillary gas chromatography column.

The instrumental conditions for the analysis of VOCs from Tenax samples are shown in Table 8-13. During a typical thermal desorption/cryogenic injection cycle, the six-port valve was placed in the load position indicated in Figure 8-2. The temperature of the cryogenic trap was cooled to -190°C and the Tenax cartridge was placed into the desorption block for eight minutes. A stream of purified helium carried the thermally desorbed analytes from the desorption chamber into the cryogenic trap where they were concentrated. The valve was then rotated to the inject position and the trap rapidly heated to 250°C. The carrier gas then swept the vapors onto the high resolution GC column.

Prior to analysis, all Tenax cartridges were loaded with two external standards, perfluorobenzene and perfluorotoluene. These standards served as checks on the operation of the thermal desorption/GC/MS system during analyses. They were also used as quantitation and retention time standards.

TABLE 8-13. INSTRUMENTAL OPERATING PARAMETERS FOR VOC ANALYSIS

Parameter	Setting
Inlet-manifold	
Thermal desorption temperature	270°C
Valve and fitting temperature	270°C
Capillary trap temperature	
- minimum	-190°C
- maximum	250°C
Transfer line temperature	200°C
He flow rate	1.3 mL/min
Gas Chromatography	
Column	60 m x 0.32 mm DB-1 fused silica capillary column
Temperature program	-45 (5 min hold) to 125°C, 4°C/min
Carrier (He) flow	1.3 mL/min
Mass Spectrometry	
Instrument	Hewlett Packard, Model 5988A
Scan range	m/z 45 → 350
Emission current	0.3 mA
Electron multiplier	1700 volts[a]

[a] Typical value.

VOC identifications were based on chromatographic retention times relative to the external standards and on relative abundances of the extracted ion fragments selected for quantitation. Fragment ions were selected based on the analysis of a Tenax cartridge spiked with high levels (~500 ng per component) of the target VOCs. Criteria for fragment ions were identical to those for VVOC analysis. Where available, fragment ions that showed good performance on previous research contracts were selected. Fragment ions used for quantitation are given in Table 8-14.

Quantitation of VOCs from the Tenax cartridges was accomplished using chromatographic peak areas derived from extracted ion profiles. Specifically, relative response factors (RF) for each target compound were generated from the analysis of standard cartridges prepared at four different concentrations (Table 8-15). For each standard, RFs were calculated as:

$$RF_T = \frac{A_T \bullet Amt_{QS} \text{ (ng)}}{A_{QS} \bullet Amt_T \text{ (ng)}}$$

where A_T is the peak area of the quantitation ion for the target VOC and A_{QS} is the peak area for the 186 ion of the external standard, PFB. Amt_T is the mass of target compound in the standard sample and Amt_{QS} is the relative mass of the PFB loaded onto the standard sample.

Mean values and standard deviations of the RFs were then calculated for each target analyte. The calibration curve was considered acceptable if the standard deviation for each response factor was less than 30%. During each day of analysis, an additional standard was analyzed. If the RF values for this standard were within ± 30% of the mean RFs for the same concentration standard obtained for the calibration curve, the GC/MS system was considered "in control" and the mean RF values from the calibration

TABLE 8-14. MASS SPECTRAL FRAGMENT IONS SELECTED FOR VOC ANALYSIS

Compound	Ions[a] Primary	Secondary
Allyl chloride	76	78
1,1,1-Trichloroethane	97	61
Benzene	78	74
Carbon tetrachloride	117	121
Trichloroethylene	130	95
1,4-Dioxane	88	58
Ethylene dibromide	107	109
Perchloroethylene	94	133
Chlorobenzene	112	114
m,p-Xylene	91	106
Styrene	104	78
o-Xylene	91	106
Benzyl chloride	91	126
p-Dichlorobenzene	146	148

[a] Primary ion is used for quantitation, secondary ion used to confirm compound identification.

TABLE 8-15. STANDARD CARTRIDGES FOR VOC CALIBRATION

	Concentration of Target Analytes (ng/cartridge)			
Compound	0.1X Standard	0.5X Standard	1.0X Standard	2.0X Standard
Allyl Chloride	19.7	98.5	197	394
1,1,1-Trichloroethane	20.0	100	200	400
Benzene	20.0	100	200	401
Carbon tetrachloride	20.1	101	201	403
1,4-Dioxane	20.5	102	205	411
Ethylene dibromide	16.2	81.1	162	325
Perchloroethylene	37.1	185	370	743
Chlorobenzene	20.4	102	204	410
m,p-Xylene	38.8	199	388	779
Styrene	19.1	95.6	191	382
o-Xylene	11.4	57.4	114	230
Benzyl chloride	23.1	115	231	462
p-Dichlorobenzene	20.9	104	209	417

samples were used to calculate the concentrations of the target VOCs (Amt_{TS}) as:

$$Amt_{TS}(ng) = \frac{A_T \bullet Amt_{QS}(ng)}{A_{QS} \bullet RF_T}$$

8.3.2.2 Quality Control Sample Analysis--

Field controls, field blanks, duplicate samples and QL samples were used to evaluate method performance and monitor uncontrolled contamination and losses. Spiking levels for field controls and QL samples are given in Table 8-16.

Results of the field blank analysis are summarized in Table 8-17. The mean and standard deviation calculated for the amount of each target are given. With the exception of benzene, all field blanks showed little contamination of target compounds with all values below 3 ng/cartridge. For benzene, field blank levels were 7.0 ± 3.1 ng/cartridge, which is considered acceptable. Results for the analysis of the field control samples are given in Table 8-18. The control samples generally showed good precision and accuracy with the exception of benzyl chloride. Greater variability of benzyl chloride recovery was due to low recoveries from two of the field controls.

Results of analysis of duplicate samples in Table 8-19 show relative mean deviations for duplicate sample pairs with measurable values. Data show reasonable agreement between duplicate pairs.

Method quantifiable limits were determined from the analysis of eight spiked QL samples. These parameters were calculated as:

$$MQL = 3 \times S.D.$$

where S.D. is the standard deviation of the amount of each target analyte found on the QL samples. The resulting MQLs are presented in Table 8-20.

TABLE 8-16. SPIKING LEVELS FOR VOC FIELD CONTROLS AND QL SAMPLES

	Spike Level			
	Field Sample		QL Sample	
Compound	(ng/sample)	($\mu g/m^3$)[a]	(ng/sample)	($\mu g/m^3$)[a]
Allyl chloride	98.5	5.4	9.85	0.54
1,1,1-Trichloroethane	100	5.6	10.0	0.56
Benzene	100	5.6	10.0	0.56
Carbon tetrachloride	99.0	5.5	9.90	0.55
Trichloroethylene	202	11.2	20.2	1.1
1,4-Dioxane	101	5.6	10.1	0.56
Ethylene dibromide	81.1	4.4	8.1	0.44
Perchloroethylene	185	10.4	18.5	1.0
Chlorobenzene	102	5.8	10.2	0.58
m,p-Xylene	199	10.8	19.9	1.1
Styrene	95.6	5.3	9.6	0.53
o-Xylene	57.4	3.3	5.74	0.33
Benzyl chloride	115	6.3	11.5	0.63
p-Dichlorobenzene	104	5.8	10.4	0.58

[a] Calculated assuming a sample volume of 18 L.

TABLE 8-17. BACKGROUND LEVELS OF VOCs ON FIELD BLANK SAMPLES[a]

Compound	Amount Found ± S.D. (ng/sample)
Vinyl chloride	ND[b]
1,1,1-Trichloroethane	0.45 ± 0.41[c]
Benzene	7.0 ± 3.1
Carbon tetrachloride	0.31 ± 1.1[c]
Trichloroethylene	0.02 ± 0.06[c]
1,4-Dioxane	ND
Ethylene dibromide	ND
Perchloroethylene	ND
Chlorobenzene	0.47 ± 0.23[c]
m,p-Xylene	0.39 ± 0.56[c]
Styrene	2.4 ± 1.4[c]
o-Xylene	0.01 ± 0.02[c]
Benzyl chloride	ND
p-Dichlorobenzene	1.7 ± 2.8[c]

[a] n=13.
[b] No instrumental response.
[c] Below the method quantifiable limit.

TABLE 8-18. PERCENT RECOVERY OF VOCs FROM FIELD CONTROLS

Compound	Mean % Recovery ± S.D. (n = 13)
Allyl chloride	106 ± 18
1,1,1-Trichloroethane	70 ± 13
Benzene	102 ± 16
Carbon tetrachloride	83 ± 7
Trichloroethylene	101 ± 11
1,4-Dioxane	94 ± 18
Ethylene dibromide	93 ± 10
Perchloroethylene	99 ± 13
Chlorobenzene	79 ± 9
m,*p*-Xylene	112 ± 15
Styrene	104 ± 11
o-Xylene	76 ± 9
Benzyl Chloride	76 ± 39
p-Dichlorobenzene	109 ± 12

TABLE 8-19. RESULTS OF DUPLICATE SAMPLE ANALYSIS FOR VOC COMPOUNDS[a]

Compound	N[b]	Relative Mean Deviation			
		Mean	Median	Min	Max
1,1,1-Trichloroethane	24	0.18	0.14	0.00	0.56
Benzene	24	0.21	0.17	0.00	0.60
Carbon tetrachloride	23	0.21	0.13	0.00	0.67
_m,p_-Xylene	24	0.20	0.13	0.00	0.62
_o_-Xylene	24	0.21	0.16	0.00	0.60
_p_-Dichlorobenzene	18	0.19	0.11	0.00	0.57
Perchloroethylene	13	0.21	0.18	0.00	0.60
Styrene	20	0.19	0.14	0.00	0.59
Trichloroethylene	9	0.23	0.19	0.00	0.60

[a] For compounds for which measurable data was available.
[b] N = Number of duplicate pairs.

TABLE 8-20. METHOD QUANTIFIABLE LIMITS (MQLs) FOR VOCs

Compound	Mean Amount Found on QL Samples[a] ± S.D.[b] (ng/sample)	MQL[b] (ng/sample)	MQL[b] ($\mu g/m^3$)[c]
Ally chloride	8.0 ± 1.8	5.3	0.30
1,1,1-Trichloroethane	6.5 ± 0.57	1.7	0.10
Benzene	16 ± 2.1	6.3	0.35
Carbon tetrachloride	5.0 ± 1.3	3.9	0.22
Trichloroethylene	13 ± 1.9	5.6	0.31
1,4-Dioxane	7.9 ± 0.89	2.7	0.15
Ethylene dibromide	4.0 ± 0.72	2.2	0.12
Perchloroethylene	13 ± 1.5	4.6	0.26
Chlorobenzene	7.8 ± 1.4	4.1	0.23
m,p-Xylene	15 ± 2.2	6.5	0.36
Styrene	12 ± 1.2	3.5	0.19
o-Xylene	14 ± 0.77	2.3	0.13
Benzyl chloride	13 ± 2.6	7.8	0.44
p-Dichlorobenzene	13 ± 1.9	5.8	0.32

[a] n = 8

[b] Number rounded to two significant figures after MQL calculations were made.

[c] Estimated using sample volume of 18 L.

8.3.3 Semivolatile Organic Compounds

8.3.3.1 Background--

Unlike the VOCs and VVOCs, standard methods were not available for the collection and analyses of the range of SOCs of interest to the ARB. For this project, a method was proposed based on our own work and reported literature methods for similar chemicals(1,7,8,9). Since this was not a methods development contract, the approach (as requested by the ARB) was to field test the proposed method during the Pilot Study. Method deficiencies were addressed and the method optimized during a laboratory evaluation. The modified method was tested using spiked laboratory controls and was then applied directly to the collection and analysis of air samples as part of the main study without additional field testing. Unfortunately, several problems were encountered during the analyses of actual field samples, thus additional modifications were made in the final method.

Table 8-21 summarizes information on the method as it was proposed, optimized, and finally used. The rationale for selecting various procedures is also given. Many of the method problems encountered here were associated with the collection and analyses of phenolic compounds. Due to their polar and acidic nature, these chemicals are very difficult to extract and analyze. Similar problems have been noted in EPA's Non-Occupational Pesticide Exposure Survey and Housedust Infant Pesticide Study where very poor recoveries (<10%) were reported for pentachlorophenol(18). During this ARB study, the very low targeted detection limits placed additional stringent requirements on both analytical sensitivity and selectivity that were difficult to achieve.

At each phase of testing, discussions were held with personnel at the ARB to outline method deficiencies and their proposed solutions. The general approach was to attempt to modify the method and then provide

TABLE 8-21. BACKGROUND INFORMATION ON THE SOC METHOD

Procedure	Description	Rationale
Proposed Method		
Collection	~2.8 m^3 sample collected on a cartridge containing a glass fiber filter backed by a 5 cm XAD-2 resin bed.	Both XAD and polyurethane foam (PUF) have been used to collect semivolatile organics from air samples. For ECD analysis, PUF is generally a cleaner matrix. However, XAD resin has better retention efficiency. XAD resin was selected to provide good collection efficiency for the lower molecular weight species such as nitrobenzene and 2,4,6-trichlorophenol.
Extraction	Soxhlet extraction with methylene chloride.	This is a common laboratory method with good recovery reported for neutral SOCs. The method was used on EPA's Non-Occupational Pesticide Exposure Study (NOPES) for extracting pentachlorophenol (PCP)(17). Although the NOPES method performed poorly for PCP, this was attributed to poor chromatography rather than poor extraction efficiency(17).
Analysis	GC/ECD - single column.	Because of excellent sensitivity, this is the most common analytical method used for chemicals with electron capturing substituents. This was the primary analytical method for SOCs on NOPES.
Optimized Method		
Collection	~4.3 m^3 sample collected on a cartridge containing a glass fiber filter backed by a 5 cm XAD-2 resin bed.	Larger sample size was selected to provide increased sensitivity. XAD-2 resin did have some background contamination during ECD analysis; but this did not interfere with sample components during pilot testing. The revised extraction procedure (sonication extraction) precluded the use of PUF.
Extraction/ Processing	Material sonic extracted with acidified methyl-t-butyl ether, concentrated extract derivatized with diazomethane.	Revised extraction procedure was required to efficiently recover phenols; more polar extracting solvent was used; acid was added to keep phenols in their neutral form; sonication was required to keep resin material in contact with acid. Derivatization was required to allow GC analysis of low levels (~20 pg on column) of phenols. Underivatized phenols require very high levels (>50 ng on column) for acceptable GC analysis. Results of pilot study and laboratory testing showed acceptable recovery and reproducibility using laboratory blanks and controls.
Analysis	GC/ECD - single column	No modifications were recommended
Final Method Used on Main Study		
Collection	Followed optimized method procedure	
Extraction/ Processing	Followed optimized method procedure	During the laboratory evaluation, only a single batch of standards and samples were derivatized and analyzed; for field sample, nine batches were processed. Results showed that derivatization efficiency between batches was not uniform especially for the less acidic phenols. Background contamination varied between extraction/ derivatization batches. Several of the sample batches were derivatized several times in an attempt to improve derivatization yields.
Analysis	GC/ECD - dual column and GC/MS.	High and variable background interferences in GC/ECD chromatograms made SOC identifications impossible. Dual column GC/ECD was used to provide greater selectivity. Selectivity was still not sufficient. Samples were then analyzed by GC/MS to provide additional selectivity. For some compounds, sensitivity was not sufficient to detect chemicals spiked at low levels in field controls (20 ng/sample).

semiquantitative monitoring data for the SOCs. This approach was considered more valuable than simply stopping the analyses. The results reported here should, at least, provide the ARB with a preliminary assessment of indoor and personal exposures to the SOCs. In addition, a method for SOC analyses (including the phenols) was developed that should be capable of providing good quality data for future studies although a complete validation under field conditions is required.

8.3.3.2 Analytical Method--

The modified method (evaluated after the pilot study) was used to extract and analyze SOCs collected on field samples. Sorbed chemicals were recovered from the sampling cartridges and quartz fiber filters by sonication extraction with acidified methyl-t-butyl ether. Prior to sample processing, all glassware was scrupulously cleaned and rinsed with solvent to minimize background contamination.

For extraction, XAD-2 resin was removed from the glass cartridge and placed in a 50 mL centrifuge tube. The corresponding quartz fiber filter was placed in the same tube. Acidified methyl-t-butyl ether (40 mL) was then added to each tube and the tube sonicated for 30 minutes. A 27 mL aliquot was removed and saved. A second 30 mL aliquot of fresh solvent was then added to the tube. The tube was sonicated again and 30 mL of the solvent removed. The two extracted aliquots from each sample were combined and concentrated to ~0.5 mL by nitrogen blowdown. Octachloronaphthalene (OCN) and 2,3',4,4',6-pentachlorobiphenyl (PCB 119) were added to each concentrated extract to serve as external quantitation and retention time standards. The extracts were then derivatized using diazomethane and reconcentrated to ~0.5 mL.

The discussion that follows provides detailed information on the sampling and analysis method that were used during the main study.

The SOC samples were processed and analyzed in nine batches. Batches usually included 3 method blanks, 3 method controls, and 30 field samples, field controls, or field blanks. Method blanks consisted of the extracting solvent concentrated, derivatized, and analyzed using the same methods as for field samples. Method controls were extracting solvent spiked with target SOCs then processed and analyzed. In addition, standard solutions of the ECD calibration standards were prepared and derivatized with each batch of samples. This was done since the stability of the derivatized standards was unknown at the start of the study.

Derivatized extracts were analyzed for target SOCs by gas chromatography with electron capture detection (GC/ECD). Analyses were performed using both DB-1701 and DB-225 capillary columns. General instrumental conditions are listed in Table 8-22, although the conditions were varied slightly between batches in an attempt to optimize analytical conditions for each batch.

Prior to analysis for any batch, the calibration standards (Table 8-23) prepared with that batch were analyzed. For each standard, RFs were calculated as:

$$RF_T = \frac{A_T \bullet C_{ES}}{A_{ES} \bullet C_T}$$

where A_T is the chromatographic peak area for the target SOC and A_{ES} is the chromatographic peak area for the external standard. C_T is the concentration of the target compound and C_{ES} is the concentration of the external standard in the sample. RFs were calculated using both external standards.

TABLE 8-22. GC/ECD CONDITIONS FOR SOC ANALYSIS

Parameter	Conditions
Instrument	Varian gas chromatograph Model 3700 or Hewlett Packard 5880A
Column, analytical	15 m DB-1701 or DB-225 fused silica capillary
Inner diameter	0.32 mm
Film thickness	0.25 µm
Helium carrier flow	about 2 mL/min
Split ratio	18:1
Splitless	60 sec
Temperature program	50-240°C/min
Initial hold	0 min
Injector temperature	240°C
Detector temperature	300°C
Detector type	Variable pulse frequency ^{63}Ni ECD
Makeup gas	Nitrogen @ 25 mL/min
Injection volume	1.0 µL

TABLE 8-23. CALIBRATION STANDARDS FOR GC/ECD ANALYSIS OF SOCs

Compound	Concentration (pg/uL)[a]						
	1	2	3	4	5	6	7
Nitrobenzene	0	108	271	542	1080	2710	5420
2,4,6-Trichlorophenol	0	7.32	18.3	36.6	73.2	183	366
2,3,4,6-Tetrachlorophenol	0	2.90	7.25	14.5	29.0	72.5	145
Hexachlorobenzene	0	2.14	5.35	10.7	21.4	53.5	107
Pentachlorophenol	0	1.81	4.53	9.05	18.1	45.3	90.5
Di-2-ethylhexylphthalate	0	89.2	223	446	892	2230	4460
PCB 119[b]	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Octachloronaphthalene[b]	25.0	25.0	25.0	25.0	25.0	25.0	25.0

[a] Concentrations of analytes for each solution were selected to give an approximately equal ECD response.
[b] External standard.

Mean values and standard deviations of the RFs were then calculated. The linear range of the calibration curve was established from the calibration standards for each batch of samples. The linear range was defined by those calibration standards whose mean RF value gave a % relative standard deviation less than 30%. At least three points in the calibration curve had to be included for the calibration to be considered acceptable. For each batch of samples, the external standard that showed the fewest interference problems was used for quantitation.

The mean RF values from the calibration standards from a sample batch were used to calculate the concentration of target SOCs, Amt_T, in each sample from that batch as:

$$Amt_T \text{ (ng)} = \frac{A_T \bullet C_{ES} \bullet EV}{A_{ES} \bullet RF_T \bullet F}$$

where EV is the extract volume and F is the fraction of the sample extract that was taken for concentration and analysis.

The average amount of target SOCs found in the field blanks (Amt_{TB}) was then subtracted from the amount found in each sample (Amt_{TS}). Sample concentration (C_T) was calculated by dividing by sample volume:

$$C_T(\text{ng/m}^3) = \frac{Amt_{TS} - Amt_{TB}}{\text{sample volume (m}^3\text{)}}$$

SOC identifications were based on retention times in sample extracts compared to retention times observed for standard solutions. A compound had to be found using both GC columns for a positive identification.

8.3.3.3 Method Performance--

Analysis of standards between batches gave variable RFs. The variability could have been due to changing instrumental response over time, poor stability of the derivatized standards, or variability in standard preparation between batches. Table 8-24 shows the response factors calculated for the derivatized standards prepared with each batch. The data shown in Table 8-24 were determined at the end of sample analysis by reanalyzing all of the standards under a uniform set of GC conditions such that changing instrumental response would not be a factor. Results for the neutral SOCs (i.e., nitrobenzene and hexachlorobenzene) showed fairly constant response factors. Results for the phenols, particularly 2,4,6-trichlorophenol and 2,4,5,6-tetrachlorophenol, showed highly variable response factors between batches suggesting that complete derivatization was not achieved for some batches.

During the analysis for batches 1 to 3, it appeared that excess derivatizing reagent was increasing background contamination in sample extracts; therefore, for batches 4 to 7, the amount of derivatizing reagent used was decreased. These batches showed incomplete derivatization for the less acidic phenols (2,4,6-trichloro- and 2,4,5,6-tetrachlorophenol). Due to poor derivatization and interferences in the standards, quantitative analysis of 2,4,6-trichlorophenol in batches 4 through 7 and 2,4,5,6-tetrachlorophenol in batches 6 through 9 could not be performed. Although quantitation was performed for pentachlorophenol in batches 6 and 7, incomplete derivatization yields may have also effected quantitation here.

Tables 8-25 through 8-28 summarize results for the method blanks, method controls, field blanks, and field controls obtained using GC/ECD analysis.

Results for blank samples show variable background contamination with higher levels found in the field blanks. Except where there were derivatization problems, control samples showed reasonable calculated amounts compared to the amount spiked; however, there was significant

TABLE 8-24. CALCULATED MEAN RESPONSE FACTORS (RFs) FOR DERIVATIZED STANDARDS IN EACH SAMPLE BATCH[a]

	Mean RF ± S.D.				
Batch	Nitrobenzene	2,4,6-Trichlorophenol	2,4,5,6-Tetrachlorophenol	Hexachlorobenzene	Pentachlorophenol
1	0.69 ± 0.17	1.3 ± 0.26	1.8 ± 71	4.8 ± 0.32	7.0 ± 0.55
2	NT[b]	NT	NT	NT	NT
3	NT	NT	NT	NT	NT
4	0.70 ± 0.051	0.19 ± 0.017	2.2 ± 0.003	4.9 ± 0.31	4.3 ± 0.67
5	0.42 ± 0.024	0.10 ± 0.028	1.0 ± 0.045	3.3 ± 0.67	3.8 ± 0.55
6	0.45 ± 0.10	ND[c]	INT[d]	3.4 ± 0.67	1.3 ± 0.2
7[e]	0.42	ND	ND	4.0	1.0
8	0.40 ± 0.09	1.5 ± 0.16	INT	3.0 ± 0.52	3.5 ± 0.6
9	0.99 ± 0.18	2.2 ± 0.43	INT	4.5 ± 0.34	6.4 ± 1.0

[a] Instrument used for testing did not give a good response to Di-2-ethylhexylphthalate.
[b] Standards had gone to dryness during storage and were not analyzed during this evaluation.
[c] Not detected.
[d] Interference in standard.
[e] Only a single standard was analyzed.

TABLE 8-25. **RESULTS FOR METHOD BLANK ANALYSIS FOR SOCs BY GC/ECD**

Batch	Calculated Amounts (ng)					
	Nitrobenzene	2,4,6-Trichlorophenol	2,4,5,6-Tetrachlorophenol	Hexachlorobenzene	Pentachlorophenol	Di-2-ethylhexylphthalate
Test[a]	38	ND[b]	ND	ND	0.8	ND
1[c]	110	4.9	ND	ND	ND	ND
2	110	3.8	8.3	0.67	ND	14
	ND	3.3	9.0	0.98	0	5.0
	ND	1.3	8.8	ND	0.52	42
3	ND	20	2.1	ND	0.69	ND
	ND	9.7	2.1	0.15	ND	67
	ND	11	1.6	ND	ND	ND
4	ND	SU[d]	5.1	ND	3.0	ND
	ND	SU	5.0	ND	ND	ND
	190	SU	26	ND	8.0	ND
5	ND	SU	ND	0.46	1.5	140
	ND	SU	ND	0.98	1.9	160
	ND	SU	ND	1.1	2.8	180
6	170	SU	SU	ND	3.3	37
	99	SU	SU	ND	ND	110
	160	SU	SU	2.1	2.3	60
7	ND	SU	SU	ND	ND	75
	ND	SU	SU	1.2	ND	40
	ND	SU	SU	ND	26	35
8	96	ND	SU	3.9	ND	ND
	80	ND	SU	4.2	ND	ND
	67	11	SU	1.4	ND	51
9	140	ND	SU	ND	ND	210

[a] Peliminary tests on proposed method were performed prior to beginning sample analysis.
[b] Not detected.
[c] Only a single method blank analyzed with batch.
[d] Analysis of standards was unacceptable.

TABLE 8-26. RESULTS FOR METHOD CONTROL ANALYSIS FOR SOCs BY GC/ECD

	Calculated Amounts (ng)[a]					
Batch	Nitrobenzene	2,4,6-Trichlorophenol	2,4,5,6-Tetrachlorophenol	Hexachlorobenzene	Pentachlorophenol	Di-2-ethylhexylphthalate
Amount Spiked (ng)	1084	73	29	18	21	890
Test[b]	750	36	13	10	13	490
	440	31	18	13	18	550
	550	28	10	7.6	13	850
1[c]	1250	8.2	INT[d]	INT	INT	INT
2	310	27	18	4.1	6.2	500
	830	71	26	13	17	1200
	770	74	27	14	17	1200
3	1100	110	26	20	22	1300
	1100	110	23	19	23	1000
	1000	120	28	21	22	1200
4	640	SU[e]	41	12	13	700
	1000	SU	26	16	17	890
	880	SU	85	13	49	720
5	620	SU	29	12	16	890
	780	SU	39	15	20	720
	680	SU	26	12	16	790
6	640	SU	SU	17	23	820
	870	SU	SU	23	32	960
	540	SU	SU	15	21	780
7	1540[f]	SU	SU	28[f]	114[f,g]	2000[f]
	780	SU	SU	17	57[g]	800
	1030	SU	SU	17	44[g]	1100
8	870	ND	INT	20	15	1100
	1100	0.8	INT	21	21	980
	950	ND	INT	24	18	870
9[h]	SL	SL	SL	SL	SL	SL

[a] Not corrected for amount found on blank samples.
[b] Preliminary tests on proposed methods were performed prior to beginning sample analysis.
[c] Only a single method control analyzed with this batch.
[d] Large interference in chromatogram prevented analysis.
[e] Analysis of standards was unacceptable.
[f] Low internal standard area may have resulted in an overestimate of the sample amount.
[g] Poor derivatization of standards may have resulted in an overestimate of the sample amount.
[h] Method control lost for this batch.

TABLE 8-27. RESULTS OF FIELD BLANK ANALYSIS FOR SOCs BY GC/ECD

Sample Code	Batch	Calculated Amounts (ng) Nitrobenzene	2,4,6-Trichlorophenol	2,4,5,6-Tetrachlorophenol	Hexachlorobenzene	Pentachlorophenol	Di-2-ethylhexylphthalate
FB1[a]	Test[b]	50	13	4.8	ND[c]	ND	870
FB2	2	ND	6.3	4.9	1.2	1.4	200
FB3	2	ND	5.1	5.1	1.6	1.2	450
FB4	2	ND	2.1	7.4	3.9	0.56	380
FB5	3	24	ND	6.2	3.9	0.65	280
FB6	4	ND	SU[d]	5.6	ND	6.3	ND
FB7	5	ND	SU	ND	13	6.4	110
FB8	6	120	SU	SU	14	ND	120
FB9	6	180	SU	SU	6.8	ND	200
FB10	3	35	ND	4.8	7.6	ND	79

[a] Field blank designation.

[b] Preliminary tests on proposed methods were performed prior to beginning sample analysis.

[c] Not detected.

[d] Analysis of standards was unacceptable.

TABLE 8-28. RESULTS OF LABORATORY AND FIELD CONTROL ANALYSES FOR SOCs BY GC/ECD

Sample Code	Batch	Calculated Amounts (ng)[a]					
		Nitrobenzene	2,4,6-Trichlorophenol	2,4,5,6-Tetrachlorophenol	Hexachlorobenzene	Pentachlorophenol	Di(2-ethylhexyl)pthalate
Amount Spiked		1084	73	29	18	21	890
<u>Laboratory Controls</u>[b]							
LC1	Test[c]	470	39	29	21	33	970
LC2	Test	490	53	28	23	28	930
LC3	Test	580	44	29	20	29	830
<u>Field Controls</u>							
FC1	Test	770	58	22	14	27	1400
FC2	1	650	39	17	10	4.8	1600
FC3	Test	720	130	37	20	37	800
FC4	Test	650	130	38	18	36	800
FC5	2	600	170	43	22	26	1300
FC6	-	NT[d]	NT	NT	NT	NT	NT
FC7	4	890	SU	26	19	39	540
FC8	5	800	SU	33	27	28	810
FC9	6	NT	NT	NT	NT	NT	NT
FC10	7	1000	SU[e]	SU	37	74	1600
FC11	3	870	130	38	24	21	1400
FC12	7	530	SU	SU	20	41	730
FC13	8	550	ND[f]	SU	18	16	990
FC14	9	NT	NT	NT	NT	NT	NT
FC15	9	440	ND	INT[g]	9.3	8.9	690

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[a] Not corrected for amount found in blank samples.
[b] Laboratory controls were XAD resin spiked with test SOCs then processed and analyzed as with samples.
[c] Preliminary test on proposed methods were performed prior to beginning sample analysis.
[d] Not analyzed.
[e] Analysis of standards was unacceptable.
[f] Not detected.
[g] Large intereference prevented quantitation.

variability with greatest variability seen in the field controls. Given that the blank chromatograms showed high background noise during GC/ECD analysis, controls should have been spiked at a higher level (i.e., 3 to 4 times higher) to allow reliable quantitative analysis to be performed.

