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The Total Exposure Assessment Methodology (TEAM) Study:

Summary and Analysis: Volume I

by

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Section 1.
Introduction

The TEAM Study was planned in 1979 and completed in 1985. The goals of this study were: (1) to develop methods to measure individual total exposure (exposure through air, food, and water) and resulting body burden of toxic and carcinogenic chemicals, and (2) to apply these methods within a probability-based sampling framework to estimate the exposures and body burdens of urban populations in several U.S. cities. To achieve these goals, the following approach was adopted:

1. A small personal sampler was developed to measure personal exposure to airborne toxic chemicals;
2. A specially-designed spirometer was developed to measure the same chemicals in exhaled breath; and
3. A survey design involving a three-stage stratified probability selection approach was adopted to insure inclusion of potentially highly exposed groups.

Pilot Study (Phase I)

A pilot study was conducted between July and December 1980 to test 30 sampling and analytical protocols for four groups of chemicals potentially present in air, water, food, house dust, blood, breath, urine, and human hair.

The four groups of chemicals were:

1. Volatile organics (15 target chemicals including benzene, vinyl chloride, chloroform, and tetrachloroethylene)
2. Semivolatile organics (8 target pesticides and PCBs)
3. Metals (lead, cadmium, arsenic)
4. Polyaromatic hydrocarbons (6 compounds including benzo-a-pyrene)

In this pilot study, nine subjects from New Jersey and three from North Carolina collected environmental and biological samples for several days on three separate visits over the six-month period. They also filled out a series of household questionnaires and activity recall questionnaires that had been approved by the Office of Management and Budget (OMB).

The results of the pilot study (1,2) indicated that the TEAM goals could be met at present for only one group of compounds: the volatile organics. Adequate methods existed to determine their concentrations in personal air, ambient air, exhaled breath, and drinking water. They were not present in food (with the exception of chloroform in beverages), so that food could safely be ignored.

Each of the other three groups of chemicals had measurement method problems. Both metals and pesticides have a major route of exposure in solid foods—yet the sampling and analytical protocols for measuring individual meals do not exist. For the PAHs, no personal air monitor capable of collecting sufficient amounts to analyze existed.

Thus, it was decided to concentrate the main TEAM Study on the volatile organics. This group of some hundreds of compounds includes a dozen or so known or suspected human carcinogens, including many organics contained in the list of 37 potential Hazardous Air Pollutants that EPA's Office of Air and Radiation must decide whether to regulate or not; several solvents of interest to the Office of Toxic Substances; and compounds that the Office of Drinking Water will soon regulate.

Main Study (Phases II and III)

The main TEAM Study measured the personal exposures of 600 people to a number of toxic or carcinogenic chemicals in air and drinking water. A total of 20 target chemicals were selected on the basis of their toxicity, carcinogenicity, mutagenicity, production volume, presence in preliminary sampling and pilot studies, and amenability to collection on Tenax. The subjects were selected to represent a total population of 700,000 residents of cities in New Jersey, North Carolina, North Dakota, and California. Each participant carried a personal air sampler throughout a normal 24-hour day, collecting a 12-hour daytime sample and a 12-hour overnight sample. Identical samplers were set up near some participants' homes to measure the ambient air. Each participant also collected two drinking water samples. At the end of the 24 hours, each participant contributed a sample of exhaled breath. All air, water, and breath samples were analyzed for 20 target chemicals.

Phase II of the TEAM Study was conducted during three seasons (summer, fall, and winter) in New Jersey and also in two comparison areas in North Carolina and North Dakota. Phase III was conducted in two target areas in California—an area in southwest Los Angeles County and the communities of Antioch, Pittsburg, and West Pittsburg, northeast of Oakland. The Phase II questionnaires were revised and received OMB approval. Also, nine chemicals were added to, and three dropped from, the list of target compounds. Otherwise, the Phase III study used the same general procedures as the Phase II study. The Los Angeles area was monitored during two seasons (winter and spring) and the Antioch/Pittsburg area was monitored during the spring season.

Special Studies

A series of special studies were undertaken as part of the TEAM Study. They include:

1. *Nursing Mothers Study.* Air, water, breath, blood, urine, and mothers' milk samples were collected from 17 nursing mothers in Bayonne and Elizabeth, NJ to determine whether the target chemicals were accumulating in mothers' milk and the relationships between exposure and body burden. Several target chemicals were more highly concentrated in mothers' milk; therefore, it may be an important contributor to babies' exposure.

2. *Dry Cleaners Study.* Eight employees in three dry cleaners collected personal, workplace, ambient, and home air samples on one work day and one weekend day to investigate their exposures to tetrachloroeth-

ylene, 1,1,1-trichloroethane, and aromatic solvents. Exposures and breath levels ranged up to 1000 times typical nonoccupational levels.

3. *Swimming Pool Study.* Lifeguards at three pools were investigated for possible elevated chloroform exposures.

4. *Indoor Air Study.* Four public buildings were investigated to determine levels of volatile organics, pesticides, PCBs, respirable particulates, metals, and formaldehyde in indoor air. Several hundred VOCs were identified, including about two dozen mutagens and carcinogens.

All TEAM studies are summarized in Table 1.

In this four-volume Final Report, Volume I is an overview of the TEAM Study. Volume II deals with Phase II (NJ, NC, ND) and Volume III with Phase III (CA). Volume IV is a compilation of Standard Operating Procedures developed for the TEAM Study and applicable to similar studies of human exposure to volatile organic compounds.

Table 1. Summary of TEAM Studies

Name and Description of Study	Time of Study	References	Ref. No.[a]
1. Lamar University - UNC Study	March 1980;	Wallace 1982a	1
	June 1980	Zweidinger, 1982	2
Eleven college students at Lamar Univ. and six at UNC-Chapel Hill were studied to field-test the personal air monitors, the spirometer for collecting breath samples, and the analytical techniques for air, water, breath, blood, and urine. Large variations in exposure (2-3 orders of magnitude) were noted, as was a correlation between breath values and air exposures for some chemicals.			
2. TEAM Pilot Study—Phase I	July-Dec 1980	Pellizzari, 1980,1982	3,4
		Entz, 1982	5
		Sparacino, 1982a,b	6,7
		Wallace, 1982b,c	8,9
		1984a	10
Nine persons in the Bayonne-Elizabeth area of New Jersey and three persons in the Research Triangle Park area of North Carolina were visited three times for three days at a time between July and December 1980. Seven consecutive 8-hour air samples were collected on each visit, as were food, house dust, drinking water, blood, urine, hair, and breath samples. Twenty-eight sampling and analytical protocols were tested for use in determining personal exposures and body burdens for four groups of chemicals: volatile organics, metals, pesticides and PCBs, and polyaromatic hydrocarbons (PAHs). It was concluded that only the volatile organics could successfully be included in a total exposure study. Problems with air and food sampling and analysis protocols prevented inclusion of metals, pesticides, and PAHs.			
3. TEAM Study—Phase II	Sept-Feb 1983	Pellizzari, 1981, 1983	11,12
		1984a,b	13,14
		Hartwell, 1984	15
		Wallace, 1984b, 1985a	16,17
		1985b,c	18,19
		Pellizzari, 1985a	24

Table 1. (continued)

Name and Description of Study	Time of Study	References	Ref. No.[a]
350 persons in Bayonne and Elizabeth, New Jersey; 25 in Greensboro, North Carolina; and 25 in Devil's Lake, North Dakota participated in this study, which is described in Volume II of this report and also in a number of journal articles.			
4. TEAM Study—Phase III	Feb-June 1984	Pellizzari, 1985b,c Wallace, 1985	25,26 23
200 persons in Los Angeles, Antioch, and Pittsburg, California participated in this study, which is described in Volume III of this report.			
5. TEAM Study—Indoor Air	March 1982- June 1985	Pellizzari, 1984 Wallace, 1984c Sheldon, 1985a	22 20 27
Four commercial and public-access buildings were studied to test indoor air monitoring methods and to obtain an initial view of indoor air levels of volatile organics, inhalable particulates, pesticides, and metals. One new office building was visited when newly finished, one month later, and three months later to determine temporal variation of organics. Several organics, such as 1,1,1-trichloroethane, were greatly elevated on the first trip but declined sharply on succeeding trips. One (trichloroethylene) increased on the last two trips, indicating a possible contribution of consumer products to indoor air pollutants loadings. A chamber study of common materials (paint, sheetrock, wallpaper, carpet, glue, cleansers, and insecticide) identified nearly all the target toxic chemicals in emissions from these materials.			
6. Special Study I—Dry Cleaners		Pellizzari, 1984	29
The TEAM methodology was tested on a group of potentially highly exposed persons, dry cleaning workers, to determine relationships between air, blood and breath levels at work and at home. Eight workers in three dry cleaning shops (one using 1,1,1-trichloroethane, the second tetrachloroethylene, and the third a mixture of tetrachloroethylene and Stoddard solvent (a hydrocarbon mixture)) were monitored using personal air monitors and fixed monitors indoors and out at home and at work. Levels of 20-25 mg/m^3 tetrachloroethylene were observed in both air and breath. A long biological half-life for tetrachloroethylene was indicated by the fact that weekend values did not decrease.			

Table 1. (continued)

Name and Description of Study	Time of Study	References	Ref. No.[a]
7. Special Study II—Swimming Pools		Unpublished	
Because of suspicions that swimmers might be exposed to chloroform, the TEAM methods were applied to eight lifeguards at one indoor and two outdoor swimming pools. Air, water, and breath samples were taken at the pools and at home. Data analysis has not yet been made available.			
8. Special Study III—Mothers Milk		Sheldon, 1985b	28
A study of nursing mothers was made to determine levels of volatile organics and pesticides/PCBs in mothers milk and relationships between exposure in air and body burden in blood, breath, and urine. Seventeen mothers were selected to represent an estimated population of 324 nursing mothers in Bayonne and Elizabeth, NJ as part of the TEAM Phase II Study. Many volatile organics and pesticides/PCBs were identified in milk samples. Nursing mothers exhaled relatively smaller amounts of volatile organics in breath, indicating a possible increased bioconcentration in fat compared to nonnursing mothers.			
9. Special Study IV—"Washout" Study		Gordon, 1985	21
To establish effective biological half-lives in blood and breath of the TEAM target volatiles at normal environmental levels, four persons remained in a room-sized pure air chamber at IIT Research Institute for 10 hours, allowing 18 breath samples to be collected. Half-lives of a few hours (benzene) to 21 hours (tetrachloroethylene) were established.			

[a] See Table 52 for bibliography.

Section 2.
Recommendations

The major finding of this study is the observation that personal and indoor exposures to these toxic and carcinogenic chemicals are nearly always greater—often much greater—than outdoor concentrations. We are led to the conclusion that indoor air in the home and at work far outweighs outdoor air as a route of exposure to these chemicals.

Since federal and state environmental regulators and directors of research have until now focused most of their attention on sources affecting outdoor concentrations, it is important to verify this finding and, if true, incorporate it into future research and regulatory strategies.

An appropriate next step would be to investigate the sources of these exposures more systematically than was possible in the TEAM Study. The relative contribution of building materials, furnishings, personal activities, and consumer products to personal exposures should be determined by intensive studies in a number of homes, office buildings, schools, and other structures where people spend much of their time. In particular, the following specific recommendations are made:

1. *Extend studies of human exposure to other cities and rural areas.* The studies in Greensboro, NC and Devils Lake, ND were too small to provide much stability to their estimates of human exposure. Thus, additional studies of medium-sized cities and rural areas are needed. Also, the larger studies in Elizabeth, Bayonne, Los Angeles, Antioch and Pittsburg all took place in areas of intensive chemical manufacturing and petroleum refining. Future studies should include large cities without such sources to determine the applicability of TEAM findings to the types of locations in which most people in the U.S. live.

2. *Follow up previous studies to determine the reasons for elevated exposures.* By using the persons (or homes) already measured, high-exposure persons (homes) that represent known numbers of other persons (homes) can be selected without an expensive screening process.

3. *Perform special studies to determine the strength of hypothesized sources.* These may include experimental studies in occupied houses or emission studies in chambers.

4. *Develop emission inventories of major sources of indoor and personal exposure.* These should emphasize consumer products, building materials, and personal activities such as smoking, filling gas tanks, showering, visiting dry cleaners, etc.

5. *Develop models capable of combining emissions from indoor sources, personal activity patterns, outdoor concentrations, and air exchange rates to predict exposures for large populations.*

The second major finding has been the great utility of breath sampling to estimate levels in the body due to normal daily exposure to toxic chemicals.

Breath sampling is noninvasive and is much more sensitive and less costly and difficult than blood sampling. In this study, breath sampling alone was effective in distinguishing between populations exposed to specific sources and those not so exposed. The technique should be investigated for possible use in the following situations:

6. *Estimate dosages of persons exposed to chemical spills or releases.*
7. *Survey healthy persons to establish normal baselines and ranges of biological variability*
8. *Study diseased persons to establish possible early diagnostic procedures.*
9. *Study acute health effects associated with organic emissions ("sick building syndrome") to determine the extent of the loss of productivity of U.S. workers due to degraded indoor air quality in the workplace.*

A third finding has been the demonstration of the utility of this personal monitoring approach not only in estimating the exposure of entire urban area populations, but also in gaining an understanding of the sources of exposure. The general methodology appears applicable for determining exposures to many other pollutants (e.g., pesticides and metals) provided adequate sampling and analysis protocols for individual meals can be developed. With the development of better instruments, it should also be possible to carry out large-scale studies of exposure to inhalable particulates and NO_2 in the near future.

Control of Toxic Emissions

Reduction of exposure to the toxic chemicals measured in the TEAM Study may come about through two types of action: individual and organizational.

Individual Actions. Several of the sources identified in the TEAM Study may be dealt with by simple means. For example, unused paint cans, aerosol sprays, cleansers, solvents, etc. may be disposed of or stored in a detached garage or tool shed. Charcoal filters attached to the kitchen and bathroom taps can remove chloroform and other trihalomethanes from water supplies. (However, some filters are relatively ineffective: an EPA study and a *Consumer Reports* article have identified effective and ineffective brands.) Discontinuing use of room air fresheners or switching to brands that do not contain *p*-dichlorobenzene will reduce exposure to that chemical. Discontinuing smoking, smoking only outdoors or in well-ventilated rooms, or installing air cleaners can reduce involuntary smoking by children or spouses. Dry-cleaned clothes could be aired out for a few hours on a balcony or porch before hanging them in a closet.

Organizational Actions. As in the case of formaldehyde, manufacturers may reduce toxic emissions from their products, either by modifying manufacturing processes or substituting less toxic chemicals. Voluntary building standards may be adopted, limiting emissions for building materials. Local, state, or federal governments could adopt a variety of legislative solutions, such as the various laws restricting smoking in public buildings.

The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) has for many years set voluntary guidelines for ventilation of buildings.

Associations such as the Air Pollution Control Association, the American Lung Association, the Association for Standards and Testing of Materials, the Consumer Federation of America, the National Institute for Building Sciences, the American Institute of Architects, and others have in recent years recognized the importance of indoor air pollution and have programs designed to encourage research, communicate research results, establish standards, and/or develop control techniques.

Section 3.
Summary and Conclusions

The major findings of the TEAM Study may be summarized as follows:

1. Measurement of personal exposures using the Tenax personal monitors was shown to be a feasible approach, acceptable to essentially all subjects (ages 7 to 85), and capable of detecting exposures to most of the target compounds at normal environmental concentrations.

2. Measurement of exhaled breath proved to be a sensitive and noninvasive way to determine the presence of the target chemicals in the blood.

3. Mean personal air exposures to essentially every one of the eleven prevalent target chemicals were greater than mean outdoor concentrations at 7 of 8 locations/monitoring periods. (The one exception was Los Angeles in February, where strong overnight inversions led to elevated outdoor concentrations.) The upper 10% of personal exposures always exceeded the upper 10% of outdoor concentrations for all sites and time periods.

4. A major reason for these higher personal exposures appears to be elevated indoor air levels at work and at home.

5. The elevated indoor air levels appear to be due to a variety of sources, including consumer products, building materials, and personal activities.

6. The breath levels correlated significantly with personal air exposures to nearly all chemicals but did *not* correlate with outdoor air levels. This is further corroboration of the relative importance of indoor air compared to outdoor air.

7. A number of specific sources of exposure were identified, including:

   a. Smoking (benzene, xylenes, ethylbenzene, styrene in breath)

   b. Passive smoking (same chemicals in indoor air)

   c. Visiting dry cleaners (tetrachloroethylene in breath)

   d. Pumping gas or being exposed to auto exhaust (benzene in breath)

   e. Various occupations, including: chemicals, plastics, wood processing, scientific laboratories, garage or repair work, metal work, printing, etc. (mostly aromatic chemicals in daytime personal air)

8. Other sources were hypothesized, including:
   a. Use of hot water (showers, washing clothes) in the home (chloroform in indoor air)
   b. Room air fresheners, toilet bowl deodorizers, or moth crystals (*p*-dichlorobenzene in indoor air)
9. In most cases, these sources far outweighed the impact of traditional "major" point sources (chemical plants, petroleum refineries, petrochemical plants) and area sources (dry cleaners and service stations) on personal exposure.
10. For all chemicals except the trihalomethanes, the air route provided >99% of the exposure. Drinking water provided nearly all of the exposure to the three brominated trihalomethanes, and a substantial fraction of most personal exposures to chloroform.

Section 4.
Overview

The TEAM Study was designed by the USEPA to develop and demonstrate methods to measure human exposure to toxic substances in air and drinking water. All field operations were carried out by the Research Triangle Institute (RTI) as the prime contractor. Precursor studies were undertaken in 1980 at Lamar University in Beaumont, Texas and the University of North Carolina at Chapel Hill. A field test of the methodology (Phase I) was carried out between July and December 1980 in Bayonne and Elizabeth, New Jersey and Research Triangle Park, North Carolina. The objective of Phase II, carried out between September 1981 and February 1983, was to estimate the distribution of exposures to target substances for a target population in an industrial/chemical manufacturing area (Bayonne and Elizabeth, New Jersey) and to compare these estimated exposures to those estimated for populations in non-chemical manufacturing areas (Greensboro, NC and Devils Lake, ND). Phase III, carried out between February and June 1984, involved the application of the methodology refined during Phase II to target populations in California.