SOCs could be identified in the control samples with reasonable confidence based on GC retention times. However, for actual sample extracts, compound identifications were extremely difficult to make. Problems were encountered since there were many peaks along with a high and variable background in the chromatograms of actual air samples. Along with problems resulting from very complex chromatograms, chemical constituents in the sample extracts caused retention times of the internal standards to shift in the sample extracts compared to the standards. Since identifications were based on GC retention times, these shifts precluded positive identification even when two GC columns were used. As a result, SOC data for field samples could not be generated using GC/ECD analysis, and GC/MS analysis was used to reanalyze sample extracts.

8.3.3.4 Gas Chromatography/Mass Spectrometry Analysis--

Results of the GC/ECD analyses indicated that electron capture detection was not selective enough to allow sample quantitation in complex air samples even when a dual-column approach was taken. As an alternative, GC/MS analysis using selected ion monitoring had the potential to provide the required overall selectivity and sensitivity and was used to reanalyze sample extracts.

Prior to GC/MS analysis, each sample extract was spiked with the external standard, tetrachloronaphthalene (TCN), then rederivatized, and concentrated to 0.3 mL. Only those sample extracts that had remained intact during storage (i.e. contained more than 0.2 mL solvent) were reanalyzed. Analysis was then performed using GC/MS in the electron ionization mode. Selected ion monitoring was used for compound identification and quantitation. The instrumental conditions for the analysis of SOCs in sample extracts are shown in Table 8-29.

SOC identifications were based on chromatographic retention times relative to the external standard and on relative abundances of the ion fragments selected for quantitation. Fragment ions were selected based on the analysis of a standard solution spiked with high levels (~100 ng/µL) of the target SOCs. Criteria for fragment ions were identical to those for VVOC analysis. Selected fragment ions are shown in Table 8-30. For nitrobenzene, only m/z 123 and m/z 77 provide sufficient signal to be used for quantitation; however, m/z 77 showed interferences in sample extracts. Therefore, only a single ion was used for quantitation.

Quantitation of SOCs in sample extracts was accomplished using chromatographic peak areas derived from extracted ion profiles. Specifically, relative response factors (RF_T) for each target compound were generated from the analysis of standards prepared at four different concentrations (Table 8-31). For each standard, RFs were calculated as:

$$RF_T = \frac{A_T \bullet C_{QS}}{A_{QS} \bullet C_T}$$

where A_T is the peak area of the quantitation ion for the target SOC and A_{QS} is the peak area for the ion of the external standard, TCN. C_T is the concentration of target compound in the standard sample and C_{QS} is the concentration of the external standard injected.

Mean values and standard deviations of the RFs were then calculated for each target analyte. The calibration curve was considered acceptable if the relative standard deviation for each response factor was less than 30%. During each day of analysis, an additional 100 standard (Table 8-31) was analyzed. If the RF values for this standard were within ±30% of the mean

TABLE 8-29. INSTRUMENTAL OPERATING PARAMETERS FOR SOC ANALYSIS by GC/MS

Parameter	Setting
Gas Chromatograph	
Instrument	Hewlett Packard 5890
Column	30 m x 0.25 mm i.d. DB-5 fused silica capillary column, 0.1 µm film
Temperature program	50°C (1 min hold) to 250°C @ 10°/min (10 min final hold)
Carrier gas (He) flow	1.0 mL/min
Injection Type	Splitless/split (0.5 min)
Injection Temperature	300°C
Interface Temperature	300°C
Mass Spectrometer	
Instrument	Hewlett Packard, Model 5988A
Ionization mode	Electron Ionization Selected Ion Monitoring
Emission current	0.3 mA
Electron multiplier	2600 volts[a]
Source Temperature	200°C

[a] Typical value.

TABLE 8-30. MASS SPECTRAL FRAGMENT IONS SELECTED FOR GC/MS ANALYSIS OF SOCs

Compound	Ions	
	Primary[a]	Secondary[b]
Nitrobenzene	123	77[c]
2,4,6-Trichlorophenol	210	197
2,4,5,6-Tetrachlorophenol	231	246
Hexachlorobenzene	288	290
Pentachlorophenol	265	237
Di-2-ethylhexylphthalate	149	167

[a] Used for quantitation.
[b] Used for confirmation.
[c] Proposed but not used due to interferences in sample extracts.

TABLE 8-31. CALIBRATION STANDARDS FOR GC/MS ANALYSIS OF SOCs

Compound	Concentration (pg/μL)			
	20	100	200	500
Nitrobenzene	27.6	138	276	690
2,4,6-Trichlorophenol	23.2	116	232	580
2,4,5,6-Tetrachlorophenol	28.6	143	286	715
Hexachlorobenzene	24.2	121	242	605
Pentachlorophenol	19.3	96.4	193	482
Di-2-ethylhexylphthalate	106	530	1060	2650
Tetrachloronaphthalene (ES)[a]	182	182	182	182

[a] External standard.

RFs obtained for the calibration curve for the 100 standard, the GC/MS system was considered "in control" and the mean RF values from the calibration samples were used to calculate the amount of target SOCs (Amt_{TS}) in each sample as:

$$Amt_{TS} = \frac{A_T \bullet C_{QS} \bullet EV}{A_{QS} \bullet RF_T \bullet F}$$

where EV is the extract volume and F is the fraction of sample extract that was taken for concentration and analysis.

The average amount of target VOCs found in the blanks (Amt_{TB}) was then subtracted from the amount found in each sample (Amt_{TS}). Concentration of SOCs in air samples (C_T) was calculated by dividing by sample volume:

$$C_T = \frac{Amt_{TS} - Amt_{TB}}{\text{sample volume}}$$

As described previously, control and blank samples were used to assess method performance. Results for analysis of QC samples are given in Tables 8-32 and 8-33. It should be stressed that both the method and field control were spiked at very low levels that are near or possibly below the method quantifiable limits. Results generally show that target SOCs, except for 2,4,6-trichlorophenol, were detected in the method and field controls (Table 8-32) although at somewhat low and variable recoveries. Although reported and included with the results, field control amounts for hexachlorobenzene and pentachlorophenol were sometimes below the estimated instrumental quantifiable limit. Even though all samples were rederivatized, 2,4,6-trichlorophenol was probably not found in control samples because of poor derivatization yields. Low recovery for nitrobenzene is probably due to volatility losses during storage and multiple concentration steps. Results for the method and field blanks showed little background

TABLE 8-32. RESULTS OF SOC CONTROL SAMPLES ANALYZED BY GC/MS

		Amounts Found ± S.D. (ng)[a]	
Compound	Amount Spiked (ng)	Method Controls (n = 13)	Field Controls (n = 7)
Nitrobenzene	1084	377 ± 192	163 ± 194
2,4,6-Trichlorophenol	73	0.07 ± 0.17	0.08 ± 0.16
2,4,5,6-Tetrachlorophenol	29	5.1 ± 2.6	5.0 ± 3.9
Hexachlorobenzene	18	9.8 ± 3.1	5.2 ± 3.3
Pentachlorophenol	21	5.1 ± 2.4	5.4 ± 3.4
Di-2-ethylhexylphthalate	890	142 ± 338 (890 ± 423)[b]	636 ± 571

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[a] Corrected for amount on blank sample, all values including those found below the estimated instrumental quantifiable limit are included.

[b] Calculated with value from one high method blank deleted.

TABLE 8-33. RESULTS OF SOC BLANK SAMPLES ANALYZED BY GC/MS

Compound	Amounts Found ± S.D. (ng)	
	Method Blanks (n = 4)	Field Blanks (n = 4)
Nitrobenzene	ND[a]	ND
2,4,6-Trichlorophenol	ND	ND
2,4,5,6-Tetrachlorophenol	ND	ND
Hexachlorobenzene	ND	ND
Pentachlorophenol	ND	ND
Di-2-ethylhexylphthalate	834 ± 953 (79 ± 74)[b]	265 ± 247

[a] Below the estimated quantifiable limit as shown in Table 8-34.

[b] Calculated with one high method blank value removed.

contamination (Table 8-33) except for di-2-ethylhexylphthalate which was rather high and variable.

Because of the method problems encountered, SOC sample extracts underwent many manipulations prior to GC/MS analysis. These included rederivatization, several sample concentration steps, and GC/ECD analyses of the same extracts at least five times. In addition, sample extracts were stored for an extended period of time while method deficiencies were identified and addressed. Since each of these problems could effect quantitative analyses and since the field controls were spiked near the quantifiable limit, a decision was made not to provide quantitative results for each analyte. Rather, sample values were reported in one of four categories.

- not detected - below the instrumental quantifiable limit
- greater than the instrumental quantifiable limit but less than 5 ng/m^3
- greater than 5 ng/m^3 but less than 50 ng/m^3
- greater than 50 ng/m^3 but less than 100 ng/m^3

To estimate an instrumental quantifiable limit, a minimum peak area of 100 was arbitrarily defined as quantifiable and was applied against the respective response factor. Estimated instrumental quantifiable limits (EIQL) are given in Table 8-34, although it should be kept in mind that EIQLs may be substantially lower than MQLs.

For di-2-ethylhexylphthalate, the method quantifiable limit was estimated to be equal to the standard deviation of the amount found on field blanks. This amount was 247 ng/sample, or 57.4 ng/m^3 if a 4.3 m^3 sample volume is assumed.

Since di-2-ethylhexylphthalate was spiked at higher levels in the controls and was detected at higher levels in the samples, quantitative estimates have been provided; however, it should be kept in mind that

TABLE 8-34. ESTIMATED INSTRUMENTAL QUANTIFIABLE LIMITS (EIQL) FOR SOCS

Compound	EIQL	
	ng/sample[a]	ng/m^3[b]
Nitrobenzene	1.4	0.32
2,4,6-Trichlorophenol	1.6	0.37
2,4,5,6-Tetrachlorophenol	1.4	0.32
Hexachlorobenzene	3.6	0.83
Pentachlorophenol	3.0	0.70
Di-2-ethylhexylphthalate	0.5	0.11

[a] Calculated using primary ion.

[b] Calculated assuming a sample volume of 4.3 m^3.

analytical results here could also be affected by prolonged sample storage, extensive handling, and variable background contamination.

8.3.3.5 Overall Method Evaluation--

The method for the SOCs as originally proposed was a preliminary test method. During sample analysis, multiple problems were encountered due to rather high and variable background interference in GC/ECD chromatograms. This was a significant problem, since extremely low limits of detection were required to detect the target SOCs at ambient levels. The high background combined with very high levels of other ECD sensitive compounds in the sample extracts made it impossible to identify and quantify target SOCs in sample chromatograms.

Our first approach was to analyze extracts using two GC columns with dissimilar phases to provide greater selectivity. However, after multiple analysis of the sample extracts, it was determined that this approach still would not provide the required selectivity.

GC/MS analysis is a technique that offers the requisite selectivity, and it was felt that analysis in the selected ion monitoring mode should provide adequate sensitivity. After preliminary evaluations, sample extracts were analyzed in this mode. Some problems were encountered, primarily due to the long storage time for sample extracts and the multiple manipulations that were performed in an effort to find a suitable analytical method. Thus, the resulting data here is only semiquantitative.

Results of the GC/MS preliminary evaluation and results from sample analysis indicate that the final method developed here can be used for the analysis of the target SOCs in fixed site and personal air samples. Estimated quantitation limits for the method should be ~5 ng/m^3. Preliminary performance data indicate:

- good collection efficiency of target SOCs (12),
- good selectivity for target SOCs,
- low background interferences for all compounds except di-2-ethylhexylphthalate in either blank or ambient air samples,
- good recovery of target SOCs from control samples when sample analysis is performed shortly after preparation and extraction.

Thus, although the overall objectives for the SOC analyses were not met, several useful results were achieved. First, semiquantitative estimates have been made for SOC concentrations in air samples. These data should provide the ARB with at least a preliminary assessment of indoor and personal exposures to SOCs. Second, a method for SOC analysis was developed that should be capable of providing good quality data for future studies.

If the method developed here is to be used in additional studies, further laboratory testing should be performed to optimize the derivatization procedure for chlorophenols. Storage stability for SOCs both on sample cartridges and in sample extracts should also be evaluated. Finally, a pilot study that involves the collection and analysis of actual air samples should be performed.

SECTION 9

STATISTICAL ANALYSIS

9.1 Types of Data

A number of different types of data were available for analysis. These included: (1) VVOC, VOC, and SOC data, (2) the Study Questionnaire (SQ) results, (3) Record of Activities and Environments (RAE) results, and (4) the results of the Time and Activity Diary (TAD). Data for the VVOCs and VOCs included quantitative air concentration estimates by compound, method of collection, type of sample, and an indicator as to whether the air concentration was above the quantifiable limit. For the SOCs, similar information was compiled, but only semiquantitative data were provided on compound concentrations. The Study Questionnaire results gave the general characteristics of the house and the participant. Experiences of the participant during the 24 hours of monitoring were described in the RAE. The type of activity, along with length of time and location associated with each activity, were recorded in the TAD.

9.2 Analysis Methods

The data analysis was conducted to meet the objectives listed in Table 9-1. To achieve these objectives, various analysis methods were required. To characterize the indoor, outdoor, and personal VOC air concentrations and indoor VVOC air concentrations (Objectives 1 and 2), weighted percentages of air concentrations above the quantifiable limit, weighted arithmetic and geometric mean air concentrations and their standard errors, and weighted percentiles for air concentrations were calculated. The various weights used in these analyses are listed in Table 9-2. Weights W1 through W5 were used to expand sample and subsample

TABLE 9-1. RESEARCH OBJECTIVES

1. Provide residential indoor air concentrations for VOCs, SOCs, and VVOCs during a single season in the study area.
2. Provide personal exposure data for VOCs and SOCs during a single season in the study area.
3. Examine whether VOC, SOC, and VVOC exposures are principally from indoor or outdoor microenvironments for this single season study.
4. Examine whether exposures to VOCs and SOCs are primarily from residential or other indoor microenvironments for this single season study.
5. Examine whether residential indoor concentrations correlate to potential sources in the home for this single season study.
6. Examine whether personal exposure correlates to microenvironmental data, time/activity patterns, and potential indoor sources for this single season study.
7. Compare time/activity data for the study population to the rest of the state.
8. Compare selected volatiles data form the proposed study with previous TEAM data for California.

TABLE 9-2. LIST OF SAMPLING WEIGHTS

Weight	Description	Application
W1	= household level sampling weight associated with sample of 130 homes	SQ data, Indoor SOCs[a], Indoor VOCs (canister and Tenax)
W2	= household level sampling weight associated with subsample of 110 homes	Indoor VOCs (Tenax)
W3	= household level sampling weight associated with subsample of 60 homes	Indoor VVOCs
W4	= household level sampling weight associated with subsample of 50 homes	Outdoor SOCs[a]
W5	= household level sampling weight associated with subsample of 50 homes	Outdoor VOCs
W6	= person level sampling weight associated with sample of 130 persons	TAD data
W7	= person level sampling weight associated with subsample of 100 persons	Personal VOCs
W8	= person level sampling weight associated with subsample of 50 persons for whom corresponding outdoor VOC data are available	Personal VOCs

[a] = Not used during analysis.

results to the target population of households; W6, W7 and W8 expand results to the target population of individuals. As described in Section 9.3, SUDAAN software (13) was used to calculate the weighted estimates and their standard errors. Unweighted statistics were calculated for outdoor VVOC air concentrations and SOC indoor, outdoor and personal air concentration estimates.

To study the relationships between personal, indoor, and outdoor air levels (Objectives 3 and 4), unweighted Spearman and Pearson correlations were calculated using SAS[1] procedures. Weighted descriptive statistics (like those indicated above) were also calculated for the ratio of indoor to outdoor VOC air concentrations.

To examine the possible associations between indoor and personal air concentrations and activities (Objectives 5 and 6), exposed and nonexposed groups were formed based on the answers to selected RAE questions. Weighted arithmetic and geometric mean concentrations for personal and indoor air samples were calculated for each group and then tested (using a t-test) to determine if the exposed and nonexposed groups had significantly different means.

The results of the Time and Activity Diary were summarized according to environment and extent of exposure to smoking (Objective 7). The weighted percentage of time in each environment was calculated and compared with a study of the whole state.

[1] SAS is the registered trademark of SAS Institute, Inc., Cary, NC 27511, USA.

Finally, results of the study were compared to results of previous TEAM studies performed in California (Objective 8). Data from winter and summer monitoring in Los Angeles in 1984, winter and summer monitoring in Los Angeles in 1987, summer monitoring in Contra Costa county in 1984, and monitoring from the Woodland pilot study (November, 1988) were included (2, 12).

9.3 Statistical Weighting Methods

Proper analysis of the data collected in a survey based on a probability sample must be performed with consideration for the probabilities of selection and the other features of the sampling design, such as stratification and multistage sampling. Robust statistical inferences are based on the sampling distribution of survey statistics generated by the known probability sampling design.

Thus, the Woodland data were analyzed using SUDAAN, special-purpose software developed for analysis of sample survey data (13). Sampling variances were computed from differences between FSU-level totals within the five first-stage sample selection strata presented in Section 6-3. Statistical analysis weights, defined in Table 9-2, were utilized to weight the observations inversely to their probabilities of selection. Referring to Table 9-2, the first five sample weights (W_1 to W_5) were adjusted to sum to an estimated 15,008 permanent residences in the target portion of the city of Woodland at the time of the survey. The weights for the person-level data bases (W_6-W_8) were adjusted to sum to an estimated 31,470 residents aged 12 or older in these households. Design-unbiased estimates of linear statistics are achieved by weighting the observations in this manner. In addition, the analysis weights were adjusted to partially compensate for survey nonresponse. Complete details of the weighting procedures are provided in Appendix C.

9.4 Quantifiable Limits

Due to process and equipment limitations, compound concentrations below certain levels cannot be quantified; this level is referred to as the method quantifiable limit (MQL). For VOCs and VVOCs, MQLs were calculated using the approach outlined by EPA and used in previous TEAM projects (2). As described in Section 8, MQLs are based on the variability of measured concentrations for low levels of target chemicals spiked into control samples and are intended to reflect overall method performance.

MQLs for VOC samples vary due to differences in collected air volumes during field monitoring. The MQLs for VOCs are summarized by matrix and compound in Tables 9-3 through 9-5 showing the mean, median, minimum and maximum MQL values by sample matrix. Since the range of collected sample volumes was small, the MQLs for VOCs show little variability within each compound. This is shown by the small differences between median and maximum MQLs reported in the tables. Occasionally, pumps that had been modified for low flow VOC sample collection would speed up during monitoring resulting in large sample volumes and correspondingly low MQLs. The minimum MQLs represent this worst case scenario, which occurred in less than 5% of the samples. The MQLs for VOCs also show little difference between matrices as can be seen by comparing results in Tables 9-3 to 9-5.

The MQLs for samples analyzed by the VVOC method remain constant between samples because of the fixed volume of sample used for analysis. The MQLs for VVOCs are also given in Tables 9-3 and 9-4. As shown in the

TABLE 9-3. SUMMARY STATISTICS FOR METHOD QUANTIFIABLE LIMITS (MQL) FOR INDOOR VOC AND VVOC SAMPLES

Compound	N[a]	VOC MQL ($\mu g/m^3$) Mean	Median	Minimum	Maximum	VVOC MQL ($\mu g/m^3$)
1,1,1-Trichloroethane	114	0.11	0.12	0.04	0.15	0.90
1,3-Butadiene	.[b]	.	.	.	.	1.2
1,4-Dioxane	114	0.11	0.12	0.04	0.15	0.60
Acrolein	.	.	.	.	.	2.0
Acrylonitrile	.	.	.	.	.	2.1
Allyl Chloride	113	0.25	0.25	0.08	0.32	1.2
Benzene	114	0.38	0.38	0.12	0.48	1.6
Benzyl Chloride	114	0.22	0.22	0.07	0.28	0.60
Bromomethane	.	.	.	.	.	0.90
Carbon Tetrachloride	114	0.15	0.15	0.05	0.20	0.60
Chlorobenzene	114	0.23	0.23	0.08	0.30	0.60
Chloroform	.	.	.	.	.	1.2
Ethylene Dibromide	114	0.15	0.15	0.05	0.19	0.80
Ethylene Dichloride	.	.	.	.	.	0.80
m,p-Xylene	114	0.35	0.35	0.11	0.44	1.2
Methylene Chloride	.	.	.	.	.	2.8
o-Xylene	114	0.11	0.11	0.04	0.15	0.60
p-Dichlorobenzene	114	0.26	0.26	0.09	0.33	0.50
Perchloroethylene	114	0.26	0.26	0.09	0.33	0.70
Styrene	114	0.18	0.18	0.06	0.23	1.2
Trichloroethylene	114	0.31	0.31	0.10	0.39	0.30
Vinlyidine Chloride	.	.	.	.	.	0.70
Vinyl Chloride	.	.	.	.	.	1.2

[a] N = number of samples.
[b] Not included in VOC analysis.

TABLE 9-4. SUMMARY STATISTICS FOR METHOD QUANTIFIABLE LIMITS (MQL) FOR OUTDOOR VOC AND VVOC SAMPLES

Compound	N[a]	VOC MQL (μg/m^3)				VVOC MQL (μg/m^3)
		Mean	Median	Minimum	Maximum	
1,1,1-Trichloroethane	53	0.11	0.12	0.07	0.14	0.90
1,3-Butadiene	.[b]	.	.	.	.	1.2
1,4-Dioxane	53	0.11	0.12	0.07	0.14	0.60
Acrolein	.	.	.	.	.	2.0
Acrylonitrile	.	.	.	.	.	2.0
Allyl Chloride	53	0.25	0.25	0.16	0.31	1.2
Benzene	53	0.38	0.38	0.24	0.46	1.6
Benzyl Chloride	53	0.21	0.22	0.14	0.26	0.60
Bromomethane	.	.	.	.	.	0.90
Carbon Tetrachloride	53	0.15	0.15	0.10	0.19	0.60
Chlorobenzene	53	0.23	0.23	0.15	0.28	0.60
Chloroform	.	.	.	.	.	1.2
Ethylene Dibromide	53	0.15	0.15	0.09	0.18	0.80
Ethylene Dichloride	.	.	.	.	.	0.80
m,*p*-Xylene	53	0.34	0.35	0.22	0.42	1.2
Methylene Chloride	.	.	.	.	.	2.8
o-Xylene	53	0.11	0.11	0.07	0.14	0.60
p-Dichlorobenzene	53	0.26	0.26	0.16	0.32	0.50
Perchloroethylene	53	0.26	0.26	0.17	0.32	0.70
Styrene	53	0.18	0.18	0.11	0.22	1.2
Trichloroethylene	53	0.30	0.31	0.19	0.37	0.30
Vinlyidine Chloride	.	.	.	.	.	0.70
Vinyl Chloride	.	.	.	.	.	1.2

[a] N = number of samples.
[b] Not included in VOC analysis.

TABLE 9-5. SUMMARY STATISTICS FOR METHOD QUANTIFIABLE LIMITS (MQL) FOR PERSONAL VOC SAMPLES

Compound	Number of Samples	MQL ($\mu g/m^3$)			
		Mean	Median	Minimum	Maximum
1,1,1-Trichloroethane	103	0.11	0.12	0.07	0.14
1,4-Dioxane	103	0.11	0.12	0.07	0.14
Allyl Chloride	103	0.25	0.25	0.15	0.30
Benzene	103	0.37	0.38	0.23	0.45
Benzyl Chloride	103	0.21	0.22	0.13	0.26
Carbon Tetrachloride	103	0.15	0.15	0.09	0.18
Chlorobenzene	103	0.23	0.23	0.14	0.27
Ethylene Dibromide	103	0.15	0.15	0.09	0.18
_m_,_p_-Xylene	103	0.34	0.35	0.21	0.41
_o_-Xylene	103	0.11	0.11	0.07	0.13
_p_-Dichlorobenzene	103	0.26	0.26	0.16	0.31
Perchloroethylene	103	0.26	0.26	0.16	0.31
Styrene	103	0.18	0.18	0.11	0.21
Trichloroethylene	103	0.30	0.31	0.19	0.36

tables, MQLs for VVOC analysis are generally higher than those for VOC analysis.

For the SOCs, sufficient data were not available to generate MQLs. Rather, instrumental quantifiable limits were estimated based on instrumental response to standard solutions. It should be stressed that this approach only evaluates instrumental performance and may provide estimated quantifiable limits that are unrealistically low. Estimated instrumental quantifiable limits (EIQL) are summarized in Table 9-6. For di-2-ethylhexylphthalate, an estimated method quantifiable limit is given.

For VOCs and VVOCs, all sample concentrations including those measured below the MQL, were calculated, entered into the data file, and used during statistical analysis. However, only when the resulting statistic is above the MQL has it been reported. When there was no instrumental signal during analysis, the measured air concentration was reported as zero and this zero value was generally used for statistical analysis. Two exceptions to this were the following: first, since the logarithm of zero is undefined, one-eighth of the MQL was substituted for zero to calculate geometric mean concentrations. Second, one-eighth of the MQL was also used in place of zero to calculate indoor/outdoor concentration ratios.

9.5 Comparison of VOC and VVOC Methods

For the analysis of VOCs, indoor air samples were collected in all homes, but using a combination of monitoring methods. The VOC (Tenax) method was used exclusively in 69 homes, both VOC (Tenax) and VVOC (canister) methods were used in 40 homes, while the VVOC (canister) method was used exclusively in 19 homes. Our study design assumed that the two methods would provide comparable data for the target VOCs and that results

TABLE 9-6. ESTIMATED INSTRUMENTAL QUANTIFIABLE LIMITS (EIQL) FOR SOCs

Compound	EIQL (ng/m^3)[a]
Nitrobenzene	0.32
2,4,6-Trichlorophenol	0.37
2,4,5,6-Tetrachlorophenol	0.32
Hexachlorobenzene	0.83
Pentachlorophenol	0.70
Di-2-ethylhexylphthalate	57.4[b]

[a] Calculated using a mean sample volume of 4.3 m^3.
[b] Estimated method quantifiable limit. Calculated from results of field blank analyses.

from the two sample types could be combined for statistical analysis. Using both monitoring methods in a subset of homes allowed us to test this assumption. Paired VVOC and VOC samples were also collected for a subset of outdoor air samples.

Agreement between the two methods was evaluated based on precision and correlations for measured air concentrations for paired samples collected and analyzed by both methods. During this comparison, only those paired samples where compound concentrations were above the MQL for the VVOC method were used. Precision was evaluated by calculating a relative mean deviation (RMD) for each pair of reported air concentrations. The RMD was calculated as

$$\frac{|C_C - C_T|}{(C_C + C_T)/2}$$

where C_C is calculated canister concentration and C_T is calculated Tenax concentration.

Descriptive statistics summarizing these RMDs are given in Table 9-7. To evaluate further the relationship between Tenax and canister results, Pearson correlations were also calculated. Table 9-7 also shows the computed correlations between measured VOC and VVOC concentrations. Results generally show very good agreement between the two methods.

Although RMD data show precision, they will not indicate bias for the two methods. Additional analyses that measured percent differences between the pairs indicated that levels determined by the VVOC method were higher for benzene, carbon tetrachloride, m,p-xylene, and trichloroethylene. However, for styrene, perchloroethylene, and o-xylene, concentrations

TABLE 9-7. RELATIVE MEAN DEVIATION (RMD) FOR MATCHED VOC AND VVOC DATA

Compound	N[a]	RMD Median	RMD Mean	RMD Minimum	RMD Maximum	Pearson Correlation[b]
1,1,1-Trichloroethane	43	0.08	0.12	0.00	0.60	0.87
Benzene	16	0.17	0.20	0.04	0.51	0.61[c]
Carbon tetrachloride	8	0.16	0.18	0.04	0.36	0.69[c]
_m_,_p_-Xylene	47	0.11	0.15	0.00	0.66	0.87[c]
_o_-Xylene	45	0.13	0.17	0.00	0.75	0.87[d]
_p_-Dichlorobenzene	18	0.27	0.25	0.03	0.92	0.97
Perchloroethylene	6	0.06	0.13	0.01	0.45	0.94[d]
Styrene	4	0.33	0.33	0.29	0.38	0.96[d]
Trichloroethylene	12	0.22	0.21	0.00	0.39	0.95[d]

The RMD was calculated as

$$\frac{|C_C - C_T|}{(C_C + C_T)/2}$$

where: = C_C is calculated canister concentration and C_T is calculated Tenax concentration.

Both concentration values were above the MQL for VVOCs

[a] = Number of pairs.

[b] All values are significantly different from zero at 0.05 level.

[c] VVOC concentrations tended to be higher.

[d] VOC concentrations tended to be higher.

determined by the VOC method tended to be higher. These results are also indicated in Table 9-7.

Table 9-8 compares the results obtained for duplicate VOC and VVOC analysis with the results obtained for paired VOC and VVOC samples. The results show that for most compounds, precision (measured as mean RMD) is as good for paired samples analyzed by the two methods as it is for duplicate samples analyzed using the same method. Only styrene and p-dichlorobenzene show poorer precision compared to the paired duplicate samples.

Results of this comparison suggest that the VOC and VVOC methods are comparable. Based on these results, summary statistics for indoor VOCs have been generated and reported using both data from the two methods independently and from both methods combined.

9.6 Percentage of Concentrations above the Quantifiable Limit

The percentage of samples with air concentrations above the method quantifiable limits (percent quantifiable) was calculated by type of sample and compound. For most of these analyses, sample weights were used. However, for the outdoor VVOC data, only a small subsample of houses were monitored and these results were therefore not weighted. SOC data were not weighted because of the semiquantitative nature of the analytical results.