Selection of Target Chemicals

Several criteria were used to select target chemicals for the TEAM Study. These included:

1. Toxicity, carcinogenicity, mutagenicity

2. Production volume

3. Presence in ambient air or drinking water at the field sites, as determined by initial ambient sampling prior to each TEAM study

4. Existence of NBS permeation standards

5. Amenability to collection on Tenax

Each of these criteria will be discussed in turn. Toxic, carcinogenic, and mutagenic chemicals received high priority because of their possible human health effects. Thus, benzene (a human carcinogen); and four animal carcinogens (chloroform, carbon tetrachloride, trichloroethylene, and tetrachloroethylene) were selected. Mutagenic compounds such as styrene, 1,1,1-trichloroethane, 1,2-dichloroethane, various brominated compounds, and the dichlorobenzene isomers were also selected. (Recently, a National Toxicology Program (NTP) test of *p*-dichlorobenzene has shown it to be an animal carcinogen.) Certain compounds considered neither carcinogenic nor mutagenic at the time, but known to be toxic at high concentrations were also selected: xylenes and ethylbenzene. Many common nontoxic compounds such as hexane, heptane, cyclohexane, and trimethylbenzenes were omitted. All the trihalomethanes (bromoform, chloroform, bromodichloromethane, and dibromochloromethane) were included because of their prevalence in drinking water. In the California portion of the study, several straight-chain hydrocarbons, some of which are promoters, or co-carcinogens, were added: octane, decane, undecane, and dodecane. Another mutagen (α-pinene) was also added at this time. Three compounds, vinylidene chloride, toluene, and 1,2-dichloropropane, were dropped because of low breakthrough volume, contamination of blanks, and nondetectable environmental concentrations, respectively.

Production volume was also considered in selecting chemicals. High-volume chemicals such as benzene, toluene, xylenes, ethylbenzene, styrene, and others were favored over low-volume chemicals, based on the probability of finding them in the general populations.

Presence in ambient air and drinking water was determined in both New Jersey and California by preliminary sampling trips, during which sites were established near known point sources (chemical plants, petroleum refineries, etc.) and a series of 2-hr integrated samples collected on Tenax and qualitatively analyzed to identify all chemicals collected via GC-MS analysis and comparison with a library of spectra. These visits resulted in verifying the presence of most of the initially selected target chemicals.

Existence of NBS permeation standards was the most stringent criterion: at the time of planning the study, only 30-40 such standards existed. Without such standards, only semiquantitative estimates could be made.

Amenability to collection on Tenax ruled out several chemicals of interest. High-volatility chemicals such as vinyl chloride, methylene chloride, and vinylidene chloride have breakthrough volumes on Tenax well below the planned sampling volume of 20 L. Reactive chemicals such as formaldehyde cannot be collected on Tenax. Benzaldehyde, acetophenone, and phenols are known artifacts of Tenax sampling and therefore could not be included. Toluene was originally a target chemical, but was found in such high and variable amounts on the blank cartridges prepared by the principal laboratory that it could not be included. (This may not be a fundamental problem of Tenax, but rather a problem related to high levels of toluene in the primary laboratory.)

Despite the above exclusions, the final target list of 20 compounds in New Jersey (Table 2) and 26 in California (Table 3) included many of the most prevalent toxic and carcinogenic volatile organic chemicals in outdoor and indoor air and drinking water.

Table 2. Target Compounds Selected for Monitoring in Environmental Media[a]: New Jersey

Vinylidene chloride	*Dibromochloropropane*
Chloroform	m-*Dichlorobenzene*
1,2-Dichloroethane	o-*Dichlorobenzene*
1,1,1-Trichloroethane	p-*Dichlorobenzene*
Carbon tetrachloride	*Benzene*
Trichloroethylene	*Styrene*
Bromodichloromethane	*Ethylbenzene*
Dibromodichloromethane	o-*Xylene*
Tetrachloroethylene	m-*Xylene*
Chlorobenzene	p-*Xylene*
Bromoform	

[a] *All compounds monitored in personal air, fixed-site air, breath and water.*

Table 3. Target Compounds Selected for Monitoring in Environmental Media: California

Matrix: Personal and Fixed-Site Air

Chloroform
1,1,1-Trichloroethane
Benzene
Carbon tetrachloride
Trichloroethylene
Tetrachloroethylene
n-*Decane*
Dodecane
1,4-Dioxane
1,1,1,2-Tetrachloroethane
α-Pinene
Chlorobenzene
Styrene
o,m,p-*Dichlorobenzenes*
Ethylbenzene
o,m,p-*Xylenes*
1,2-Dibromoethane
Undecane
n-*Octane*
1,2-Dichloroethane
1,1,2,2-Tetrachloroethane

Matrix: Drinking Water

Chloroform
Trichloroethylene
Dibromochloromethane
Chlorobenzene
1,1,1-Trichloroethane
Bromodichloromethane
Tetrachloroethylene
Bromoform

Matrix: Breath

Bromodichloromethane
Dibromochloromethane
Chloroform
1,1,1-Trichloroethane
Benzene
Carbon tetrachloride
Tetrachloroethylene
n-*Decane*
Dodecane
1,4-Dioxane
1,1,1,2-Tetrachloroethane
Bromoform
Chlorobenzene
Styrene
o,m,p-*Dichlorobenzene*
Ethylbenzene
o,m,p-*Xylenes*
Trichloroethylene
1,2-Dibromoethane
n-*Octane*
Undecane
1,2-Dichloroethane
1,1,2,2-Tetrachloroethane
α-Pinene

Study Design

Phase II: New Jersey, North Carolina, and North Dakota

An initial probability sample of 5500 households located in 108 areas in the two New Jersey cities was used to collect stratification data (age, socio-economic status, occupation, proximity to major point sources) on over

10,000 residents of these cities. A stratified probability sample of these individuals yielded 355 participants for the Phase II study. Each eligible person selected for monitoring had a "weight" equal to the inverse of his selection probability. (For example, a person selected with a probability of 1 in 1000 had a "weight" of 1000—he represented 1000 persons.) These weights were then adjusted for nonresponse—if only half the eligible persons in one stratum responded, all the weights in that stratum were multiplied by two. Occupationally-exposed persons were overrepresented. The probability-based survey design provides a basis for robust inferences to the approximately 128,000 members of the target population—individuals who were residents of the target cities and over six years of age when the Phase II study was conducted in the fall of 1981.

Each of the 355 participants carried a personal sampler during normal daily activities for two consecutive 12-hour periods. An identical sampler operated in the backyard of one participant in each of the 108 clusters of homes for the same two 12-hour periods. Two drinking water samples were also collected for each participant. At the end of the 24-hour sampling period, a sample of exhaled breath, which was analyzed for the same compounds, was collected for each participant. All participants also completed questionnaires about their personal and household characteristics and activities during the sampling period.

A return visit was made to 157 of the original participants in the summer of 1982, and a final visit was made to 49 of these 157 persons in January-February of 1983. The individuals contacted on each return visit were a probability sample of the participants from the previous visit.

A small comparison study was undertaken in Greensboro, North Carolina in May 1982. Greensboro was selected because its population is similar in size to the Bayonne-Elizabeth area and it has similar small industries, but no chemical manufacturing or petroleum refining operations. The target sample size was set at 25 for a three-stage sample survey design to represent approximately 131,000 Greensboro residents. Monitoring methods were identical to those employed in New Jersey.

A second comparison site was selected to investigate whether the population of a small, rural, agricultural town far from any industry would exhibit personal exposures clearly different from those of the Northern New Jersey population. Once again, the target sample size was set at 25 subjects to represent approximately 7000 residents of Devils Lake, North Dakota.

Both comparison studies were meant to provide only a rough indication of the range of likely exposures. Assuming a normal or log-normal distribution, the median value for a sample of 25 would be expected to lie between the 30th and 70th percentiles of the true distribution with 95% confidence.

Phase III: California

This final phase of the TEAM Study was designed to replicate the New Jersey study (using streamlined questionnaires and other improvements) in areas of different meteorological conditions and complex chemical manufacturing and petroleum refining industries.

Between February 3 and March 2, 1984, 117 residents selected from the South Bay section of Los Angeles (Torrance, Carson, Hermosa Beach, Redondo Beach, Manhattan Beach, El Segundo, Lomita, West Carson, six Census tracts in Los Angeles, and seven adjoining Census tracts, with a total population of 360,000) participated in the study. As in New Jersey, they collected two consecutive 12-hour personal air samples and gave a breath sample at the end of the 24-hour monitoring period (usually between 6 pm and 9 pm). The technicians collected a tap water sample on their final two visits to each home. These were analyzed separately and averaged. Participants also filled out the household questionnaire and a 24-hour activity recall diary.

The second Los Angeles trip (May 21 – June 2, 1984) included 52 participants, all of whom had participated in the first season study. The final trip (June 3-25, 1984) included 71 residents of Antioch and Pittsburg, California. These cities northeast of Oakland have extensive petrochemical facilities and a combined population of 91,000.

Table 4 summarizes the locations and seasons of the TEAM Study, as well as the numbers of participants for each location/season, and the target populations at each site.

Response Rates

In New Jersey, 4426 of the 5578 households contacted agreed to fill out the questionnaire, providing information on 11,414 people. The response rates to the household screening stage ranged from 85% in New Jersey to 95% in North Carolina and 96% in North Dakota. The response rates of those asked to participate in the full study ranged from a low of 53% in New Jersey (first visit) to 67% in North Dakota and 80% in North Carolina (Table 5). The return visits to the New Jersey respondents showed successively higher response rates of 79% and 91%.

The overall response rate is a product of the rates at each stage. Thus, the New Jersey rate (first visit) is 85% x 51% = 44%. The North Carolina overall response rate is 76% and the North Dakota rate is 64%.

In California, 1864 homes were screened (1260 in Los Angeles, 604 in Contra Costa County) with an 88% completion rate. From the information collected on more than 5000 residents of these homes, a total of 311 were selected to participate, of which 293 were eligible, with 188 (64%) completing the study. Thus, the overall response rate was 56% (88% x 64%).

Respondent Characteristics

Characteristics of the participants are listed in Table 6. Half are males and 10-15% Black or Hispanic. Median ages were 30-35. About 60% were employed. Smokers ranged from 31% (Contra Costa) to 46% (New Jersey).

Table 4. Sites Visited in the Main TEAM Study

Site Visit Code	*Location*	*Time of Visit*	*Number of Respondents*	*Population Represented*
NJ1	*Bayonne and Elizabeth, NJ*	*Sept-Nov 1981*	*355*	*128,000*
NJ2	*Bayonne and Elizabeth, NJ*	*July-Aug 1982*	*157*[a]	*109,000*
NJ3	*Bayonne and Elizabeth, NJ*	*Jan-Feb 1983*	*49*[b]	*94,000*
NC	*Greensboro, NC*	*May 1982*	*24*	*131,000*
ND	*Devils Lake, ND*	*October 1982*	*24*	*7,000*
LA1	*Los Angeles, CA*	*February 1984*	*117*	*360,000*
LA2	*Los Angeles, CA*	*May 1984*	*52*[c]	*333,000*
CC	*Antioch and Pittsburg, CA (Contra Costa County)*	*June 1984*	*71*	*91,000*
TOTAL	*7 cities*		*591*	*717,000*

[a] *Subset of NJ1 respondents.*

[b] *Subset of NJ2 respondents.*

[c] *Subset of LA1 respondents.*

Table 5. ***Response Rates: All TEAM Sites***

	New Jersey	*North Carolina*	*North Dakota*	*Los Angeles*	*Antioch/ Pittsburg*
Households screened	*5578*	*307*	*104*	*1260*	*604*
Eligible households	*5208*	*295*	*91*	*1219*	*561*
Screening completed	*4426* *(85%)*	*280* *(95%)*	*87* *(96%)*	*1063* *(87%)*	*502* *(89%)*
Persons					
Selected	*852*	*33*	*45*	*190*	*121*
Eligible	*693*	*30*	*36*	*182*	*111*
Completed study	*355* *(51%)*	*24* *(80%)*	*24* *(67%)*	*117* *(64%)*	*71* *(64%)*
Overall response rate[a]	*44%*	*76%*	*64%*	*56%*	*57%*

[a] *Overall response rate = Screening rate x completion rate.*

Table 6. ***Respondent Characteristics***

Category		*NJ1*	*LA1*	*CC*
Sex	*Male*	*183*	*62*	*36*
	Female	*179*	*55*	*34*
Race	*White*	*249*	*77*	*51*
	Black	*60*	*19*	*5*
	Hispanic	*44*	*7*	*5*
	Asian	*1*	*11*	*7*
Age	*5-17*	*54*	*17*	*14*
	18-29	*100*	*38*	*22*
	30-39	*76*	*24*	*15*
	40-49	*40*	*14*	*13*
	50-59	*44*	*11*	*4*
	60-69	*36*	*8*	*2*
	70-89	*11*	*5*	*0*
Heating Fuel	*Gas*	*161*	*97*	*68*
	Oil	*182*	*0*	*0*
Stove Type	*Gas*	*342*	*85*	*10*
	Electric	*28*	*62*	*59*
Employed	*Yes*	*203*	*78*	*44*
	No	*159*	*39*	*26*
Potential Occupational Exposure	*Yes*	*120*	*38*	*22*
	No	*230*	*87*	*52*
Smoking Status	*Current*	*168*	*39*	*22*
	Ex	*60*	*20*	*12*
	Never	*134*	*58*	*36*
Smoke During Monitoring Period	*Yes*	*161*	*36*	*22*
	No	*199*	*81*	*49*
Close Contact With Smokers	*Yes*	*215*	*45*	*31*
	No	*144*	*71*	*39*

Measurement Methods

A complete description of the sampling and analytical protocols and Standard Operating Procedures employed in this study may be found in Volumes II, III, and IV of this report (refs. 22-24, Table 52). The following is a brief description.

Personal and outdoor air samplers employed a glass cartridge containing the solid granular sorbent Tenax-GC. A small Du Pont pump drew air at ~30 mL/min through the cartridge for ~12 hrs to collect a target volume of 20 L. A sampling vest was designed to hold the pump and the cartridge close to breathing level (Figure 1) while leaving the participant's hands free for normal activities.

Breath samples were collected using a specially-designed spirometer (Figure 2) mounted in a van (Figure 3). The subject provided the breath sample at his home in the evening (6-9 pm) at the end of the 24-hour sampling period.

Water samples were collected from the tap at each participant's home after a 20-second flushing period. Samples were collected in 2-oz glass jars containing sodium thiosulfate to quench residual chlorine reactions.

Air and breath samples were analyzed by capillary gas chromatography mass spectrometry (GC-MS) techniques followed by a combination of manual and automated analyses of spectra. Water samples were analyzed by a purge and trap GC method utilizing a Hall Electroconductivity detector for halogenated compounds and a flame ionization detector for aromatics.

Depending on temperature, the sampling volume of ~20 L sometimes exceeded the breakthrough volumes for two of the target compounds: chloroform and 1,1,1-trichloroethane. For these samples, concentrations were calculated by dividing by the breakthrough volume rather than the sampling volume. Thus in hot weather the concentrations of these two chemicals reflect the final portion of the sampling period only

Two sampling protocol refinement studies were performed as a result of difficulties encountered during sample collection and analysis. The first study addressed sources of contamination associated with breath collection and resulted in a greatly improved spirometer design. The second study evaluated various approaches to preparation of clean Tenax cartridges and reduction of contamination during storage, transport, and sampling. Improvements to the sampling and analysis protocols resulting from these modifications were implemented in subsequent sampling trips.

A total of nearly 5000 air, breath, and drinking water samples were collected for 400 respondents (600 person-days) in the New Jersey, North Carolina, and North Dakota sites. This represented about 95% of all samples originally scheduled. During the California phase, about 1800 air, breath, and drinking water samples were collected from 188 respondents (240 person-days). This represented about 98% of all samples originally scheduled (Table 7).

Quality of the Data

An extensive quality assurance (QA) program was carried out. About 30% of all samples were either blanks, spikes, or duplicates. Analysis of each medium (air, water, breath) was repeated for 10% of samples in external QA laboratories (IIT Research Institute and the University of Miami Medical School). Audits of all laboratory activities were undertaken by EPA's Environmental Monitoring Systems Laboratory at Research Triangle Park, North Carolina (EMSL-RTP) and spiked samples were supplied by EMSL-RTP (air) and EPA's Environmental Monitoring and Support Laboratory in Cincinnati (water). A separate QA report (included in its entirety in the

Appendix to Volume II of this four-volume report (ref. 22 in Table 52)) was written by an independent laboratory (Northrop Services, Inc.) concluding that no significant analytical differences could be found among the three air monitoring laboratories (Research Triangle Institute, IIT Research Institute, and EMSL-RTP).

Figure 1. ***Personal monitor and vest, showing glass cartridge containing Tenax-GC sorbent, Vel-Cro flap to protect cartridge, and Dupont pump (in pocket).***

Figure 2. **Schematic of breath sampling apparatus.**

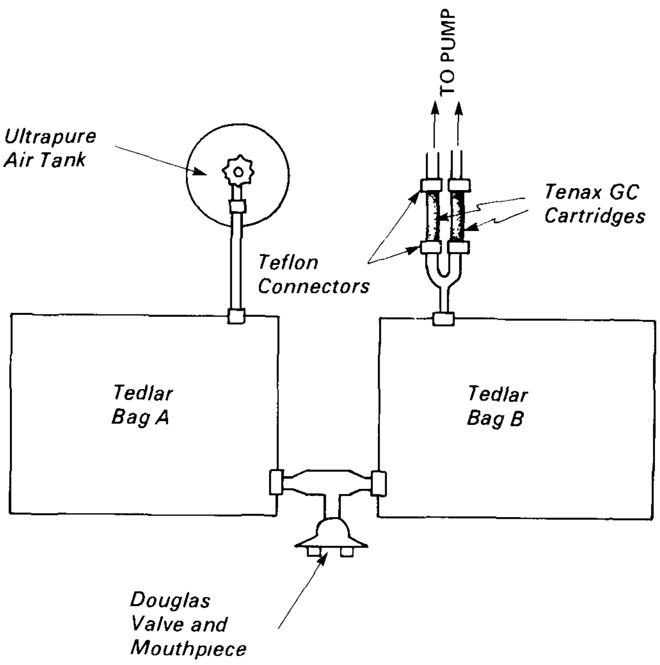


Figure 3. **Breath sampling system inside van with subject giving exhaled air.**

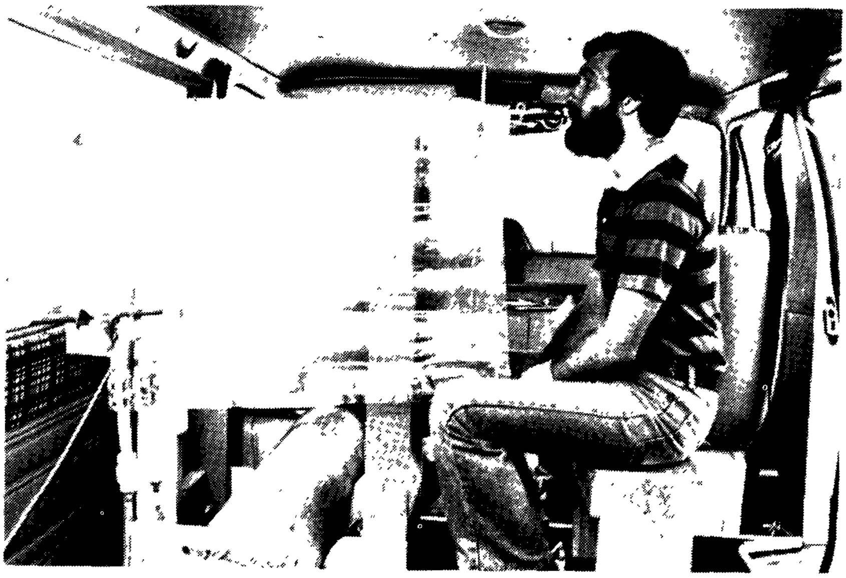


Table 7. Samples Collected at All TEAM Sites

	NJ	*NC*	*ND*	*CA*	*Total*
Personal air	*1114*	*48*	*47*	*480*	*1689*
Drinking water	*1130*	*48*	*48*	*486*	*1712*
Breath	*559'*	*24*	*24*	*238*	*845*
Outdoor air	*341*	*12*	*10*	*118*	*481*
QA/QC[a]	*1282*	*108*	*108*	*512*	*2010*
Total	*4426*	*240*	*237*	*1834*	*6737*

[a] *Includes blanks, controls, and duplicates.*

Results

Quality Control/Quality Assurance

Recovery Efficiencies and Blank Values. In New Jersey, 155 field and laboratory blanks analyzed during the first trip (Fall 1981) showed generally low background levels (<10 ng/cartridge, the equivalent of 0.5 $\mu g/m^3$) for all target compounds except benzene, 1,1,1-trichloroethane, chloroform, and *m,p*-xylene (Table 8). Recovery efficiencies ranged from 80-110%.

In California, 40 blank cartridges for air and breath samples normally contained less than 10 ng of all chemicals except benzene (15-36 ng), chloroform (2-58 ng), and 1,1,1-trichloroethane (6-36 ng) (Table 9).

Recoveries on 41 control cartridges ranged between 70-130% for most chemicals, with the exception of the four trihalomethanes (42-200%). Cartridges loaded with deuterated benzene, deuterated chlorobenzene, and deuterated ethylbenzene gave recoveries ranging between 70-100%, indicating acceptable operating losses.

Blanks for the water samples were very clean (Table 10); however, recoveries were generally low: 50-90%.

After completion of the second visit to New Jersey in July-August 1982, analysis of field blanks revealed very high background levels for a significant portion of the Tenax cartridges. An investigation determined that renovations had occurred at the hotel before the sampling team arrived. Although the field cartridges were stored in paint cans, contamination apparently occurred. The effect of the high blank levels can be seen in the increased coefficients of variance (CVs) for the duplicate samples. Comparison of the variance of the observed values with the variance of the duplicate samples indicates that, except for benzene, the high blank values did not invalidate the results; however, the possibility of a systematic bias due to over- and under-correction for the blank values cannot be ruled out. Also, the correction factors that should be applied to the observed frequency distributions are larger in the second season than in the other seasons. In short, the precision of the second season results is worse than the other seasons, and the residual bias could be larger and of unknown direction.

Following this incident, all Tenax cartridges in the field were placed under a constant helium bath during temporary storage in the field headquarters site.

Because of the very large number of samples collected, some were not analyzed until 2-3 months after they were collected. However, blanks and controls stored with the field cartridges for the same length of time showed acceptable contamination levels and recovery efficiency.

Table 8. ***Blank Values and Recovery Efficiencies for Air and Breath Samples: New Jersey***

	Blanks (ng/cartridge ± SD)		*Controls (% recovery ± SD)*	
Compound	*Field (N=76)*	*Lab (N=79)*	*Field (N=110)*	*Lab (N=91)*
Vinylidene chloride	1 ± 2	<1	85 ± 23	110 ± 33
Chloroform	22 ± 20	8 ± 6	89 ± 22	90 ± 39
1,2-Dichloroethane	<1	<1	100 ± 15	106 ± 31
1,1,1-Trichloroethane	33 ± 21	14 ± 17	87 ± 19	94 ± 28
Benzene	97 ± 64	41 ± 26	86 ± 22	90 ± 26
Carbon tetrachloride	2 ± 3	15 ± 42	80 ± 20	93 ± 24
Trichloroethylene	3 ± 5	1 ± 2	95 ± 12	99 ± 24
Bromodichloromethane	ND	ND	96 ± 19	98 ± 11
Dibromochloromethane	ND	ND	95 ± 17	93 ± 13
Tetrachloroethylene	11 ± 10	2 ± 4	108 ± 18	109 ± 29
Chlorobenzene	1 ± 3	2 ± 3	110 ± 24	109 ± 32
Bromoform	ND	ND	96 ± 19	82 ± 15
Dibromochloropropane	<1	ND	96 ± 17	77 ± 24
Styrene	2 ± 3	2 ± 3	104 ± 14	92 ± 15
p-*Dichlorobenzene*	3 ± 7	1 ± 1	101 ± 11	87 ± 13
Ethylbenzene	12 ± 13	5 ± 10	95 ± 14	95 ± 18
o-*Xylene*	8 ± 9	3 ± 5	100 ± 13	88 ± 19
p-*Xylene*	22 ± 21	7 ± 11	100 ± 14	91 ± 18
o-*Dichlorobenzene*	1 ± 2	1 ± 1	96 ± 13	85 ± 15

Precision. Results of the duplicate analyses for eleven prevalent target compounds in air and breath samples indicate that median coefficients of variance (CV) ranged from 20-30% during most visits (Table 11 summarizes precision data from the first trip to New Jersey).

In California, 86 duplicate air and breath samples displayed improved median precisions of about 10-20% (Table 12). Only chloroform and chlorobenzene were always worse than 20%. Forty-eight duplicate water samples gave excellent precisions of 1-13% for the trihalomethanes (Table 13).

The precision for most targets in personal air samples was consistently superior to the same compounds in breath samples. However, benzene gave poor precision in samples collected at three of the eight site visits, and therefore values are not reported for those sites. This was probably due in part to its chronic high and variable background levels on the blank Tenax cartridges. Another target compound, toluene, also had high backgrounds and was therefore omitted from all summary tables. Certain target compounds were normally associated with the best precision: xylenes, tetrachloroethylene, and the dichlorobenzene isomers.

Side-by-Side Sampling. Three side-by-side 24-hour outdoor air samples were collected by the California Air Resources Board (CARB) and RTI. CARB

Table 9. ***Ranges of Mean Recoveries and Backgrounds for Field Controls and Blanks—Air and Breath Samples: California***

	Range of Mean Recoveries[a] (%)		Range of Mean Backgrounds[a] (ng/cartridge)	
Compound	Personal Air (N=34)	Breath (N=16)	Personal Air (N=33)	Breath (N=16)
1,2-Dichloroethane	100-150	87-100	ND[b]	ND
1,1,1-Trichloroethane	93-140	71-106	6-8	8-36
Benzene	90-120	77-117	17-31	15-36
Carbon tetrachloride	68-110	56-90	ND	ND
Bromodichloromethane	NA[c]	48-74	NA	ND
Trichloroethylene	100-130	97-120	ND-1	1-4
p-Dioxane	69-120	64-100	ND-5	ND-5
Chlorodibromoethane	NA	42-92	NA	ND
1,2-Dibromoethane	74-120	74-130	ND	ND
n-Octane	97-120	88-100	ND-2	ND-7
Tetrachloroethylene	78-120	91-100	ND-3	2-10
Chlorobenzene	85-110	84-100	ND-1	ND
Ethylbenzene	91-100	93-98	ND-5	3-4
p-Xylene	90-110	89-95	2-5	6-9
Styrene	85-100	69-97	2-13	6-11
o-Xylene	96-120	95-99	2-3	3-6
α-Pinene	79-110	80-90	ND	ND-2
p-Dichlorobenzene	81-110	81-98	2-8	2-6
Bromoform	NA	46-52	NA	ND
o-Dichlorobenzene	85-110	88-100	3-6	ND-4
n-Decane	91-110	71-94	ND-3	3-9
n-Undecane	86-110	88-98	4-5	4-13
n-Dodecane	80-110	92-100	ND-2	ND-7
Chloroform	80-140	45-200	2-58	8-29
1,1,1,2-Tetrachloroethane	82-100	92-110	ND-5	ND-3
1,1,2,2-Tetrachloroethane	82-140	100-110	ND-9	ND-8

[a] *Each mean value calculated for a separate batch of Tenax—5 batches used for personal sampling; 3 batches for breath sampling.*
[b] *Not detected.*
[c] *Not analyzed.*

used Tedlar bags with GC/ECD analysis for halogens and GC/PID for benzene. The TEAM samples were collected as part of the main study in the normal fashion: two consecutive 12-hour samples using Tenax with GC/MS analysis.

The results indicate close agreement for five compounds above the detection limits (Table 14); an additional six compounds were below the detection limits of each system. The CARB results for trichloroethylene

Table 10. ***Recoveries and Backgrounds for Field Controls and Blanks—Water Samples***

	Recoveries (Percent ± S.D.)			Blanks (ng/ml)		
	LA1[a] (N=12)	LA2[b] (N=6)	CC[c] (N=7)	LA1 (N=12)	LA2 (N=6)	CC (N=3)
Chloroform	86 ± 16	72 ± 10	62 ± 16	1.0	ND[d]	ND
Bromodichloro-methane	72 ± 27	58 ± 10	50 ± 19	ND	ND	ND
Chlorodibromo-methane	46 ± 56	26 ± 12	47 ± 25	ND	ND	ND
Bromoform	NA[e]	28 ± 13	47 ± 16	NA	ND	ND
1,1,1-Trichloroethane	88 ± 18	71 ± 13	53 ± 26	ND	0.10	0.06
Trichloroethylene	86 ± 14	68 ± 11	55 ± 21	ND	0.06	ND
Tetrachloroethylene	78 ± 16	67 ± 11	51 ± 22	ND	ND	ND
Chlorobenzene	65 ± 15	56 ± 12	53 ± 11	ND	ND	ND

[a] Los Angeles—First trip—February 1984.
[b] Los Angeles—Second trip—May 1984.
[c] Contra Costa (Antioch/Pittsburg)—June 1984.
[d] Not detected.
[e] Not analyzed.

Table 11. ***Coefficients of Variation (%) for Duplicate Air and Breath Samples in New Jersey—Season I***

	Median			75th Percentile		
Compound	Personal[a]	Outdoor[b]	Breath[c]	Personal	Outdoor	Breath
Chloroform	20	24	36	35	70	63
1,1,1-Trichloroethane	27	23	46	45	67	56
Benzene	36	47	41	69	67	73
Carbon tetrachloride	24	15	42	37	32	59
Trichloroethylene	14	25	28	31	37	48
Tetrachloroethylene	21	20	18	37	31	41
Styrene	18	18	22	38	37	41
p-Dichlorobenzene	23	22	16	40	27	43
Ethylbenzene	20	27	30	42	35	66
o-Xylene	19	21	15	41	43	56
m,p-Xylene	24	24	23	50	48	58

[a] N = 134.
[b] N = 34.
[c] N = 35.

exceeded the TEAM values in every case, while the reverse was true for 1,1,1-trichloroethane.

Performance Audits. EPA spiked the Tenax cartridges (provided by RTI) with nine target compounds. These performance audit samples were submitted blind to the RTI analyst. The samples from the third New Jersey visit exhibited the lowest bias over all sites, reflecting improvement in the

Table 12. ***Duplicate Air and Breath Samples—Median Relative Standard Deviations (%): California***

	Personal Air			Breath			Outdoor Air		
Target Chemicals	*LA1*[a]	*LA2*[b]	*CC*[c]	*LA1*[a]	*LA2*[b]	*CC*[c]	*LA1*[a]	*LA2*[b]	*CC*[c]
No. of Samples	24	10	14	12	5	7	6	6	2
Chloroform	28	30	26	25	—[d]	—	34	40	111
1,2-Dichloroethane	12	21	—	—	—	—	9	—	—
1,1,1-Trichloroethane	8	22	19	11	13	43	18	25	46
Benzene	13	13	46	20	52	18	6	10	11
Carbon tetrachloride	15	9	12	7	14	0	28	17	43
Trichloroethylene	12	47	54	10	24	—	9	—	—
Tetrachloroethylene	12	14	13	15	28	18	21	17	—
Styrene	28	40	41	24	—	17	20	27	—
p-*Dichlorobenzene*	30	16	21	11	45	17	9	21	—
Ethylbenzene	13	10	15	26	—	25	12	27	29
o-*Xylene*	13	11	11	14	—	5	17	45	35
p-*Xylene*	15	10	9	20	33	14	18	18	20
n-*Decane*	12	11	9	26	—	15	24	14	17
n-*Dodecane*	13	20	11	19	—	8	37	6	—
1,4-Dioxane	20	—	—	—	—	—	8	—	—
n-*Octane*	11	19	19	4	—	3	20	20	—
n-*Undecane*	15	17	7	51	—	7	24	26	—
α-Pinene	14	20	10	11	25	19	10	22	—
Chlorobenzene	72	—	—	—	—	—	—	—	—
o-*Dichlorobenzene*	12	—	24	115	—	—	77	—	—

[a] *Los Angeles—First trip—January 1984.*
[b] *Los Angeles—Second trip—May 1984.*
[c] *Contra Costa County (Antioch/Pittsburg)—June 1984.*
[d] *No measurable values.*

field procedures over time. The observed biases associated with most of the target chemicals during all other trips were less than 30%, except for the North Dakota samples, which exhibited the highest bias, apparently due to a substandard batch of Tenax.

The performance audit water samples were provided by EMSL/EPA in Cincinnati. In general, recoveries ranged from 80-90%. Bromine-containing targets were recovered less completely (40-75%).

Percent Measurable

All measurements were classified into three groups: nondetectable, trace, and measurable. Nondetectable values were those falling below the Limit of Detection (LOD). Trace values exceeded the LOD, but fell below the Quantifiable Limit (QL), generally chosen to be 4 times the LOD. Measurable values exceeded the QL.

Table 13. ***Duplicate Water Samples—Median Relative Standard Deviations (%)***

Chemical	LA1[a] (N=24)	LA2[b] (N=10)	CC[c] (N=14)
Chloroform	6	1	9
Bromodichloromethane	4	3	3
Chlorodibromomethane	4	3	6
Bromoform	13	8	5
1,1,1-Trichloroethane	17	4	57[d]
Tetrachloroethylene	2	7	3
Trichloroethylene	NA[e]	7	3

[a] *Los Angeles—First trip—January 1984.*

[b] *Los Angeles—Second trip—May 1984.*

[c] *Contra Costa County (Antioch/Pittsburg)—June 1984.*

[d] *Only one sample measurable.*

[e] *Not analyzed.*

Table 14. Comparison of TEAM and CARB Co-located Sampling Results (in ppb)

Chemical	Manhattan Beach (Feb 19-20)		Manhattan Beach (Feb 20-21)		Carson (Feb 21-22)	
	T[a]	C[b]	T	C	T	C
Benzene	8.0	10	6.2	6.2	5.2	4.7
Carbon tetrachloride	0.11	0.08	0.14	0.11	0.10	0.09
Chloroform	0.24	0.15	0.62	0.63	0.068	0.065
1,2-Dichloroethane	0.08	0.22	0.06	<0.10	0.03	<0.10
1,1,1-Trichloroethane	5.9	1.4	6.5	1.7	4.7	1.5
Trichloroethylene	0.08	0.47	0.18	0.30	0.09	0.19
Tetrachloroethylene	1.2	1.2	2.0	2.1	1.2	1.3

[a] *TEAM results: average of two consecutive 12-hour outdoor air samples collected on Tenax and analyzed by GC/MS.*

[b] *CARB results: one 24-hour Tedlar bag sample analyzed by GC/ECD (halocarbons) and GC/PID (benzene).*

Because of unavoidable losses of sampled materials on sorbents, values below ~1 $\mu g/m^3$ of most substances could not be reliably quantitated. Thus, a classification of Not Detected cannot be construed to mean the chemical was not present. In fact, most of the target chemicals have nonzero global backgrounds.

For New Jersey, the target chemicals may be sorted into several categories based on the percent of samples exceeding the QL (Table 15).

The first class, ubiquitous chemicals that were found in 33-100% of all air and breath samples, includes two common solvents (1,1,1-trichloroethane and tetrachloroethylene); several aromatic components of gasoline, paints, and other petrochemical products (benzene, the xylene isomers, and ethylbenzene); and two isomers of dichlorobenzene, used in moth crystals and deodorizers.

The second class, compounds often but not always found in all sample types, includes one additional solvent (trichloroethylene); a compound mainly found in drinking water (chloroform); and a common component of consumer

Table 15. Target Compounds Sorted by Percent Measurable in Breath and Air Samples — All Three Seasons

Category and Compound	*Range of % Measurable*
Ubiquitous Compounds	
Benzene	*55 - 100*
Tetrachloroethylene	*66 - 100*
Ethylbenzene	*62 - 100*
o-*Xylene*	*58 - 100*
m,p-*Xylene*	*68 - 100*
m,p-*Dichlorobenzene*	*44 - 100*
1,1,1-Trichloroethane	*33 - 99*
Often Found	
Chloroform	*4 - 92*
Trichloroethylene	*33 - 79*
Styrene	*46 - 91*
Occasionally Found	
Vinylidene chloride	*0 - 95*
1,2-Dichloroethane	*0 - 22*
Carbon tetrachloride	*0 - 53*
Chlorobenzene	*2 - 40*
o-*Dichlorobenzene*	*1 - 34*
Bromodichloromethane	*0 - 24*
Dibromochloromethane	*0 - 1*
Bromoform	*0 - 1*
Dibromochloropropane	*0 - 1*

products (styrene, used in insulation and plastics). The sources of styrene and the dichlorobenzenes may have been in the home based on the much greater frequencies of measurable amounts in personal air samples (70-80%) compared to outdoor air samples (20-40%).