Percent quantifiable data for VOC and VVOC samples are given in Tables 9-9 and 9-10. VOC indoor air results are provided in Table 9-9 for samples quantitated using the VOC method alone and for samples quantitated using either VVOC or VOC methods. The various weights used are identified in Table 9-2. Note that two different populations are represented, a

TABLE 9-8. MEAN RELATIVE MEAN DEVIATION (RMD) FOR TENAX AND CANISTER DATA

Compound	Tenax/ Canister	Canister/ Canister	Tenax/ Tenax
1,1,1-Trichloroethane	0.12	0.13	0.18
Benzene	0.20	0.21	0.21
Carbon tetrachloride	0.18	0.05	0.21
m,p-Xylene	0.15	0.05	0.20
o-Xylene	0.17	0.06	0.21
p-Dichlorobenzene	0.25	0.14	0.19
Perchloroethylene	0.13	0.20	0.21
Styrene	0.33	0.07	0.19
Trichloroethylene	0.21	0.13	0.23

TABLE 9-9. WEIGHTED PERCENT OF SAMPLES WITH REPORTED AIR CONCENTRATIONS ABOVE THE METHOD QUANTIFIABLE LIMIT

Compound[a]	Percent Quantifiable				
	VOC[b]			VOC/VOCC[c]	VVOC[d]
	Outdoor	Personal	Indoor	Indoor	Indoor
Ubiquitous in personal, indoor, and outdoor air samples					
1,1,1-Trichloroethane	98.6	100.0	99.2	99.4	100.0
Benzene	100.0	100.0	98.3	95.1	74.2
Carbon tetrachloride	97.7	98.5	97.7	98.2	96.2
o-Xylene	100.0	100.0	99.2	99.4	95.5
m,*p*-Xylene	100.0	100.0	99.2	99.4	100.0
Ubiquitous in personal and indoor air samples					
Perchloroethylene	31.5	71.7	55.3	52.2	19.5
Styrene	34.8	100.0	97.6	86.7	15.7
p-Dichlorobenzene	26.4	87.6	76.4	74.1	59.3
*Methylene chloride	NT[e]	NT	NT	NT	66.8
*Acrolein	NT	NT	NT	NT	79.6
Occasionally quantifiable in indoor air samples					
Chloroform	NT	NT	NT	NT	28.2
Trichloroethylene	1.6	36.6	32.8	38	40.3
1,4-Dioxane	0.0	20.2	21.2	27.2	22.4
Rarely or never quantifiable in air samples					
Chlorobenzene	0.0	13.3	9.6	8.0	0.0
*Vinylidine chloride	NT	NT	NT	NT	0.0
Ethylene dichloride	NT	NT	NT	NT	1.3
Ethylene dibromide	0.0	0.0	0.0	0.0	0.0
*Vinyl chloride	NT	NT	NT	NT	0.0
*Allyl chloride	0.0	0.0	0.0	0.0	0.0
*1,3-Butadiene	NT	NT	NT	NT	9.8
*Acrylonitrile	NT	NT	NT	NT	8.8
*Benzyl Chloride	0.0	0.0	0.9	0.7	0.0
*Bromomethane	NT	NT	NT	NT	3.2
Number of Samples	47-48	91-93	102-104	115-125	47-62

a* TAPs not analyzed in previous TEAM studies.
b Samples collected and analyzed by VOC method alone.
c Samples collected and analyzed by the VVOC and VOC methods.
d Samples collected and analyzed by the VVOC method alone.
e Not monitored.

TABLE 9-10. PERCENT OF OUTDOOR VVOC SAMPLES WITH REPORTED AIR CONCENTRATIONS ABOVE THE METHOD QUANTIFIABLE LIMIT

	Percent Quantifiable	
Compound[a]	Outdoor[b]	Indoor[c]
Ubiquitous in indoor and outdoor air samples		
1,1,1-Trichloroethane	100	100
Benzene	70.0	74.2
Carbon tetrachloride	92.3	96.2
o-Xylene	66.7	95.5
m,p-Xylene	91.7	100.0
Ubiquitous in indoor air samples		
p-Dichlorobenzene	16.7	59.3
*Methylene chloride	30.8	66.8
*Acrolein	38.5	79.6
Occasionally quantifiable in indoor air samples		
Perchloroethylene	9.1	19.5
Styrene	0.0	15.7
Chloroform	7.7	28.2
Trichloroethylene	0.0	40.3
1,4-Dioxane	0.0	22.4
Rarely or never quantifiable in air samples		
Styrene	0.0	15.7
*Acrylonitrile	0.0	8.8
*1,3-Butadiene	0.0	9.8
*Allyl chloride	0.0	0.0
*Benzyl chloride	0.0	0.0
*Bromomethane	0.0	3.2
Chlorobenzene	0.0	0.0
Ethylene dibromide	0.0	0.0
Ethylene dichloride	0.0	1.3
*Vinylidine chloride	0.0	0.0
*Vinyl chloride	0.0	0.0
Number of Samples	8-13	47-62

[a] * TAPs not analyzed in previous TEAM studies.
[b] Unweighted statistic.
[c] Weighted statistic.

population of individuals (e.g., for personal samples) and a population of households (e.g., for indoor and outdoor samples). Table 9-10 gives unweighted percent quantifiable values for outdoor VVOC samples.

In both tables, target chemicals were sorted into several classes based on percent quantifiable values. Chemicals with percent quantifiable values greater than 65% were termed ubiquitous, chemicals with percent quantifiable values between 20% and 65% were termed occasionally found. Finally, chemicals with percent quantifiable values less than 20% were termed rarely found.

Referring to Table 9-9, 1,1,1-trichloroethane, benzene, carbon tetrachloride, and the xylenes were ubiquitous in all sample types. Several other chemicals including perchloroethylene, styrene, and p-dichlorobenzenes, were ubiquitous in indoor and personal air samples. Methylene chloride and acrolein were ubiquitous in indoor air samples; personal air samples were not collected for these two compounds. Percent quantifiable values for all five chemicals in outdoor air samples was less than 35%. Several chemicals were occasionally found at quantifiable levels in indoor samples. These included chloroform, trichloroethylene, and 1,4-dioxane. Again percent quantifiable values for these chemicals were greater for indoor and personal air samples compared to outdoor air samples. Finally, there were a number of chemicals that were rarely or never found above the quantifiable limit. Chlorobenzene, vinylidine chloride, ethylene dibromide, ethylene dichloride, vinyl chloride, allyl chloride, 1,3-butadiene, acrylonitrile, benzyl chloride, and bromomethane are included in the group.

A comparison of indoor VOC to VVOC data in Table 9-9 shows similar percent quantifiable values for a number of compounds, including 1,1,1-trichloroethane, carbon tetrachloride, trichloroethylene, the xylenes, and 1,4-dioxane. On the other hand, percent quantifiable values for benzene, perchloroethylene, styrene, and p-dichlorobenzene were lower for indoor VVOC air samples compared to indoor VOC air samples. This is most likely a reflection of the higher MQL values calculated for the VVOC method. Data for the combined VOC/VVOC results are generally similar to the VOC results. Again, where lower percent quantifiable values are reported, this probably reflects higher MQLs for the VVOC method.

The unweighted percent quantifiable values calculated for outdoor VVOC samples are shown in Table 9-10. For comparison purposes, the weighted quantifiable values calculated for indoor VVOC samples are also given. The chemicals that are found in each category on this table are very similar to those seen in Table 9-9. The exceptions to this general pattern are perchloroethylene, styrene and p-dichlorobenzene. As discussed above, these changes are probably a reflection of different quantifiable limits for the VOC and VVOC methods.

For the chemicals that were monitored on this study and the TEAM studies, there were very similar patterns for compound prevalence (i.e., percent quantifiable or percent detectable). However, a number of other chemicals were monitored on this study and are designated on Tables 9-9 and 9-10. These chemicals were selected as targets because they are TAPs of interest to ARB. It is interesting to note that very few of the added TAPs were found above the quantifiable limits in any air samples. Methylene chloride and acrolein are two exceptions. Both chemicals had high percent quantifiable values for indoor air samples, although they were found less frequently in outdoor air samples.

The unweighted percentages of SOC samples that had measured air concentrations above the estimated instrumental quantifiable limit are summarized in Table 9-11. Results show very low percent quantifiable values for all compounds except di-2-ethylhexylphthalate. For this compound, highest percent quantifiable values occurred for automobile samples, followed by personal and indoor air samples. Di-2-ethylhexylphthalate was rarely measured outdoors.

9.7 Weighted Descriptive Statistics

Weighted descriptive statistics for measured air concentrations were calculated. These statistics are presented in Tables 9-12 through 9-16 for indoor, personal, and outdoor VOC air samples and for indoor VVOC air samples. Indoor VOC air concentration statistics are presented using the VOC sample data alone and a combination of the VOC and VVOC sample data. Data are compared between matrices and methods in Table 9-17 using geometric mean concentrations.

For indoor and personal air samples (see Tables 9-12 through 9-15), m,p-xylene, 1,1,1-trichloroethane, benzene, and o-xylene gave the highest geometric mean and median concentrations. On the other hand, highest arithmetic mean concentrations for indoor and personal air samples were calculated for p-dichlorobenzene. This compound shows a skewed concentration distribution with a small portion of the air samples showing very high concentrations. These several high concentration samples tend to elevate the arithmetic mean but not the geometric mean air concentration.

TABLE 9-11. PERCENT OF SOC SAMPLES WITH REPORTED AIR CONCENTRATIONS ABOVE THE ESTIMATED INSTRUMENTAL QUANTIFIABLE LIMIT

	Percent Quantifiable[a]			
Compound	Indoor	Outdoor	Personal	Auto
Nitrobenzene	14.8	10.0	11.1	0.0
2,4,6-Trichlorophenol	NR[b]	NR	NR	NR
2,4,5,6-Tetrachlorophenol	9.1	0.0	11.1	0.0
Hexachlorobenzene	11.4	0.0	0.0	0.0
Pentachlorophenol	31.8	10.0	11.1	12.5
Di-2-ethylhexylphthalate[c]	31.8	13.3	33.3	75.0
Sample Number	88	30	9	8

[a] All results unweighted.
[b] Not reported, compound was not detected in field controls.
[c] Estimated method quantifiable limit used.

TABLE 9-12. WEIGHTED DESCRIPTIVE STATISTICS[a] FOR INDOOR VOC AIR CONCENTRATIONS ($\mu g/m^3$)-- VOC DATA ONLY

		Arith.		Geo.		Percentiles					
Compound	N[b]	Mean	S.E.[c]	Mean	S.E.	10th	25th	50th	75th	90th	Range
1,1,1-Trichloroethane	102	6.5	1.3	3.6	0.33	1.5	1.9	3.0	7.2	11	NQ-94
Benzene	104	4.7	1.1	2.5	0.29	0.92	1.3	2.2	5.1	8.3	NQ-130
Carbon Tetrachloride	103	0.56	0.03	0.48	0.03	0.36	0.40	0.49	0.55	0.99	NQ-2.4
Trichloroethylene	104	0.68	0.18	NQ[d]	-	NQ	NQ	NQ	0.48	2.0	NQ-9.3
Perchloroethylene	104	1.1	0.36	0.34	0.05	NQ	NQ	0.28	0.80	2.3	NQ-11
Styrene	104	2.8	1.1	1.0	0.15	0.29	0.47	0.95	2.0	3.9	NQ-140
p-Dichlorobenzene	104	18	3.9	1.2	0.31	NQ	NQ	1.1	4.3	36	NQ-300
o-Xylene	104	3.0	0.34	2.0	0.20	0.74	1.1	1.9	4.1	6.5	NQ-19
m,p-Xylene	104	6.3	0.74	4.1	0.45	1.5	2.2	3.8	8.0	13	NQ-36
1,4-Dioxane	104	NQ	-	NQ	-	NQ	NQ	NQ	NQ	0.25	NQ-3.4

[a] Represents the estimated 15,008 permanent residences in Woodland target area at the time of the survey.
[b] Number of observations.
[c] S.E.=Standard error.
[d] NQ=Not quantifiable (below the method quantifiable limit).

TABLE 9-13. WEIGHTED DESCRIPTIVE STATISTICS[a] FOR INDOOR VOC AIR CONCENTRATIONS ($\mu g/m^3$)--VOC AND VVOC DATA COMBINED

		Arith.		Geo.		Percentiles					
Compound	N[b]	Mean	S.E.[c]	Mean	S.E.	10th	25th	50th	75th	90th	Range
1,1,1-Trichloroethane	115	7.1	1.6	3.7	0.37	1.5	1.9	3.2	6.7	12	NQ-94
Benzene	124	4.5	0.92	2.5	0.28	0.84	1.5	2.2	4.8	9.4	NQ-130
Carbon Tetrachloride	124	0.64	0.03	0.58	0.03	0.39	0.49	0.59	0.72	0.94	NQ-2.6
Trichloroethylene	125	0.65	0.14	NQ[d]	-	NQ	NQ	NQ	0.56	1.9	NQ-9.3
Perchloroethylene	124	1.44	0.55	0.36	0.06	NQ	NQ	NQ	0.73	2.3	NQ-30
Styrene	123	2.40	0.87	0.78	0.10	NQ	0.33	0.74	1.8	3.8	NQ-140
p-Dichlorobenzene	125	16	3.5	1.1	0.28	NQ	0.26	1.1	3.6	28	NQ-300
o-Xylene	125	3.3	0.49	1.9	0.16	0.74	1.1	1.8	3.3	5.5	NQ-49
m,p-Xylene	125	7.4	1.2	4.4	0.40	1.6	2.5	4.1	7.6	12	NQ-120
1,4-Dioxane	125	1.4	0.95	NQ	-	NQ	NQ	NQ	0.15	0.65	NQ-140

[a] Represents the estimated 15,008 permanent residences in Woodland target area at the time of the survey.
[b] N=Number of observations.
[c] S.E.=Standard error.
[d] NQ=Not quantifiable (below the method quantifiable limit).

TABLE 9-14. WEIGHTED DESCRIPTIVE STATISTICS[a] FOR INDOOR VVOC AIR CONCENTRATIONS ($\mu g/m^3$)

		Arith.		Geo.		Percentiles					
Compound	N[b]	Mean	S.E.[c]	Mean	S.E.	10th	25th	50th	75th	90th	Range
Chloroform	62	NQ[d]	-	NQ	-	NQ	NQ	NQ	1.2	2.7	NQ -4.0
1,1,1-Trichloroethane	50	6.0	1.8	3.5	0.53	1.1	1.9	3.1	5.4	9.1	0.93-77
Benzene	55	4.0	0.74	2.5	0.47	NQ	NQ	2.8	5.3	10	NQ-18
Carbon Tetrachloride	62	0.85	0.06	0.81	0.03	0.67	0.71	0.77	0.86	0.97	NQ-2.9
Trichloroethylene	62	0.54	0.11	NQ	-	NQ	NQ	NQ	0.57	0.96	NQ-7.2
p-Dichlorobenzene	62	12	7.9	1.0	0.29	NQ	NQ	0.99	2.4	11	NQ-260
o-Xylene	62	3.5	1.2	1.8	0.20	0.73	1.1	1.6	2.5	5.2	NQ-49
m,*p*-Xylene	62	9.3	3.1	5.0	0.60	2.0	2.9	4.6	7.0	11	1.4-120
1,4-Dioxane	62	2.4	1.6	NQ	-	NQ	NQ	NQ	NQ	1.5	NQ-140
Methylene Chloride	61	83	29	9.6	3.2	NQ	NQ	15	57	160	NQ-1700
Acrolein	59	7.1	1.7	4.1	1.0	1.2	2.2	4.1	9.0	21	NQ-29

[a] Represents the estimated 15,008 permanent residences in Woodland target area at the time of the survey.
[b] N=Number of observations.
[c] S.E.=Standard error.
[d] NQ=Not quantifiable (below the method quantifiable limit).

TABLE 9-15. WEIGHTED DESCRIPTIVE STATISTICS[a] FOR PERSONAL VOC AIR CONCENTRATIONS ($\mu g/m^3$)

		Arith.		Geo.		Percentiles					
Compound	N[b]	Mean	S.E.[c]	Mean	S.E.	10th	25th	50th	75th	90th	Range
1,1,1-Trichloroethane	92	22	5.6	6.2	0.92	1.4	2.2	4.2	14	36	1.1-360
Benzene	93	5.0	0.80	3.4	0.32	1.3	2.1	3.1	5.4	8.9	0.35-46
Carbon Tetrachloride	91	0.68	0.12	0.51	0.04	0.36	0.40	0.45	0.58	0.83	NQ-6.0
Trichloroethylene	93	2.3	1.1	NQ[d]	-	NQ	NQ	NQ	0.69	3.4	NQ-150
Perchloroethylene	93	1.6	0.40	0.48	0.08	NQ	NQ	0.36	0.89	3.0	NQ-30
Styrene	93	2.4	0.73	1.3	0.09	0.33	0.72	1.2	2.0	3.3	0.20-48
p-Dichlorobenzene	93	21	4.5	2.3	0.54	NQ	0.50	1.5	7.8	88	NQ-180
o-Xylene	93	4.5	0.64	3.0	0.30	1.0	1.9	3.0	4.5	9.4	0.37-44
m,p-Xylene	93	9.3	1.3	6.2	0.64	2.2	3.8	5.9	11	18	0.79-84
1,4-Dioxane	93	0.24	0.12	NQ	-	NQ	NQ	NQ	NQ	0.25	NQ-16

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[a] Represents the estimated 31,470 residents age 12 or older in households in Woodland.

[b] N=Number of observations.

[c] S.E.=Standard error.

[d] NQ=Not quantifiable (below the method quantifiable limit).

TABLE 9-16. WEIGHTED DESCRIPTIVE STATISTICS FOR OUTDOOR VOC AIR CONCENTRATIONS (μg/m^3)

		Arith.		Geo.		Percentiles					
Compound	N[b]	Mean	S.E.[c]	Mean	S.E.	10th	25th	50th	75th	90th	Range
1,1,1-Trichloroethane	48	1.5	0.10	1.3	0.11	1.0	1.2	1.3	1.5	1.9	NQ-3.7
Benzene	48	1.2	0.89	1.1	0.08	0.67	0.83	1.1	1.4	1.9	0.46-3.0
Carbon Tetrachloride	48	0.52	0.03	0.48	0.04	0.41	0.42	0.49	0.59	0.66	NQ-1.5
Perchloroethylene	47	0.53	0.29	NQ[c]	-	NQ	NQ	NQ	0.26	0.59	NQ-6.6
Styrene	48	0.24	0.07	NQ	-	NQ	NQ	NQ	0.21	0.70	NQ-1.9
p-Dichlorobenzene	48	0.30	0.08	NQ	-	NQ	NQ	NQ	0.27	0.94	NQ-2.1
o-Xylene	48	0.92	0.07	0.82	0.07	0.45	0.53	0.77	1.2	1.5	0.26-2.3
m,*p*-Xylene	48	1.8	0.15	1.6	0.14	0.89	1.0	1.5	2.3	2.9	0.48-4.3

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[a] Represents the estimated 31,470 residents age 12 or older in households in Woodland.

[b] N=Number of observations.

[c] S.E.=Standard error.

[d] NQ=Not quantifiable (below the method quantifiable limit).

TABLE 9-17. WEIGHTED GEOMETRIC MEAN AIR CONCENTRATIONS FOR VOCs AND VVOCs.

	INDOOR						PERSONAL		OUTDOOR	
	VVOC		VVOC/VOC		VOC					
Compound	Mean	S.E.[a]	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Chloroform	NQ[b]	-	NT[c]	-	NT	-	NT	-	NT	-
1,1,1-Trichloroethane	3.5	0.53	3.7	0.37	3.6	0.33	6.2	0.92	1.3	0.11
Benzene	2.5	0.47	2.5	0.28	2.5	0.29	3.4	0.32	1.1	0.08
Carbon Tetrachloride	0.81	0.03	0.58	0.03	0.48	0.03	0.51	0.04	0.48	0.04
Trichloroethylene	NQ	-	NQ	-	NQ	-	NQ	-	NQ	-
Perchloroethylene	NQ	-	0.36	0.06	0.34	0.05	0.48	0.08	NQ	-
Styrene	NQ	-	0.78	0.10	1.0	0.15	1.3	0.09	NQ	-
p-Dichlorobenzene	1.0	0.29	1.1	0.28	1.2	0.31	2.3	0.54	NQ	-
o-Xylene	1.8	0.20	1.9	0.16	2.0	0.20	3.0	0.30	0.82	0.07
m,p-Xylene	5.0	0.60	4.4	0.40	4.1	0.45	6.2	0.64	1.6	0.14
1,4-Dioxane	NQ	-	NQ	-	NQ	-	NQ	-	NQ	-
Methylene Chloride	9.6	3.2	NT	-	NT	-	NT	-	NT	-
Acrolein	4.1	1.0	NT	-	NT	-	NT	-	NT	-
Sample Size Range	50-62		115-125		102-104		91-93		47-48	

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[a] S.E.=Standard error.

[b] NQ=Not quantifiable (below the method quantifiable limit).

[c] NT=Not tested.

For outdoor air samples (see Table 9-16), m,p-xylene, 1,1,1-trichloroethane, benzene, and o-xylene showed the highest concentrations in that order for all computed statistics. Outdoor air concentrations were generally lower than indoor or personal air concentrations. In addition, the range of measured concentrations was smaller for outdoor air samples compared to the other sample types. For example, for 1,1,1-trichloroethane in outdoor air samples, the ratio of air concentration at the 90th percentile to that at the 10th percentile was 1.9. For indoor and personal air samples the ratio was 7.3 and 25.7, respectively. Similar trends can be seen for the other chemicals.

Figure 9-1 graphically summarizes the median air concentration data for 1,1,1,-trichloroethane, benzene, and the xylenes by sample matrix. As can be seen in the figure, personal air samples showed the highest concentrations followed by indoor air then outdoor air samples. This trend suggests that personal activity may provide a substantial contribution to personal exposure. Alternately, high exposures in other indoor microenvironments could be responsible for elevated VOC levels.

Two VVOCs, methylene chloride and acrolein, also showed high indoor air concentrations (Table 9-14). Like p-dichlorobenzene, methylene chloride showed a skewed distribution with very high measured concentrations at the 75th (57 $\mu g/m^3$) and 90th (160 $\mu g/m^3$) percentiles. Reported air concentrations for methylene chloride should, however, be viewed with some caution. Although the field blanks (n = 13) and QL samples (n = 8) for methylene chloride showed very low contamination levels, two of the field controls showed high background. This result in

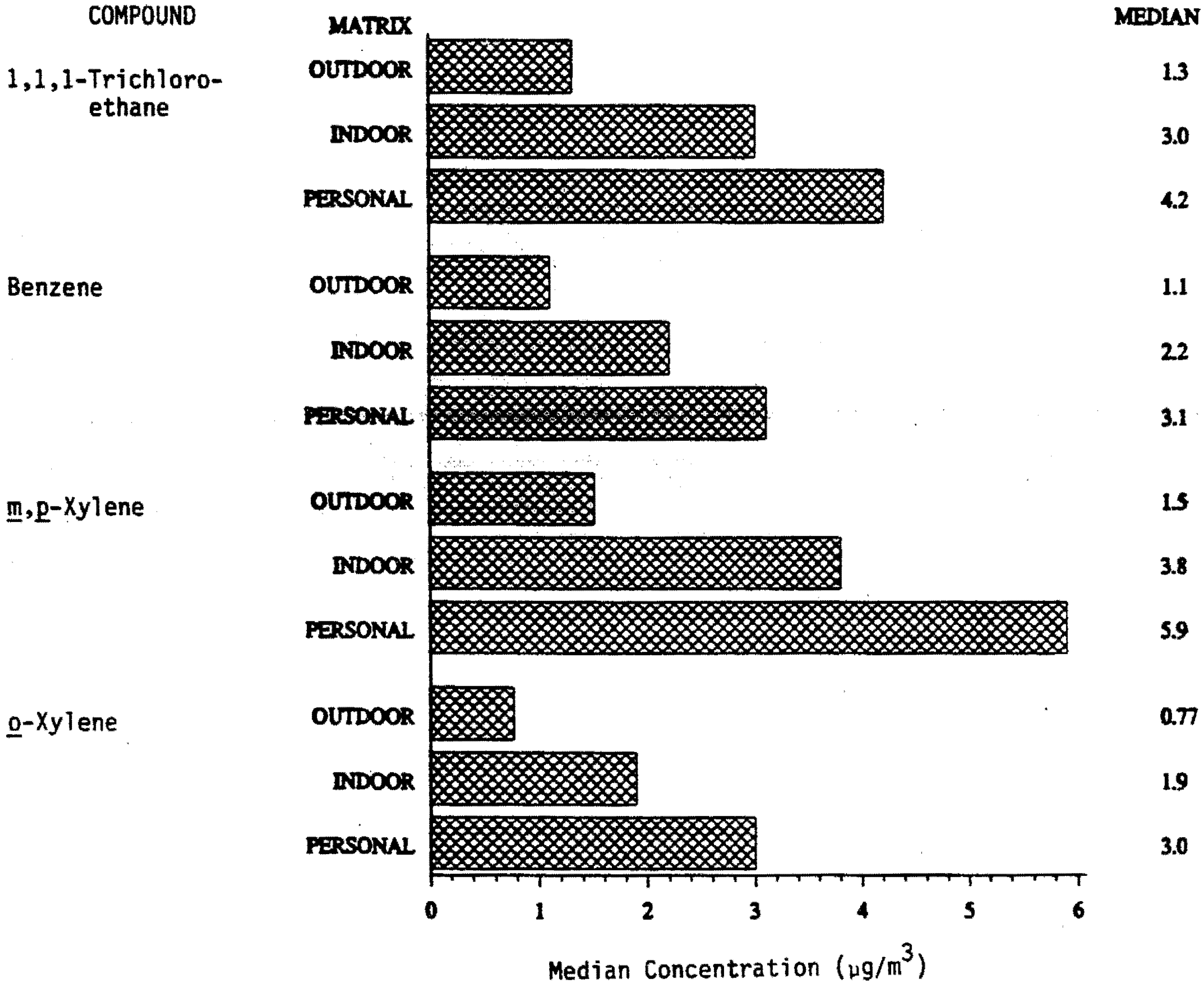

Figure 9-1. Comparison of Median VOC Concentrations (μg/m^3).

the field controls was most likely due to contamination while preparing the controls and thus field sample values should not be affected. Although less likely, this could also have been a result of random contamination during analysis, which could then result in high concentrations found in field samples.

Good agreement is seen between the indoor air concentration statistics generated for samples using the VOC method alone (Table 9-12) and the combined VOC/VVOC data (Table 9-13). These results again suggest that the two monitoring methods are comparable under field conditions.

9.8 Additional Descriptive Statistics

For those VOC and VVOC compounds where less than 20 percent of the samples had quantifiable concentrations, unweighted descriptive statistics were computed. These statistics, shown in Table 9-18, include the number of samples that had quantifiable concentrations, the unweighted mean of the quantifiable air concentrations, and the maximum air concentration.

For the subsample of homes with outdoor VVOC monitoring, unweighted descriptive statistics are given for samples with at least 20 percent quantifiable (see Table 9-19). In general, these outdoor air concentrations were low in comparison with the indoor levels (Table 9-14). Methylene chloride showed the highest levels (mean 15 $\mu g/m^3$), but this may have been caused by a few high values, and as discussed earlier, could have been a result of sample contamination.

Unweighted concentration statistics are given in Table 9-20 for di-2-ethylhexylphthalate. Results show highest concentrations in automobile air followed by indoor and personal air. Outdoor air samples

TABLE 9-18. DESCRIPTIVE AIR CONCENTRATION STATISTICS ($\mu g/m^3$) FOR COMPOUNDS WITH LESS THAN 20% QUANTIFIABLE VALUES

Type	Compound	Total Sample Size	Estimated Percent Quantifiable[a]	Summary of Measured Concentrations		
				Number Measurable	Unweighted Mean Conc. ($\mu g/m^3$)	Maximum Conc. ($\mu g/m^3$)
VVOC Indoor	1,3-Butadiene	62	9.8	5	4.7	10
	Acrylonitrile	47	8.8	4	9.1	27
	Bromomethane	62	3.2	2	2.0	2.8
	Ethylene Dichloride	59	1.3	1	0.95	0.95
	Perchloroethylene	60	19.5	13	4.8	30
	Styrene	55	15.7	7	5.4	14
VVOC Outdoor	Chloroform	13	7.7[b]	1	1.2	1.2
	p-Dichlorobenzene	12	16.7[b]	2	1.0	1.1
	Perchloroethylene	11	9.1[b]	1	0.92	0.92
VOC Indoor	Benzyl Chloride	104	0.9	1	0.85	0.85
	Chlorobenzene	104	9.6	10	0.31	0.52
VOC Outdoor	Trichloroethylene	48	1.6	1	0.25	0.25
VOC Personal	Chlorobenzene	92	13.3	13	0.47	0.95

[a] Based on weighted data except where noted.
[b] Based on unweighted data due to small sample size.

TABLE 9-19. DESCRIPTIVE STATISTICS FOR OUTDOOR AIR VVOC CONCENTRATIONS ($\mu g/m^3$)

Compound	N[a]	Outdoor Concentration ($\mu g/m^3$) Mean	Minimum	Median	Maximum	Indoor[b] Concentration ($\mu g/m^3$)
1,1,1-Trichloroethane	8	1.5	0.91	1.4	2.6	6.0
Acrolein	13	2.0	NQ[c]	NQ	8.6	7.1
Benzene	10	1.7	NQ	1.8	3.4	4.0
Carbon tetrachloride	13	0.74	NQ	0.76	0.95	0.85
m,p-Xylene	12	2.0	NQ	1.8	3.2	9.3
Methylene chloride	13	15	NQ	NQ	110	83
o-Xylene	12	0.76	NQ	0.74	1.2	3.5

[a] N = Number of samples.
[b] Arithmetic mean concentration.
[c] NQ = Not Quantifiable (concentration below the MQL).

TABLE 9-20. UNWEIGHTED SUMMARY STATISTICS FOR DI-2-ETHYLHEXYLPHTHALATE CONCENTRATIONS (ng/m^3)

	Concentration (ng/m^3)			
	Indoor Air	Outdoor Air	Personal Air	Automobile Air
Number of samples	88	30	9	8
Arithmetic Mean ±S.D.	59±99	NQ[a]	86±110	190±190
Percentiles				
25th	NQ	NQ	NQ	82
50th	NQ	NQ	NQ	130
75th	81	NQ	160	240
Maximum	640	140	320	640

[a] Below the estimated instrumental quantifiable limit.

were generally below the estimated method quantitation limit. Table 9-21 summarizes concentration data for the other SOCs giving the percentage of samples within specified concentration ranges. Results show that even when target SOCs were detected in air samples, they were at very low levels (<5 ng/m^3).

9.9 Comparisons Between Matrices

As a first step in studying relationships between VOC air concentrations in the various matrices, Spearman and Pearson correlations were computed. Correlation is a measure of the linear relationship between two variables, with 1.00 or -1.00 symbolizing perfect correlation (i.e., one variable can be expressed as an exact linear function of the other). If there is no relationship between the two variables, then the correlation will be close to 0.00. Spearman's rank correlation uses the ranks of the concentrations, which tends to counteract the effects of extreme values or skewness. The Pearson product-moment correlation is calculated using the actual concentrations and may be influenced by the presence of such extreme values in the data.

Table 9-22 shows Spearman rank correlations for all samples while Table 9-23 shows them for pairs of samples for which both air concentrations were above the quantifiable limit. Except for perchloroethylene (all amounts) and p-dichlorobenzene (quantifiable amounts), the correlations between personal and indoor air concentrations were higher than correlations between indoor and outdoor air concentrations. The highest correlations between indoor and personal air concentrations (quantifiable amounts only) were for styrene (0.72), benzene (0.63), perchloroethylene

TABLE 9-21. PERCENTAGE OF SAMPLES WITH TARGET SOCs MEASURED IN A SPECIFIED CONCENTRATION RANGE

Compound	Percentages of Samples			
	Less Than EIQL[a]	>EIQL to <5 ng/m^3	>5 ng/m^3 to <50 ng/m^3	>50 ng/m^3 to <100 ng/m^3
Indoor Air (n=88)[b]				
Nitrobenzene	85.2	14.8	0	0
2,4,5,6-Tetrachlorophenol	90.9	9.1	0	0
Hexachlorobenzene	100	0	0	0
Pentachlorophenol	88.6	11.4	0	0
Outdoor Air (n=30)				
Nitrobenzene	90	10	0	0
2,4,5,6-Tetratchlorophenol	100	0	0	0
Hexachlorobenzene	100	0	0	0
Pentachlorophenol	90	10	0	0
Personal Air (n=9)				
Nitrobenzene	88.9	0	0	11.1
2,4,5,6-Tetratchlorophenol	88.9	11.1	0	0
Hexachlorobenzene	100	0	0	0
Pentachlorophenol	88.9	11.1	0	0
Automobile (n=8)				
Nitrobenzene	100	0	0	0
2,4,5,6-Tetratchlorophenol	100	0	0	0
Hexachlorobenzene	100	0	0	0
Pentachlorophenol	88.5	12.5	0	0

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[a] Estimated instrumental quantifiable limit.

[b] Number of samples.

TABLE 9-22. SPEARMAN RANK CORRELATIONS BETWEEN VOC SAMPLES FOR ALL AMOUNTS

	Personal with Indoor		Indoor with Outdoor	
Compound	N[a]	Corr.	N	Corr.
1,1,1-Trichloroethane	87	0.36[b]	47	0.05
1,4-Dioxane	90	0.32[b]	-	-
Benzene	90	0.65[b]	47	0.36[b]
Carbon Tetrachloride	87	0.21	47	0.05
m,*p*-Xylene	90	0.56[b]	47	0.37[b]
o-Xylene	90	0.58[b]	47	0.36[b]
p-Dichlorobenzene	90	0.72[b]	47	0.58[b]
Perchloroethylene	90	0.50[b]	46	0.58[b]
Styrene	90	0.73[b]	47	0.27
Trichloroethylene	90	0.71[b]	-	-

[a] N = Number of samples.
[b] Significantly greater than zero at the 0.05 level.

TABLE 9-23. SPEARMAN RANK CORRELATIONS BETWEEN VOC SAMPLES FOR QUANTIFIABLE AMOUNTS ONLY

	Personal with Indoor		Indoor with Outdoor	
Compound	N[a]	Corr.	N	Corr.
1,1,1-Trichloroethane	86	0.36[b]	46	0.11
1,4-Dioxane	8	0.71[b]	-	-
Benzene	88	0.63[b]	47	0.36[b]
Carbon Tetrachloride	82	0.22[b]	44	0.08
m,*p*-Xylene	89	0.55[b]	47	0.37[b]
o-Xylene	89	0.57[b]	47	0.36[b]
p-Dichlorobenzene	66	0.59[b]	10	0.62
Perchloroethylene	44	0.73[b]	10	0.35
Styrene	88	0.72[b]	17	0.14
Trichloroethylene	27	0.40[b]	-	-

[a] N = Number of samples.
[b] Significantly greater than zero at the 0.05 level.

(0.73), and 1,4-dioxane (0.71). The highest correlations between indoor and outdoor air concentrations (quantifiable amounts only) that were significantly different than zero at the 0.05 level were benzene and the xylenes. These latter correlations could be positive due to the ubiquitous nature of the aromatic VOCs. Except for carbon tetrachloride (all amounts), all correlations between personal and indoor air were significantly greater than zero at the 0.05 level. The Pearson correlations for indoor with personal air concentrations and indoor with outdoor air concentrations for all amounts and quantifiable amounts only are given in Appendix D, Tables D-1 and D-2.

Correlations between compounds within a matrix are also calculated and are given in Appendix D (Tables D-3 to D-18). Data for the highest Spearman rank correlations (quantifiable amount only) are summarized in Table 9-24. As the results show, correlations were high for certain chemicals in all media. For example, benzene and the xylene isomers showed correlations greater than the 0.80 for microenvironmental samples (indoor and outdoor air) and correlations greater than 0.70, for personal air samples. Measured concentrations for styrene also showed some correlation with benzene and the xylenes in indoor and personal air samples. Again the highest correlation was for indoor air samples. Finally, 1,1,1-trichloroethane and 1,4-dioxane gave a very high correlation coefficient (0.90) in personal air samples; some correlation was also seen in indoor air samples. High correlations may suggest a common source for different chemicals. This is presumably the case between benzene and the xylenes. The same may be true for these aromatic chemicals and styrene. Three percent of

TABLE 9-24. SPEARMAN RANK CORRELATION BETWEEN VOC COMPOUNDS (QUANTIFIABLE AMOUNTS ONLY)

Compound	Correlation Coefficient[a]		
	Personal Air	Indoor Air	Outdoor Air
Benzene/*m*,*p*-xylene	0.76	0.87	0.88
Benzene/*o*-xylene	0.71	0.84	0.86
m,*p*-Xylene/*o*-xylene	0.91	0.98	0.99
Styrene/benzene	0.51	0.62	NS[b]
Styrene/*m*,*p*-xylene	0.54	0.68	NS
Styrene/*o*-xylene	0.51	0.66	NS
1,1,1-Trichloroethane/1,4-dioxane	0.90	0.60	NS

[a] Correlations significantly greater than zero at the 0.05 level.

[b] Correlation was not significantly greater than zero at the 0.05 level.

1,4-dioxane is added to most grades of 1,1,1-trichloroethane as an antioxidant, which could be responsible for the strong correlation between these two chemicals.

To further analyze the relationship between indoor and outdoor air quality, the ratio of indoor to outdoor air concentrations was calculated for each compound. Table 9-25 gives the statistics summarizing the indoor/outdoor air concentration ratios for all samples, while Table 9-26 gives ratios only if both concentrations were quantifiable. With the exception of carbon tetrachloride, the indoor levels were usually higher than the outdoor levels, indicated by the predominance of values greater than one. For carbon tetrachloride, all levels were near the MQL. Styrene and p-dichlorobenzene had the highest indoor/outdoor air concentration ratios, suggesting that these chemicals are predominantly from indoor sources.

9.10 Analysis of Questionnaire Data

Selected questions from the Record of Activities and Environments were analyzed to determine if certain activities were related to elevated levels of exposure. For each question, arithmetic and geometric mean air concentrations and their standard errors were determined for two groups based on questionnaire data: exposed individuals or homes and non-exposed individuals or homes. Pairwise t-tests were then performed to test for group difference using geometric or arithmetic mean air concentrations. Since multiple activities were performed by each individual and in each environment, only those activities that are a very strong source for a

TABLE 9-25. WEIGHTED DESCRIPTIVE STATISTICS FOR THE RATIO OF INDOOR TO OUTDOOR VOC AIR CONCENTRATIONS

Compound	N[a]	Geo. Mean	Geo. S.E.[b]	Percentiles 10th	Percentiles 25th	Percentiles 50th	Percentiles 75th	Percentiles 90th
1,1,1-Trichloroethane	47	2.8	0.42	0.94	1.4	2.1	4.7	8.0
Benzene	47	2.1	0.38	1.0	1.3	1.8	3.7	6.7
Carbon tetrachloride	47	1.0	0.11	0.55	0.76	0.98	1.2	2.3
Perchloroethylene	46	1.9	0.40	0.52	0.81	1.7	3.9	9.5
Styrene	47	8.5	2.4	2.0	3.0	6.6	28	50
p-Dichlorobenzene	47	7.8	3.1	0.72	2.9	8.1	31	69
o-Xylene	47	2.5	0.36	1.0	1.5	2.4	3.6	6.1
m,*p*-Xylene	47	2.5	0.43	1.0	1.6	2.2	4.3	7.3

[a] N = Number of observations.
[b] S.E. = Standard error.

TABLE 9-26. WEIGHTED SUMMARY DESCRIPTIVE FOR THE RATIO OF INDOOR TO OUTDOOR VOC AIR CONCENTRATIONS IF BOTH QUANTIFIABLE

		Geo.		Percentiles				
Compound	N[a]	Mean	S.E.[b]	10th	25th	50th	75th	90th
1,1,1-Trichloroethane	46	2.6	0.34	0.94	1.4	2.1	4.1	8.0
Benzene	47	2.1	0.38	1.0	1.3	1.8	3.7	6.7
Carbon tetrachloride	44	1.0	0.07	0.63	0.78	0.98	1.2	1.9
Perchloroethylene	10	1.8	0.52	0.70	0.92	1.7	2.1	17
Styrene	17	4.1	1.7	0.92	1.4	2.9	13	28
p-Dichlorobenzene	10	6.9	5.3	0.35	1.7	8.5	31	75
o-Xylene	47	2.4	0.36	1.0	1.5	2.4	3.6	6.1
m,*p*-Xylene	47	2.5	0.43	1.0	1.6	2.2	4.3	7.3

[a] N = Number of observations.
[b] S.E. = Standard error.

particular chemical would be expected to show significant differences between the exposed and non-exposed groups.

Data relating indoor air concentrations to questionnaire results are summarized in Table 9-27. Calculated mean air concentrations are given for exposed and nonexposed groups for those chemicals that had higher air concentrations for the exposed group. Air concentrations that are significantly higher at the 0.05 level are shown in the table. The table also indicates which chemicals would be expected to have higher air concentrations for the exposed group based on chemical composition or emissions and which chemicals have been reported at higher concentrations for the exposed group on previous TEAM studies (2). Table 9-28 gives similar results for personal air concentrations. Several observations can be made based on information in the tables.

1. Many of the common VOCs have higher mean concentrations calculated for the exposed vs. the non-exposed groups. Although the results are often not significant at the 0.05 level, an overall pattern can be observed that may suggest a source/concentration relationship.

2. The xylenes and styrene are the VOCs most often found at elevated concentrations for the exposed groups. Benzene and 1,1,1-trichloroethane also showed elevated air concentrations for many of the exposed groups. Again, these results are often not significant, but they may suggest potential exposure sources.

3. Air conditioning appeared to have had the greatest effect on indoor VOC concentrations. 1,1,1-Trichloroethane, benzene, styrene, and the xylenes all had significantly higher indoor concentrations (at the 0.05 level) in homes that used air conditioning compared to those that did not. This may be a result of lower air exchange rates in air conditioned homes.

4. Use of petroleum-based products, exposure to vehicle exhausts, and exposure to gasoline appeared to have the greatest impact on personal air concentrations. The xylenes, benzene, and 1,1,1-trichloroethane often had significantly higher mean air concentrations at the 0.05 level for individuals in these exposure groups.

TABLE 9-27. WEIGHTED MEANS FOR INDOOR VOC AIR CONCENTRATIONS BY SELECTED VARIABLES

Exposure[a]	Chemicals with Higher Concentration for Exposed Group	Air Concentrations ($\mu g/m^3$) Arith. Mean Exposed	Arith. Mean Not Exposed	Geo. Mean Exposed	Geo. Mean Not Exposed
Smoking					
Heavy Smoking >20 cigarettes per day (15/64)	Benzene[b,c]	5.5	3.6	3.6	2.3
	Trichloroethylene	1.2	0.60	NQ[d]	NQ
	Perchloroethylene	1.9	0.58	0.31	0.30
	p-Dichlorobenzene	34	16	1.5	0.93
	o-Xylene	3.6	3.3	2.5	2.0
	m,p-Xylene	8.0	6.5	5.6	4.0
Consumer Products					
Paint (24/80)	1,1,1-Trichloroethane[b]	8.0	6.1	3.5	3.7
	Styrene[c]	6.8	1.7	1.0	1.0
	o-Xylene[b,c]	4.6	2.6	2.2	1.9
	m,p-Xylene[b,c]	8.9	5.5	4.5	4.0
Glues (14/90)	Trichloroethylene	0.96	0.64	NQ	NQ
	Styrene	12	1.6	1.6	0.95
	o-Xylene	4.8[e]	2.8	3.0	1.9
	m,p-Xylene	9.3	5.8	5.8	3.9
Moth Balls[f] (42/62)	1,1,1-Trichloroethane	7.1	6.1	3.8	3.5
	Trichloroethylene	0.86	0.56	NQ	NQ
	Styrene	4.6	1.5	1.1	0.94
Petroleum Products (68/36)	Trichloroethylene[b]	0.83[e]	0.41	NQ	NQ
	Perchloroethylene	1.4	0.54	0.40	0.26
	Styrene	3.4	1.6	1.0	0.96
	p-Dichlorobenzene	25[e]	6.0	1.5	0.75
	o-Xylene[b]	3.4	2.3	2.1	1.8
	m,p-Xylene[b]	6.9	5.1	4.3	3.7
Dry Cleaned Clothes (9/94)	1,1,1-Trichloroethane	13	6.0	4.5	3.6
Household Characteristics					
Gas Cooking (45/59)	1,1,1-Trichloroethane	8.4	5.1	3.8	3.5
	Benzene	6.2	3.6	2.6	2.4
	Carbon Tetrachloride	0.64	0.51	0.55	0.44
	p-Dichlorobenzene	25	13	1.6	0.95

continued

TABLE 9-27. WEIGHTED MEANS FOR INDOOR VOC AIR CONCENTRATIONS BY SELECTED VARIABLES (continued)

Exposure[a]	Chemicals with Higher Concentration for Exposed Group	Air Concentrations ($\mu g/m^3$) Arith. Mean Exposed	Arith. Mean Not Exposed	Geo. Mean Exposed	Geo. Mean Not Exposed
Household Characteristics (continued)					
Air Conditioning (45/55)	1,1,1-Trichloroethane	7.1	6.3	5.1[e]	2.9
	Benzene	4.9	4.6	3.5[e]	1.9
	Styrene	4.7	1.4	1.4[e]	0.77
	o-Xylene	4.2[e]	2.1	3.0[e]	1.4
	m,p-Xylene	8.4[e]	4.5	5.9[e]	3.0
Vehicles Running Within 50 ft of Home (33/71)	Benzene[b]	7.7	3.6	2.4	2.5
	Styrene	5.7	1.6	0.92	1.0
	o-Xylene	4.0	2.7	2.0	2.0
	m,p-Xylene[b]	8.1	5.5	4.2	4.0
Pets in Home (53/47)	Benzene	5.8	3.6	2.5	2.4
	Trichloroethylene	1.1[e]	0.28	NQ	NQ
	Styrene	4.1	1.3	1.1	0.9

[a] Numbers in parentheses indicates number of homes in exposed/nonexposed groups.
[b] Chemicals that might be expected to be higher in the exposed groups.
[c] Chemicals reported as higher in the exposed group on previous TEAM studies (2).
[d] Mean below the MQL.
[e] Means significantly higher for the exposed group at the 0.05 level.
[f] Moth balls, room fresheners, and room deodorizers.

TABLE 9-28. WEIGHTED MEANS FOR PERSONAL VOC AIR CONCENTRATIONS BY SELECTED VARIABLES

		Air Concentrations ($\mu g/m^3$)			
		Arith. Mean		Geo. Mean	
Exposure[a]	Chemicals with Higher Concentration for Exposed Group	Exposed	Not Exposed	Exposed	Not Exposed
Smoking					
Any Smoking (21/43)	Benzene[b,c]	5.6	4.4	3.9	3.1
	Perchloroethylene	3.7	1.1	0.85	0.33
	p-Dichlorobenzene	32	16	2.3	2.5
Heavy Smoking >20 cigarettes per day (6/43)	Benzene[b,c]	5.1	4.4	4.5	3.1
	Trichloroethylene	1.3	1.1	0.36	NQ[d]
	p-Dichlorobenzene	23	16	3.0	2.5
Consumer Products					
Paint (23/70)	Trichloroethylene[b]	5.1	1.4	0.36	NQ
	Perchloroethylene[b]	3.3	1.1	0.77	0.41
	Styrene[c]	4.9	1.6	1.5	1.2
	o-Xylene[b,c]	6.8	3.8	3.4	2.9
	m,p-Xylene[b,c]	13	8.0	6.5	6.1
Glues (14/79)	1,1,1-Trichloroethane[b]	88	10	27	4.9
	Carbon Tetrachloride	1.5	0.54	0.65	0.49
	Styrene	7.3	1.6	1.9	1.2
	o-Xylene	4.7	4.5	3.7	2.9
Moth Balls[f] (38/55)	Trichloroethylene	3.8	1.3	NQ	NQ
	Styrene	3.6	1.6	1.4	1.1
Petroleum Products (61/31)	1,1,1-Trichloroethane	29.0[e]	6.8	7.4	4.0
	Trichloroethylene	2.9[e]	1.1	NQ	NQ
	Perchloroethylene	2.1[e]	0.54	0.56	0.35
	Styrene	2.8	1.0	1.4	1.1
	p-Dichlorobenzene	24	16	2.7	1.6
	o-Xylene[b]	5.2[e]	3.2	3.4	2.4
	m,p-Xylene[b]	10.0[e]	6.9	6.8	5.0
Aerosols (41/52)	Perchloroethylene	2.0	1.3	0.50	0.46
	Styrene	3.4	1.6	1.5	1.1
	m,p-Xylene	9.4	9.1	7.3	5.3

continued

TABLE 9-28. WEIGHTED MEANS FOR PERSONAL VOC AIR CONCENTRATIONS BY SELECTED VARIABLES (continued)

		Air Concentrations ($\mu g/m^3$)			
		Arith. Mean		Geo. Mean	
Exposure[a]	Chemicals with Higher Concentration for Exposed Group	Exposed	Not Exposed	Exposed	Not Exposed
Insecticides, Pesticides, Herbicides (11/81)	Benzene	6.6	4.8	3.2	3.4
Gas or Exhaust					
Automobile Gas (37/56)	1,1,1-Trichloroethane	25	19	6.4	6.1
	Benzene[b]	6.1	4.2	4.0[e]	3.0
	Trichloroethylene	3.9	1.1	NQ	NQ
	Perchloroethylene	2.8[e]	0.75	0.61	0.40
	o-Xylene[b]	6.1[e]	3.4	4.0[e]	2.4
	m,p-Xylene[b]	12[e]	7.0	8.1[e]	5.0
Exhaust (31/61)	Benzene[b]	7.2	3.9	4.4[e]	3.0
	Trichloroethylene	3.5	1.7	NQ	NQ
	Perchloroethylene	1.8	1.5	0.65	0.41
	Styrene	3.9	1.6	1.5	1.2
	o-Xylene[b]	6.8[e]	3.3	4.5[e]	2.5
	m,p-Xylene[b]	14[e]	6.9	9.4[e]	5.0
Working					
Work at Regular Occupation (41/52)	1,1,1-Trichloroethane	37[e]	8.9	7.7	5.2
	Trichloroethylene	3.8	1.1	NQ	NQ
	Styrene	3.4	1.6	1.3	1.2
	o-Xylene	6.0[e]	3.4	3.7	2.6
	m,p-Xylene	10[e]	7.1	7.5	5.3

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[a] Numbers in parenthesis indicates number of homes in exposed/nonexposed groups.

[b] Chemicals that might be expected to be higher in the exposed groups.

[c] Chemicals reported as higher in the exposed group on previous TEAM studies (2).

[d] Mean below the MQL.

[e] Means significantly higher for the exposed group at the 0.05 level.

[f] Moth balls, room fresheners, and room deodorizers.

5. For indoor and personal air samples, smoking appeared to elevate benzene concentrations (but not significantly) compared to not smoking. Mean benzene personal air concentrations for heavy smokers (> 20 cigarettes/day) were no higher than for all smokers.

6. Wallace (2) reported elevated styrene concentrations for smokers. Similar trends were not found here.

7. p-Dichlorobenzene concentrations were not associated with the use of mothballs, air fresheners, or bathroom deodorizers. Since these are the most common sources for p-dichlorobenzene, the use for elevated concentrations in personal and indoor air samples is unknown.

8. As on the TEAM studies (2), individuals who worked away from home in a regular occupation showed significantly higher VOC concentrations compared to those who stayed at home during the monitoring period.

Generally, results here agreed fairly well with results reported on previous TEAM studies and with predicted results. Although some interesting trends are suggested, larger sample sizes, better defined exposure categories, and better designed questionnaires may be required to fully expose the relationship between air concentrations and activity or source use patterns. A compilation of all results are given in Appendix D (Tables D-19 through D-38).

The frequencies and weighted percentages for the Study Questionnaire and the Record of Activities and Environments Questionnaire are also given in Appendix D, Tables D-39 and D-40.

9.11 Time Activity Diary Results

The information collected in the diaries is summarized in Table 9-29. The weighted mean percentage of time spent by the total population in each environment is presented. Next, the number of people in the sample who actually spent time in the environment (doers) is given, followed by the weighted mean percentage of time the sub-population of doers were in the

TABLE 9-29. WEIGHTED PERCENTAGES FROM DIARY DATA

Microenvironment	Mean % Time (n=127)	No. of Doers	Mean % Time for Doers
Indoor-Home, Smoking	9.7	43	29.8
Indoor-Home, Nonsmoking	58.7	123	60.2
Outdoor-Home	3.4	76	6.2
Indoor-Away from Home, Smoking	4.5	47	12.0
Indoor-Away from Home, Nonsmoking	13.0	100	16.3
Outdoor-Away from Home	5.0	46	12.7
Enclosed Transit, Smoking	0.8	27	3.8
Enclosed Transit, Nonsmoking	2.8	88	4.1
Outdoor Transit	1.0	38	2.9
Unknown	1.1	95	1.5
Indoor-Home	68.4	127	68.4
Indoor-Away from Home	17.6	107	20.6
Enclosed Transit	3.5	101	4.6
Outdoor Transit	1.0	38	2.9
Outdoor	8.4	97	11.0

environment. For example, 9.67 percent is the (weighted) estimate of the time the population spent indoors at home exposed to tobacco smoke based on the sample of 127 people. However, only 43 of the 127 participants in the study actually did spend time indoors at home exposed to tobacco smoke. For the subgroup of people in the population who actually did spend time in such an environment, a weighted estimate of 29.84 percent was calculated. Over two-thirds of the time was spent indoors at home and most of this time was in a non-smoking environment.

In the statewide survey of activity patterns (11), Californians greater than 11 years of age, on average, reported spending 61.9 percent of their time indoors at home, 24.6 percent indoors not at home, 5.1 percent outdoors, 7.6 percent in enclosed transit, and 0.7 percent in outdoor transit (i.e. walking or biking). These numbers are similar to the percentages reported in the daily diaries for this study.

9.12 Comparison to Other Studies

Results of air measurement for VOCs generated during this study are compared to similar data generated during other TEAM studies in California. Included are results from field studies performed in Los Angeles in January 1984, May 1984, February 1987 and July 1987. Data from the Contra Costa county study (June 1984) and the Woodland pilot study (November 1988) are also presented. Tables 9-30, 9-31, and 9-32 compare median concentration data for indoor, personal and outdoor air, respectively. Table 9-33 provides data for median indoor/outdoor air concentration ratios.

TABLE 9-30. COMPARISON OF INDOOR VOC AIR CONCENTRATIONS TO THOSE REPORTED IN OTHER STUDIES

Compound	Median Concentration (μg/m³)						
	Woodland [a] Main (n=104) May-June 1990	Woodland [a] Pilot (n=8) Nov. 1989	LA [b,c] (n=112) Feb. 1984	LA [b] (n=50) May 1984	LA [e] (n=42) Feb. 1987	LA [e] (n=40) July 1987	CC [b,d] (n=71) June 1984
1,1,1-Trichloroethane	3.0	6.9	26	7.2	19	9.1	4.3
Benzene	2.2	8.8	15	4.4	11	4.5	4.6
Carbon tetrachloride	0.5	0.7	0.7	0.7	0.9	0.8	0.7
Trichloroethylene	0.3	2.3	1.1	0.3	0.7	0.3	0.3
Perchloroethylene	0.3	1.6	8.3	1.9	4.8	1.5	1.8
Styrene	1.0	1.3	2.8	0.8	2.7	0.9	0.7
p-Dichlorobenzene	1.1	1.7	2.6[f]	0.8[f]	2.3	0.7	0.5[f]
o-Xylene	1.9	6.5	9.7	2.5	10	3.6	2.2
m,*p*-Xylene	3.8	16	22	8.7	30	10	6.1

[a] 24-hour sample.
[b] 12-hour overnight personal sample.
[c] Los Angeles.
[d] Contra Costa County.
[e] 12-hour overnight kitchen sample.
[f] Reported as *m*,*p*-dichlorobenzene.

TABLE 9-31. COMPARISON OF PERSONAL VOC AIR CONCENTRATIONS TO THOSE REPORTED IN OTHER STUDIES

	Median Concentration ($\mu g/m^3$)						
Compound	Woodland [a] Main (n=93) May-June 1990	Woodland [a] Pilot (n=8) Nov. 1989	LA [b,c] (n=110) Feb. 1984	LA [b] (n=50) May 1984	LA [b,c] (n=48) Feb. 1987	LA [b,c] (n=40) July 1987	CC [b,d] (n=76) June 1984
1,1,1-Trichloroethane	4.2	9.4	26	7.2	19	7.7	4.2
Benzene	3.1	9.3	15	4.5	12	5.2	4.6
Carbon tetrachloride	0.5	0.6	0.7	0.7	0.7	0.7	0.7
Trichloroethylene	NQ[e]	6.3	1.1	0.3	0.7	0.3	0.3
Perchloroethylene	0.4	2.1	8.3	1.9	6.8	2.0	1.8
Styrene	1.2	1.5	2.8	0.8	3.0	1.0	0.7
p-Dichlorobenzene	22	5.4	2.6[f]	0.8[f]	1.9	1.4	0.5[f]
o-Xylene	3.0	6.0	9.7	2.5	12	3.3	2.2
m,p-Xylene	5.9	17	22	8.7	31	9.5	6.1

[a] 24-hour sample.
[b] 12-hour sample.
[c] Los Angeles.
[d] Contra Costa County.
[e] Below the MQL.
[f] Reported as m,p-dichlorobenzene.
[g] Not reported.

TABLE 9-32. COMPARISON OF OUTDOOR VOC AIR CONCENTRATIONS TO THOSE REPORTED IN OTHER STUDIES

Compound	Median Concentration (μg/m³)						
	Woodland [a] Main (n=48) May-June 1990	Woodland [a] Pilot (n=4) Nov. 1989	LA [b,c] (n=24) Feb. 1984	LA [b] (n=23) May 1984	LA [b] (n=45) Feb. 1987	LA [b] (n=40) July 1987	CC [b,d] (n=10) June 1984
1,1,1-Trichloroethane	1.4	2.6	29	4.0	12	4.3	2.1
Benzene	1.1	9.0	19	2.5	7.9	2.0	1.7
Carbon tetrachloride	0.5	0.7	0.7	0.7	0.7	0.8	0.3
Trichloroethylene	NQ[e]	NQ	0.7	NQ	0.3	NQ	NQ
Perchloroethylene	0.2	0.7	7.4	1.3	4.2	1.0	0.3
Styrene	0.1	1.3	4.2	0.6	1.9	0.3	0.2
_p_-Dichlorobenzene	0.1	0.9	1.7[f]	0.5[f]	1.8	0.3	0.5[f]
_o_-Xylene	0.8	5.8	13	1.9	5.7	2.4	0.4
_m,p_-Xylene	1.6	14.2	30	7.3	9.7	6.5	1.3

[a] 24-hour sample.
[b] 12-hour overnight sample.
[c] Los Angeles.
[d] Contra Costa County.
[e] Below the MQL or method detection limit.
[f] Reported as _m,p_-dichlorobenzene.

TABLE 9-33. COMPARISON OF MEDIAN INDOOR/OUTDOOR VOC AIR CONCENTRATION RATIOS TO THOSE REPORTED IN OTHER STUDIES

Compound	Woodland[a] Main (n=42) May-June 1990	Woodland[a] Pilot (n=4) Nov. 1989	LA[b,c] (n=24) Feb. 1984	LA[b] (n=23) May 1984	CC[b,d] (n=10) June 1984
1,1,1-Trichloroethane	2.1	2.0	0.8	2.0	2.0
Benzene	1.8	1.0	1.1	1.7	2.3
Carbon tetrachloride	0.9	1.0	1.0	1.1	2.2
Trichloroethylene	7.3	13	1.8	4.8	3.2
Perchloroethylene	1.7	1.8	1.2	1.3	8.4
Styrene	6.6	1.1	0.9	1.0	1.5
p-Dichlorobenzene	8.1	3.9	1.6	1.4	1.8
o-Xylene	2.4	1.2	1.0	1.2	4.7
m,p-Xylene	2.2	1.2	0.9	1.1	4.3

[a] 24-hour sample.
[b] 12-hour overnight personal sample was used as indoor sample.
[c] Los Angeles.
[d] Contra Costa County.

Although all studies were performed using similar methods, several differences existed that should be noted when making the comparisons.

1) All samples for this study were collected over a single 24-hour period compared to 12-hour daytime and nighttime samples that were collected on the other studies. Where two 12-hour samples were collected, data from the overnight sample are given.
2) For the 1984 studies, indoor air samples were not collected. For comparisons, we have assumed that the 12-hour overnight personal air sample is comparable to an overnight indoor air sample.
3) For the 1987 studies, indoor samples were collected in the kitchen. VOC levels in the kitchen should be similar to those in the primary living area which is the indoor area that was monitored during this study.
4) For all three studies, different methods for estimating MQLs were used.

Comparison of data for this study to the other studies shows several interesting trends. First, all of the air concentrations reported for thismain study are lower than those reported for the other studies. This trend is observed for indoor, outdoor, and personal air samples. Air concentrations reported for this study are most similar to those reported for the 1984 Contra Costa County study which was the only other study performed outside of the Los Angeles area.

Comparison of winter and summer data for the Los Angeles studies, as well as the pilot and main study here, suggest seasonal trends in VOC air concentrations. In both cases, the highest VOC concentrations are found in the winter. Again, this trend is apparent for indoor, personal, and outdoor air samples.

Median indoor/outdoor air concentration ratios, calculated for each study, are given in Table 9-33. For 1,1,1-trichloroethane, styrene, and p-dichlorobenzene, the highest ratios are reported for the present study.

For other VOCs, except trichloroethylene, the Contra Costa County study shows the highest indoor/outdoor air concentration ratios. These are not surprising results, since the lowest measured outdoor concentrations were found for these two studies.

Results suggest that for the ubiquitous compounds (i.e., 1,1,1-trichloroethane, benzene, and the xylenes), when outdoor air concentrations are high (Los Angeles in the winter), then both the indoor and personal air concentrations are also high. Under these conditions, indoor sources and personal activities do not appear to have a large impact on indoor and personal air concentrations. Conversely, when the outdoor air concentrations are low (i.e., Woodland main study and Contra Costa study), then indoor sources and personal activities appear to have a higher impact on exposure concentrations.

SECTION 10

QUALITY ASSURANCE/QUALITY CONTROL

10.1 Introduction

No formal Quality Assurance Project Plan was prepared for this study; however, a program of Quality Assurance and Quality Control activities was included as a part of this research program. These activities included:

- Meeting with project management to discuss QA matters,
- Conducting systems audits of major project components,
- Monitoring situations requiring corrective action,
- Monitoring analysis of QC samples, and
- Submitting reports.