The third class of substances were only occasionally found (<10% measurable in most sample types). This class includes ethylene dichloride, vinylidene chloride, carbon tetrachloride, bromodichloromethane, chlorobenzene, and *o*-dichlorobenzene.

Finally, three brominated substances were almost never found in air or breath: bromoform, dibromochloromethane, and dibromochloropropane.

Fewer target chemicals were found in drinking water in New Jersey (Table 16), and only the three trihalomethanes were ubiquitous. A second group of three solvents appeared at low levels in nearly all tap water samples collected in Elizabeth but in hardly any of the Bayonne samples.

For the personal air and breath samples collected at the two comparison sites in Greensboro, North Carolina and Devils Lake, North Dakota, most of the prevalent chemicals in New Jersey air and breath samples were again found (Table 17). Only carbon tetrachloride appeared considerably less often

Table 16. Target Compounds Sorted by Percent Measurable in Water Samples — NJ — All Three Seasons

Category and Compound	*Range of % Measurable*
Ubiquitous Compounds	
Chloroform	*99 - 100*
Bromodichloromethane	*99 - 100*
Dibromochloromethane	*93 - 100*
Often Found	
1,1,1-Trichloroethane	*46 - 50*
Trichloroethylene	*44 - 51*
Tetrachloroethylene	*43 - 53*
Occasionally Found	
Vinylidene chloride	*26 - 43*
1,2-Dichloroethane	*1*
Benzene	*1 - 25*
Carbon tetrachloride	*6 - 18*
Bromoform	*2 - 6*
Chlorobenzene	*0 - 1*
Dichlorobenzene isomers	*0 - 3*
Never Found	
Ethylbenzene	*0*
Styrene	*0*
Xylene isomers	*0*

than in New Jersey. In water samples, the same chemicals (trihalomethanes) were detected as in New Jersey (Table 18).

In California, all 26 target chemicals were found in at least a few air or water samples. Many were present in nearly every air or breath sample (Table 19). The 11 prevalent airborne chemicals in New Jersey were also prevalent in California; in addition, six of the ten new target chemicals were also present much of the time.

In drinking water (Table 20) bromoform appeared in 70-90% of the samples, compared to almost none of the New Jersey water samples. Once again, the common solvents (trichloroethylene, tetrachloroethylene, and 1,1,1-trichloroethane) were present but at very low levels.

Concentrations

New Jersey (Fall 1981). Weighted frequency distributions for the combined Bayonne-Elizabeth target population of 128,000 persons are shown for all personal air, outdoor air, and breath samples of the eleven most prevalent chemicals (Figures 4-14). Notable are the great range of exposures (< 1 $\mu g/m^3$ to > 100 $\mu g/m^3$); the greater personal exposures than outdoor

Table 17. ***Target Compounds Sorted by Percent Measurable in Air Breath Samples — NC and ND***

Category and Compound	Range of % Measurable NC	 ND
Ubiquitous Compounds		
1,1,1-Trichloroethane	72 - 76	80 - 91
Tetrachloroethylene	50 - 100	73 - 95
m,p-*Dichlorobenzene*	71 - 80	56 - 89
Ethylbenzene	90 - 100	60 - 80
o-*Xylene*	90 - 100	66 - 91
m,p-*Xylene*	85 - 100	80 - 97
Benzene	a	a
Often Found		
Chloroform	47 - 68	22 - 65
Trichloroethylene	8 - 68	33 - 52
Styrene	41 - 64	59
Occasionally Found		
1,2-Dichloroethane	4 - 14	5 - 17
Carbon tetrachloride	4 - 6	8 - 14
Bromodichloromethane	0	14
Chlorobenzene	0 - 16	7 - 44
o-*Dichlorobenzene*	0 - 2	0 - 10
Bromoform	0 - 4	0
Never Found		
Dibromochloromethane	0	0
Dibromochloropropane	0	0

[a]Benzene was ubiquitous, but high background contamination prevented quantifying the results.

Table 18. Target Compounds Sorted by Percent Measurable in Drinking Water Samples — NC and ND[a]

Category and Compound	Range of % Measurable NC	 ND
Ubiquitous Compounds		
Chloroform	93	100
Bromodichloromethane	93	73
Often Found		
Dibromochloromethane	93	18
1,1,1-Trichloroethane	24	42
Occasionally Found		
Tetrachloroethylene	74	0
Vinylidene chloride	10	0
Carbon tetrachloride	3	0
Trichloroethylene	5	5
Toluene	NM[b]	30
1,2-Dichloroethane	0	2
Chlorobenzene	0	2
Bromoform	0	8
Dichlorobenzene isomers	0	2
Never Found		
Benzene	NM	0
Styrene	NM	0
Ethylbenzene	NM	0
Xylene isomers	NM	0

[a] *NC = North Carolina, ND = North Dakota.*
[b] *Not measured.*

concentrations; and the greater breath concentrations than outdoor concentrations in many cases.

As these figures illustrate, personal exposures were usually greater than outdoor concentrations for all 11 prevalent target chemicals. The arithmetic means of the daytime and overnight (i.e., indoor) personal air exposures are several times the outdoor mean concentrations (Figures 15 and 16). Because the distributions were more nearly log-normal than normal, the geometric means are also compared (Figures 17 and 18).

Average 24-hour exposures were calculated from the two consecutive 12-hour values for each subject, and weighted estimates of the population frequency distributions were determined for the five aromatic compounds (Figure 19) and the six halocarbons (Figure 20). Similarly, average 48-hour exposures were calculated for the 157 persons who had both fall and summer measurements. The 48-hour frequency distributions display similar characteristics to the 12-hour distributions (Figure 21), with only a slight decrease in the geometric standard deviation.

New Jersey (all three seasons). Estimates of 24-hour arithmetic mean personal air exposures, breath concentrations, and outdoor air concentrations during all three seasons in New Jersey are summarized in Table 21. Since the overnight (6 pm - 6 am) personal air exposures were essentially measures of indoor air (85% of persons did not go outside during the 12-hour monitoring period) it is possible to compare indoor air concentrations directly with outdoor air values just outside the residence. In 28 of 30 cases, the mean overnight

Table 19. Target Compounds Sorted by Percent Measurable in Air and Breath Samples

	Range of Percent Measurable		
	Los Angeles, CA		*Antioch/Pittsburg, CA*
Category and Compound	*1st Season*	*2nd Season*	
Ubiquitous Compounds			
1,1,1-Trichloroethane	*99-100*	*89-100*	*49-100*
Benzene	*95-100*	*79-100*	*82-100*
Tetrachloroethylene	*97-100*	*99-100*	*58-100*
Ethylbenzene	*82-100*	*70-100*	*64-100*
o-*Xylene*	*91-100*	*57-100*	*58-100*
m,p-*Xylene*	*100*	*100*	*84-100*
Often Found			
n-*Octane*	*81-99*	*59-94*	*29-96*
n-*Decane*	*53-96*	*25-81*	*48-100*
m,p-*Dichlorobenzene*	*79-100*	*61-87*	*0-75*
Styrene	*47-100*	*37-94*	*56-91*
Carbon tetrachloride	*12-100*	*11-100*	*14-96*
α-Pinene	*62-98*	*47-92*	*0-85*
Chloroform	*36-99*	*31-80*	*12-79*
Occasionally Found			
Trichloroethylene	*50-97*	*4-66*	*0-72*
n-*Undecane*	*56-99*	*48-74*	*8-88*
n-*Dodecane*	*30-96*	*17-45*	*0-77*
1,2-Dichloroethane	*4-68*	*0-23*	*0-30*
o-*Dichlorobenzene*	*13-59*	*0-19*	*0-19*
1,4-Dioxane	*8-70*	*3-21*	*5-25*
Chlorobenzene	*1-12*	*0-8*	*0-18*
1,2-Dibromoethane	*0-4*	*0-13*	*0-2*
1,1,1,2-Tetrachloroethane	*0-3*	*0-12*	*0-18*
1,1,2,2-Tetrachloroethane	*0-10*	*0-18*	*0-18*

Table 20. Target Compounds Sorted by Weighted Percent Measurable in Drinking Water Samples

	Range of Percent Measurable		
	Los Angeles		Antioch/Pittsburg
Category and Compound	Jan-Feb 1984	May 1984	
Ubiquitous			
Chloroform	94	86	94
Bromodichloromethane	93	96	96
Dibromochloromethane	89	85	85
Often Found			
Bromoform	69	90	69
Occasionally Found			
1,1,1-Trichloroethane	48	14	10
Tetrachloroethylene	22	19	94
Trichloroethylene	8	12	66
Chlorobenzene	13	5	6

Figure 4. **Benzene: Estimated frequency distributions of personal air exposures, outdoor air concentrations, and exhaled breath values for the combined Elizabeth-Bayonne target population (128,000). All air values are 12-hour integrated samples. The breath value was taken following the daytime air sample (6:00 am-6:00 pm). All outdoor air samples were taken in the vicinity of the participants' homes.**

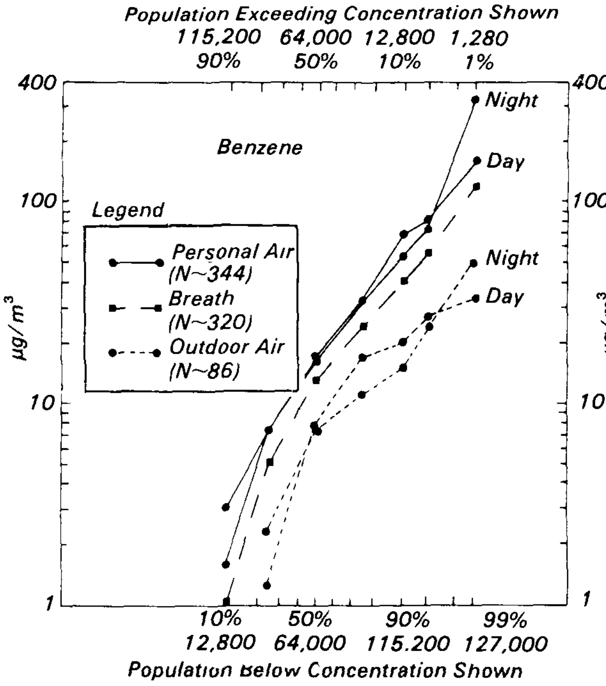
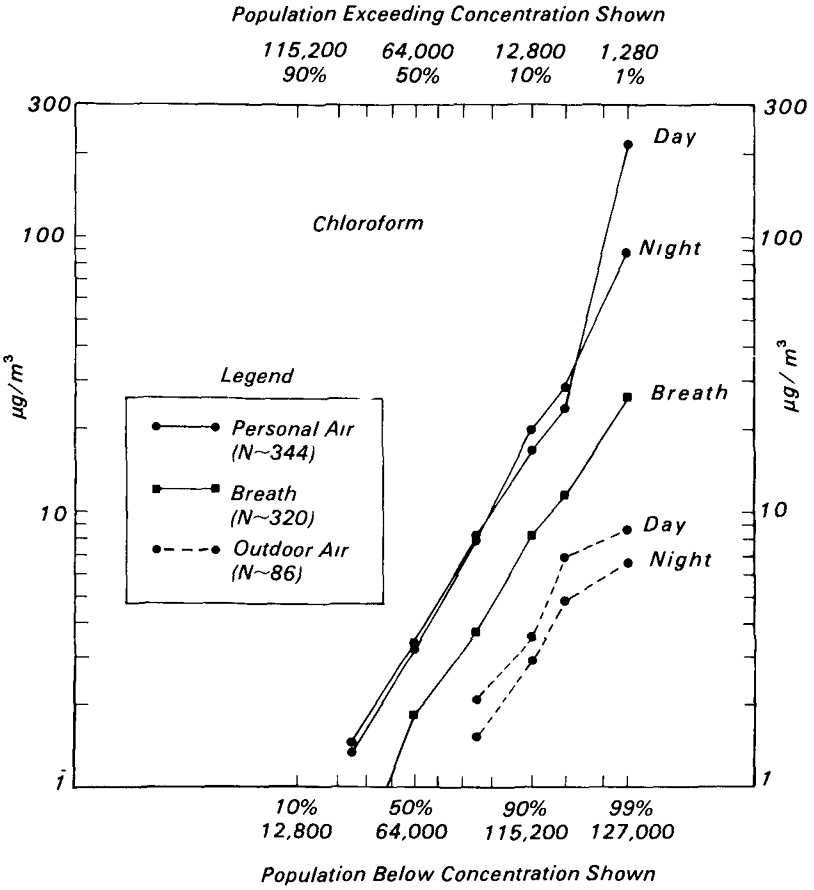


Table 21. **Weighted Estimates of Air and Breath Concentrations of 11 Prevalent Compounds for 130,000 Elizabeth-Bayonne Residents (Fall 1981); 110,000 Residents (Summer 1982); and 49,000 Residents (Winter 1983)**

	Season I (Fall)			Season II (Summer)			Season III (Winter)		
Compound	Pers-onal Air (N = 340)	Out-door Air (86)	Breath (300)	Pers-sonal Air (150)	Out-door Air (60)	Breath (110)	Pers-sonal Air (49)	Out-door Air (9)	Breath (49)
1,1,1-Trichloroethane	94[a]	7.0[a]	15[b]	67	12	15	45	1.7	4.0
m,p-Dichlorobenzene	45	1.7	8.1	50	1.3	6.3	71	1.2	6.2
m,p-Xylene	52	11	9.0	37	10	10	36	9.4	4.7
Tetrachloroethylene	45	6.0	13	11	6.2	10	28	4.2	11
Benzene	28	9.1	19	NC[c]	NC	NC	NC	NC	NC
Ethylbenzene	19	4.0	4.6	9.2	3.2	4.7	12	3.8	2.1
o-Xylene	16	4.0	3.4	12	3.6	5.4	13	3.6	1.6
Trichloroethylene	13	2.2	1.8	6.3	7.8	5.9	4.6	0.4	0.6
Chloroform	8.0	1.4	3.1	4.3	13	6.3	4.0	0.3	0.3
Styrene	8.9	0.9	1.2	2.1	0.7	1.6	2.4	0.7	0.7
Carbon tetrachloride	9.3	1.1	1.3	1.0	1.0	0.4	ND[d]	ND	ND
Total (11 compounds)	338	48	80	200	59	66	216	25	31

[a] Average of arithmetic means of day and night 12-hour samples (μg/m^3)
[b] Arithmetic mean
[c] Not calculated—high background contamination
[d] Not detected in most samples

Figure 5. ***Chloroform: Estimated frequency distributions of personal air exposures, outdoor air concentrations, and exhaled breath values for the combined Elizabeth-Bayonne target population (128,000). All air values are 12-hour integrated samples. The breath value was taken following the daytime air sample (6:00 am-6:00 pm). All outdoor air samples were taken in the vicinity of the participants' homes.***



personal air exposures exceeded the overnight outdoor air concentrations, usually by factors of 2-10 (Table 22). The most extreme example was the combined *m*- and *p*-dichlorobenzene isomers, with arithmetic means indoors of about 50 μg/m³ compared to outdoor values of less than 2 μg/m³. The maximum personal air values for all chemicals were consistently in the hundreds or thousands of μg/m³, while maximum outdoor concentrations were usually less than 100 μg/m³ (Table 23). Even breath maximum values normally exceeded the outdoor air maxima. Finally, the comparison of drinking water values across the three seasons (Table 24) shows that only the three trihalomethanes had nonnegligible concentrations in the tap water samples. Also clear is the sharp decline in the winter levels of trihalomethanes in drinking water.