10.2 Standard Operation Procedures and Protocols

No workplan or protocols were prepared for this study. Methods and procedures were described in the proposal (19) and the Draft Interim Report (12). In addition, SOPs in use during previous air monitoring programs were used:

- ACS-SOP-331-001 Revision 2 (Personal Sampling, Tenax)
- ACS-SOP-331-002 Revision 2 (Fixed Site Sampling, Tenax)
- ACS-SOP-320-001 (Preparation of Tenax)

Training manuals were prepared and provided to the field interviewers.

10.3 Systems Audits

Systems audits are conducted as a quality assurance check on the adherence to project QC measures. A Quality Assurance Statement which summarizes audits and inspections is included at the end of this section.

10.4 Quality Control Samples

Blanks (analyte-free sampling media) were prepared for all sampling media, taken to the field, returned, and analyzed along with field samples to monitor accidental contamination during field sampling, shipping and, storage. Spiked control samples were also prepared for all media, taken to the field, returned, and analyzed along with field samples. The percent recovery of target compounds reflects analyte losses during field sampling, shipping, and storage. In addition, method blanks and controls were prepared for semivolatile organic chemical sample extraction and processing in order to monitor the contribution of solvents, reagents, and glassware to the background (blanks) and to monitor the method performance (controls).

Duplicate (co-located) samples were collected and analyzed to obtain a precision estimate for the overall sampling and analysis procedures.

10.4.1 Very Volatile Organic Chemicals

A summary of results of analysis of canister blank, control and duplicate samples is shown in Table 10-1. Quality assurance objectives were not developed for this study, and comparable QC data are not available for comparison; however, the following objectives can be considered typical for canister sampling and analysis:

Precision (%RSD between duplicate samples), < 30

Recovery (% Recovery from spiked controls), > 80

Completeness (% valid data relative to proposed), > 95

10.4.2 Volatile Organic Chemicals

A summary of results of analysis of Tenax blank, control and duplicate samples is shown in Table 10-2. Quality assurance objectives

TABLE 10-1. SUMMARY OF ANALYTICAL RESULTS FOR QC SAMPLES -VERY VOLATILE ORGANIC COMPOUNDS

Type	Number	Comments
Blanks	4	The background concentration of all analytes was low except for benzene. Benzene could not be accurately quantitated in the blanks because of background contamination in the low level calibration standard. Reference: Table 8-9.
Controls	3	Recoveries good (>90%) for all analytes except 1,4-dioxane. Variability greatest for least volatile analytes. Recovery of methylene chloride could not be evaluated. Reference: Table 8-10.
Duplicates	8 pair	Not enough data above the quantifiable limit for evaluation for most analytes. For those analytes with sufficient data, 1,1,1-trichloroethane, benzene, carbon tetrachloride, m,p-xylene, o-xylene, p-dichlorobenzene and trichloroethylene show good agreement (<40% RMD); methylene chloride shows greater variability (50% RMD). Reference: Table 8-11.

TABLE 10-2. SUMMARY OF ANALYTICAL RESULTS FOR QC SAMPLES - VOLATILE ORGANIC COMPOUNDS

Type	Number	Comments
Blanks	13	Background concentration of all target compounds except benzene were low and uniform and show that the Tenax used remained clean throughout the study. Reference: Table 8-17.
Controls	13	Recovery from spiked controls was generally good; benzyl chloride results were quite variable, and 1,1,1-trichloroethane recovery was low. Reference: Table 8-18.
Duplicates	25 pair	For those analytes with data above the quantifiable limit, agreement is good (mean RMD $<$ .40).

were not developed for this study, but general comparisons can be made to similar studies. The quality assurance objectives prepared for the TEAM Follow-up Study, California 1987 (20) are:

Precision (%RSD for interlaboratory analysis of duplicates), $<$ 40

Recovery (% Recovery from spiked controls), 85-100

Completeness (% valid data relative to proposed), 95

10.4.3 Semivolatile Organic Compounds

A summary of the results of the analysis of SOC blank, control and duplicate samples is shown in Table 10-3. Only results from GC/MS analysis are included, and these must be interpreted with caution due to the limited data available and long storage time. Quality assurance objectives were not detailed for SOCs since the sampling and analysis protocol was being developed and tested as part of this study. There are no other suitable studies with quality assurance objectives available for comparison.

10.5 Internal Quality Control Procedures

10.5.1 Quality Control for Survey Operations

A training program was implemented for all interviewers working on the project, and training manuals were prepared to be used as reference documents, as well as training aids. All survey documents were checked each day for completeness and scanned for problems, and daily phone conferences were conducted with RTI Survey Operations staff to discuss progress and problems.

10.5.2 Quality Control for Sample Collection in the Field

Sets of blanks and spiked controls were prepared for each sampling matrix and sent to the sampling site to monitor accidental contamination and analyte loss. In addition, duplicate (co-located) samples were

TABLE 10-3. SUMMARY OF ANALYTICAL RESULTS FOR QC SAMPLES - SEMIVOLATILE ORGANIC COMPOUNDS

Type	Number	Comments
Field Blanks	8[a]	No analytes detectable except di-2-ethylhexylphthalate. Reference: Table 8-32.
Method Blanks	4[b]	No analytes found above quantifiable limits except di-2-ethylhexylphthalate, which was high and variable. Reference: Table 8-32.
Field Controls	7[c]	Very low or no recovery for all analytes except di-2-ethylhexylphthalate. Reference: Table 8-31.
Method Controls	13[b]	Very low or no recovery for all analytes except nitrobenzene and di-2-ethylhexylphthalate. Reference: Table 8-31.
Duplicates	10[d]	Not evaluated due to length of storage.

[a] 10 field blanks scheduled; 8 analyzed by GC/MS.

[b] Only samples which remained intact during storage were analyzed.

[c] 15 field controls scheduled; 7 analyzed by GC/MS.

[d] 20 scheduled; 10 analyzed by GC/MS.

collected for each sample type to obtain an estimate of the precision of sampling and analysis. In the field, collected samples and field data were checked daily for completeness and errors.

10.5.3 Quality Assurance for Sample Extraction

For VVOCs and VOCs, samples were analyzed directly without sample extraction. For SOCs, method blanks and spiked controls were prepared for each batch (10 to 15 per batch) of XAD-2 sample cartridges extracted to monitor contamination from reagents and glassware, and losses from sample extraction, concentration, and storage.

10.5.4 Quality Assurance for Sample Analysis

Proper instrument performance, based on acceptable chromatographic criteria (GC) and accurate mass assignments (MS), was established before sample analysis began. Calibration, based on response factors (RF), was prepared for each sample type. Each day, a standard was analyzed, and the calculated RF for each target analyte was compared to a reference RF. Acceptance criteria had to be met before analysis could begin that day. A summary of the criteria are shown in Table 10-4.

10.6 Summary and Recommendations

1. A number of problems occurred with the Survey Operations phase of the study. These included problems of availability of and training for field interviewers, problems with the laptop computer/software combination, excessive length of the recall questionnaire. Most of these problems would be avoided if a survey supervisor were on-site during the course of the study.

2. Collection of samples in the field went smoothly. The appointments were scheduled so that there was adequate time to meet the schedule without overburdening the field staff. Some difficulty was encountered with completing personal sampling, but this should be overcome by better informing the participant about the goals of the study and the procedures that will be followed.

3. Analysis of Tenax samples went smoothly and no problems were encountered. Background contamination prevented calibration for benzene at lowest level.

TABLE 10-4. SUMMARY OF ANALYTICAL QC SAMPLES
GC/MS

Type	Criteria
Tenax (VOC)	
Calibration	Duplicate analyses at 4 levels; RSD for each response factor (RF) must be less than 30%.
Daily Check	Calculated RF values for analytes must be within ± 30% of reference value, usually mean of several analyses at the same loading level as the daily check standard.
Canisters (VVOC)	
Calibration	Duplicate analyses at 3 concentration levels; RSD for each response factor must be less than 30%.
Daily Check	Mid-level calibration standard analyzed; calculated RF values must be within ± 30% of reference value.
XAD-2 (SOC)	
Calibration	Duplicate analyses at 4 levels; RSD for each response factor must be less than 30%.
Daily Check	Mid-level calibration standard analyzed; calculated RF values must be within ±30% of reference value.

4. Analysis of canister samples went smoothly. The only problem encountered was background contamination by benzene which made quantitation at low levels unreliable. The source of this contamination must be determined and quality control procedures developed to minimize the problem.

5. Analysis of XAD-2 samples proved difficult. The protocol for sampling and analysis by GC/MS was necessary due to the high background of organic compounds collected. The results, however, must be viewed with caution since the samples were stored for a long time, and the analysis protocol has not undergone rigorous validation.

6. Future studies should include the use of performance evaluation samples (or analysis of Standard Reference Materials) and provisions for duplicate sample analysis by an independent reference laboratory. These measures of accuracy and precision are needed to assess the quality of data and allow for comparison to other data sets.

SECTION 11

REFERENCES

1. Sheldon, L., Zelon, H., Sickles, J., Eaton, C. and Hartwell, T. "Indoor Air Quality in Public Buildings", EPA Report No. 600/6-88/009a and b, August 1988.

2. Wallace, L.A. "The Total Exposure Assessment Methodology (TEAM) Study: Summary and Analysis: Volume 1." EPA/600/6-87/002a, June 1987.

3. Pellizzari, E., Hartwell, T., Sparacino, C., Sheldon, L., Whitmore, R., Leininger, C. and Zelon, H. "Total Exposure Assessment Methodology (TEAM) Study: First Season--Northern New Jersey", Report, Contract Number 68-02-3679, U.S. Environmental Protection Agency, Washington, DC, 1984.

4. Wallace, L., Pellizzari, E., Hartwell, T., Sparacino, C., Whitmore, R., Sheldon, L., Zelon, H. and Perritt, K. Environ. Research, 43:290-304, 1984.

5. Sheldon, L. and Whitaker, D. "VOC Commuter Exposure Study", Contract No. 68-02-4544, U.S. Environmental Protection Agency, Research Triangle Park, NC, June 1988.

6. Whitaker, D. and Pellizzari, E. "Measurements of VOC Concentration in Clinical Exposures", Draft Final Report, Contract No. 68-02-4544, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1989.

7. Sheldon, L. and Keever, J. "Collection and Analysis of NASA Clean Room Air Samples", NASA Contractor Report 3947, November 1985.

8. Chuang, J., Hunnar, S. and Wilson, M. Environ. Sci. Technol., 21:798, 1987.

9. Lewis, R.G. and McLeod, K.E. Anal. Chem., 49:1668, 1977.

10. Hartwell, T., Pellizzari, E., Perritt, R., Whitmore, R., Zelon, H. and Wallace, L., Atmospheric Environ., 21:1195, 1987.

11. Jenkins, P.L., Phillips, T.J. and Mullberg, E.J. "Activity Patterns of Californians: Use of an Proximity to Indoor Pollutant Sources", Proceedings of the 15th International Conference on Indoor Air Quality and Climate, 1990, Vol. 2, pp 465-470.

12. Sheldon, L.S. "Indoor Pollutant Concentrations and Exposures, Revised Interim Report", California Air Resources Board Contract Number A833-156, Research Triangle Institute, Research Triangle Park, NC, January 1990.

13. Shah, B.V., LaVange, L.M., Barnwell, B.G., Killinger, J.E. and Wheeless, S.C. "SUDAAN: Procedures for Descriptive Statistics, User's Guide", Research Triangle Institute, Research Triangle Park, NC, 1989.

14. Particle Total Exposure Assessment Methodology (PTEAM): Pilot Study. EPA Contract No. 68-02-4544, Work Assignment No. 67, ARB Agreement No. A833-060.

15. Krost, K., Pellizzari, E., Washburn, L., and Hubbard, S., Anal. Chem., 54:810 (1982).

16. Jayanty, R.K.M., Albritton, J., and Straley, Y., "Stability of ppb and ppm Organic Cylinder Gases Used for Calibration and Audits", 84th Annual AWMA National Meeting, Vancouver, B.C., June 1991.

17. Hsu, J.P., Wheeler, H.G., Shattenberg, H.J., Camann, D.E., Lewis, R.G., Bond, A.E., and Bond, A.E. (1988). J. of Chromato. Sci., 26, 181.

18. Sheldon. L. (1990b). House Dust/Infant Pesticides Exposure Study, EPA Contract No. 68-02-4544. Work Assignment #75. Research Triangle Institute, Research Triangle Park, NC.

19. "Indoor Pollutant Concentrations and Exposure", RTI Technical Proposal 321-89-12, February, 1989.

20. Smith, D.J. Quality Assurance Project Plan for "Total Exposure Assessment Methodology (TEAM) Follow-up Study in California," EPA Contract Number 68-01-6826, December, 1986.

APPENDIX A

Household Enumeration Questionnaire
Participant Consent Form
Participant Incentive Receipt
Study Questionnaire
Record of Activity and Environments

3/5/90

Research Triangle Institute
California Air Resources Board - Indoor Air Study
HOUSEHOLD ENUMERATION QUESTIONNAIRE

A. Household Identification

Segment No: ☐☐

SHU No: ☐☐☐-☐

Street Address

City State Zip ☐☐☐☐☐

County

Telephone Number Obtained

☐☐☐-☐☐☐-☐☐☐☐

No phone ...00
Refused 01

B. Record of Calls

Day	Date	Time	Result of Call	Code	FI ID Number
		am/pm			
		am/pm			
		am/pm			
		am/pm			
		am/pm			
		am/pm			

C. Final Screening Result

Ineligible HU: (Circle One)

Vacant	01	
Not an HU	02	Section D
Temporary/Vacation Home	03	

Screening Not Completed:

Refusal (Provide Documentation)	04	
No one at home (after repeated visits)	05	FS Approval
No eligible respondent (after repeated visits)	06	
Language Barrier	07	
Other (SPECIFY)	08	

Screening complete 09

D. Informant ID

Name:

Address:

City State Zip ☐☐☐☐☐

Relationship/Title:

Telephone Number:

☐☐☐-☐☐☐-☐☐☐☐

No phone 00
Refused 01

Comments:

FS USE ONLY

FS APPROVAL:

Verified ?

Yes ...01
No 02

Date of Verification

__/__/__

NOTES:

INTRODUCTION: Hello. I'm (NAME) from the Research Triangle Institute in North Carolina. We are conducting a research study for the California Air Resources Board. We are interested in sources of indoor air exposures to various chemicals. Here is a letter that explains the study. (HAND MATERIAL AND ALLOW TIME FOR READING.)

BE SURE YOU ARE TALKING TO AN ELIGIBLE RESPONDENT: FULL-TIME RESIDENT OF THE HOUSEHOLD AT LEAST 16 YEARS OF AGE. First I need some information about the residents of the household.

1. How many people currently live in this household?

   ______ people

2. What are the names of all the people who live here? Let's list them in order of age, starting with the oldest.

CHECKPOINT: DOES THE NUMBER OF NAMES IN THE ROSTER EQUAL THE ENTRY FOR QUESTION 1?

☐ Yes - CONTINUE WITH QUESTION 3

☐ No - RESOLVE WITH RESPONDENT, CORRECT QUESTION 1, OR ROSTER AS NECESSARY, THEN CONTINUE.

3. For each person in the roster including yourself, I need to know the following:
   a. age (in years at last birthday),
   b. sex,
   c. relationship to head of household,
   d. if the person is a smoker,
   e. current job title,
   f. industry or type of business in which they work,
   g. if their job requires driving, and
   h. if their job involves working outdoors.

CIRCLE THE LINE NUMBER FOR THE RESPONDENT

	Household Member Name	(a) Age (Years)	(b) Sex M/F	(c) Relation to head	(d) Smoker Y/N	(e) Job Title	(f) Industry or Business	(g) Driving Y/N	(h) Outdoors Y/N
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

Now I need some information about your home.

4. In what year was this house built? ________

5. For how many years have you lived in this house? ____ years

6. How close is the nearest freeway, major highway, major intersection, or busy street?

☐ 1-3 blocks ☐ more than 3 blocks

INTERVIEWER: RECORD BY OBSERVATION

7. What is the distance, <u>in feet</u>, between the street and the living area of the house closest to the street? ______feet

8. Does this household appear to be predominately Hispanic?

1) Yes 2) No 3) Unable to determine

9. Describe character of neighborhood.

☐ urban ☐ suburban ☐ rural

10. Describe this housing unit.

☐ separate single family house ☐ apartment building

☐ attached single family house ☐ mobile home or trailer

☐ Other SPECIFY ____

INTERVIEWER: USE SAMPLING PROCEDURES ON NEXT PAGE TO DETERMINE IF A MEMBER OF THE HOUSEHOLD IS TO BE INCLUDED IN STUDY. IF NO MEMBER IS INCLUDED, THANK RESPONDENT FOR COOPERATION, ANSWER ANY QUESTIONS, AND LEAVE. IF HOUSEHOLD MEMBER IS SELECTED, DETERMINE IF THEY ARE PRESENT AND BEGIN RECRUITMENT PROCEDURES. IF THE PERSON IS NOT PRESENT, OR DOESN'T HAVE TIME TO TALK TO YOU NOW, DETERMINE A CONVENIENT TIME TO RETURN. (RECORD BELOW.)

Selected Participant's Name: ____________________________________

Recruitment effort completed during enumeration visit. YES ___ NO ___

Appointment to return for recruitment:

Day: ______________ Date: _____________ Time: _____________

Appointment made by:

Selected participant ____
Enumeration respondent ____

Recruitment Effort: Successful ___ Refusal ___ (Complete Refusal Documentation)

Equipment Set-up Appointment:

Day: ______________ Date: _____________ Time: _____________

SAMPLE SELECTION (Instructions and Matrix)

A. Sampling Instructions

1. Count the number of household residents 12 years of age or older listed in the roster.
2. Circle the number determined in Step 1 in the first column of the sampling label.
3. Read across the row containing the circled number and determine in column 2 if this household has been selected for monitoring. (Y/N)
4. Continue reading across the same row and determine the number in column 3 of the person selected for monitoring (0 = no person selected; 1,2,3, etc. = number of the person selected). Be sure that roster is in descending age order; renumber if necessary.
5. Use next 8 columns to determine what samples are collected in this household. Provide this information to selected participant.
6. Enter the selected participant's name on page 3 and continue with recruiting effort.

B.

(Place Sample Matrix Label Here)

3/5/90

California Air Resources Board
Indoor Air Quality Study

Participant Consent Form

I understand that the Research Triangle Institute, (RTI) under contract from the California Air Resources Board (ARB), is engaged in a study of the potential indoor air exposure of residents of California living in this area. I understand that this study is being conducted in order to help measure the levels of exposure to selected substances and is limited to the purpose stated. I further understand that the survey is being conducted in cooperation with and under sponsorship of the California Air Resources Board.

I do hereby freely consent to participate in this study of potential exposure to selected chemical compounds and substances and understand that my participation will consist of providing some or all of the following data: (1) answers to questions related to environmental exposure and work and living conditions, (2) a record of my activities and locations during the time that I am being monitored, (3) responses to supplementary questions about activities of interest that I have undertaken, (4) samples of the air that I breath collected through the use of a personal exposure monitor (PEM), and (5) samples of the air inside and outside my home collected through the use of a fixed location, micro environmental monitor (MEM).

I understand that an agent of the Research Triangle Institute will administer the questionnaires. I understand that I will receive an incentive payment of twenty-five dollars ($25.00) for my complete participation. I further understand that a sample of the participating households may be contacted again during a different season of the year. At that time they will be asked to repeat some or all of the activities and will receive a second incentive payment.

I understand that my name will not be voluntarily disclosed, and that my name will not be referred to in anyway when compiling and evaluating the results of the study. I understand that participation in this study may result in no direct benefits to me, other than the results of my sample analyses which I will receive upon written request, and that I am free to withdraw at anytime. It has been explained to me that there are no significant risks to me from participation in this study. I further understand that while participating in this study I will be free to ask any questions concerning the study; If I have any further questions about the project, I know that I am free to contact:

Harvey Zelon or Michele Hoffman, Center for Survey Operations, Research Triangle Institute, toll-free 1-800-334-8571.

or

Peggy Jenkins, ARB   Telephone (916) 323-1504

Participant Name: ______________________________
(Print)

____
(Signature)

Guardian of Minor Respondent: ______________________________
(Signature)

Participant ID: ____________ Date: ___/___/___

Witness: ______________________

CALIFORNIA AIR RESOURCES BOARD
Indoor Air Quality Study

Participant Incentive Receipt

I __________________________, hereby acknowledge receipt of ____
(Print Participant Name)
dollars ($___.___) from the Research Triangle Institute for my participation in this study, through the provision of various environmental samples and accompanying data.

Participant ID: ____________________

Date: ___/___/___

Participant Signature: ____________________________

Signature of Parent or Guardian
if Participant is a minor: ______________________________

RTI Representative: ______________________________

3/5/90

California Air Resources Board
Indoor Air Quality Study

Sponsored by:

California Air Resources Board
Sacremento, California

Conducted by:

Research Triangle Institute
P.O. Box 12194
Research Triangle Park, NC 27709

STUDY QUESTIONNAIRE

The Research Triangle Institute of Research Triangle Park, North Carolina, is undertaking a research study for the California Air Resources Board to assess levels of human exposure during normal daily activities. The information recorded in this questionnaire will be held in strict confidence and will be used solely for research into the effects of environmental factors on public health. All results will be summarized for groups of people; no information about individual persons will be released without the consent of the individual. While you are not required to respond, your cooperation is needed to make the results of this survey comprehensive accurate, and timely.

Participant ID # (Attach PID Label Here)

The purpose of this questionnaire is to obtain information about you, your residence, your occupation and the environment in which you work. We are asking the same questions of each respondent in the study.

First, I would like to ask some general questions about you.

1. Sex? (by observation)   1 Male   2 Female

2. What is your date of birth? ____ / ____ / ____
Month Day Year

3. What is the last year of school which you completed? (CIRCLE ONE)
(IF CURRENTLY IN SCHOOL, INDICATE CURRENT YEAR)

Elementary	1 2 3 4 5 6
Jr/Sr. High	7 8 9 10 11 12
College (Tech School)	13 14 15 16
Graduate	17 17+

Next, I would like to ask some questions about your residence.

4. Does YOUR HOUSE have an attached garage or a parking area underneath it?

1 Yes   2 No (GO TO QUESTION 5)

a. Is there usually one or more motor vehicles parked in it for some part of each day?

1 Yes   2 No

5. Is there insulation and/or weatherstripping between the garage and the house?

1 Insulation
2 Weatherstripping
3 Both
4 Neither
5 DK

6. Do you have a gas range or oven?

1 Yes 2 No (GO TO QUESTION 7)

a. Does your gas range or oven have one or more gas pilot lights which are always lit?

1 Yes 2 No 3 Don't Know

7. Do you have a gas hot water heater?

1 Yes 2 No (GO TO QUESTION 8)

a. Does the hot water heater have a gas pilot light which is always lit?

1 Yes 2 No 3 Don't know

8. Do you have a gas clothes dryer?

1 Yes 2 No (GO TO QUESTION 9)

a. Does the gas clothes dryer have a gas pilot light which is always lit?

1 Yes 2 No 3 Don't know

b. Where is it located?

1 Room or closet inside living quarters

2 Utility room outside living quarters

3 Garage

4 Basement

5 Outside

c. How is the dryer vented?

1 Vented inside the living area (including utility room)

2 Vented to the outdoors

3 Vent can be switched to inside or outside

4 Vents to garage

5 Don't know

9a. Is your water supplied by a municipality or corporation?

1 Yes 2 No 3 Don't Know

b. Do you regularly use bottled water?

1 Yes 2 No

10a. Did you or any member of the household use pesticides in the home in the past 6 months?

1 Yes 2 No (GO TO QUESTION 11)

b. In which rooms? (READ ALL RESPONSES AND CIRCLE ALL THAT APPLY.)

1 Living Room
2 Dining Room
3 Kitchen
4 Den
5 Master Bedroom
6 Other Bedroom (SPECIFY WHOSE) ____________________
7 Other Room (SPECIFY) ____________________
____

11a. Did you pay someone to have your home treated for pests in the past 6 months?

1 Yes 2 No (GO TO QUESTION 12)

b. About how many times in the past 6 months?

_____ Times

12. Do you have a fireplace in your home?

1 Yes 2 No

13a. Is all or part of your home carpeted?

1 All 2 Part 3 None (GO TO QUESTION 14)

b. Other than vacuuming or carpet sweeping, when was any part of the carpet last cleaned, and what method was used?

When Cleaned	Method Used
____ Within past 30 days	1. Steam cleaned
____ Within past 30-90 days	2. Professionally dry cleaned
____ Within past 90-360 days	3. Spot cleaned or dry cleaned by resident
	4. Other ____________________

14. In which areas of your home do you and other household members spend most of your waking hours? (CIRCLE ALL THAT APPLY)

1) Living Room

2) Dining Room

3) Kitchen

4) Den

5) Master Bedroom

6) Other Bedroom (SPECIFY WHOSE)

____

7) Other Room (SPECIFY

____

15. Do you store cleaning supplies (e.g., chlorine bleaches, detergents) in the following places?

	Yes	No	DK	N/A
Kitchen	1	2	3	4
Utility Room	1	2	3	4
Bathroom	1	2	3	4
Attached Garage	1	2	3	4
Other (SPECIFY)	1	2	3	4

____

16. Do you store paints, varnishes or paint thinners or removers in the following places?

	Yes	No	DK	N/A
Attached garage	1	2	3	4
Basement	1	2	3	4
Attic	1	2	3	4
Attached shop or workroom	1	2	3	4
Utility Room	1	2	3	4
Other (SPECIFY)	1	2	3	4

____

17. Do you store kerosene, gasoline, pesticides, insecticides, or lawn and garden chemicals in the following places?

	Yes	No	DK	N/A
Attached garage	1	2	3	4
Basement	1	2	3	4
Attic	1	2	3	4
Attached shop or workroom	1	2	3	4
Utility Room	1	2	3	4
Other (SPECIFY)	1	2	3	4

____

Next, I have a few questions about you and your occupation.

18. Are you currently employed?

1 Yes 2 No (GO TO QUESTION 26)

19. How many hours per day and days per week do you work during a normal work week at your primary job?

____Hours/day ____ Days/week

20. What is your job title? ____________________________

21. In what type of industry or business do you work? ____________________

22. What is the zip code for your primary work location? ________

23. How many miles (one way) is it from your residence to your job?

_____ Miles

24. How long does it take you to commute one-way to your job? _____ Mins.

25. How do you travel to work most often? (PROBE AND CHECK ALL THAT APPLY.)

1 Work at home
2 Walk
3 Bicycle
4 Motorcycle
5 Bus
6 Car, Cab, Van
7 Truck
8 Train
9 Other (SPECIFY) ____________________

(GO TO QUESTION 27)

26. If not currently employed, which of the following describe your status? (CHECK ALL THAT APPLY.)

1 Disabled
2 Looking for work
3 On layoff from work
4 Retired
5 Going to school
6 Keeping house
7 Other (SPECIFY) ____________________

27. Do you have a part-time job or work regularly as a volunteer?

1 Yes 2 No (GO TO QUESTION 30)

28. What is your part-time or volunteer job title? ____________________

29. In what type of industry or business do you work part-time or as a volunteer? ______________________

30. This completes the interview. Are there any questions which you have that I can answer? (ANSWER ANY QUESTIONS AND CONTINUE) I would like to schedule the appointments for the sampling team to come to your home and set up their equipment. (SCHEDULE APPOINTMENT AND RECORD ON HEQ.) Thank you very much for your cooperation.

Interviewer # ☐☐☐☐☐☐

Date of Interview ☐☐-☐☐-☐☐

Comments:

____

____

____

03/05/90

RESEARCH TRIANGLE INSTITUTE
California Air Resources Board
Indoor Air Quality Study

RECORD OF ACTIVITIES AND ENVIRONMENTS

Participant Identification Number

(Attach PID Label Here)

For Further Information call:

Harvey Zelon - RTI 800-334-8571

or

Peggy Jenkins - ARB 916-323-1504

03/05/90

Description of Activities

THE FOLLOWING QUESTIONS ARE FOR THE PAST 24-HOUR PERIOD.

1.	a.	Did you spend any time at a gas station or in a parking garage or auto repair shop during the past 24 hours?	1 Yes	2 No (GO TO QUESTION 2)
	b.	How long did you spend in those places?	_____Hrs.	_____Mins.
2.	a.	Did you pump or pour gasoline during the past 24 hours?	1 Yes	2 No (GO TO QUESTION 3)
	b.	Was it leaded or unleaded gasoline?	1 Leaded	2 Unleaded
3.	a.	Do you have clothes in the house that have been dry-cleaned in the past week?	1 Yes	2 No (GO TO QUESTION 4)
	b.	Did you wear any of these clothes in the past 24 hours?	1 Yes	2 No (GO TO QUESTION 4)
4.	a.	Did you smoke any cigarettes during the monitoring period, that is, between (TIME) and (TIME)?	1 Yes	2 No (GO TO QUESTION 5)
	b.	About how many cigarettes did you smoke?	_______	

5. Have you used or worked with insecticides, pesticides, or herbicides in any way, including farming or gardening in the past 24 hours?	1 Yes 2 No (GO TO QUESTION 6)
(1) ENTER SPECIFIC PRODUCT NAME.	____________________
a. For how long did you use it?	____Hrs. ____Mins.
b. Were you primarily	____Indoors or ____Outdoors
(2) ENTER SPECIFIC PRODUCT NAME.	____________________
a. For how long did you use it?	____Hrs. ____Mins.
b. Were you primarily	____Indoors or ____Outdoors
(3) ENTER SPECIFIC PRODUCT NAME.	____________________
a. For how long did you use it?	____Hrs. ____Mins.
b. Were you primarily	____Indoors or ____Outdoors
6. Did you go to work today in your regular occupation?	1 Yes 2 No 3 Unemployed

Have you used or been near any of the following in the past 24 hours?

7. Paints/solvents (e.g. oil based or latex/water based paints, acetone, chloroform, toluene)? 1 Yes 2 No (GO TO QUESTION 8)

(1) SPECIFY THE PRODUCT NAME. IF PAINT SPECIFY OIL OR WATER BASED. ____________________

a. For how long? _____Hrs. _____Mins.

(2) SPECIFY THE PRODUCT NAME. ____________________

a. For how long? _____Hrs. _____Mins.

(3) SPECIFY THE PRODUCT NAME. ____________________

a. For how long? _____Hrs. _____Mins.

8. Vaporizing or odorous glues or adhesives? 1 Yes 2 No (GO TO QUESTION 9)

(1) SPECIFY THE PRODUCT NAME. ____________________

a. For how long? _____Hrs. _____Mins.

(2) SPECIFY THE PRODUCT NAME. ____________________

a. For how long? _____Hrs. _____Mins.

(3) SPECIFY THE PRODUCT NAME. ____________________

a. For how long? _____Hrs. _____Mins.

Have you used or been near any of the following in the past 24 hours?

9. Moth crystals, room air freshener, or bathroom deodorizers? 1 Yes 2 No (GO TO QUESTION 10)

(1) SPECIFY THE PRODUCT NAME. ____________________

a. For how long? ____Hrs. ____Mins.

(2) SPECIFY THE PRODUCT NAME. ____________________

a. For how long? ____Hrs. ____Mins.

(3) SPECIFY THE PRODUCT NAME. ____________________

a. For how long? ____Hrs. ____Mins.

10. Petroleum products (e.g., gasoline, fuel oil, motor oil, kerosene, etc., exluding pumping your own gas? 1 Yes 2 No (GO TO QUESTION 11)

(1) SPECIFY THE PRODUCT NAME. ____________________

a. For how long? ____Hrs. ____Mins.

(2) SPECIFY THE PRODUCT NAME. ____________________

a. For how long? ____Hrs. ____Mins.

(3) SPECIFY THE PRODUCT NAME. ____________________

a. For how long? ____Hrs. ____Mins.

11. Auto/truck/lawn mover exhausts (heavy or long exposure, e.g., attached garage, tunnel, expressway)? 1 Yes 2 No (GO TO QUESTION 12)

a. For how long? ____Hrs. ____Mins.

Have you used or been near any of the following in the past 24 hours?

12. Cleaning solutions (including household cleaners or chemicals)?	1 Yes	2 No (GO TO QUESTION 13)
(1) SPECIFY THE PRODUCT NAME.	________________________	
a. For how long?	____Hrs.	____Mins.
(2) SPECIFY THE PRODUCT NAME.	________________________	
a. For how long?	____Hrs.	____Mins.
(3) SPECIFY THE PRODUCT NAME.	________________________	
a. For how long?	____Hrs.	____Mins.
13. Flea collars, flea powder, or pet shampoo?	1 Yes	2 No (GO TO QUESTION 14)
(1) SPECIFY THE PRODUCT NAME.	________________________	
a. For how long?	____Hrs.	____Mins.
(2) SPECIFY THE PRODUCT NAME.	________________________	
a. For how long?	____Hrs.	____Mins.
(2) SPECIFY THE PRODUCT NAME.	________________________	
a. For how long?	____Hrs.	____Mins.

Have you used or been near any of the following in the past 24 hours?

14. Aerosol personal care products such as hair sprays or deodorants?	1 Yes	2 No (GO TO QUESTION 15)
(1) SPECIFY THE PRODUCT NAME.	______________________	
a. For how long?	____Hrs.	____Mins.
(2) SPECIFY THE PRODUCT NAME.	______________________	
a. For how long?	____Hrs.	____Mins.
(3) SPECIFY THE PRODUCT NAME.	______________________	
a. For how long?	____Hrs.	____Mins.
15. Polishing or waxing agents?	1 Yes	2 No (GO TO QUESTION 16)
(1) SPECIFY THE PRODUCT NAME.	______________________	
a. For how long?	____Hrs.	____Mins.
(2) SPECIFY THE PRODUCT NAME.	______________________	
a. For how long?	____Hrs.	____Mins.
(3) SPECIFY THE PRODUCT NAME.	______________________	
a. For how long?	____Hrs.	____Mins.

Have you used or been near any of the following in the past 24 hours?

16. Any other product that involved exposure to chemicals? 1 Yes 2 No (GO TO QUESTION 17)

(1) SPECIFY THE PRODUCT NAME. ____________________

a. For how long? _____Hrs. _____Mins.

(2) SPECIFY THE PRODUCT NAME. ____________________

a. For how long? _____Hrs. _____Mins.

(3) SPECIFY THE PRODUCT NAME. ____________________

a. For how long? _____Hrs. _____Mins.

17. a. Did you use or were you near any barbeque or grill? 1 Yes 2 No

18. a. Did you take any showers or baths in the house or anywhere else in the past 24 hours? 1 Yes 2 No (GO TO QUESTION 19)

b. How long did the water run? _____Mins.

19. a. Did anyone else take showers or baths <u>in the house</u> in the past 24 hours? 1 Yes 2 No (GO TO QUESTION 20)

b. How many baths and showers were taken? _____

20. Was a dishwasher in use while you were in the house in the past 24 hours? 1 Yes 2 No

21. Was a clotheswasher in use in the house in the past 24 hours? 1 Yes 2 No (GO TO QUESTION 22)

    a. How many loads were washed with:

       (1) hot or warm water? _____Loads

       (2) cold water? _____Loads

    b. Was bleach used? 1 Yes 2 No (GO TO QUESTION 23)

    c. What brand name? ______________________________

22. In the past 24 hours, which of the following combustion sources were used (i.e., turned on) by anyone in your home or in attached structures, such as a garage, basement, or storage room? (CIRCLE ALL THAT APPLY.)

	YES	NO	NOT SURE
a. Gas cooking range or oven	1	2	3
b. Gas water heater	1	2	3
c. Gas clothes dryer	1	2	3
d. Gas space heater	1	2	3
e. Kerosene space heater	1	2	3
f. Fireplace	1	2	3
g. Wood stove	1	2	3
h. Gas furnace	1	2	3
i. Oil furnace	1	2	3
j. Other combustion appliances (SPECIFY)	1	2	3

____

____

Description of Environments

These questions are used to describe your home and work environment during the time period they were being monitored.

FOR EACH QUESTION READ ALL POSSIBLE RESPONSES.

A. HOME HEATING, VENTILATION, AND AIR CONDITIONING

1. Was any part of your home heated during this monitoring period?

1 Yes 2 No (GO TO QUESTION 2)

What source(s) of heat energy were used? (CHECK ALL THAT APPLY.)

1 Electricity
2 Gas
3 Oil
4 Solar
5 Wood
6 Kerosene
7 Other, SPECIFY ____________

What type of device was used to create the heat? (CHECK ALL THAT APPLY.)

1 Basement furnace
2 Wall furnace
3 In-floor furnace
4 Outside furnace
5 Wood stove
6 Kerosene stove
7 Baseboard heater
8 Radiant heater
9 Fireplace
10 Heat pump
11 Fireplace insert
12 Space heater
13 Other, SPECIFY ____________

2. Was your home air conditioned during this monitoring period?

1 Yes 2 No (GO TO QUESTION 3)

Was the air conditioning done by?

1 Central unit (GO TO (a))

2 Window/wall units (GO TO (b))

3 Both (COMPLETE BOTH (a) and (b))

(a) Does the central unit cool by:

1 Evaporation (swamp cooler)

2 Refrigeration

3 Unable to determine

Does the central unit:

1 Recirculate inside air

2 Bring in outside air through a vent

3 Combination

4 Unable to determine

(b) How many window/wall units are in the home? _____

How many were used for at least 50% of the monitoring period? _____

3. Which of the following ventilation devices were in use during this monitoring period? (CHECK ALL THAT APPLY AND INDICATE THE NUMBER OF HOURS IN USE, OR INDICATE DON'T KNOW (DK).

Device	Used	Number of hours	DK
Whole house fan	____	____	____
Ceiling fan(s)	____	____	____
Window fan(s)	____	____	____
Portable room fan(s)	____	____	____
Bathroon or kitchen exhaust fan(s)	____	____	____
Door(s) open (natural ventilation)	____	____	____
Window(s) open (natural ventilation)	____	____	____
Other, SPECIFY ____________________	____	____	____
None used	____	____	____

4. Which of the following air cleaning or treating devices were in use during this monitoring period? (CHECK ALL THAT APPLY AND INDICATE THE NUMBER OF HOURS IN USE, OR INDICATE DON'T KNOW (DK).

Device	Used	Number of hours
Filters in air handling system	____	____
Charcoal air filters	____	____
Electrostatic Precipitator	____	____
Ionizer	____	____
Hot steam humidifier	____	____
Cold air mist humidifier	____	____
Dehumidifier	____	____
None used	____	____

B. HOME ENVIRONMENT

1a. Was your stove or oven (<u>excluding</u> microwave ovens) in use during this monitoring period?

1 Yes   2 No (GO TO QUESTION 2)

b. Was it used for: (CHECK ALL THAT APPLY.)

1 cooking

2 heating the room

3 cooking <u>and</u> heating

4 some other purpose

c. For how many minutes (total) during the period was the stove or oven turned on? _____ minutes

2a. Was a clothes dryer used during the monitoring period?

1 Yes   2 No (GO TO QUESTION 3)   3 No dryer present (GO TO QUESTION 3)

b. How long was the dryer used? _____Mins.

c. Was the dryer vented into the house?

1 Yes   2 No   3 DK

3a. How many motor vehicles were parked within 50 feet of the home? ____

b. How many of the vehicles were <u>running</u> while parked near the home? ____

c. Indicate where each vehicle that <u>ran</u> was parked.

	Vehicle #1	#2	#3	#4
Attached garage/carport				
Detached garage/carport				
Driveway				
On the street				

4. Were domestic pets (cats, dogs, gerbils, birds, etc.) present in the home?

1 Yes 2 No (GO TO QUESTION 5)

How many pets? _____

5. How many cigarettes, cigars, or pipes were smoked in the home during the monitoring period?

Cigarettes _____

Cigars _____

Pipes _____

6. Indicate which of the following hobbies/activities were done by anyone in the house during the monitoring period and for how long.

Activity	Done	Time (minutes)
Gardening/yardwork		
Painting (any type)		
Woodworking		
Furniture refinishing		
Metal working (include welding and soldering)		
Model building		
Auto repair/engine repair		
Animal handling		
Other (Specify) ______________		

7. Were any of the following kinds of items stored in your house or in an attached garage <u>during</u> the monitoring period?

	Yes	No	DK
(1) Gasoline and Petroleum Products (e.g., kerosene)	1	2	3
(2) Paints and Paint Products (oil-based and latex)	1	2	3
(3) Paint thinner	1	2	3
(4) Cleaners (petroleum-based, water-based, solids; e.g., laundry detergents, degreasing compound)	1	2	3
(5) Insecticides, Pesticides, Herbicides (e.g., mothballs)	1	2	3
(6) Aerosal Sprays/personal care products (e.g., hair spray, deodorants)	1	2	3
(7) Chlorine Bleach	1	2	3
(8) New interior furnishings (e.g., floor or wall coverings, furniture)	1	2	3
(9) Room Deodorizers	1	2	3
(10) Glues and Adhesives	1	2	3
(11) New Building Materials, excluding wood, concrete, sheetrock (e.g., polyurethane insulation)	1	2	3
(12) Automotive Care Products (e.g., carburetor cleaner, wax, polishes)	1	2	3
(13) Other chemicals	1	2	3

C. PERSONAL

1. Did you have to limit your activity during the monitoring period because of asthma symptoms, cold, flu or any other illness or disability?

1 Yes
2 No }
3 Don't know } → GO TO SECTION D
4 Refused }

2. What kind of illness or disability did you have?

   1 Asthma or asthma symptoms
   2 Cold
   3 Flu
   4 Some other illness or disability
   (SPECIFY)______________________
   5 Don't know; can't say
   6 Refused

D. ACTIVITY MODIFICATION

During the introduction to this study, we explained that one main objective was to capture data which describes what Californians routinely do. Therefore monitoring normal activity patterns is vital to assessing routine exposures. In order to estimate how much your activities were like others, we would like your best answers to the following questions.

1. Were there any activities which you decided that you had to modify as a result of your participation in this study?

   1 Yes, SPECIFY______________________________
   2 No

2. Were there any activities which you did not do as a result of your participation in this study?

   1 Yes, SPECIFY______________________________
   2 No

3/6/90

Motor Vehicle Questionnaire

A. IDENTIFICATION

1. Participant ID Number: ☐☐ ☐☐☐-☐

2. Car Model: ______________________________

3. Year car manufactured: _________

4. Was car purchased new or used?

☐ New

☐ Used

5. When was car purchased? ____/____/____
Mo Day Year

B VEHICLE USAGE

Please answer the following questions for the period of time your car was being monitored.

1. Where was the car parked overnight?

☐ Attached garage

☐ Detached garage

☐ Carport

☐ Driveway

☐ Street

☐ Other, Specify: ______________________________

2. How many separate trips away from home were taken in the car?

____________ Trip(s)

3/6/90

3. How many miles was the car driven? Please sum for all trips.

   ____________ Miles

4. How many hours was the car driven?

   ____________ Hour(s)

5. How much time were the following ventilation methods used?

   Air-conditioning ____________

   Mechanical Ventilation ____________

   Windows ____________

   None ____________

6. How much time was spent in:

   heavy traffic, with frequent stops ____________

   heavy traffic, moving steadily ____________

   light traffic ____________

   in-town traffic ____________

7. During the <u>day</u>, how much time was the car parked in:

   Direct sunlight ____________

   Shade ____________

   Other, Specify:__________________ ____________

8. Has anyone ever smoked in this car?

   ☐ Yes

   ☐ No

9. Did anyone smoke in the car during the monitoring period?

   ☐ Yes, for about how many minutes? ________

   ☐ No

10. Were any household chemicals or other chemical products transported or stored in the car during the monitoring period.

☐ Yes, Specify: ______________________________

____

____

☐ No

11. Did the car pass any chemical plants or other sources of exposure during the monitoring period?

☐ Yes, Specify: ______________________________

____

____

☐ No

APPENDIX B

Sample Losses

APPENDIX B

Sample Losses During Collection

VVOC - 076-CNO*-501 - Valve not opened
100-CNO*-501 - No suitable outdoor site

VOC - 091-TXO*-501 - No suitable outdoor site
100-TXO*-501 - No suitable outdoor site
079-TXP*-501 - Pump failure
089-TXP*-501 - Pump failure
091-TXP*-501 - Participant broke cartridge
105-TXP*-501 - Pump failure
124-TXP*-501 - Pump failure

SOC - 010-XDI*-501 - Pump failure
015-XDI*-501 - Pump failure
070-XDI*-501 - Pump failure
078-XDI*-501 - Pump failure
086-XDI*-501 - Pump failure
095-XDI*-501 - Pump failure
116-XDI*-501 - Pump failure
010-XDO*-501 - Pump failure
089-XDO*-501 - Pump failure
106-XDO*-501 - No suitable outdoor site
051-XDP*-501 - Pump failure
063-XDP*-501 - Pump failure
068-XDP*-501 - Participant broke cartridge
116-XDP*-501 - Participant refusal
119-XDP*-501 - Pump failure

Sample Losses During Analysis

VVOC - None

VOC - 013-TXI*-501 - No external standard on cartridge
- 065-TXI*-501 - No external standard on cartridge
- 079-TXI*-D01 - Computer error
- 117-TXI*-501 - Bad injection
- 038-TXP*-501 - No external standard on cartridge
- 065-TXP*-501 - No external standard on cartridge
- 074-TXP*-501 - No external standard on cartridge
- 075-TXP*-501 - Computer error
- 084-TXP*-501 - Bad injection
- 003-TXP*-501 - No external standard or cartridge

SOC - only a subset of samples analyzed after extended storage

APPENDIX C

Sample Weighting Methods

APPENDIX C

C.1 Weights Based on the Sampling Design

Because a three-stage sampling design was used to select housing units and people for monitoring, the sampling weights have three weight components: one for each stage of sampling. At each stage of sampling, the weight component is the reciprocal of the conditional probability of selection at that stage of sampling.

First-stage sampling units (FSUs) were selected with probabilities proportional to size. Thus, the weight factors for the first stage of sampling are the reciprocals of the expected frequencies of selection given by equation (6.1). Three of the sample FSUs, or area segments, were subsegmented, and their sampling weights are the reciprocals of the expected frequencies of selection for the subsegments given by equation (6.3).

Sample housing units were selected for screening interviews at the second stage of sampling. Sampling weights were computed as the reciprocals of the probabilities of selection given by equation (6.5) for all 336 sample lines in the primary and reserve samples. However, as discussed in Section 6.4, multi-family dwellings were excluded from the sample after May 31. The status of each sample line was determined in the weighting process, and 37 of the 336 sample lines were determined to have been excluded because of being located in multi-family dwellings. The remaining 53 multi-family units in the sample were then treated as a simple random sample selected from all 90 multi-family units included in the 336 sample lines. Hence, the weight component for subsampling units in multi-family dwellings was 90/53 for the 53 multi-family units included in the sample and was 1.00 for all other sample lines.

Every household that contained two or more age-eligible members (12 years of age or older) was selected for environmental monitoring, but only half the households with exactly one age-eligible member were randomly selected for monitoring. Since the reciprocal of the probability of selection is the sampling weight component, the weight component associated with selection for monitoring was 1.00 for households containing two or more age-eligible members and was 2.00 for households containing only one age-eligible member.

The regimen of environmental samples to be collected in each sample home was determined by the "sample type" that was pre-printed on the sample selection label, as discussed in Section 6.5. The sample type determines inclusion in eight different data bases for which sampling weights were developed as shown in Table C-1. Because the sample types were assigned at pre-determined sampling rates, as discussed in Section 6.5, the known sampling rates were used to weight the analysis data sets inversely to the probabilities of selection as follows:

Analysis Data Base	Weight Component
1 or 6	130/130
2	130/110
3	130/60
4, 5, or 8	130/50
7	130/100

The person-level data bases (6, 7, and 8) had an additional weight component, the reciprocal of the number of age-eligible members of the household, because one person was selected at random for participation.

TABLE C-1. LIST OF DATA BASES FOR WHICH ANALYSIS WEIGHTS WERE PREPARED, ASSOCIATED SAMPLE TYPES, AND RESPONSE RATES

Analysis Data Base Description	Sample* Types	Number Selected	Number Participating	Percent Participating
1. Homes with indoor XAD samples plus either Tenax or canister indoor samples	1-7	174	128	73.6
2. Homes with indoor Tenax samples	2-7	149	104	69.8
3. Homes with indoor canister samples	1,6,7	81	62	76.5
4. Homes with outdoor XAD samples	1,4	69	50	72.5
5. Homes with outdoor Tenax samples	5-7	70	48	68.6
6. People with Study Questionnaire, Time Activity Diary, and Record of Activities and Environments	1-7	174	128	73.6
7. People with personal Tenax samples	3-7	140	93	66.4
8. People with both personal Tenax samples and outdoor Tenax samples	5,6	70	44	62.8

*See Table 6-2.

C.2 Weight Adjustments for Nonresponse

Nonresponse occurred in the Woodland study at two stages of sampling: households selected for screening and households selected for monitoring. Weight adjustment procedures were used to partially compensate for the potential bias due to nonresponse. The weight adjustment procedures partition the respondents and nonrespondents into weighting classes. The sampling weight of each respondent is simply multiplied by the ratio of a control total for each weighting class divided by the sum of the sampling weights of the respondents that belong to the weighting class. The adjusted weights of the respondents then sum to the control total. If the respondents and nonrespondents are more alike within classes than between classes with respect to their survey responses and/or their propensity to respond, then nonresponse bias is likely to be reduced. However, weighting classes are generally required to contain at least 20 to 30 respondents to avoid loss of precision due to unequal weighting.

The results of the household screening sample for the Woodland study are presented in Table C-2. We see that 285 of the 299 sample lines were occupied permanent residences and, therefore, eligible for the survey. Of these 285 eligible residences, a completed screening interview (household roster) was obtained for 196 residences. Therefore, the response rate for the screening phase of the study was 68.8 percent. This is a rather low response rate for a short, face-to-face interview. The rate of occurrence of refusals was quite high (23.2 percent of the eligible households). We expect that the high refusal rate occurred because the interviewers explained the full purpose of the study before conducting the screening

TABLE C-2. SCREENING SAMPLE RESULTS

Result	Frequency Count	 Percent
Eligible	285	95.3
Completed Screening Interview	196	65.6
Refused	66	22.1
No One Home	16	5.4
No Eligible Respondent Home	4	1.3
Language Barrier	3	1.0
Ineligible	14	4.7
Vacant	11	3.7
Not a Housing Unit	3	1.0
TOTAL	299	100.0

interviews. Therefore, people were refusing to complete the screening interview because they had no interest in participating in the monitoring phase of the study.

Weighting classes for screening nonresponse were based on the geographic sample selection strata discussed in Section 6.2. The weighting classes were defined as follows:

Weighting Class	Sampling Stratum	Number Eligible	Number Responding	Response Rate
1	1,3,5	132	80	60.6%
2	2,4	153	116	75.8%

The first weighting class is the union of the area north of Main Street and the area south of Gibson Road. The second weighting class is the portion of Woodland between these two streets. As shown above, the screening response rates are considerably different for these two strata. Since these two strata have reasonably large sample sizes and considerably different response rates, they are ideal nonresponse adjustment classes. The control total to which the sum of the respondents' weights were adjusted for each weighting class was the sum of the sampling weights of all survey-eligible sample housing units belonging to each weighting class, which is the best survey-based estimate of the number of households belonging to each weighting class.

Monitoring sample results are presented in Table C-3. Twenty-two of the 196 households that completed the screening interview were single-person households that were not selected for participation in the monitoring phase. Of the 174 households selected for participation, 128 completed the monitoring phase. Therefore, the response rate for the monitoring phase of the study was 73.6 percent. The overall study response

TABLE C-3. SCREENING SAMPLE RESULTS

Result	Frequency	
	Count	Percent
Household Selected for Monitoring	174	88.8
Completed Monitoring	128	65.3
Refused	33	16.8
Missed or Canceled Appointment	11	5.6
Participant Not at Home	2	1.0
Household Not Selected for Monitoring	22	11.2
TOTAL	196	100.0

rate, the product of the response rates for the two separate phases, was then 50.6 percent (0.688 * 0.736). This response rate is low and considerable potential for nonresponse bias may exist. However, it is not inconsistent with the response rates achieved in comparable exposure monitoring studies, as shown in Table 7-2.

Weight adjustments for nonresponse in the monitoring phase were implemented for all eight analysis data bases listed in Table C-1 using the same two weighting classes as for the screening phase nonresponse adjustments. For six of the eight data bases, the monitoring phase response rate was higher for the second weighting class, which had the lower response rate for the screening phase. The control total to which the respondents' weights were adjusted for each weighting class was the estimated weighting-class total based on the screening interviews. Since a larger sample of homes was available for the screening sample, this provided more accurate estimates of the control totals. The weights for the household-level data bases, the first five data bases listed in Table C-1, were adjusted to sum to an estimated 15,008 permanent residences in the target portion of the city of Woodland at the time of the survey. The weights for the person-level data bases, the last three data bases listed in Table C-1, were adjusted to sum to an estimated 31,470 residents aged 12 or older in these households.

The survey design effect attributable to unequal weighting was computed for each of the eight sets of final analysis weights as follows:

$$DEFF_{WT} = n\ S \bullet WT^2/(S \bullet WT)^2$$

where n is the number of respondents and WT is the final analysis weight. This design effect due to unequal weighting is 1.00 if all the weights are equal and is the variance inflation factor (>1) otherwise. For the five household-level sets of analysis weights, the unequal weighting design effect was approximately 1.15, whereas it was approximately 1.20 for the three person-level sets of analysis weights. Therefore, the sample selection and weighting strategy achieved the goal of having comparable effects of unequal weighting with slightly less effect for household-level inferences.

References

Shah, B. V., LaVange, L. M, Barnwell, B. G., Killinger, J. E., and Wheeless, S. C. (1989). SUDDAN; Procedures for Descriptive Statistics, User's Guide. Research Triangle Institute, Research Triangle Park, NC.

APPENDIX D

Additional Statistical Analysis

TABLE D-1. PEARSON CORRELATIONS FOR ALL AMOUNTS

Compound	PERSONAL WITH INDOOR		INDOOR WITH OUTDOOR	
	N	Corr.	N	Corr.
1,1,1-Trichloroethane	87	0.02	47	0.30*
1,4-Dioxane	90	0.16*	-	-
Benzene	90	0.66	47	0.33*
Carbon Tetrachloride	87	0.10*	47	0.06
m,p-Xylene	90	0.47*	47	0.21
o-Xylene	90	0.47*	47	0.20*
p-Dichlorobenzene	90	0.86*	47	0.88*
Perchloroethylene	90	0.59*	46	0.88
Styrene	90	0.96	47	0.06
Trichloroethylene	90	0.12	-	-

TABLE D-2. PEARSON CORRELATIONS FOR QUANTIFIABLE AMOUNTS ONLY

Compound	PERSONAL WITH INDOOR		INDOOR WITH OUTDOOR	
	N	Corr.	N	Corr.
1,1,1-Trichloroethane	86	0.02*	46	0.34*
1,4-Dioxane	8	0.96*	-	-
Benzene	88	0.66	47	0.33*
Carbon Tetrachloride	82	0.08*	44	0.06
m,p-Xylene	89	0.47*	47	0.21
o-Xylene	89	0.47*	47	0.20*
p-Dichlorobenzene	66	0.85*	10	0.92*
Perchloroethylene	44	0.87*	10	0.90
Styrene	88	0.96	17	-0.06
Trichloroethylene	27	-0.04	-	-

TABLE D-3. PEARSON CORRELATIONS[a] BETWEEN INDOOR VOC COMPOUND CONCENTRATIONS FOR ALL AMOUNTS

COMPOUND	5	6	7	11	15	17	20	21	25
(4) 1,1,1-Trichloroethane	0.36								0.67
(5) Benzene		0.35	0.35	0.33		0.25	0.34	0.39	
(6) Carbon Tetrachloride							0.32	0.35	0.22
(7) Trichloroethylene									
(11) Perchloroethylene						0.37		0.21	
(15) Styrene							0.21	0.27	
(17) *p*-Dichlorobenzene							0.24	0.26	
(20) *o*-Xylene								0.98	
(21) *m*,*p*-Xylene									
(25) 1,4-Dioxane									

[a] Only correlations significantly different from zero at the 0.05 level are shown.

TABLE D-4. SPEARMAN RANK[a] CORRELATIONS BETWEEN INDOOR VOC COMPOUND CONCENTRATIONS FOR ALL AMOUNTS

COMPOUND	5	6	7	11	15	17	20	21	25
(4) 1,1,1-Trichloroethane	0.39	0.45	0.34	0.51	0.44	0.33	0.43	0.41	0.22
(5) Benzene		0.30			0.66		0.85	0.88	0.28
(6) Carbon Tetrachloride				0.26	0.28	0.20	0.27	0.29	
(7) Trichloroethylene					0.28				
(11) Perchloroethylene					0.28	0.44	0.30	0.29	
(15) Styrene						0.23	0.69	0.71	0.26
(17) *p*-Dichlorobenzene									0.19
(20) *o*-Xylene								0.98	0.28
(21) *m*,*p*-Xylene									0.27
(25) 1,4-Dioxane									

[a] Only correlations significantly different from zero at the 0.05 level are shown.

TABLE D-5. PEARSON CORRELATIONS[a] BETWEEN INDOOR VOC COMPOUND CONCENTRATIONS FOR QUANTIFIABLE AMOUNTS ONLY

COMPOUND	5	6	7	11	15	17	20	21	25
(4) 1,1,1-Trichloroethane		0.35							0.96
(5) Benzene		0.35		0.32		0.24	0.34	0.38	
(6) Carbon Tetrachloride							0.30	0.33	
(7) Trichloroethylene					0.43				
(11) Perchloroethylene						0.42			
(15) Styrene							0.21	0.27	
(17) *p*-Dichlorobenzene							0.34	0.36	
(20) *o*-Xylene								0.98	
(21) *m*,*p*-Xylene									
(25) 1,4-Dioxane									
SAMPLE SIZE RANGE	100	99	33-34	21-56	34-100	24-77	34-102	34-103	7-20

[a] Only correlations significantly different from zero at the 0.05 level are shown.

TABLE D-6. SPEARMAN RANK CORRELATIONS[a] BETWEEN INDOOR VOC COMPOUND CONCENTRATIONS FOR QUANTIFIABLE AMOUNTS ONLY

COMPOUND	5	6	7	11	15	17	20	21	25
(4) 1,1,1-Trichloroethane	0.38	0.41	0.40		0.40	0.25	0.41	0.39	0.60
(5) Benzene		0.27			0.62		0.84	0.87	
(6) Carbon Tetrachloride					0.23	0.23	0.23	0.26	
(7) Trichloroethylene							0.35		
(11) Perchloroethylene						0.34	0.27	0.32	
(15) Styrene							0.66	0.68	0.46
(17) *p*-Dichlorobenzene									
(20) *o*-Xylene								0.98	
(21) *m*,*p*-Xylene									
(25) *1*,*4*-Dioxane									
SAMPLE SIZE RANGE	100	99	33-34	21-56	34-100	24-78	34-102	54-103	7-20

[a] Only correlations significantly different from zero at the 0.05 level are shown.

TABLE D-7. PEARSON CORRELATIONS[a] BETWEEN OUTDOOR VOC COMPOUND CONCENTRATIONS FOR ALL AMOUNTS

COMPOUND	5	6	11	15	17	20	21
(4) 1,1,1-Trichloroethane	0.62	0.51				0.53	0.52
(5) Benzene						0.89	0.91
(6) Carbon Tetrachloride							
(11) Perchloroethylene							
(15) Styrene							
(17) *p*-Dichlorobenzene							0.29
(20) *o*-Xylene							0.99
(21) *m*,*p*-Xylene							

[a] Only correlations significantly different from zero at the 0.05 level are shown.

TABLE D-8. SPEARMAN RANK CORRELATIONS[a] BETWEEN OUTDOOR VOC COMPOUND CONCENTRATIONS FOR ALL AMOUNTS

COMPOUND	5	6	11	15	17	20	21
(4) 1,1,1-Trichloroethane	0.46		0.38			0.46	0.45
(5) Benzene			0.29		0.58	0.86	0.88
(6) Carbon Tetrachloride							
(11) Perchloroethylene						0.32	
(15) Styrene					0.39	0.38	0.36
(17) *p*-Dichlorobenzene						0.65	0.66
(20) *o*-Xylene							0.99
(21) *m*,*p*-Xylene							

[a] Only correlations significantly different from zero at the 0.05 level are shown.

TABLE D-9. PEARSON CORRELATIONS[a] BETWEEN OUTDOOR VOC COMPOUND CONCENTRATIONS FOR QUANTIFIABLE AMOUNTS ONLY

COMPOUND	5	6	11	15	17	20	21
(4) 1,1,1-Trichloroethane	0.63	0.48				0.54	0.53
(5) Benzene						0.89	0.91
(6) Carbon Tetrachloride							
(11) Perchloroethylene							
(15) Styrene							
(17) *p*-Dichlorobenzene							
(20) *o*-Xylene							0.99
(21) *m*,*p*-Xylene							
SAMPLE SIZE RANGE	47	46-47	14	6-17	1-11	11-48	11-48

[a] Only correlations significantly different from zero at the 0.05 level are shown.