The observation of higher indoor than outdoor values in the fall of 1981 was corroborated in the summer and winter seasons. Figures 22 and 23 show an increase in the indoor/outdoor ratios of the median and 90th

Figure 6. ***1,1,1-Trichloroethane: Estimated frequency distributions of personal air exposures, outdoor air concentrations, and exhaled breath values for the combined Elizabeth-Bayonne target population (128,000). All air values are 12-hour integrated samples. The breath value was taken following the daytime air sample (6:00 am-6:00 pm). All outdoor air samples were taken in the vicinity of the participants' homes.***

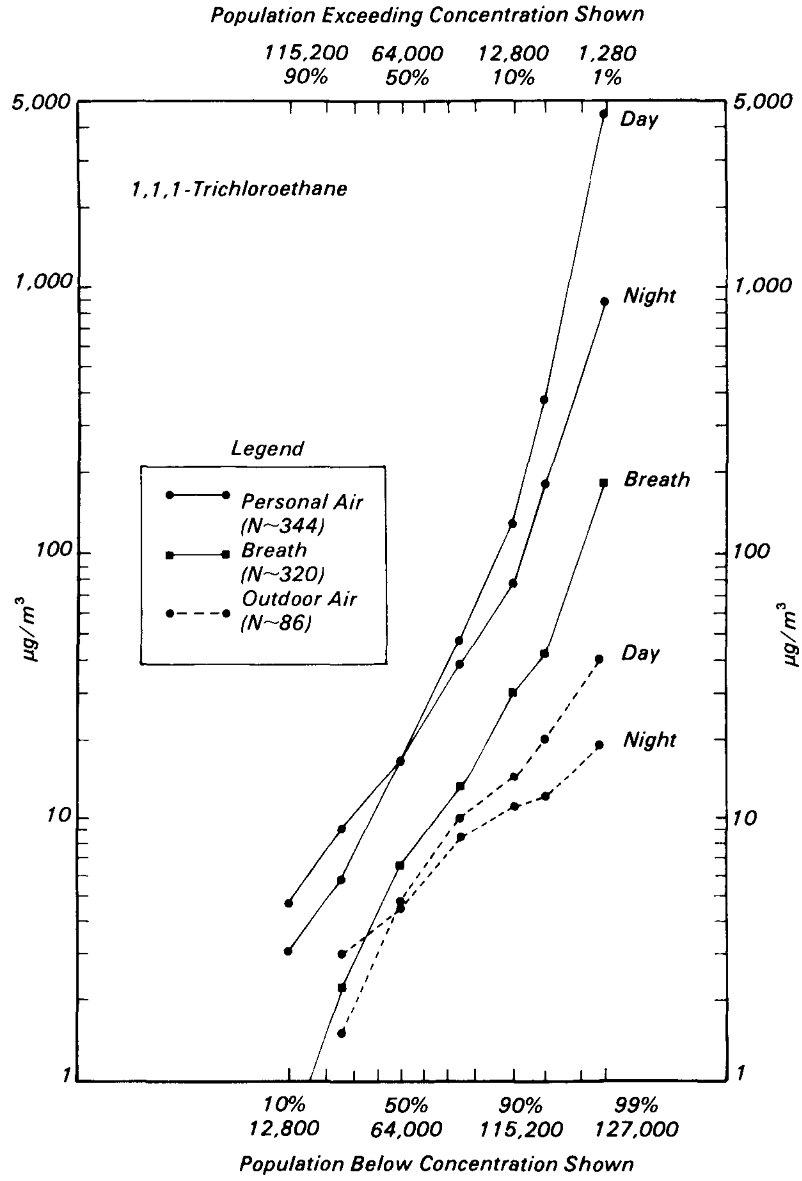
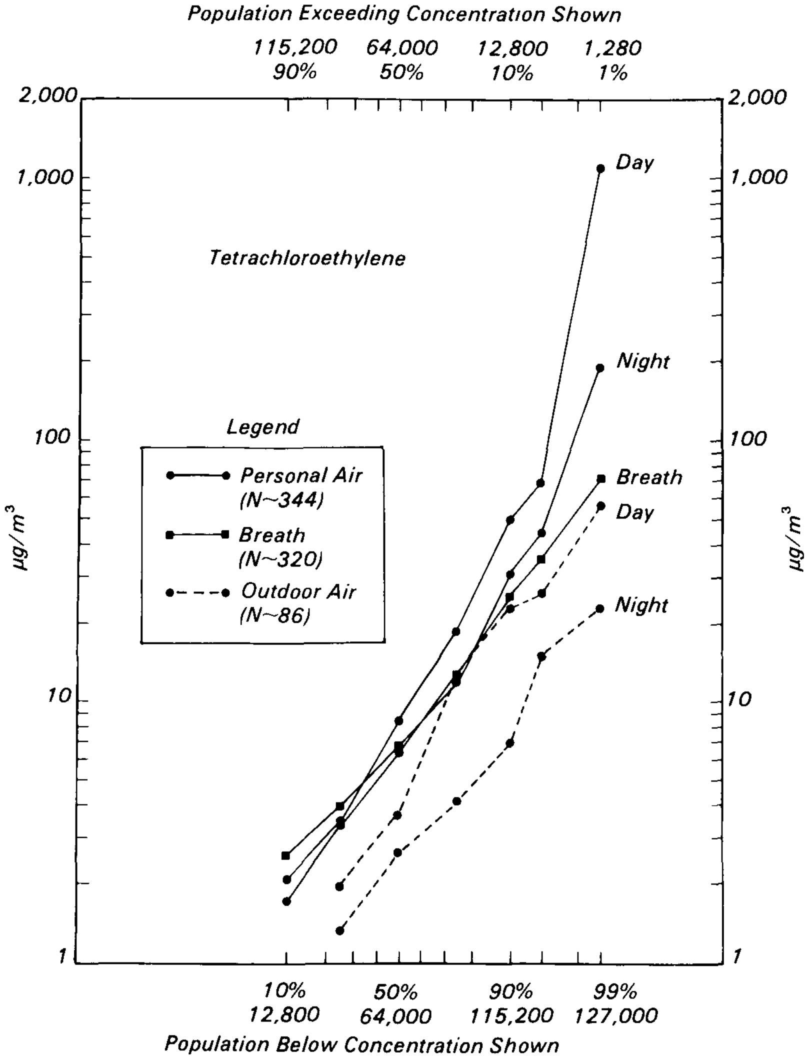


Figure 7. ***Tetrachloroethylene: Estimated frequency distributions of personal air exposures, outdoor air concentrations, and exhaled breath values for the combined Elizabeth-Bayonne target population (128,000). All air values are 12-hour integrated samples. The breath value was taken following the daytime air sample (6:00 am-6:00 pm). All outdoor air samples were taken in the vicinity of the participants' homes.***



percentile values for most chemicals from summer to fall to winter. The wintertime increase appears to be due in some cases to somewhat reduced outdoor concentrations rather than to increased indoor concentrations. However, three chemicals (1,1,1-trichloroethane, tetrachloroethylene, and *m,p*-dichlorobenzene) showed absolute increases in their indoor-outdoor differences, consistent with either increased source activity or reduced air exchange. An example of the increased indoor air concentrations in winter compared to stable outdoor air concentrations is shown for *p*-dichlorobenzene (Figure 24). (See Appendix F for other chemicals.)

Table 22. ***Weighted Arithmetic Mean Overnight Personal Exposures (Indoor Air) Compared to Outdoor Air Concentrations: NJ, All Three Seasons (μg/m^3)***

	Fall 1981 (128,000)[a]			Summer 1982 (109,000)			Winter 1983 (94,000)		
Chemical	Pers-onal	Out-door	I/O Ratio	Pers-sonal	Out-door	I/O Ratio	Pers-sonal	Out-door	I/O Ratio
1,1,1-Trichloroethane	110	5.4	20	21	10	2	31	1.4	22
m,p-Dichlorobenzene	56	1.5	37	49	1.4	35	54	1.2	45
m,p-Xylene	55	11	5	19	11	2	29	8.5	3
Tetrachloroethylene	11	3.7	3	9.0	4.0	2	13	1.9	7
Benzene	30	8.6	3	NC[b]	NC	—	NC	NC	—
Ethylbenzene	13	3.8	3	7.8	3.5	2	11	3.4	3
o-Xylene	16	4.0	4	8.0	4.3	2	9.8	3.1	3
Trichloroethylene	7.3	2.1	3	4.8	7.8	0.6	3.0	0.2	15
Chloroform	8.7	1.2	7	4.6	12	0.4	4.0	0.1	15
Styrene	2.7	0.9	3	2.0	0.6	3	2.2	0.6	4
Carbon tetrachloride	14	1.2	12	1.2	1.0	1	ND[c]	ND	—
Total (11 compounds)	324	43	7	126	56	2	157	20	8

[a] Population of Elizabeth and Bayonne for which estimates apply.
[b] Not calculated — cartridges contaminated.
[c] Not detected (most samples).

Table 23. Maximum Concentrations ($\mu g/m^3$) of Organic Compounds in Air and Breath of 350 NJ Residents

	Personal Air[a]		Outdoor Air[b]		
Chemical	Night	Day	Night	Day	Breath[c]
Chloroform	210	140	130	230	29
1,1,1-Trichloroethane	8300	330,000	51	470	520
Benzene	510	270	91	44	200
Carbon tetrachloride	1100	900	14	7.1	250
Trichloroethylene	350	1,400	61	100	30
Tetrachloroethylene	250	12,000	27	95	280
Styrene	76	6,500	11	6.3	31
m,p-Dichlorobenzene	1600	2,600	13	57	160
Ethylbenzene	380	1,500	28	39	290
o-Xylene	750	1,800	31	19	220
m,p-Xylene	3100	10,000	70	47	350

[a] Number of samples: 540 during three seasons.
[b] Number of samples: 150 during three seasons.
[c] Number of samples: 500 during three seasons.

Table 24. Arithmetic Means and Maxima ($\mu g/L$) of Organic Compounds in New Jersey Drinking Water

	Fall 1981 (128,000)[a]		Summer 1982 (109,000)[b]		Winter 1983 (94,000)[c]	
Chemical	Mean	Max	Mean	Max	Mean	Max
Chloroform	70	170	61	130	17	33
Bromodichloromethane	14	23	14	54	5.4	16
Dibromochloromethane	2.4	8.4	2.1	7.2	1.4	3
1,1,1-Trichloroethane	0.6	5.3	0.2	2.6	0.2	1.6
Trichloroethylene	0.6	4.2	0.4	8.3	0.4	3.4
Tetrachloroethylene	0.4	3.3	0.4	9.3	0.4	5.0
Toluene	0.4	2.7	—	—	—	—
Vinylidene chloride	0.2	2.4	0.1	2.5	0.2	0.9
Benzene	—	—	0.7	4.8	—	—

[a,b,c] Population of Bayonne and Elizabeth to which estimates apply.

Figure 8. ***Trichloroethylene: Estimated frequency distributions of personal air exposures, outdoor air concentrations, and exhaled breath values for the combined Elizabeth-Bayonne target population (128,000). All air values are 12-hour integrated samples. The breath value was taken following the daytime air sample (6:00 am-6:00 pm). All outdoor air samples were taken in the vicinity of the participants' homes.***

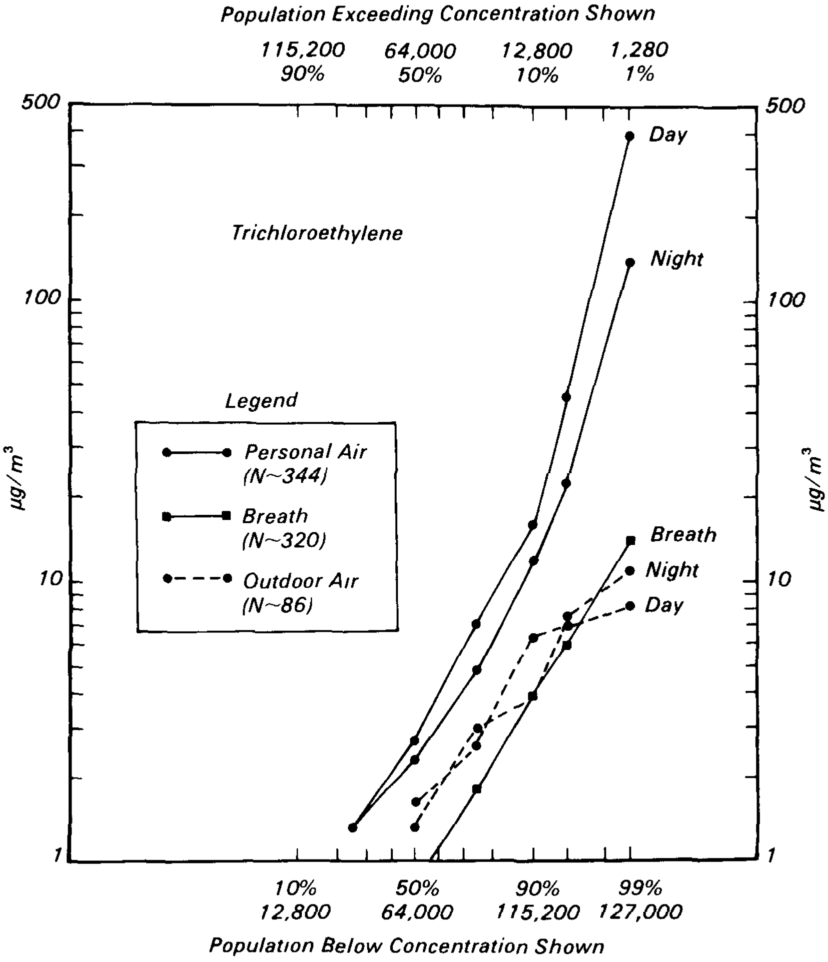


Figure 9. ***Carbon tetrachloride: Estimated frequency distributions of personal air exposures, outdoor air concentrations, and exhaled breath values for the combined Elizabeth-Bayonne target population (128,000). All air values are 12-hour integrated samples. The breath value was taken following the daytime air sample (6:00 am-6:00 pm). All outdoor air samples were taken in the vicinity of the participants' homes.***

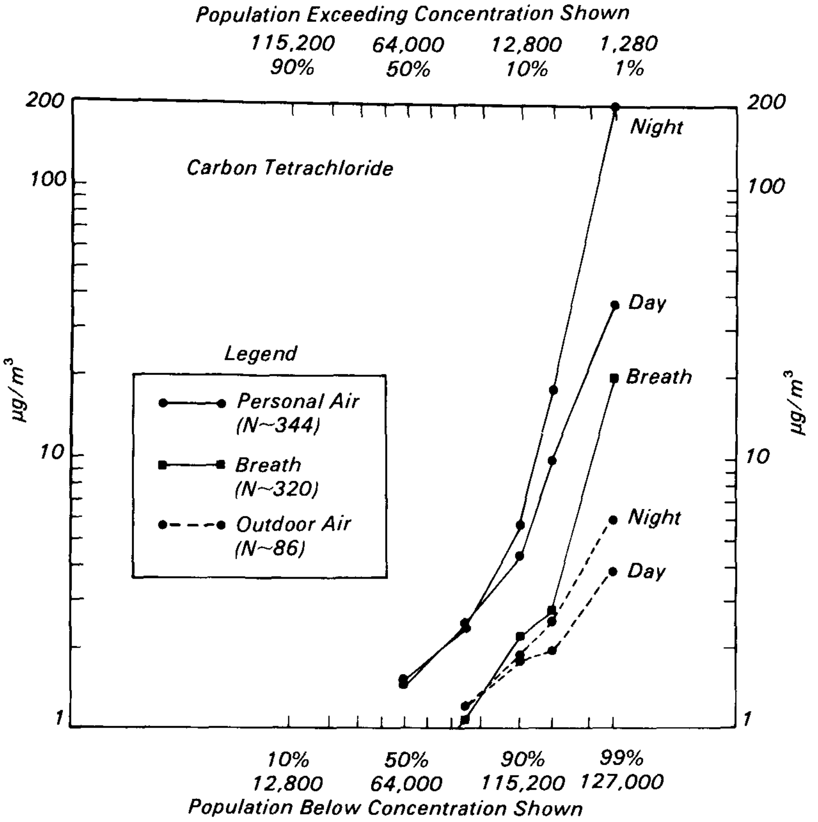


Figure 10. ***m,p-Dichlorobenzene: Estimated frequency distributions of personal air exposures, outdoor air concentrations, and exhaled breath values for the combined Elizabeth-Bayonne target population (128,000). All air values are 12-hour integrated samples. The breath value was taken following the daytime air sample (6:00 am-6:00 pm). All outdoor air samples were taken in the vicinity of the participants' homes.***

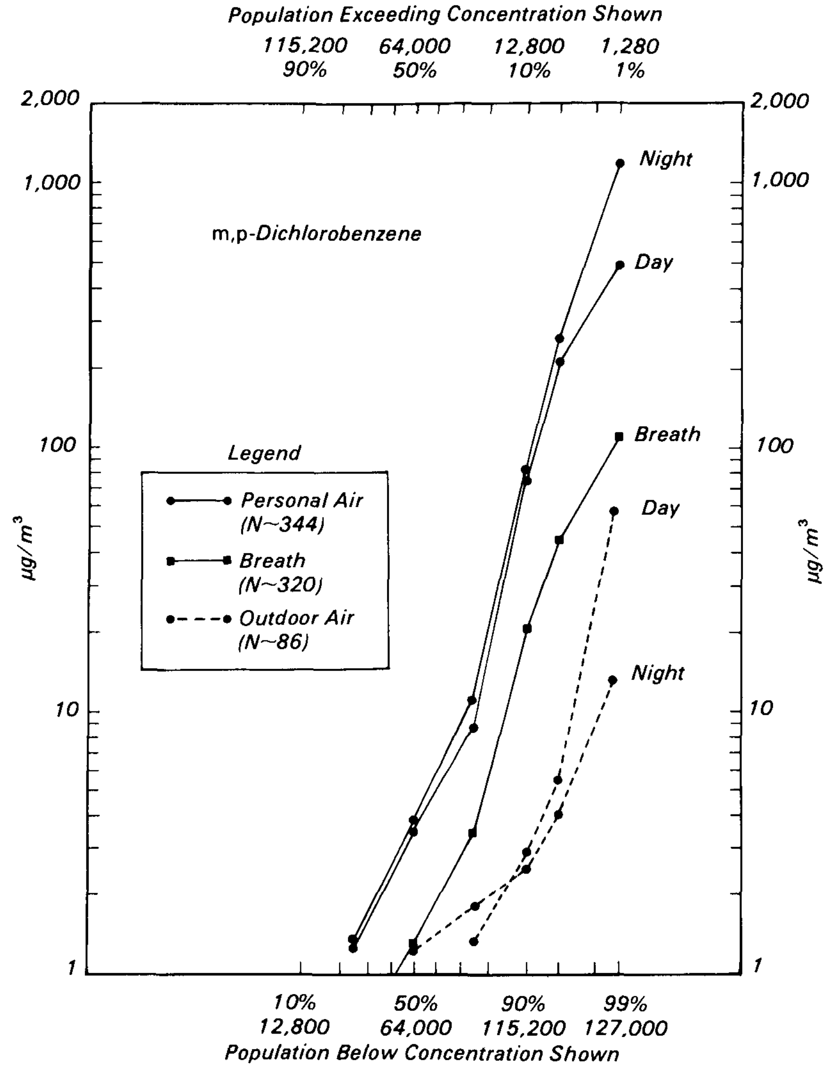


Figure 11. ***Styrene: Estimated frequency distributions of personal air exposures, outdoor air concentrations, and exhaled breath values for the combined Elizabeth-Bayonne target population (128,000). All air values are 12-hour integrated samples. The breath value was taken following the daytime air sample (6:00 am-6:00 pm). All outdoor air samples were taken in the vicinity of the participants' homes.***

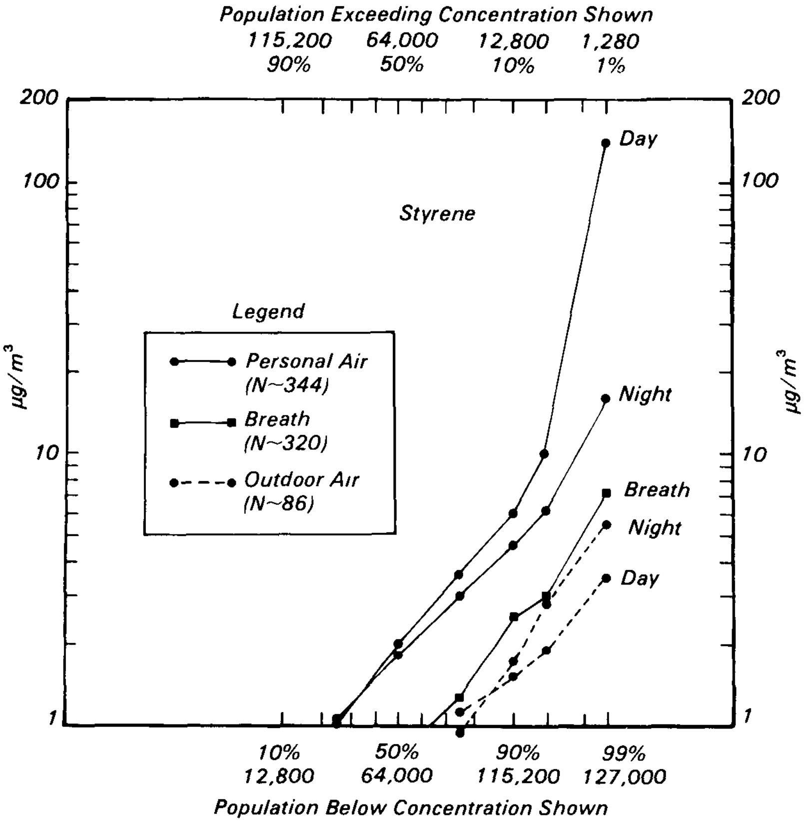


Figure 12. ***Ethylbenzene: Estimated frequency distributions of personal air exposures, outdoor air concentrations, and exhaled breath values for the combined Elizabeth-Bayonne target population (128,000). All air values are 12-hour integrated samples. The breath value was taken following the daytime air sample (6:00 am-6:00 pm). All outdoor air samples were taken in the vicinity of the participants' homes.***