TABLE D-10. SPEARMAN RANK CORRELATIONS[a] BETWEEN OUTDOOR VOC COMPOUND CONCENTRATIONS FOR QUANTIFIABLE AMOUNTS ONLY

COMPOUND	5	6	11	15	17	20	21
(4) 1,1,1-Trichloroethane	0.46					0.46	0.44
(5) Benzene						0.86	0.88
(6) Carbon Tetrachloride							
(11) Perchloroethylene							
(15) Styrene							
(17) *p*-Dichlorobenzene							
(20) *o*-Xylene							0.99
(21) *m*,*p*-Xylene							
SAMPLE SIZE RANGE	47	46-47	14	6-17	1-10	11-48	11-48

[a] Only correlations significantly different from zero at the 0.05 level are shown.

TABLE D-11. PEARSON CORRELATIONS[a] BETWEEN PERSONAL VOC COMPOUND CONCENTRATIONS FOR ALL AMOUNTS

COMPOUND	5	6	7	11	15	17	20	21	25
(4) 1,1,1-Trichloroethane		0.72	0.37	0.22					0.73
(5) Benzene						0.34	0.65	0.67	
(6) Carbon Tetrachloride									0.57
(7) Trichloroethylene									
(11) Perchloroethylene									
(15) Styrene									
(17) *p*-Dichlorobenzene							0.25	0.27	
(20) *o*-Xylene								0.99	
(21) *m*,*p*-Xylene									
(25) 1,4-Dioxane									

[a] Only correlations significantly different from zero at the 0.05 level are shown.

TABLE D-12. SPEARMAN RANK CORRELATIONS[a] BETWEEN PERSONAL VOC COMPOUND CONCENTRATIONS FOR ALL AMOUNTS

COMPOUND	5	6	7	11	15	17	20	21	25
(4) 1,1,1-Trichloroethane		0.36	0.61	0.23	0.36		0.34	0.35	0.41
(5) Benzene		0.24		0.24	0.51		0.71	0.76	
(6) Carbon Tetrachloride					0.21				0.25
(7) Trichloroethylene				0.21	0.23				0.25
(11) Perchloroethylene							0.25	0.22	
(15) Styrene							0.51	0.54	
(17) *p*-Dichlorobenzene									
(20) *o*-Xylene								0.98	
(21) *m*,*p*-Xylene									
(25) 1,4-Dioxane									

[a] Only correlations significantly different from zero at the 0.05 level are shown.

TABLE D-13. PEARSON CORRELATIONS[a] BETWEEN PERSONAL VOC COMPOUND CONCENTRATIONS FOR QUANTIFIABLE AMOUNTS ONLY

COMPOUND	5	6	7	11	15	17	20	21	25
(4) 1,1,1-Trichloroethane		0.84	0.40						0.84
(5) Benzene						0.34	0.65	0.67	
(6) Carbon Tetrachloride									0.92
(7) Trichloroethylene									
(11) Perchloroethylene						0.27			
(15) Styrene									
(17) p-Dichlorobenzene							0.28	0.30	
(20) o-Xylene								0.99	
(21) m,p-Xylene									
(25) 1,4-Dioxane									
SAMPLE SIZE RANGE	92	88-89	37-39	34-70	39-93	33-81	39-93	39-93	14-22

[a] Only correlations significantly different from zero at the 0.05 level are shown.

TABLE D-14. SPEARMAN RANK CORRELATIONS[a] BETWEEN PERSONAL VOC COMPOUND CONCENTRATIONS FOR QUANTIFIABLE AMOUNTS ONLY

COMPOUND	5	6	7	11	15	17	20	21	25
(4) 1,1,1-Trichloroethane		0.45	0.39		0.36		0.34	0.35	0.90
(5) Benzene		0.26			0.51		0.71	0.76	
(6) Carbon Tetrachloride			0.51					0.21	
(7) Trichloroethylene									
(11) Perchloroethylene									
(15) Styrene							0.51	0.54	
(17) *p*-Dichlorobenzene									
(20) *o*-Xylene								0.98	
(21) *m*,*p*-Xylene									
(25) 1,4-Dioxane									
SAMPLE SIZE RANGE	92	88-89	37-39	34-70	39-93	33-81	39-93	39-93	14-22

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[a] Only correlations significantly different from zero at the 0.05 level are shown.

TABLE D-15. PEARSON CORRELATIONS[a] BETWEEN INDOOR VVOC COMPOUND CONCENTRATIONS FOR ALL AMOUNTS

COMPOUND	4	5	6	7	17	20	21	25	34	68
(2) Chloroform			0.35						0.56	
(4) 1,1,1-Trichloroethane		0.31								0.39
(5) Benzene						0.27	0.32			0.51
(6) Carbon Tetrachloride									0.28	0.27
(7) Trichloroethylene										
(17) *p*-Dichlorobenzene										
(20) *o*-Xylene							0.99^+			
(21) *m*,*p*-Xylene										
(25) 1,4-Dioxane										0.45
(34) Methylene Chloride										
(68) Acrolein										

[a] Only correlations significantly different from zero at the 0.05 level are shown.

TABLE D-16. SPEARMAN RANK CORRELATIONS[a] BETWEEN INDOOR VVOC COMPOUND CONCENTRATIONS FOR ALL AMOUNTS

COMPOUND	4	5	6	7	17	20	21	25	34	68
(2) Chloroform	0.36			0.28					0.30	
(4) 1,1,1-Trichloroethane		0.45		0.34		0.41	0.39			0.37
(5) Benzene					-0.33	0.69	0.72			0.54
(6) Carbon Tetrachloride										
(7) Trichloroethylene										
(17) p-Dichlorobenzene								0.27		
(20) o-Xylene							0.96			0.39
(21) m,p-Xylene									0.26	0.48
(25) 1,4-Dioxane										
(34) Methylene Chloride										0.31
(68) Acrolein										

[a] Only correlations significantly different from zero at the 0.05 level are shown.

TABLE D-17. PEARSON CORRELATIONS[a] BETWEEN INDOOR VVOC COMPOUND CONCENTRATIONS FOR QUANTIFIABLE AMOUNTS ONLY

COMPOUND	4	5	6	7	17	20	21	25	34	68
(2) Chloroform										
(4) 1,1,1-Trichloroethane										0.39
(5) Benzene										0.55
(6) Carbon Tetrachloride										
(7) Trichloroethylene										
(17) *p*-Dichlorobenzene										
(20) *o*-Xylene							0.99^+			
(21) *m*,*p*-Xylene										
(25) 1,4-Dioxane										0.61
(34) Methylene Chloride										
(68) Acrolein										
SAMPLE SIZE RANGE	12	11-32	14-47	9-26	9-32	13-56	14-59	5-12	9-41	11-47

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[a] Only correlations significantly different from zero at the 0.05 level are shown.

TABLE D-18. SPEARMAN RANK CORRELATIONS[a] BETWEEN INDOOR VVOC COMPOUND CONCENTRATIONS FOR QUANTIFIABLE AMOUNTS ONLY

COMPOUND	4	5	6	7	17	20	21	25	34	68
(2) Chloroform									0.65	
(4) 1,1,1-Trichloroethane		0.45				0.54	0.39			0.34
(5) Benzene						0.60	0.67			0.59
(6) Carbon Tetrachloride										
(7) Trichloroethylene										
(17) *p*-Dichlorobenzene										
(20) *o*-Xylene							0.95			
(21) *m*,*p*-Xylene										
(25) 1,4-Dioxane										
(34) Methylene Chloride										
(68) Acrolein										
SAMPLE SIZE RANGE	12	11-32	14-47	9-26	9-32	13-56	14-59	5-12	9-41	11-47

[a] Only correlations significantly different from zero at the 0.05 level are shown.

TABLE D-19. WEIGHTED SUMMARY STATISTICS FOR PERSONAL VOC CONCENTRATIONS ($\mu g/m^3$) BY SELECTED VARIABLES

HEAVY SMOKER[a]

	YES					NO				
		Arith.		Geo.			Arith.		Geo.	
Compound	N	Mean	S.E.	Mean	S.E.	N	Mean	S.E.	Mean	S.E.
1,1,1-Trichloroethane	6	3.2	0.58	2.6	0.45	86	23[b]	5.9	6.5[b]	1.0
Benzene	6	5.1	1.1	4.5	1.0	87	5.0	0.84	3.3	0.34
Carbon Tetrachloride	6	0.48	0.04	0.46	0.04	85	0.69	0.12	0.51	0.04
Trichloroethylene	6	1.3	0.49	0.36	0.30	87	2.4	1.2	NQ	-
Perchloroethylene	6	0.93	0.32	0.53	0.12	87	1.7	0.42	0.48	0.08
Styrene	6	1.9	0.31	1.8	0.30	87	2.5	0.77	1.2	0.09
p-Dichlorobenzene	6	23	20	3.0	2.5	87	21	4.5	2.2	0.54
o-Xylene	6	3.9	0.89	3.3	0.74	87	4.6	0.67	3.0	0.32
m,*p*-Xylene	6	8.6	1.9	7.3	1.7	87	9.3	1.4	6.1	0.67

[a] Based on responses to Q4. (If smoked 20 or more cigarettes).
[b] Means significantly different between exposed and not exposed at the 0.05 level.

TABLE D-20. WEIGHTED SUMMARY STATISTICS FOR PERSONAL VOC CONCENTRATIONS ($\mu g/m^3$) BY SELECTED VARIABLES

INSECTICIDES, PESTICIDES, HERBICIDES[a]

	EXPOSED					NOT EXPOSED				
		Arith.		Geo.			Arith.		Geo.	
Compound	N	Mean	S.E.	Mean	S.E.	N	Mean	S.E.	Mean	S.E.
1,1,1-Trichloroethane	11	4.8	1.6	3.0	0.86	81	24[b]	5.9	6.8[b]	1.1
Benzene	11	6.6	3.4	3.2	1.2	82	4.8	0.85	3.4	0.38
Carbon Tetrachloride	11	0.48	0.03	0.46	0.03	80	0.70	0.13	0.52	0.04
Trichloroethylene	11	0.34	0.18	NQ	-	82	2.6	1.31	NQ	-
Perchloroethylene	11	0.99	0.62	0.28	0.14	82	1.7	0.46	0.52	0.10
Styrene	11	1.2	0.36	0.92	0.26	82	2.6	0.81	1.3	0.10
p-Dichlorobenzene	11	10	5.83	2.9	1.4	82	23	4.8	2.2	0.55
o-Xylene	11	3.0	0.66	2.4	0.54	82	4.7[b]	0.73	3.1	0.33
m,*p*-Xylene	11	5.9	1.3	4.8	1.1	82	9.7[b]	1.5	6.4	0.72

[a] Based on responses to Q5.

[b] Means significantly different between exposed and not exposed at the 0.05 level.

TABLE D-21. WEIGHTED SUMMARY STATISTICS FOR PERSONAL VOC CONCENTRATIONS ($\mu g/m^3$) BY SELECTED VARIABLES

WORK AT REGULAR OCCUPATION[a]

	YES					NO				
		Arith.		Geo.			Arith.		Geo.	
Compound	N	Mean	S.E.	Mean	S.E.	N	Mean	S.E.	Mean	S.E.
1,1,1-Trichloroethane	41	37[b]	11	7.7	1.6	51	8.9	1.7	5.2	0.86
Benzene	41	5.6	1.7	3.2	0.62	52	4.5	0.42	3.5	0.27
Carbon Tetrachloride	41	0.78	0.22	0.48	0.06	50	0.59	0.05	0.53	0.03
Trichloroethylene	41	3.8	2.5	NQ	-	52	1.1	0.57	NQ	-
Perchloroethylene	41	1.5	0.56	0.45	0.09	52	1.7	0.73	0.51	0.12
Styrene	41	3.4	1.8	1.3	0.21	52	1.6	0.15	1.2	0.13
p-Dichlorobenzene	41	16	2.6	2.1	0.45	52	25	8.9	2.4	1.2
o-Xylene	41	6.0[b]	1.2	3.7	0.47	52	3.4	0.41	2.6	0.32
m,p-Xylene	41	12[b]	2.4	7.5	0.90	52	7.1	0.87	5.3	0.68

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[a] Based on responses to Q6.

[b] Means significantly different between exposed and not exposed at the 0.05 level.

TABLE D-22. WEIGHTED SUMMARY STATISTICS FOR PERSONAL VOC CONCENTRATIONS ($\mu g/m^3$) BY SELECTED VARIABLES

MOTHBALLS[a]

Compound	EXPOSED					NOT EXPOSED				
		Arith.		Geo.			Arith.		Geo.	
	N	Mean	S.E.	Mean	S.E.	N	Mean	S.E.	Mean	S.E.
1,1,1-Trichloroethane	38	22	8.2	6.0	1.3	54	21	9.0	6.4	1.3
Benzene	38	3.6	0.33	3.0	0.25	55	5.9	1.3	3.6	0.59
Carbon Tetrachloride	38	0.52	0.08	0.42	0.04	53	0.79	0.21	0.58[b]	0.06
Trichloroethylene	38	3.8	2.7	NQ	-	55	1.3	0.51	NQ	-
Perchloroethylene	38	1.6	0.85	0.55	0.13	55	1.7	0.54	0.44	0.10
Styrene	38	3.6	1.9	1.4	0.26	55	1.6	0.22	1.1	0.13
p-Dichlorobenzene	38	16	6.0	1.8	0.52	55	25	5.8	2.7	0.70
o-Xylene	38	4.3	0.69	3.2	0.44	55	4.7	1.2	2.9	0.55
m,p-Xylene	38	8.6	1.4	6.5	0.89	55	9.7	2.4	6.0	1.1

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[a] Based on responses to Q9.

[b] Means significantly different between exposed and not exposed at the 0.05 level.

TABLE D-23. WEIGHTED SUMMARY STATISTICS FOR PERSONAL VOC CONCENTRATIONS ($\mu g/m^3$) BY SELECTED VARIABLES

AEROSOLS[a]

	EXPOSED					NOT EXPOSED				
		Arith.		Geo.			Arith.		Geo.	
Compound	N	Mean	S.E.	Mean	S.E.	N	Mean	S.E.	Mean	S.E.
1,1,1-Trichloroethane	41	17	6.2	5.3	1.1	51	26	9.5	7.3	1.3
Benzene	41	4.4	0.50	3.5	0.35	52	5.5	1.4	3.2	0.47
Carbon Tetrachloride	39	0.55	0.07	0.47	0.03	52	0.78	0.21	0.54	0.06
Trichloroethylene	41	1.3	0.57	NQ	-	52	3.2	2.1	NQ	-
Perchloroethylene	41	2.0	0.96	0.50	0.16	52	1.3	0.38	0.46	0.07
Styrene	41	3.4	1.7	1.5	0.26	52	1.6	0.28	1.1	0.13
p-Dichlorobenzene	41	16	7.2	1.7	0.50	52	26	7.0	2.9	0.91
o-Xylene	41	4.4	0.69	3.5	0.46	52	4.6	1.4	2.6	0.43
m,*p*-Xylene	41	9.4	1.4	7.3	0.98	52	9.1	2.6	5.3	0.85

[a] Based on responses to Q14.

[b] Means significantly different between exposed and not exposed at the 0.05 level.

TABLE D-24. WEIGHTED SUMMARY STATISTICS FOR PERSONAL VOC CONCENTRATIONS ($\mu g/m^3$) BY SELECTED VARIABLES

DRY-CLEANED CLOTHES[a]

	PRESENT					NOT PRESENT				
		Arith.		Geo.			Arith.		Geo.	
Compound	N	Mean	S.E.	Mean	S.E.	N	Mean	S.E.	Mean	S.E.
1,1,1-Trichloroethane	9	13	7.2	4.5	1.3	92	6.0	0.81	3.6	0.34
Benzene	9	1.8	0.46	1.5	0.26	94	5.0[b]	1.2	2.6[b]	0.32
Carbon Tetrachloride	9	0.48	0.04	0.47	0.03	93	0.58	0.03	0.49	0.03
Trichloroethylene	9	0.42	0.29	NQ	-	94	0.70	0.20	NQ	-
Perchloroethylene	9	0.71	0.34	0.38	0.10	94	1.2	0.38	0.34	0.05
Styrene	9	0.88	0.16	0.73	0.15	94	2.9	1.2	1.0	0.16
p-Dichlorobenzene	9	5.1	3.2	0.87	0.68	94	19[b]	4.1	1.2	0.31
o-Xylene	9	1.9	0.38	1.6	0.30	94	3.2[b]	0.37	2.0	0.23
m,*p*-Xylene	9	3.5	0.58	3.0	0.51	94	6.5[b]	0.80	4.2	0.49

[a] Based on responses to Q3A.

[b] Means significantly different between exposed and not exposed at the 0.05 level.

TABLE D-25. WEIGHTED SUMMARY STATISTICS FOR PERSONAL VOC CONCENTRATIONS (μg/m^3) BY SELECTED VARIABLES

PAINT[a]

	PRESENT					NOT PRESENT				
		Arith.		Geo.			Arith.		Geo.	
Compound	N	Mean	S.E.	Mean	S.E.	N	Mean	S.E.	Mean	S.E.
1,1,1-Trichloroethane	24	8.0	3.1	3.5	0.85	78	6.1	0.91	3.7	0.38
Benzene	24	4.0	0.85	2.3	0.52	80	4.9	1.5	2.5	0.36
Carbon Tetrachloride	24	0.47	0.05	0.37	0.09	79	0.59	0.04	0.52	0.03
Trichloroethylene	24	0.49	0.14	NQ	-	80	0.73	0.23	NQ	-
Perchloroethylene	24	0.66	0.28	NQ	-	80	1.2	0.45	0.38	0.07
Styrene	24	6.8	5.2	1.0	0.25	80	1.7	0.31	1.0	0.17
p-Dichlorobenzene	24	17	9.5	1.1	0.54	80	18	4.9	1.2	0.32
o-Xylene	24	4.6	1.0	2.2	0.68	80	2.6	0.30	1.9	0.22
m,*p*-Xylene	24	8.9	2.0	4.5	1.1	80	5.5	0.71	4.0	0.51

[a] Based on responses to Q7.

[b] Means significantly different between exposed and not exposed at the 0.05 level.

TABLE D-26. WEIGHTED SUMMARY STATISTICS FOR PERSONAL VOC CONCENTRATIONS (μg/m^3) BY SELECTED VARIABLES

GLUES[a]

	PRESENT					NOT PRESENT				
		Arith.		Geo.			Arith.		Geo.	
Compound	N	Mean	S.E.	Mean	S.E.	N	Mean	S.E.	Mean	S.E.
1,1,1-Trichloroethane	14	4.8	0.74	3.9	0.65	88	6.7	1.5	3.6	0.39
Benzene	14	3.2	0.58	2.4	0.42	90	4.9	1.3	2.5	0.33
Carbon Tetrachloride	14	0.49	0.03	0.48	0.02	89	0.57	0.04	0.48	0.04
Trichloroethylene	14	0.96	0.49	NQ	-	90	0.64	0.21	NQ	-
Perchloroethylene	14	0.74	0.34	0.28	0.13	90	1.2	0.40	0.35	0.06
Styrene	14	12	10	1.6	0.67	90	1.6	0.27	0.95	0.14
p-Dichlorobenzene	14	2.2	0.72	0.84	0.54	90	20[b]	4.6	1.2	0.38
o-Xylene	14	4.8[b]	0.94	3.0	0.59	90	2.8	0.36	1.9	0.23
m,*p*-Xylene	14	9.3	1.9	5.8	1.1	90	5.8	0.76	3.9	0.48

[a] Based on responses to Q8.

[b] Means significantly different between exposed and not exposed at the 0.05 level.

TABLE D-27. WEIGHTED SUMMARY STATISTICS FOR PERSONAL VOC CONCENTRATIONS ($\mu g/m^3$) BY SELECTED VARIABLES

MOTHBALLS[a]

	PRESENT					NOT PRESENT				
		Arith.		Geo.			Arith.		Geo.	
Compound	N	Mean	S.E.	Mean	S.E.	N	Mean	S.E.	Mean	S.E.
1,1,1-Trichloroethane	41	7.1	1.7	3.8	0.54	61	6.1	1.2	3.5	0.38
Benzene	42	3.6	0.61	2.3	0.31	62	5.5	1.8	2.6	0.37
Carbon Tetrachloride	42	0.52	0.05	0.42	0.06	61	0.60	0.05	0.53	0.03
Trichloroethylene	42	0.86	0.26	NQ	-	62	0.56	0.16	NQ	-
Perchloroethylene	42	0.84	0.23	0.33	0.07	62	1.3	0.61	0.35	0.07
Styrene	42	4.6	2.9	1.1	0.23	62	1.5	0.32	0.94	0.16
p-Dichlorobenzene	42	15	6.9	0.92	0.34	62	20	4.9	1.4	0.40
o-Xylene	42	3.1	0.51	1.8	0.27	62	3.0	0.45	2.1	0.23
m,*p*-Xylene	42	6.4	1.01	3.8	0.52	62	6.2	0.93	4.3	0.53

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[a] Based on responses to Q9.

[b] Means significantly different between exposed and not exposed at the 0.05 level.

TABLE D-28. WEIGHTED SUMMARY STATISTICS FOR PERSONAL VOC CONCENTRATIONS ($\mu g/m^3$) BY SELECTED VARIABLES

PETROLEUM PRODUCTS[a]

	PRESENT					NOT PRESENT				
		Arith.		Geo.			Arith.		Geo.	
Compound	N	Mean	S.E.	Mean	S.E.	N	Mean	S.E.	Mean	S.E.
1,1,1-Trichloroethane	67	6.2	1.0	3.6	0.40	35	7.0	2.3	3.7	0.61
Benzene	68	5.3	1.6	2.4	0.27	36	3.6	0.83	2.5	0.52
Carbon Tetrachloride	67	0.52	0.04	0.45	0.04	36	0.64	0.07	0.55	0.05
Trichloroethylene	68	0.83[b]	0.20	NQ	-	36	0.41	0.17	NQ	-
Perchloroethylene	68	1.4	0.62	0.40	0.09	36	0.54	0.18	0.26	0.08
Styrene	68	3.4	1.7	1.0	0.16	36	1.6	0.37	0.96	0.20
p-Dichlorobenzene	68	25[b]	6.5	1.5	0.47	36	6.0	2.2	0.75	0.25
o-Xylene	68	3.4	0.50	2.1	0.25	36	2.3	0.37	1.8	0.30
m,*p*-Xylene	68	6.9	0.99	4.3	0.49	36	5.1	1.0	3.7	0.70

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[a] Based on responses to Q7, Q8, Q12 and Q15.

[b] Means significantly different between exposed and not exposed at the 0.05 level.

TABLE D-29. WEIGHTED SUMMARY STATISTICS FOR PERSONAL VOC CONCENTRATIONS ($\mu g/m^3$) BY SELECTED VARIABLES

GAS COOKING RANGE OR OVEN[a]

	USED					NOT USED				
		Arith.		Geo.			Arith.		Geo.	
Compound	N	Mean	S.E.	Mean	S.E.	N	Mean	S.E.	Mean	S.E.
1,1,1-Trichloroethane	44	8.4	2.9	3.8	0.64	58	5.1	0.78	3.5	0.48
Benzene	45	6.2	2.4	2.6	0.39	59	3.6	0.63	2.4	0.41
Carbon Tetrachloride	44	0.64	0.05	0.55	0.04	59	0.51	0.04	0.44	0.04
Trichloroethylene	45	0.63	0.21	NQ	-	59	0.71	0.28	NQ	-
Perchloroethylene	45	0.76	0.20	0.30	0.07	59	1.4	0.64	0.37	0.10
Styrene	45	1.8	0.40	1.0	0.21	59	3.5	1.9	1.0	0.19
p-Dichlorobenzene	45	25	6.6	1.6	0.64	59	13	5.8	0.95	0.33
o-Xylene	45	2.9	0.46	2.1	0.28	59	3.2	0.49	1.9	0.30
m,p-Xylene	45	5.9	0.97	4.3	0.62	59	6.5	1.0	3.9	0.62

[a] Based on responses to Q22A.

[b] Means significantly different between exposed and not exposed at the 0.05 level.

TABLE D-30. WEIGHTED SUMMARY STATISTICS FOR PERSONAL VOC CONCENTRATIONS ($\mu g/m^3$) BY SELECTED VARIABLES

HOME AIR CONDITIONED[a]

	YES					NO				
		Arith.		Geo.			Arith.		Geo.	
Compound	N	Mean	S.E.	Mean	S.E.	N	Mean	S.E.	Mean	S.E.
1,1,1-Trichloroethane	44	7.1	0.99	5.1[b]	0.58	54	6.3	2.3	2.9	0.42
Benzene	45	4.9	0.77	3.5[b]	0.52	55	4.6	2.0	1.9	0.27
Carbon Tetrachloride	45	0.59	0.07	0.51	0.05	54	0.54	0.04	0.46	0.05
Trichloroethylene	45	0.72	0.19	NQ	-	55	0.69	0.23	NQ	-
Perchloroethylene	45	0.79	0.21	0.34	0.07	55	1.4	0.67	0.34	0.08
Styrene	45	4.7	2.9	1.4[b]	0.27	55	1.4	0.34	0.77	0.14
p-Dichlorobenzene	45	16	7.5	1.3	0.49	55	20	6.5	1.1	0.40
o-Xylene	45	4.2[b]	0.60	3.0[b]	0.44	55	2.1	0.24	1.4	0.17
m,*p*-Xylene	45	8.4[b]	1.3	5.9[b]	0.91	55	4.5	0.62	3.0	0.38

[a] Based on responses to QA2.

[b] Means significantly different between exposed and not exposed at the 0.05 level.

TABLE D-31. WEIGHTED SUMMARY STATISTICS FOR PERSONAL VOC CONCENTRATIONS ($\mu g/m^3$) BY SELECTED VARIABLES

VENTILATION[a]

	WHOLE HOUSE FAN				WINDOW FAN, OPEN DOORS OR WINDOWS				OTHER			
	Arith.		Geo.		Arith.		Geo.		Arith.		Geo.	
Compound	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
1,1,1-Trichloroethane	4.6	0.71	3.7	0.54	7.2	2.0	3.6	0.50	10.4	2.2	9.1	2.3
Benzene	3.6	0.86	2.5	0.50	5.2	1.7	2.4	0.37	5.9	1.0	5.6	1.0
Carbon Tetrachloride	0.49	0.06	0.44	0.05	0.58	0.05	0.49	0.05	0.55	0.04	0.55	0.03
Trichloroethylene	0.52	0.18	NQ	-	0.74	0.27	NQ	-	1.3	0.67	0.66	0.38
Perchloroethylene	0.65	0.19	0.32	0.11	1.4	0.49	0.36	0.07	0.47	0.17	0.29	0.19
Styrene	7.2	5.5	1.3	0.19	1.6	0.33	0.92	0.17	2.8	1.4	1.4	1.2
_p_-Dichlorobenzene	12	11	0.52	0.20	21	4.5	1.5	0.54	15	13	2.7	2.6
_o_-Xylene	3.3	0.65	2.4	0.40	2.8	0.40	1.8	0.24	7.0	3.3	4.8	1.9
_m_,_p_-Xylene	6.4	1.31	4.7	0.79	5.9	0.89	3.8	0.52	14	6.2	9.8	3.9
SAMPLE SIZE	22-23				67-68				4			

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[a] Based on responses to QA3.

[b] Means significantly different between whole house fan and window fan, open doors or windows at the 0.05 level.

TABLE D-32. WEIGHTED SUMMARY STATISTICS FOR PERSONAL VOC CONCENTRATIONS ($\mu g/m^3$) BY SELECTED VARIABLES

VEHICLES RUNNING WITHIN 50 FEET OF HOME[a]

	YES					NO				
		Arith.		Geo.			Arith.		Geo.	
Compound	N	Mean	S.E.	Mean	S.E.	N	Mean	S.E.	Mean	S.E.
1,1,1-Trichloroethane	33.	6.2	2.6	2.9	0.69	69	6.6	0.96	4.0	0.46
Benzene	33	7.7	3.9	2.4	0.56	71	3.6	0.65	2.5	0.34
Carbon Tetrachloride	33	0.52	0.05	0.40	0.09	70	0.58	0.04	0.52	0.03
Trichloroethylene	33	0.66	0.22	NQ	-	71	0.68	0.22	NQ	-
Perchloroethylene	33	0.81	0.29	0.25	0.06	71	1.2	0.49	0.38	0.07
Styrene	33	5.7	4.1	0.92	0.26	71	1.6	0.29	1.0	0.18
p-Dichlorobenzene	33	22	11	0.90	0.55	71	16	3.8	1.3	0.32
o-Xylene	33	4.0	0.88	2.0	0.54	71	2.7	0.30	2.0	0.21
m,*p*-Xylene	33	8.1	1.8	4.2	0.99	71	5.5	0.68	4.0	0.47

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[a] Based on responses to QB3B.

[b] Means significantly different between exposed and not exposed at the 0.05 level.

TABLE D-33. WEIGHTED SUMMARY STATISTICS FOR PERSONAL VOC CONCENTRATIONS ($\mu g/m^3$) BY SELECTED VARIABLES

PETS IN HOME[a]

	YES					NO				
		Arith.		Geo.			Arith.		Geo.	
Compound	N	Mean	S.E.	Mean	S.E.	N	Mean	S.E.	Mean	S.E.
1,1,1-Trichloroethane	51	5.4	0.43	3.7	0.43	47	7.8	2.9	3.6	0.55
Benzene	53	5.8	2.1	2.5	0.33	47	3.6	0.69	2.4	0.34
Carbon Tetrachloride	52	0.49	0.02	0.42	0.04	47	0.63[b]	0.06	0.56[b]	0.04
Trichloroethylene	53	1.1[b]	0.30	NQ	-	47	0.28	0.11	NQ	-
Perchloroethylene	53	0.88	0.20	0.35	0.07	47	1.4	0.76	0.33	0.08
Styrene	53	4.1	2.2	1.1	0.20	47	1.3	0.25	0.90	0.16
_p_-Dichlorobenzene	53	13	5.2	1.3	0.43	47	24	6.9	1.0	0.38
_o_-Xylene	53	2.8	0.24	1.9	0.24	47	3.2	0.56	2.0	0.27
_m_,_p_-Xylene	53	5.9	0.60	3.9	0.48	47	6.5	1.2	4.1	0.63

[a] Based on responses to QB4.

[b] Means significantly different between exposed and not exposed at the 0.05 level.