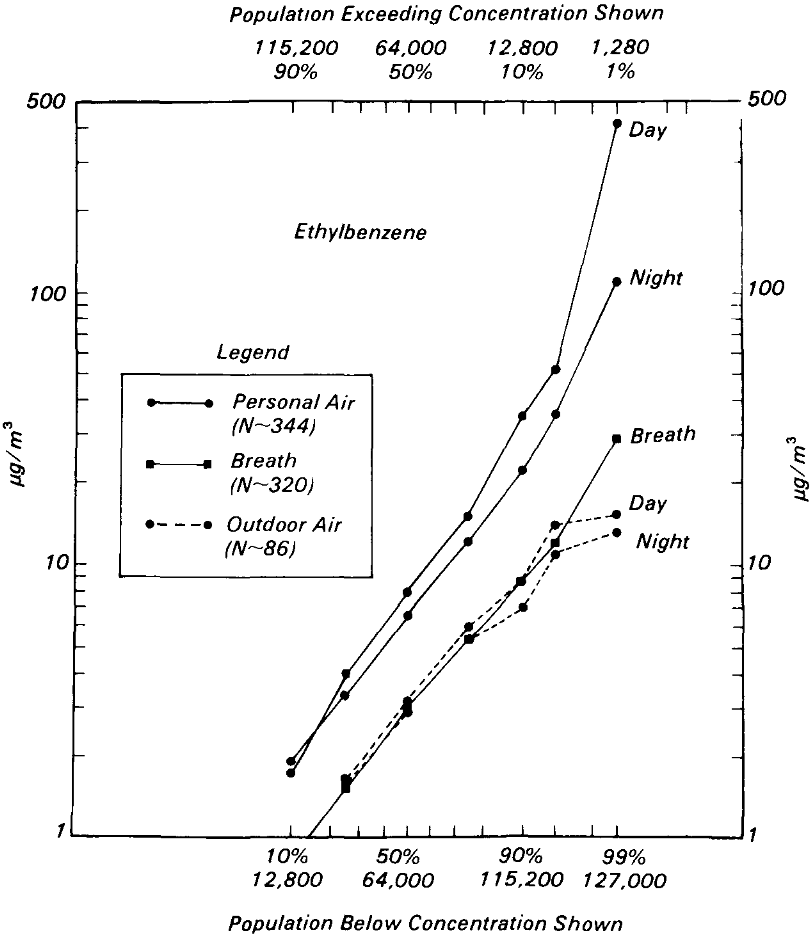


Figure 13. m,p-Xylene: Estimated frequency distributions of personal air exposures, outdoor air concentrations, and exhaled breath values for the combined Elizabeth-Bayonne target population (128,000). All air values are 12-hour integrated samples. The breath value was taken following the daytime air sample (6:00 am-6:00 pm). All outdoor air samples were taken in the vicinity of the participants' homes.

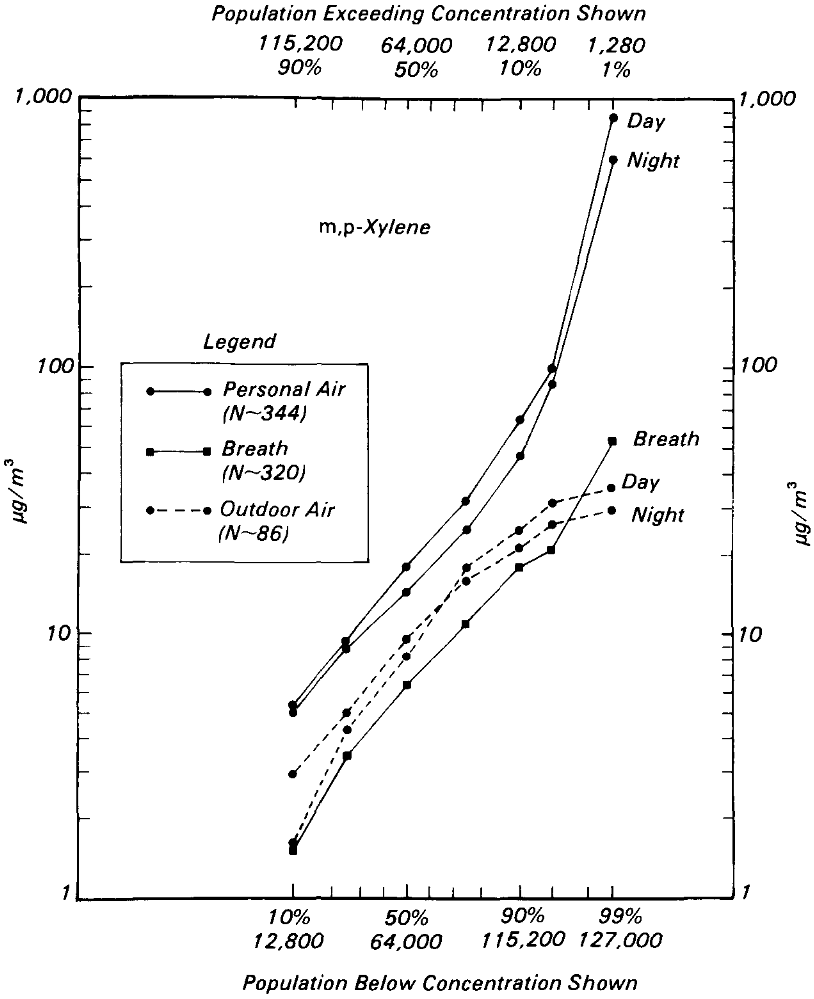


Figure 14. ***o-Xylene: Estimated frequency distributions of personal air exposures, outdoor air concentrations, and exhaled breath values for the combined Elizabeth-Bayonne target population (128,000). All air values are 12-hour integrated samples. The breath value was taken following the daytime air sample (6:00 am-6:00 pm). All outdoor air samples were taken in the vicinity of the participants' homes.***

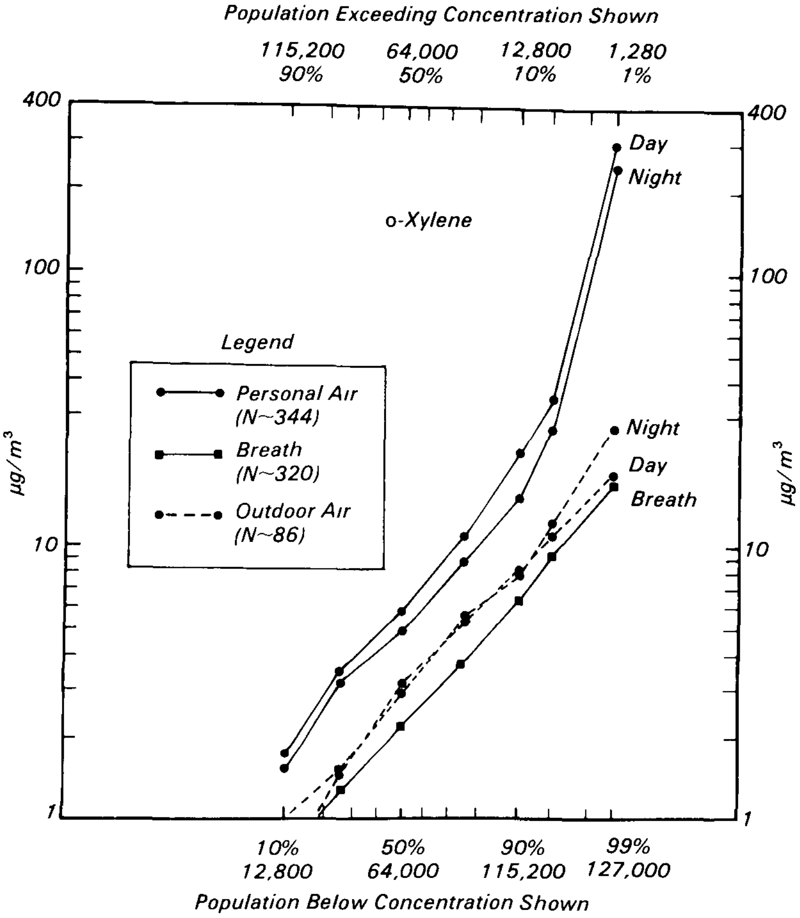


Figure 15. ***Estimated arithmetic means of 11 toxic compounds in daytime (6:00 am - 6:00 pm) air samples for the target population (128,000) of Elizabeth and Bayonne, New Jersey, between September and November 1981. Personal air estimates based on 340 samples; outdoor air estimates based on 88 samples.***

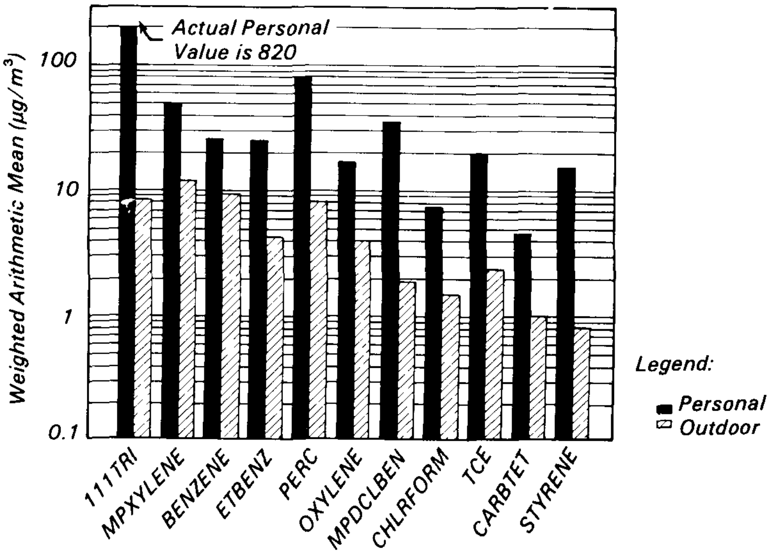


Figure 16. ***Estimated arithmetic means of 11 toxic compounds in overnight (6:00 pm - 6:00 am) air samples for the target population (128,000) of Elizabeth and Bayonne, New Jersey, between September and November 1981. Personal air (i.e., indoor) estimates based on 347 samples; outdoor air estimates based on 84 samples.***

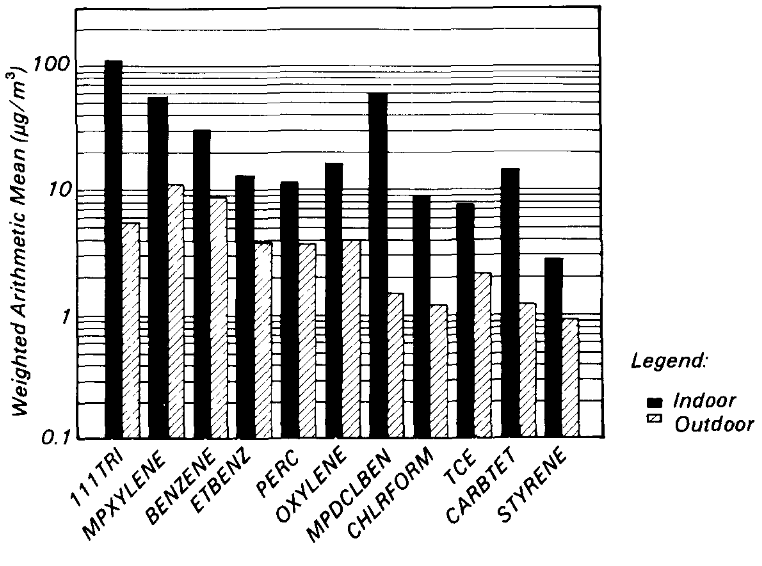


Figure 17. ***Estimated geometric means of 11 toxic compounds in daytime (6:00 am - 6:00 pm) air samples for the target population (128,000) of Elizabeth and Bayonne, New Jersey, between September and November 1981. Personal air estimates based on 340 samples; outdoor air estimates based on 88 samples.***

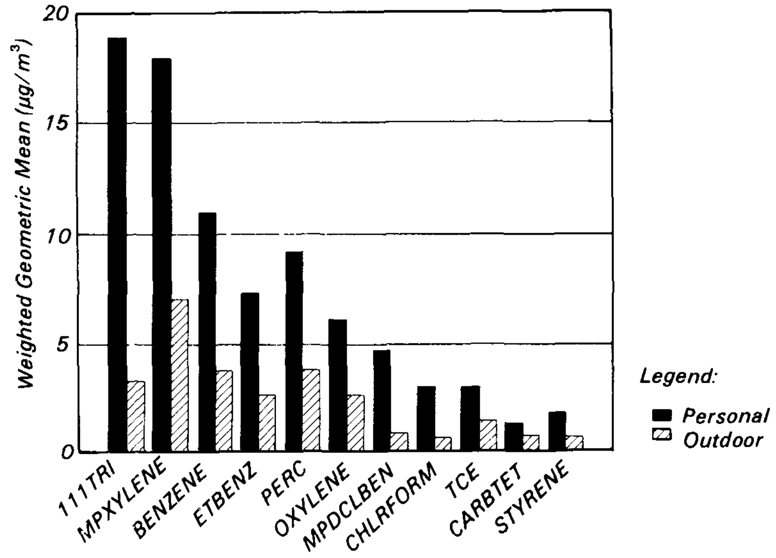


Figure 18. ***Estimated geometric means of 11 toxic compounds in overnight (6:00 pm - 6:00 am) air samples for the target population (128,000) of Elizabeth and Bayonne, New Jersey, between September and November 1981. Personal air estimates based on 340 samples; outdoor air estimates based on 84 samples.***

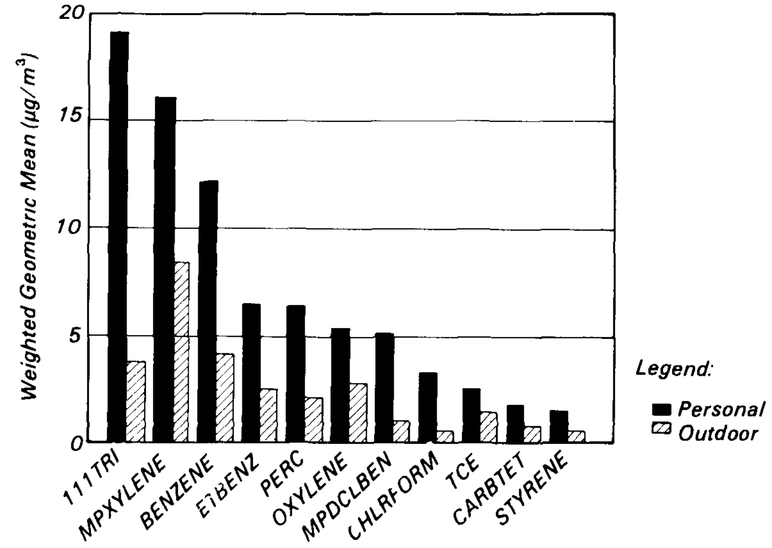


Figure 19. ***Weighted frequency distributions for 24-hour exposures of 355 New Jersey residents to aromatic compounds (Fall 1981).***

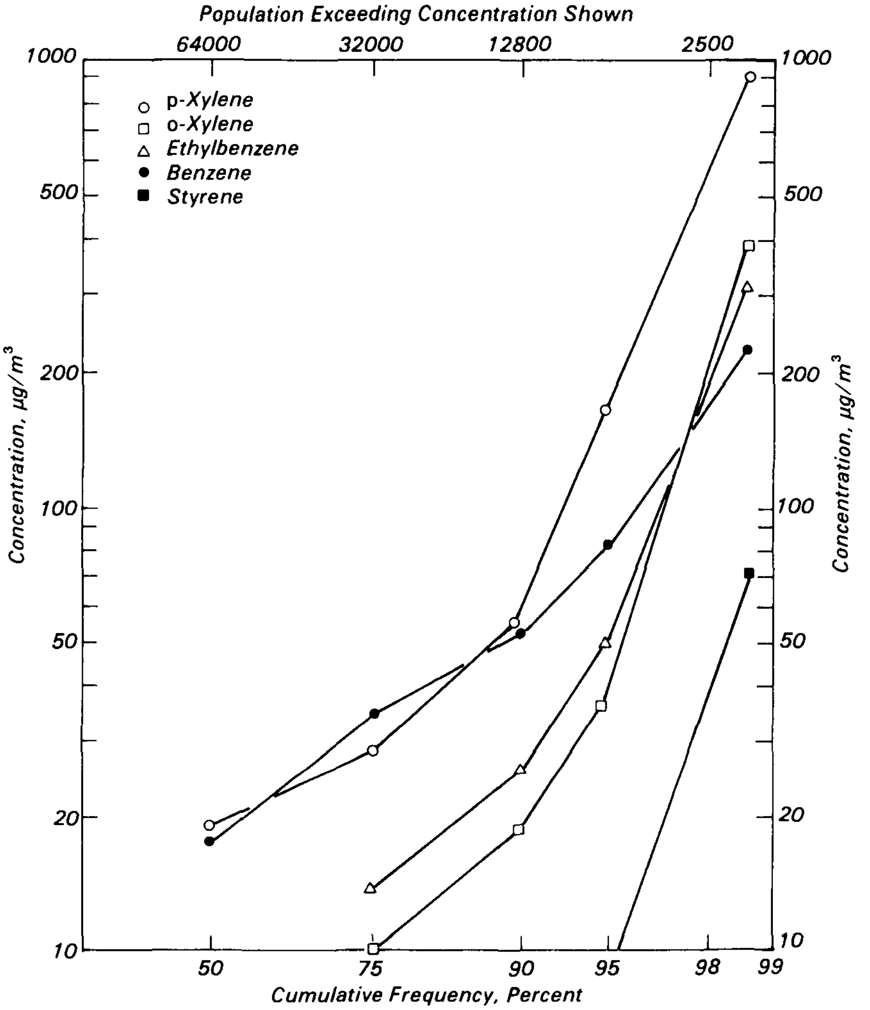


Figure 20. ***Weighted frequency distributions for 24-hour exposures of 355 New Jersey residents to six chlorinated compounds (Fall 1981).***

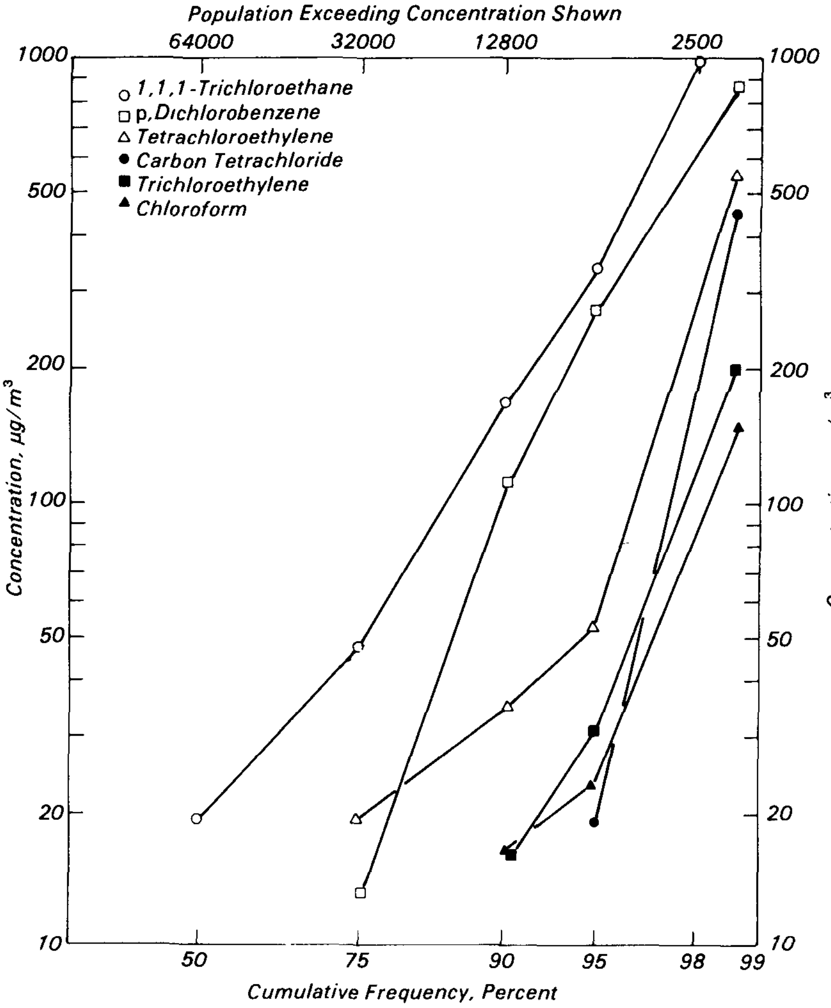
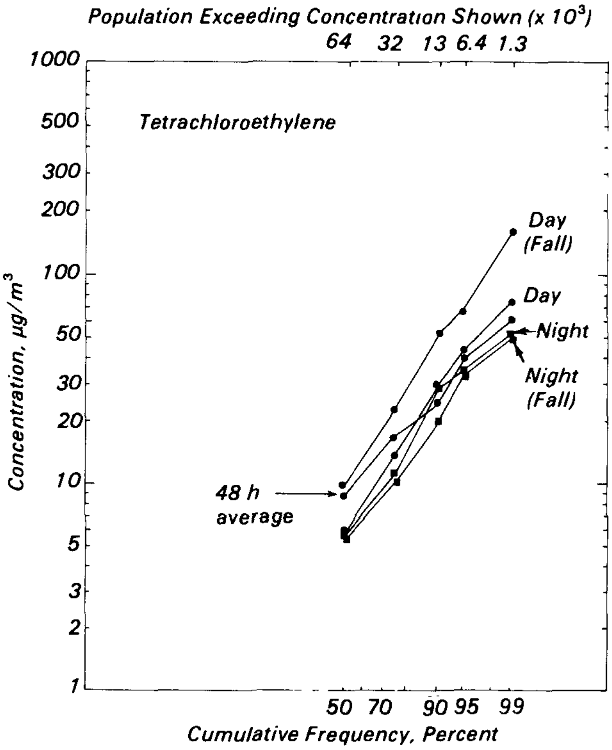


Figure 21. ***Weighted frequency distributions of day and night 12-hour personal air exposures compared to the 48-hour average for 160 New Jersey residents (Fall-Summer 1981-82).***



Two chemicals (chloroform and trichloroethylene) had elevated outdoor concentrations in summer.

Although the two smaller studies in Greensboro, North Carolina and Devils Lake, North Dakota were carried out in different seasons, a limited comparison indicates that the same chemicals with few exceptions were prevalent in air, breath, and water samples in the two cities. Personal air and breath levels were also similar in both cities.

Greensboro. A total of 242 samples were collected, of which 110 were quality control or quality assurance samples. Blank values were very high for 1,1,1-trichloroethane and benzene; thus, data for these chemicals should be viewed with caution. Precision was very good for air duplicates and acceptable for breath duplicates.

Personal air exposures were again greater than outdoor air exposures for most of the target chemicals (Table 25), although the small number of outdoor air samples makes this only a tentative conclusion. A large range in personal air exposures and breath concentrations was again evident, although mean daytime personal air values were somewhat below those observed in the winter season in New Jersey. Correlations between breath and daytime personal air exposures were significant for only three of eight prevalent chemicals.

Devils Lake. A total of 237 air, water, and breath samples were collected, of which 108 were QA/QC samples. As with the Greensboro Tenax samples,

Figure 22. ***Ratios of median 12-hour indoor air concentrations to simultaneous 12-hour outdoor air concentrations for New Jersey homes (N=85 in Fall 1981; N=70 in Summer 1981; N=10 in Winter 1983).***

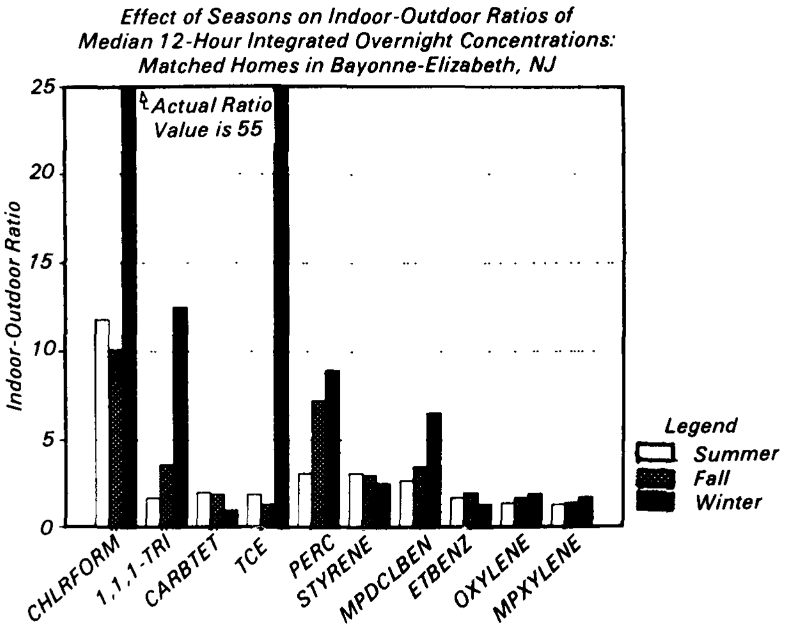


Figure 23. ***Ratios of 90th-percentile 12-hour indoor air concentrations to simultaneous outdoor air concentrations in New Jersey homes.***

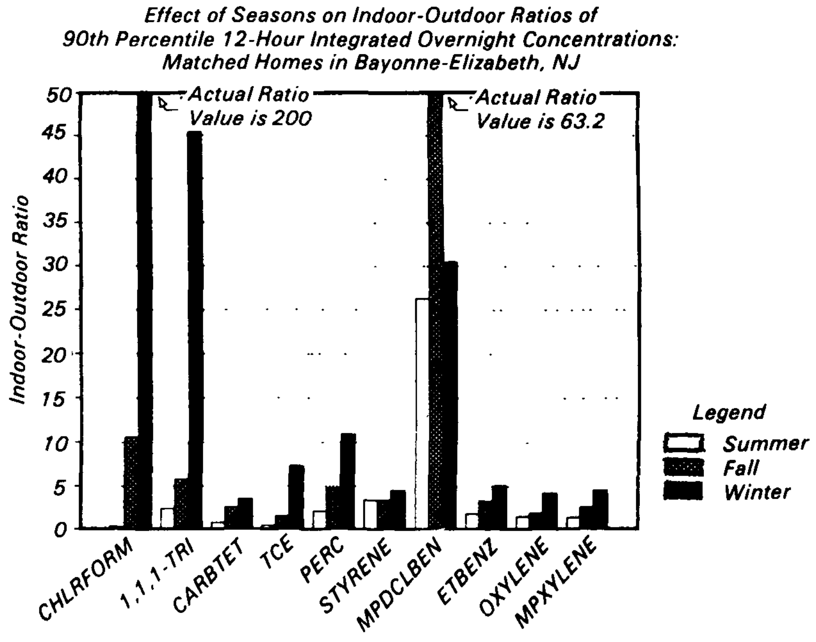
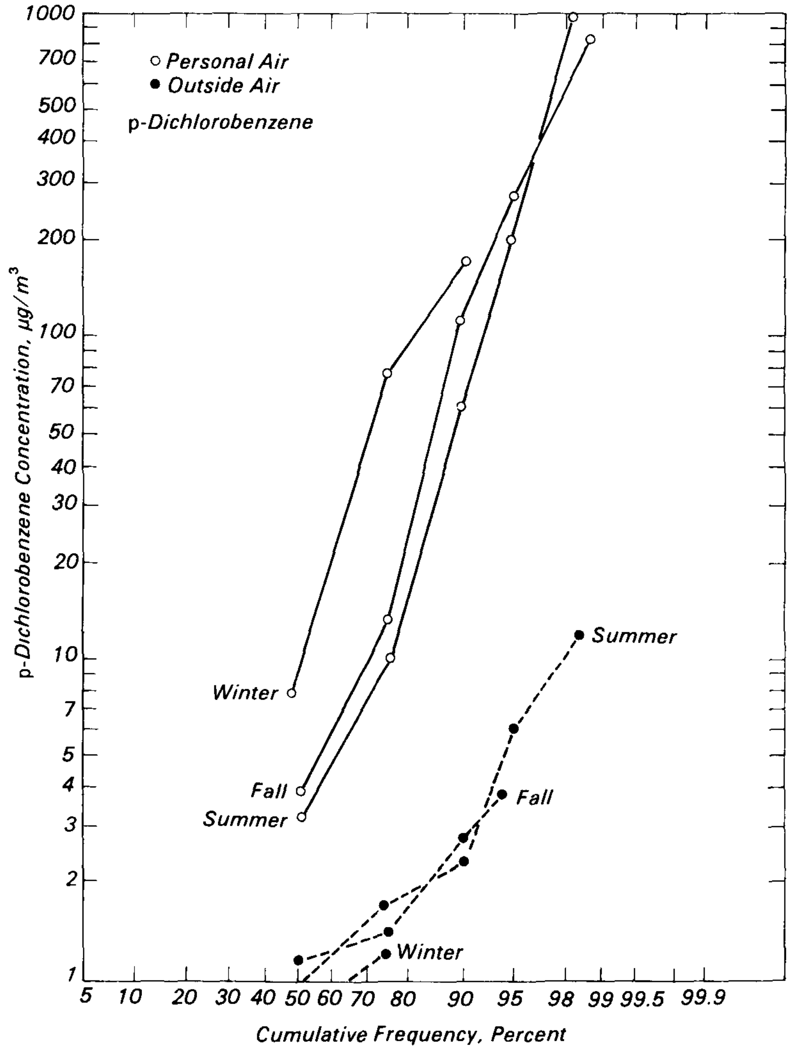


Figure 24. ***Weighted cumulative frequency distributions of overnight personal air exposures and outdoor air concentrations of*** m,p-***dichlorobenzene isomers in New Jersey. Sample sizes are 350 (Fall 1981); 160 (Summer 1982); and 50 (Winter 1983) for the personal air exposures; and 85 (Fall 1981); 70 (Summer 1982); and 10 (Winter 1983) for the outdoor air concentrations.***



unacceptably high and variable background concentrations of benzene and 1,1,1-trichloroethane occurred. Median coefficients of variance of duplicate samples were in the usual ranges of 10-30% for air, but very high levels of 30-70% for breath samples. Thus the Devils Lake breath data may be less trustworthy than other breath values.

Personal air exposures again exceeded outdoor air concentrations for all target compounds, although caution is indicated since the number of outdoor air samples was extremely small (Table 26). Most chemicals were not measurable in outdoor air, but indoor levels remained comparable to those observed in Greensboro. Drinking water concentrations of chloroform were exceedingly low (< 1 μg/L).

Los Angeles (February 1984) The 117 participants represented a total of 360,000 residents of the South Bay section of Los Angeles. The highest weighted 24-hour personal air exposures (Table 27) were to 1,1,1-trichloroethane (Figure 25), *m,p*-xylene, *m,p*-dichlorobenzene (Figure 26), benzene (Figure 27), and tetrachloroethylene (Figure 28). Outdoor concentrations, particularly at night, were unusually high, exceeding daytime outdoor levels by 50% or more. Breath means ranged from 10-30% of personal exposures for most chemicals except tetrachloroethylene (75%) and benzene (45%).The four straight-chain hydrocarbons added for the California study maintained consistent relationships among themselves in both outdoor and indoor air, with octane and undecane the highest, dodecane the lowest (Figure 29).

Figure 25. 1,1,1-Trichloroethane: Estimated frequency distributions of personal air exposures, outdoor air concentrations, and exhaled breath values for the target population of 360,000 persons in the South Bay section of Los Angeles. All air values are 10-14 hr integrated samples. The breath values were taken following the daytime air sample (6:00 am-6:00 pm). All outdoor air samples were taken in the vicinity of the participants' homes. (Feb. 1984)

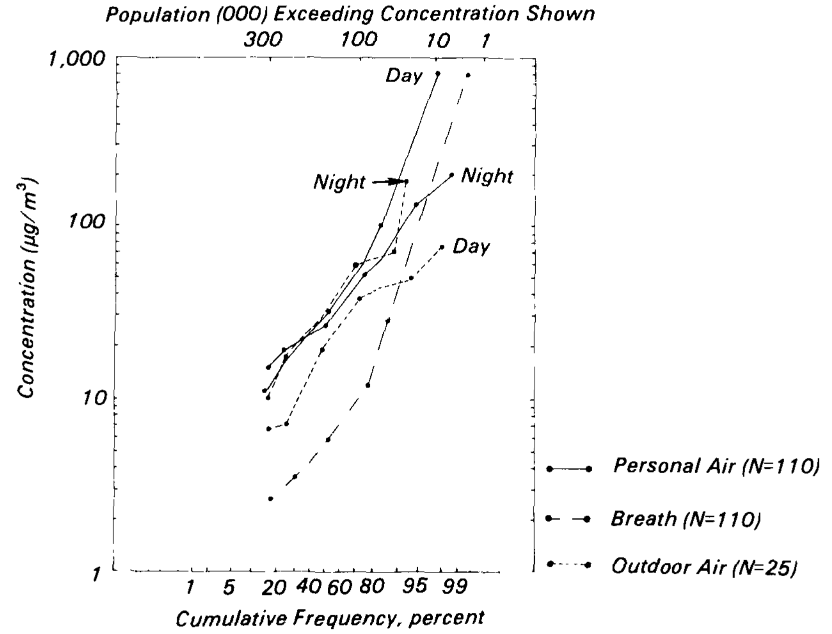


Table 25. ***Indoor/Outdoor Ratios in Greensboro, NC***

	Median Values		Ratio	Maximum Values		Ratio
Chemical	Indoor[a]	Outdoor[b]	(I/O)	Indoor	Outdoor	(I/O)
Chloroform	2.3[c]	0.14[c]	15	5.5[c]	1.3[c]	4
1,1,1-Trichloroethane	26	60	0.5	110	275.0	0.4
Benzene	11	0.4	20	43	82.0	0.5
Carbon tetrachloride	1.3	0.1	10	3.6	0.45	8
Trichloroethylene	1.0	0.2	5	8.7	2.4	3
Tetrachloroethylene	2.8	0.7	4	57	1.7	30
Styrene	0.8	0.1	8	3.1	0.31	10
m,p-Dichlorobenzene	3.4	0.4	8	72	1.7	40
Ethylbenzene	2.2	0.3	7	20	3.3	6
o-Xylene	3.7	0.6	6	26	3.8	7
m,p-Xylene	6.4	1.5	4	62	11.0	6

[a] N = 24 (overnight personal air samples).
[b] N = 6.
[c] µg/m^3.

Table 26. ***Indoor/Outdoor Radios in Devils Lake, ND***

	Median Values		Ratio	Maximum Values		Ratio
Chemical	Indoor[a]	Outdoor[b]	(I/O)	Indoor	Outdoor	(I/O)
Chloroform	0.14[c]	0.05[c,d]	3	2.8[c]	0.78[c]	3
1,1,1-Trichloroethane	37	0.05[d]	70	1100	5.0	200
Benzene	—[e]	—	—	—	—	—
Carbon tetrachloride	0.8	0.46[d]	2	10	0.84	12
Trichloroethylene	0.7	0.08[d]	9	32	1.1	30
Tetrachloroethylene	4.4	0.69	6	45	3.4	13
Styrene	—	—	—	—	—	—
m,p-Dichlorobenzene	1.7	0.07[d]	25	230	2.0	110
Ethylbenzene	2.8	0.03[d]	90	11	1.8	6
o-Xylene	3.5	0.05[d]	70	19	1.0	19
m,p-Xylene	8.4	0.05[d]	170	40	2.2	18

[a] N = 23 (overnight personal air samples).
[b] N = 5.
[c] µg/m^3.
[d] Not detectable - value equals 1/2 the limit of detection.
[e] Data uncertain based on quality assurance results.