TABLE D-34. WEIGHTED SUMMARY STATISTICS FOR PERSONAL VOC CONCENTRATIONS ($\mu g/m^3$) BY SELECTED VARIABLES

SMOKING IN HOME[a]

	HEAVY				LIGHT				NONE			
	Arith.		Geo.		Arith.		Geo.		Arith.		Geo.	
Compound	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
1,1,1-Trichloroethane	5.8	1.8	3.5	0.95	6.6	2.6	3.4	0.42	6.6	1.1	3.7[c]	0.40
Benzene	5.5	1.5	3.6	1.1	7.0	4.4	2.4	0.38	3.6	0.54	2.3[c]	0.30
Carbon Tetrachloride	0.55	0.11	0.47	0.08	0.62	0.06	0.57	0.04	0.55	0.05	0.45	0.05
Trichloroethylene	1.2	0.44	NQ	-	0.56	0.28	NQ	-	0.60	0.15	NQ	-
Perchloroethylene	1.9	1.1	0.31	0.18	2.0	0.84	0.49	0.15	0.58	0.13	0.30	0.07
Styrene	2.4	0.54	1.6	0.43	1.6	0.52	0.99	0.20	3.3	1.8	0.92	0.16
p-Dichlorobenzene	34	26	1.5	1.0	14	6.4	1.9	0.87	16	4.7	0.93	0.31
o-Xylene	3.6	0.74	2.5	0.63	2.2	0.40	1.7	0.31	3.3	0.49	2.0	0.28
m,p-Xylene	8.0	1.7	5.6	1.5	4.7	0.98	3.7	0.72	6.5	0.97	4.0	0.54
SAMPLE SIZE	15				24-25				63-64			

[a] Based on responses to QB5A, QB5B and QB5C.
[b] Means significantly different between heavy and light at the 0.05 level.
[c] Means significantly different between light land none at the 0.05 level.

Table D-35. Frequencies and Weighted Percentages for Responses to the Study Questionnaire

		Sample Frequency	Weighted Percentage
1.	SEX (BY OBSERVATION)		
	<1> MALE	69	54.6
	<2> FEMALE	59	45.4
2_Y.	WHAT IS YEAR OF BIRTH?		
	1900-1935	23	17.6
	1936-1950	20	13.7
	1951-1965	61	51.1
	1966-1978	23	17.0
	REFUSED	1	0.6
3.	What is the last year of school you completed?		
	≤8	21	17.7
	9-12	60	44.9
	13-14	26	22.4
	15-16	12	8.4
	17-18	9	6.7
4.	Does your house have an attached garage or parking area underneath it?		
	<1> YES	62	43.5
	<2> NO	66	56.5
4A.	Is there usually one or more motor vehicles parked in it for some part of each day?		
	<1> YES	39	63.1
	<2> NO	21	34.0
	<8> DON'T KNOW	2	2.9
5.	Is there insulation and/or weatherstripping between the garage and the house?		
	<1> INSULATION	8	14.3
	<2> WEATHERSTRIPPING	1	1.5
	<3> BOTH	45	71.3
	<4> NEITHER	5	8.6
	<8> DON'T KNOW	3	4.2
6.	Do you have a gas range or oven?		
	<1> YES	66	53.5
	<2> NO	62	46.5

(continued)

Table D-35 (continued)

	Sample Frequency	Weighted Percentage
6A. Does your gas range or oven have one or more gas pilot lights which are always lit?		
<1> YES	42	67.1
<2> NO	24	32.9
7. Do you have a gas water heater?		
<1> YES	106	76.1
<2> NO	19	20.5
<8> DON'T KNOW	3	3.4
7A. Does the hot water heater have a gas pilot light which is always lit?		
<1> YES	100	94.2
<2> NO	5	5.1
<8> DON'T KNOW	1	0.8
8. Do you have a gas clothes dryer?		
<1> YES	14	10.6
<2> NO	114	89.4
8A. Does the clothes dryer have a gas pilot light which is always lit?		
<1> YES	12	68.7
<2> NO	6	31.3
8B. Where is it located?		
<1> ROOM OR CLOSET INSIDE LIVING QUARTERS	3	13.4
<2> UTILITY ROOM OUTSIDE LIVING QUARTERS	11	62.4
<3> GARAGE	4	24.1
8C. How is the dryer vented?		
<1> VENTED INSIDE THE LIVING AREA INCLUDING UTILITY ROOM	2	12.4
<2> VENTED TO THE OUTDOORS	12	87.6
9A. Is your water supplied by a municipality or corporation?		
<1> YES	109	85.3
<2> NO	16	11.8
<8> DON'T KNOW	3	2.9

(continued)

Table D-35 (continued)

		Sample Frequency	Weighted Percentage
9B.	Do you regularly use bottled water?		
	<1> YES	30	22.8
	<2> NO	97	76.5
	<8> DON'T KNOW	1	0.7
10A.	Did you or any member of the household use insecticides, such as Raid, in the home in the past 6 months?		
	<1> YES	58	44.8
	<2> NO	70	55.2
10B1.	In which rooms?		
	Living Room?		
	<1> YES	23	42.8
	<2> NO	34	54.7
	<8> DON'T KNOW	1	2.4
10B2.	Dining room?		
	<1> YES	16	29.6
	<2> NO	41	68.0
	<8> DON'T KNOW	1	2.4
10B3.	Kitchen?		
	<1> YES	41	70.7
	<2> NO	16	26.9
	<8> DON'T KNOW	1	2.4
10B4.	Den?		
	<1> YES	4	6.9
	<2> NO	53	90.6
	<8> DON'T KNOW	1	2.4
10B5.	Master bedroom?		
	<1> YES	16	28.2
	<2> NO	41	69.4
	<8> DON'T KNOW	1	2.4
10B6.	Other bedroom?		
	<1> YES	9	16.0
	<2> NO	48	81.6
	<8> DON'T KNOW	1	2.4
10B7.	Some other room?		
	<1> YES	24	42.2
	<2> NO	33	55.4
	<8> DON'T KNOW	1	2.4

(continued)

Table D-35 (continued)

		Sample Frequency	Weighted Percentage
11A.	Did you pay someone to have your home treated for pests in the past 6 months?		
	<1> YES	25	21.2
	<2> NO	103	78.8
11B.	About how many times in the past 6 months?		
	NUMBER OF TIMES		
	1-	15	68.2
	2-	4	13.4
	3-	3	9.3
	>3	3	9.1
12.	Do you have a fireplace in your home?		
	<1> YES	69	48.6
	<2> NO	59	51.4
13A.	Is all or part of your home carpeted?		
	<1> ALL	86	70.1
	<2> PART	40	28.0
	<3> NONE	2	2.0
13B1.	Other than vacuuming or carpet sweeping, when was any part of the carpet last cleaned and what method was used?		
	<1> WITHIN PAST 30 DAYS	19	14.4
	<2> WITHIN PAST 31-90 DAYS	23	17.9
	<3> WITHIN PAST 91-360 DAYS	48	36.0
	<8> DON'T KNOW	12	11.3
	<9> REFUSED	24	20.4
13B2.	METHOD OF CLEANING		
	<1> STEAM CLEANED	29	21.1
	<2> PROFESSIONALLY DRY CLEANED	16	12.4
	<3> SPOT CLEANED OR DRY CLEANED BY RESIDENT	27	21.1
	<4> OTHER METHOD	54	45.4
14_1.	In which areas of your home do you and other household members spend most of your waking hours?		
	Living Room?		
	<1> YES	100	79.7
	<2> NO	28	20.3

(continued)

Table D-35 (continued)

	Sample Frequency	Weighted Percentage
14_2. Dining room?		
<1> YES	33	24.6
<2> NO	95	75.4
14_3. Kitchen?		
<1> YES	48	35.3
<2> NO	80	64.7
14_4. Den?		
<1> YES	9	6.3
<2> NO	119	93.7
14_5. Master bedroom?		
<1> YES	6	4.3
<2> NO	122	95.7
14_6. Other bedroom?		
<1> YES	8	6.5
<2> NO	120	93.5
14_7. Some other room?		
<1> YES	15	11.6
<2> NO	113	88.4
15A. Do you store cleaning supplies (such as chlorine bleaches or detergents) in the following places?		
Kitchen?		
<1> YES	96	76.0
<2> NO	32	24.0
15B. Utility room?		
<1> YES	46	33.8
<2> NO	51	38.5
<9> REFUSED	31	27.6
15C. Bathroom?		
<1> YES	68	55.0
<2> NO	57	43.1
<8> DON'T KNOW	2	1.2
<9> REFUSED	1	0.6
15D. Attached garage?		
<1> YES	59	41.9
<2> NO	49	38.1
<8> DON'T KNOW	2	1.3
<9> REFUSED	18	18.7

(continued)

Table D-35 (continued)

		Sample Frequency	Weighted Percentage
15E.	Some other place?		
	<1> YES	13	11.4
	<2> NO	102	79.0
	<8> DON'T KNOW	4	3.2
	<9> REFUSED	9	6.5
16A.	Do you store paints, varnishes, or paint thinners or removers in the following places?		
	Attached garage?		
	<1> YES	61	42.2
	<2> NO	49	37.7
	REFUSED	18	20.2
16B.	Basement?		
	<1> YES	2	1.6
	<2> NO	67	49.2
	<9> REFUSED	59	49.2
16C.	Attic?		
	<1> YES	1	0.7
	<2> NO	79	58.4
	<9> REFUSED	48	40.9
16D.	Attached shop or workroom?		
	<1> YES	8	5.3
	<2> NO	68	50.0
	<9> REFUSED	52	44.7
16E.	Utility room?		
	<1> YES	7	4.8
	<2> NO	84	61.8
	<9> REFUSED	37	33.4
16.	Other room?		
	<1> YES	28	24.6
	<2> NO	93	69.9
	<8> DON'T KNOW	1	0.7
	<9> REFUSED	6	4.8

(continued)

Table D-35 (continued)

		Sample Frequency	Weighted Percentage
17A.	Do you store kerosene, gasoline, pesticides, insecticides, or lawn and garden chemicals in the following places?		
	Attached garage?		
	<1> YES	59	41.8
	<2> NO	48	35.7
	<8> DON'T KNOW	1	0.6
	<9> REFUSED	20	21.9
17B.	Basement?		
	<1> YES	67	49.2
	<8> DON'T KNOW	1	0.6
	<9> REFUSED	60	50.2
17C.	Attic?		
	<1> YES	76	56.1
	<8> DON'T KNOW	1	0.6
	<9> REFUSED	51	43.3
17D.	Attached shop or workroom?		
	<1> YES	3	1.9
	<2> NO	70	51.8
	<8> DON'T KNOW	1	0.6
	<9> REFUSED	54	45.7
17E.	Utility room?		
	<1> YES	7	4.8
	<2> NO	80	58.8
	<9> REFUSED	41	36.4
17F.	Any other room?		
	<1> YES	41	33.1
	<2> NO	78	59.7
	<8> DON'T KNOW	2	1.3
	<9> REFUSED	7	5.8
18.	Next, I have a few questions about you and your occupation.		
	Are you currently employed?		
	<1> YES	80	63.3
	<2> NO	48	36.7

(continued)

Table D-35 (continued)

	Sample Frequency	Weighted Percentage
19H. How many hours per day and days per week do you work during a normal work week at your primary job?		
WORK HOURS		
<8	12	14.2
8	42	53.6
>8	24	30.1
DON'T KNOW	1	1.1
REFUSED	1	1.1
WORK DAYS <1-7>		
<5	8	11.4
5	58	69.4
>5	12	17.1
DON'T KNOW	1	1.1
REFUSED	1	1.1
23_1. How do you travel to work most often?		
Work at home?		
<1> YES	6	5.9
<2> NO	74	94.1
23_2. Walk?		
<1> YES	5	6.0
<2> NO	75	94.0
23_3. Bicycle?		
<1> YES	5	5.1
<2> NO	75	94.9
23_4. Motorcycle?		
<1> YES	1	0.9
<2> NO	79	99.1
23_5. Bus?		
<1> YES	1	1.0
<2> NO	79	99.0
23_6. Car, Cab, or Van?		
<1> YES	63	79.4
<2> NO	17	20.6
23_7. Truck?		
<1> YES	13	17.9
<2> NO	67	82.1

(continued)

Table D-35 (continued)

	Sample Frequency	Weighted Percentage
23_8. Train?		
<1> YES	0	
<2> NO	80	100
23_9. Some other form of transportation?		
<1> YES	2	1.9
<2> NO	78	98.1
Which of the following describe your status?		
24_1. Disabled?		
<1> YES	4	11.2
<2> NO	44	88.8
24_2. Looking for work?		
<1> YES	5	11.3
<2> NO	43	88.7
24_3. On layoff from work?		
<1> YES	2	3.6
<2> NO	46	96.4
24_4. Retired?		
<1> YES	13	25.4
<2> NO	35	74.6
24_5. Going to school?		
<1> YES	13	26.0
<2> NO	35	74.0
24_6. Keeping house?		
<1> YES	18	34.3
<2> NO	30	65.7
24_7. Some other status?		
<1> YES	5	10.5
<2> NO	43	89.5
25. Do you have a part-time job or work regularly as a volunteer?		
<1> YES	18	13.3
<2> NO	109	86.1
<8> DON'T KNOW	1	0.7

Table D-36. Frequencies and Weighted Percentages for Responses to the Record of Activities and Environments Questionnaire

	Sample Frequency	Weighted Percentage
1A. Did you spend any time at a gas station or in a parking garage or auto repair shop during the past 24 hours?		
<1> YES	32	27.5
<2> NO	95	72.5
2A. Did you pump or pour gasoline during the past 24 hours?		
<1> YES	15	13.5
<2> NO	112	86.5
2B. Was it leaded or unleaded?		
<1> LEADED	6	51.1
<2> UNLEADED	9	48.9
3A. Do you have clothes in the house that have been dry-cleaned in the past week?		
<1> YES	11	8.9
<2> NO	115	90.6
<8> DON'T KNOW	1	0.5
3B. Did you wear any of these clothes in the past 24 hours?		
<1> YES	4	38.9
<2> NO	7	61.1
4A. Did you smoke any cigarettes during the monitoring period?		
<1> YES	30	22.8
<2> NO	97	77.2
4B. About how many cigarettes did you smoke?		
NUMBER OF CIGARETTES		
≤10	11	45.5
11-20	15	44.7
>20	4	9.8

(continued)

Table D-36 (continued)

		Sample Frequency	Weighted Percentage
4C.	During the monitoring period, did anyone smoke tobacco products near you?		
	<1> YES	65	51.9
	<2> NO	61	47.4
	<8> DON'T KNOW	1	0.6
5.	Have you used or worked with insecticides, pesticides, or herbicides in any way, including farming or gardening in the past 24 hours?		
	<1> YES	13	9.7
	<2> NO	114	90.3
6.	Did you go to work today in your regular occupation?		
	<1> YES	55	44.2
	<2> NO	52	39.2
	<3> UNEMPLOYED	19	16.0
	<8> DON'T KNOW	1	0.6
7.	Have you used or been near any of the following in the past 24 hours? Paints/solvents (oil based paints, acetone, chloroform, toluene)?		
	<1> YES	30	24.8
	<2> NO	97	75.2
8.	Vaporizing or odorous glues or adhesives?		
	<1> YES	18	13.0
	<2> NO	109	87.0
9.	Moth crystals, room air freshener, or bathroom deodorizers?		
	<1> YES	49	39.1
	<2> NO	78	60.9

(continued)

Table D-36 (continued)

	Sample Frequency	Weighted Percentage
10. Petroleum products (gasoline, fuel oil, motor oil, kerosene) excluding pumping your own gas?		
<1> YES	31	25.4
<2> NO	96	74.6
11. Auto or truck or lawn mower exhausts (heavy or long exposure, such as in an attached garage or tunnel or expressway)?		
<1> YES	40	31.8
<2> NO	86	67.6
<8> DON'T KNOW	1	0.6
12. Cleaning solutions (including household cleaners or chemicals)?		
<1> YES	73	57.6
<2> NO	54	42.4
13. Flea collars, flea powder, or pet shampoo?		
<1> YES	6	5.3
<2> NO	121	94.7
14. Aerosol personal care products such as hair sprays, or deodorants?		
<1> YES	52	43.6
<2> NO	75	56.4
15. Polishing or waxing agents?		
<1> YES	13	10.3
<2> NO	114	89.7
16. Any other product that involved exposure to chemicals?		
<1> YES	23	15.8
<2> NO	103	83.6
<8> DON'T KNOW	1	0.6

(continued)

Table D-36 (continued)

	Sample Frequency	Weighted Percentage
17. Did you use or were you near any barbecue or grill?		
<1> YES	15	11.7
<2> NO	112	88.3
18A. Did you take any showers or baths in the house or anywhere else in the past 24 hours?		
<1> YES	98	75.3
<2> NO	29	24.7
18B. How long did the water run?		
NUMBER OF MINUTES		
≤10 min	49	43.2
11-20	39	45.5
>20	10	11.3
19A. Did anyone else take any showers or baths in the house in the past 24 hours?		
<1> YES	97	78.1
<2> NO	29	21.2
<8> DON'T KNOW	1	0.6
19B. How many baths and showers were taken?		
NUMBER		
1	36	31.1
2	27	25.5
3	16	21.9
>3	18	21.5
20. Was a dishwasher in use while you were in the house in the past 24 hours?		
<1> YES	36	26.5
<2> NO	90	71.5
<8> DON'T KNOW	1	2.0

(continued)

Table D-36 (continued)

	Sample Frequency	Weighted Percentage
21. Was a clotheswasher in use while you were in the house in the past 24 hours?		
<1> YES	52	36.2
<2> NO	75	63.8
21A1. How many loads were washed with hot or warm water?		
NUMBER <0-20>		
0	9	14.8
1	21	39.2
2	12	25.3
>2	9	19.0
DON'T KNOW	1	1.7
21A2. How many loads were washed with cold water?		
NUMBER <0-20>		
0	32	62.9
1	13	25.5
2	2	3.4
>2	3	4.8
DON'T KNOW	2	3.4
21B. Was bleach used?		
<1> YES	11	25.2
<2> NO	41	74.8
In the past 24 hours, which of the following combustion sources were used (turned on) by anyone in your home or in attached structures such as a garage, basement or storage room?		
22A. Gas cooking range or oven?		
<1> YES	56	47.1
<2> NO	70	52.3
<8> DON'T KNOW	1	0.6
22B. Gas water heater?		
<1> YES	109	83.3
<2> NO	17	16.1
<8> DON'T KNOW	1	0.6

(continued)

Table D-36 (continued)

	Sample Frequency	Weighted Percentage
22C. Gas clothes dryer?		
<1> YES	9	5.2
<2> NO	117	94.2
<8> DON'T KNOW	1	0.6
22D. Gas space heater?		
<1> YES	3	2.1
<2> NO	123	97.4
<8> DON'T KNOW	1	0.6
22E. Kerosene space heater?		
<1> YES	0	0.0
<2> NO	126	99.4
<8> DON'T KNOW	1	0.6
22F. Fireplace?		
<1> YES	4	2.3
<2> NO	122	97.2
<8> DON'T KNOW	1	0.6
22G. Wood stove?		
<1> YES	1	0.6
<2> NO	125	98.8
<8> DON'T KNOW	1	0.6
22H. Gas furnace?		
<1> YES	9	6.0
<2> NO	117	93.4
<8> DON'T KNOW	1	0.6
22I. Oil furnace?		
<1> YES	0	0.0
<2> NO	126	99.4
<8> DON'T KNOW	1	0.6
22J. Some other combustion source?		
<1> YES	5	4.4
<2> NO	121	95.1
<8> DON'T KNOW	1	0.6

(continued)

Table D-36 (continued)

	Sample Frequency	Weighted Percentage
A1. Was any part of your home heated during the monitoring period?		
<1> YES	4	3.2
<2> NO	119	93.3
<8> DON'T KNOW	4	3.5
A1A1. Electricity?		
<1> YES	0	
<2> NO	4	100
A1A2. Gas?		
<1> YES	4	100
<2> NO	0	
A1A3. Oil?		
<1> YES	0	
<2> NO	4	100
A1A4. Solar?		
<1> YES	0	
<2> NO	4	100
A1A5. Wood?		
<1> YES	0	
<2> NO	4	100
A1A6. Kerosene?		
<1> YES	0	
<2> NO	4	100
A1A7. Some other source of heat energy?		
<1> YES	0	
<2> NO	4	100
What type of device was used to create the heat?		
YES/NO FOR EACH TYPE		

(continued)

Table D-36 (continued)

	Sample Frequency	Weighted Percentage
A1B1. Basement furnace?		
<1> YES	0	
<2> NO	4	100
A1B2. Wall furnace?		
<1> YES	1	19.4
<2> NO	3	80.6
A1B3. In-floor furnace?		
<1> YES	0	
<2> NO	4	100
A1B4. Outside furnace?		
<1> YES	2	48.5
<2> NO	2	51.5
A1B5. Wood stove?		
<1> YES	0	
<2> NO	4	100
A1B6. Kerosene stove?		
<1> YES	0	
<2> NO	4	100
A1B7. Baseboard heater?		
<1> YES	0	
<2> NO	4	100
A1B8. Radiant heater?		
<1> YES	0	
<2> NO	4	100
A1B9. Fireplace?		
<1> YES	0	
<2> NO	4	100
A1B10. Heat pump?		
<1> YES	1	19.2
<2> NO	3	80.8

(continued)

Table D-36 (continued)

		Sample Frequency	Weighted Percentage
A1B11.	Fireplace insert?		
	<1> YES	0	
	<2> NO	4	100
A1B12.	Space heater?		
	<1> YES	0	
	<2> NO	4	100
A1B13.	Some other device to create heat?		
	<1> YES	0	
	<2> NO	4	100
A2.	Was your home air conditioned during this monitoring period?		
	<1> YES	51	39.2
	<2> NO	72	57.3
	<8> DON'T KNOW	4	3.5
A2_1.	Was the air conditioning done by:		
	<1> A Central unit	39	77.9
	<2> Window/wall units	12	22.1
A2A.	Does the central unit cool by:		
	<1> Evaporation? (swamp cooler) or	2	3.8
	<2> Refrigeration?	37	96.2
A2A1.	Does the central unit:		
	<1> Recirculate inside air?	15	33.8
	<2> Bring in outside air though a vent? or	5	11.3
	<3> A combination of both recirculation and bringing in outside air?	17	48.9
	<4> DON'T KNOW	2	6.1

(continued)

Table D-36 (continued)

		Sample Frequency	Weighted Percentage
A2B.	How many window or wall units are in the home?		
	NUMBER <1-25>		
	1	9	79.4
	2	2	14.0
	>2	1	6.6
A2B1.	How many were used for at least 50% of the past 24 hours?		
	NUMBER <0-25>		
	0	2	14.0
	1	8	67.4
	>1	2	18.6
Which of the following ventilation devices were in use during this monitoring period?			
A3A.	Whole house fan?		
	<1> YES	26	19.0
	<2> NO	92	71.4
	<3> NO VENTILATION METHODS USED	6	6.7
	<8> DON'T KNOW	3	2.9
A3B.	Ceiling fans?		
	<1> YES	39	30.8
	<2> NO	79	66.1
	<8> DON'T KNOW	3	3.1
A3C.	Window fan(s)?		
	<1> YES	7	6.1
	<2> NO	111	90.8
	<8> DON'T KNOW	3	3.1
A3D.	Portable room fan(s)?		
	<1> YES	39	31.2
	<2> NO	79	65.7
	<8> DON'T KNOW	3	3.1

(continued)

Table D-36 (continued)

		Sample Frequency	Weighted Percentage
A3E.	Bathroom or kitchen exhaust fan(s)?		
	<1> YES	50	44.7
	<2> NO	68	52.2
	<8> DON'T KNOW	3	3.1
A3F.	Doors open (natural ventilation)?		
	<1> YES	81	66.0
	<2> NO	37	30.9
	<8> DON'T KNOW	3	3.1
A3G.	Windows open (natural ventilation)?		
	<1> YES	103	85.0
	<2> NO	15	11.9
	<8> DON'T KNOW	3	3.1
A3H.	Some other type of ventilation?		
	<1> YES	4	4.2
	<2> NO	114	92.7
	<8> DON'T KNOW	3	3.1
Which of the following air cleaning or treating devices were in use during this monitoring period?			
A4A.	Filters in air handling system?		
	<1> YES	37	28.7
	<2> NO	67	50.8
	<3> NO AIR CLEANING OR TREATING DEVICES USED	19	15.9
	<8> DON'T KNOW	4	4.6
A4B.	Charcoal air filters?		
	<1> YES	0	0.0
	<2> NO	105	96.6
	<8> DON'T KNOW	3	3.4
A4C.	Electrostatic precipitator?		
	<1> YES	1	1.1
	<2> NO	104	95.5
	<8> DON'T KNOW	3	3.4

(continued)

Table D-36 (continued)

		Sample Frequency	Weighted Percentage
A4D.	Ionizer?		
	<1> YES	0	0.0
	<2> NO	105	96.6
	<8> DON'T KNOW	3	3.4
A4E.	Hot steam humidifier?		
	<1> YES	1	1.0
	<2> NO	104	95.6
	<8> DON'T KNOW	3	3.4
A4F.	Cold air mist humidifier?		
	<1> YES	0	0.0
	<2> NO	105	96.6
	<8> DON'T KNOW	3	3.4
A4G.	Dehumidifier?		
	<1> YES	0	0.0
	<2> NO	105	96.6
	<8> DON'T KNOW	3	3.4
B1A.	Was your stove or oven excluding microwave oven in use during this monitoring period?		
	<1> YES	98	79.8
	<2> NO	25	16.7
	<8> DON'T KNOW	4	3.5
B2A.	Was a clothes dryer in use during this monitoring period?		
	<1> YES	39	26.2
	<2> NO	80	66.4
	<3> NO DRYER PRESENT [goto B3A]	4	3.9
	<8> DON'T KNOW [goto B3A]	4	3.5
B2C.	Was the dryer vented into the house?		
	<1> YES	5	11.5
	<2> NO	33	86.3
	<8> DON'T KNOW	1	2.3

(continued)

Table D-36 (continued)

	Sample Frequency	Weighted Percentage
B3A. How many motor vehicles were parked within 50 feet of the home?		
ENTER NUMBER		
0	9	11.0
1-2	40	28.4
3-4	32	24.3
5-6	19	13.8
>6	27	22.5
B3B. How many of the vehicles were running while parked within 50 feet of the home?		
ENTER NUMBER		
0	69	58.2
1	16	15.3
2	15	13.6
>2	8	7.0
DON'T KNOW	3	5.8
B4. Were domestic pets (cats, dogs, gerbils, birds, etc.) present in the home?		
<1> YES	68	51.8
<2> NO	55	44.7
<8> DON'T KNOW	4	3.5
How many cigarettes, cigars, or pipes were smoked in the home during the monitoring period?		
B5A. NUMBER OF CIGARETTES <0-120>		
0	73	58.7
1-10	17	14.2
11-20	16	11.2
>20	15	12.3
DON'T KNOW	4	2.5
REFUSED	2	1.1

(continued)

Table D-36 (continued)

	Sample Frequency	Weighted Percentage
B5B. NUMBER OF CIGARS <0-30>		
0	115	90.7
1-5	4	3.4
>5	2	2.3
DON'T KNOW	4	2.5
REFUSED	2	1.1
B5C. ENTER NUMBER OF PIPES <0-20>		
NUMBER OF PIPES		
0	117	92.7
1-5	3	2.1
>5	2	2.3
DON'T KNOW	3	1.9
REFUSED	2	1.1
Which of the following hobbies/activities were done during the monitoring period and for how long?		
B6A. Gardening?		
<1> YES	35	23.5
<2> NO	87	72.4
<8> DON'T KNOW	4	3.5
<9> REFUSED	1	0.6
B6B. Painting?		
<1> YES	7	6.3
<2> NO	115	89.6
<8> DON'T KNOW	4	3.5
<9> REFUSED	1	0.6
B6C. Woodworking?		
<1> YES	4	2.4
<2> NO	118	93.5
<8> DON'T KNOW	4	3.5
<9> REFUSED	1	0.6

(continued)

Table D-36 (continued)

		Sample Frequency	Weighted Percentage
B6D.	Furniture refinishing?		
	<1> YES	2	1.2
	<2> NO	120	94.7
	<8> DON'T KNOW	4	3.5
	<9> REFUSED	1	0.6
B6E.	Metal working (including welding and soldering)?		
	<1> YES	6	4.0
	<2> NO	116	92.0
	<8> DON'T KNOW	4	3.5
	<9> REFUSED	1	0.6
B6F.	Model building?		
	<1> YES	1	1.7
	<2> NO	121	94.2
	<8> DON'T KNOW	4	3.5
	<9> REFUSED	1	0.6
B6G.	Auto repair?		
	<1> YES	6	4.1
	<2> NO	116	91.8
	<8> DON'T KNOW	4	3.5
	<9> REFUSED	1	0.6
B6H.	Animal handling?		
	<1> YES	55	40.1
	<2> NO	67	55.8
	<8> DON'T KNOW	4	3.5
	<9> REFUSED	1	0.6
B6I.	Any other activity or hobby?		
	<1> YES	20	16.6
	<2> NO	102	79.3
	<8> DON'T KNOW	4	3.5
	<9> REFUSED	1	0.6

(continued)

Table D-36 (continued)

	Sample Frequency	Weighted Percentage
Were any of the following kinds of items stored in your house or in an attached garage during the monitoring period?		
B7_1. Gasoline and petroleum products (including kerosene)?		
<1> YES	59	41.2
<2> NO	64	55.3
<8> DON'T KNOW	4	3.5
B7_2. Paints and paint products (oil based and latex)?		
<1> YES	75	54.0
<2> NO	48	42.5
<8> DON'T KNOW	4	3.5
B7_3. Paint thinner?		
<1> YES	58	41.2
<2> NO	64	54.4
<8> DON'T KNOW	5	4.4
B7_4. Cleaners, Petroleum-based, Water-based, solids (such as laundry detergents, degreasing compounds)?		
<1> YES	114	89.5
<2> NO	9	7.0
<8> DON'T KNOW	4	3.5
B7_5. Insecticides, pesticides, or herbicides?		
<1> YES	82	63.8
<2> NO	41	32.7
<8> DON'T KNOW	4	3.5
B7_6. Aerosol sprays or personal care products such as hair spray or deodorant?		
<1> YES	94	76.3
<2> NO	29	20.2
<8> DON'T KNOW	4	3.5

(continued)

Table D-36 (continued)

		Sample Frequency	Weighted Percentage
B7_7.	Chlorine bleach?		
	<1> YES	100	80.3
	<2> NO	23	16.2
	<8> DON'T KNOW	4	3.5
B7_8.	New interior furnishings such as floor or wall coverings or furniture?		
	<1> YES	28	22.6
	<2> NO	95	73.9
	<8> DON'T KNOW	4	3.5
B7_9.	Room deodorizers?		
	<1> YES	47	36.2
	<2> NO	76	60.3
	<8> DON'T KNOW	4	3.5
B7_10.	Glues and adhesives?		
	<1> YES	55	40.4
	<2> NO	66	54.6
	<8> DON'T KNOW	6	5.0
B7_11.	New building materials, excluding wood, concrete, or sheetrock (such as polyurethane insulation)?		
	<1> YES	15	10.3
	<2> NO	108	86.3
	<8> DON'T KNOW	4	3.5
B7_12.	Automotive care products (such as carburetor cleaner, waxes, or polishes)?		
	<1> YES	69	49.2
	<2> NO	53	46.8
	<8> DON'T KNOW	5	4.0
B7_13.	Other chemicals?		
	<1> YES	30	22.5
	<2> NO	91	72.9
	<8> DON'T KNOW	6	4.6