Table 27. ***Weighted Estimates of Air and Breath Concentrations of Nineteen Prevalent Compounds for 360,000 Los Angeles Residents (February 1984); 330,000 Los Angeles Residents (May 1984); and 91,000 Contra Costa Residents (June 1984)***

	LA1 *(Feb)*			LA2 *(May)*			CC *(June)*		
Chemical	*Personal Air (N=110)*	*Outdoor Air (24)*	*Breath (110)*	*Personal Air (50)*	*Outdoor Air (23)*	*Breath (50)*	*Personal Air (76)*	*Outdoor Air (10)*	*Breath (67)*
1,1,1-Trichloroethane	96^a	34^a	39^b	44	5.9	23	16	2.8	16^b
m,p-*Xylene*	28	24	3.5	24	9.4	2.8	11	2.2	2.5
m,p-*Dichlorobenzene*	18	2.2	5.0	12	0.8	2.9	5.5	0.3	3.7
Benzene	18	16	8.0	9.2	3.6	8.8	7.5	1.9	7.0
Tetrachloroethylene	16	10	12	15	2.0	9.1	5.6	0.6	8.6^b
o-*Xylene*	13	11	1.0	7.2	2.7	0.7	4.4	0.7	0.6
Ethylbenzene	11	9.7	1.5	7.4	3.0	1.1	3.7	0.9	1.2
Trichloroethylene	7.8	0.8	1.6	6.4	0.1	1.0	3.8	0.1	0.6
n-*Octane*	5.8	3.9	1.0	4.3	0.7	1.2	2.3	0.5	0.6
n-*Decane*	5.8	3.0	0.8	3.5	0.7	0.5	2.0	3.8	1.3
n-*Undecane*	5.2	2.2	0.6	4.2	1.0	0.7	2.7	0.4	1.2
n-*Dodecane*	2.5	0.7	0.2	2.1	0.7	0.4	2.1	0.2	0.4
α-Pinene	4.1	0.8	1.5	6.5	0.5	1.7	2.1	0.1	1.3
Styrene	3.6	3.8	0.9	1.8	—	—	1.0	0.4	0.7
Chloroform	1.9	0.7	0.6	1.1	0.3	0.8	0.6	0.3	0.4

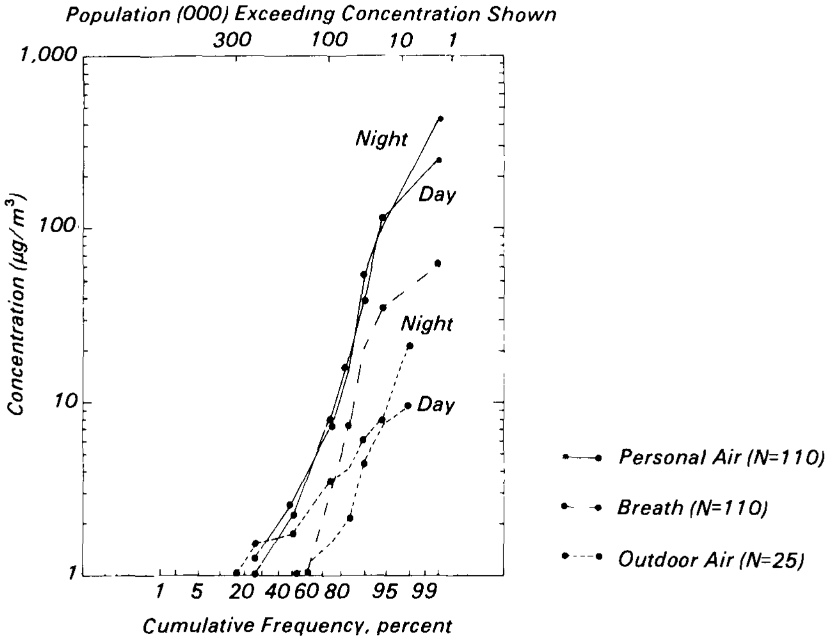
Table 27. **(continued)**

Chemical	LA1 *(Feb)* Personal Air (N=110)	LA1 *(Feb)* Outdoor Air (24)	LA1 *(Feb)* Breath (110)	LA2 *(May)* Personal Air (50)	LA2 *(May)* Outdoor Air (23)	LA2 *(May)* Breath (50)	CC *(June)* Personal Air (76)	CC *(June)* Outdoor Air (10)	CC *(June)* Breath (67)
Carbon tetrachloride	1.0	0.6	0.2	0.8	0.7	0.2	1.3	0.4	0.2
1,2-Dichloroethane	0.5	0.2	0.1	0.1	0.06	0.05	0.1	0.05	0.04
p-Dioxane	0.5	0.4	0.2	1.8	0.2	0.05	0.2	0.1	0.2
o-Dichlorobenzene	0.4	0.2	0.1	0.3	0.1	0.04	0.6	0.07	0.08
Total (19 compounds)	240	120	80	150	33	56	72	16	44

[a] Average of arithmetic means of day and night 12-hour samples (µg/m^3)

[b] One very high value removed

Figure 26. *p-Dichlorobenzene: Estimated frequency distributions of personal air exposures, outdoor air concentrations, and exhaled breath values for the target population of 360,000 persons in the South Bay section of Los Angeles. All air values are 10-14 hr integrated samples. The breath values were taken following the daytime air sample (6:00 am-6:00 pm). All outdoor air samples were taken in the vicinity of the participants' homes. (Feb. 1984)*



Los Angeles (May 1984). The second trip to 50 of the original participants resulted in estimates of exposures for 330,000 Los Angeles residents (Table 27). Concentrations, both personal and outdoor, were considerably reduced for 18 of the 19 prevalent chemicals. However, the same chemicals appeared in roughly the same order. Outdoor overnight values no longer exceeded daytime levels, and personal exposures nearly always exceeded outdoor concentrations. Benzene (Figure 30) and *m,p*-dichlorobenzene (Figure 31) concentrations in air and breath are presented as examples.

Contra Costa (June 1984). Seventy-one residents of Antioch and Pittsburg, California represented a target population of 91,000 persons. Weighted air and breath exposures were lower than in Los Angeles (Table 27), but again the same five chemicals were responsible for the highest exposures. Air and breath concentrations of benzene (Figure 32) and *m,p*-dichlorobenzene (Figure 33) are again presented for comparison. The relative concentrations of the straight-chain hydrocarbons were different in Contra Costa, with decane highest outdoors (Figure 34).

Concentrations in Drinking Water. Table 28 gives the levels of chemicals measured in drinking water. Chloroform was the predominant trihalomethane. Brominated trihalomethanes were very evident also, especially bromoform during the May 1984 period in Los Angeles, where the arithmetic mean was 8 μg/L.

Figure 27. ***Benzene: Estimated frequency distributions of personal air exposures, outdoor air concentrations, and exhaled breath values for the target population of 360,000 persons in the South Bay section of Los Angeles. All air values are 10-14 hr integrated samples. The breath values were taken following the daytime air sample (6:00 am-6:00 pm). All outdoor air samples were taken in the vicinity of the participants' homes. (Feb. 1984)***

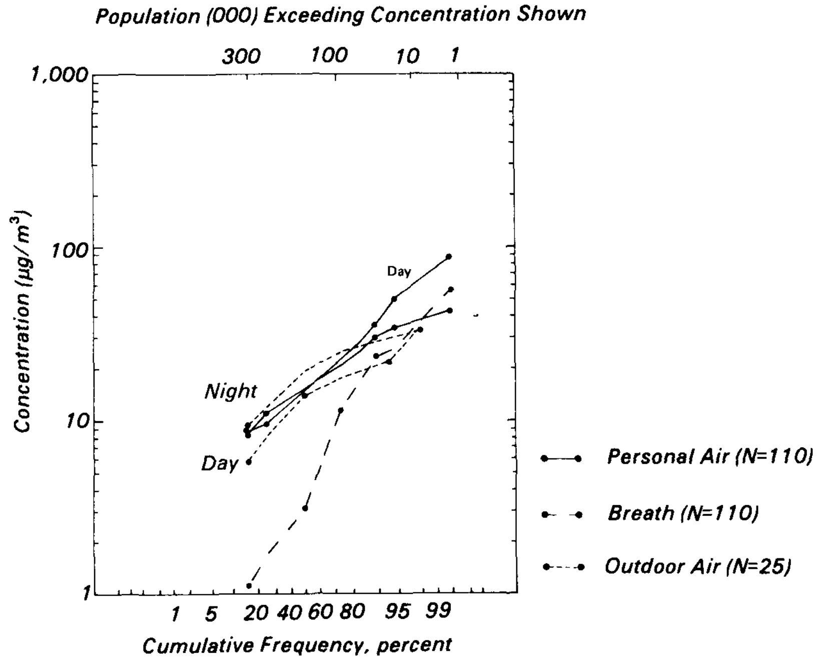
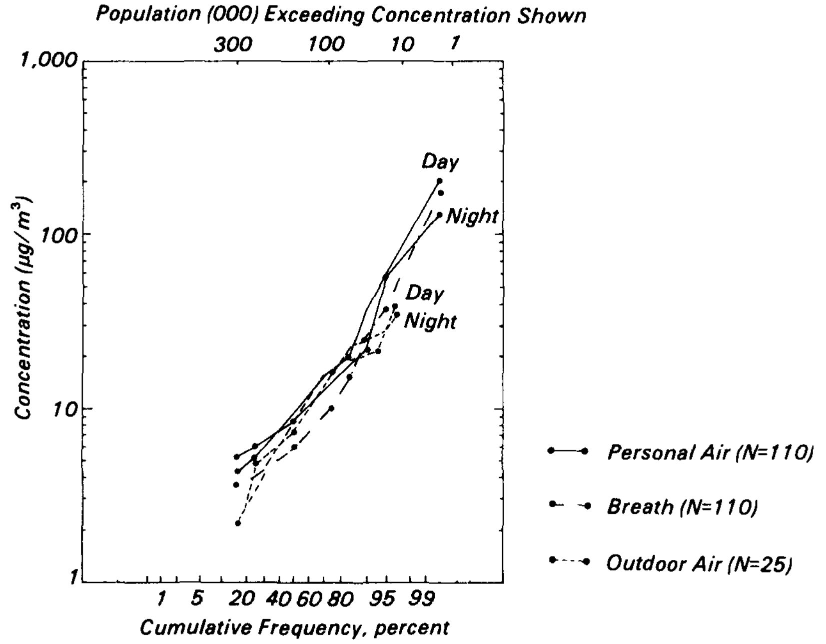


Table 28. ***Estimates of Drinking Water Concentrations for California Residents***

	Los Angeles (N=117) Feb. 1984		Los Angeles (N=52) May 1984		Contra Costa (N=71) June 1984	
Chemical	*Arith. Mean*	*SE*	*Arith. Mean*	*SE*	*Arith. Mean*	*SE*
Chloroform	14[a]	1.41[a]	29[a]	3.4[a]	42[a]	3.1[a]
Bromodichloromethane	11	0.84	20	2.3	21	1.4
Dibromochloromethane	9.4	0.91	28	3.1	8	0.56
Bromoform	0.8	0.14	8	2.4	0.8	0.09
1,1,1-Trichloroethane	0.15	0.04	0.08	0.02	0.09	0.04
Trichloroethylene	0.08	0.01	0.07	0.02	0.06	0.01
Tetrachloroethylene	0.07	0.01	0.04	0.02	0.10	0.09

[a] µg/L.

Figure 28. ***Tetrachloroethylene:*** ***Estimated frequency distributions of personal air exposures, outdoor air concentrations, and exhaled breath values for the target population of 360,000 persons in the South Bay section of Los Angeles. All air values are 10-14 hr integrated samples. The breath values were taken following the daytime air sample (6:00 am-6:00 pm). All outdoor air samples were taken in the vicinity of the participants' homes. (Feb. 1984)***



Indoor-Outdoor Comparisons

Since most participants remained in their homes during the overnight sampling period (6 pm - 6 am), these personal air samples may be considered indoor air samples and may be compared with the outdoor air samples collected concurrently in the backyards of the homes. Most chemicals were higher indoors than outdoors at all locations: many were significantly higher (Table 29).

Correlations

Breath versus Personal Air. Spearman rank correlation coefficients were calculated for the breath measurements and the preceding 12-hour personal air exposures. The Spearman nonparametric statistics were employed to avoid the problems of parametric statistics in dealing with highly skewed distributions. Ten of the eleven prevalent chemicals in the breath of the 355 New Jersey residents were significantly correlated (most at probabilities $p < .0001$) with the previous 12-hour average air exposures (Table 30). (The 11th chemical, chloroform, showed a significant correlation between breath and drinking water concentrations.) Since many of these chemicals are metabolized, excreted through other pathways than breath, and stored in different body compartments for different characteristic residence times, and since their concentration in breath depends partially on the previous blood concentration at the beginning of the monitoring period and also on the

Figure 29. Octane, Decane, Undecane, and Dodecane: Estimated frequency distributions of overnight concentrations in participants' homes compared to overnight outdoor air concentrations. (L.A., Feb. 1984)

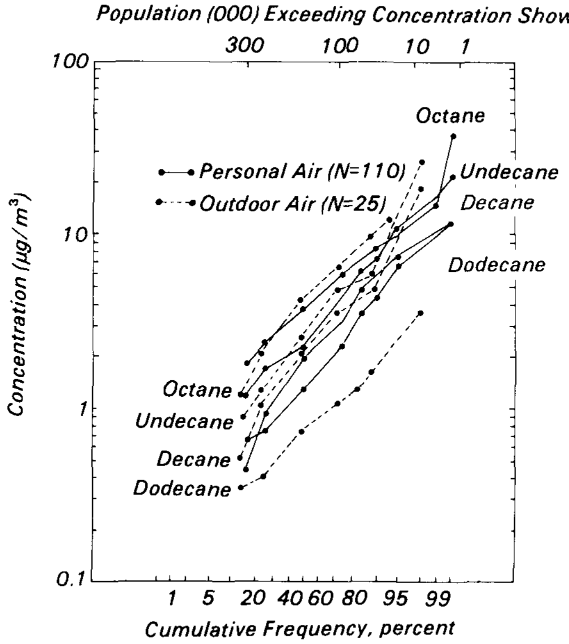


Figure 30. Benzene: Estimated frequency distributions of personal air exposures, outdoor air concentrations, and breath values for the target population of 330,000 residents in the South Bay section of Los Angeles. All air values are 10-14 hr integrated samples. The breath values were taken following the daytime air sample (6:00 am-6:00 pm). All outdoor air samples were taken in the vicinity of the participants' homes. (May 1984)

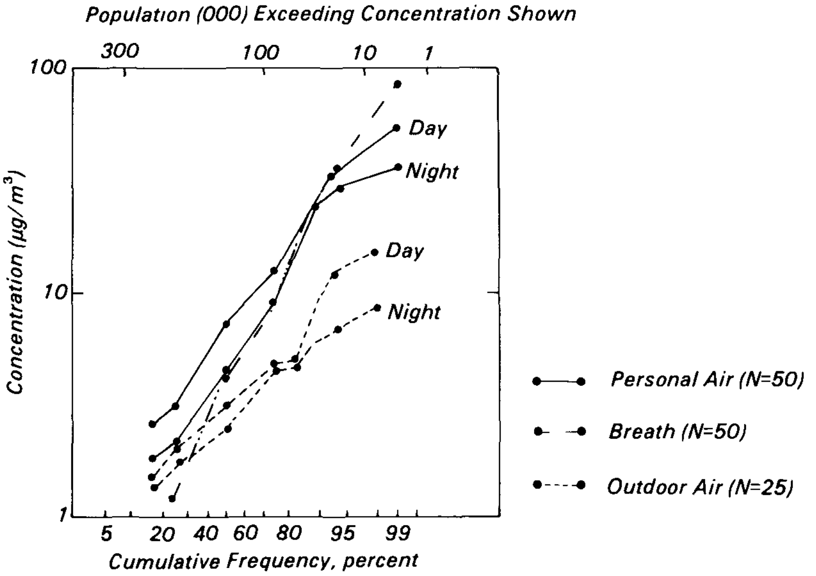


Table 29. Indoor-Outdoor Comparisons for Matched Samples: Median Overnight Concentrations (μg/m^3)

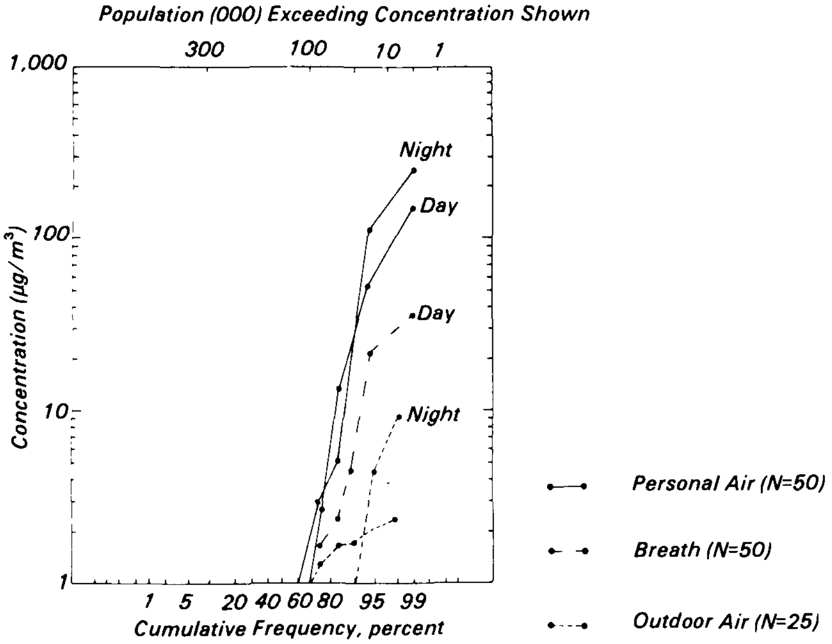
	Los Angeles						Contra Costa		
	January 1984 (N=24)			May 1984 (N=23)			June 1984 (N=10)		
	In	Out	Ratio	In	Out	Ratio	In	Out	Ratio
m,p-*Xylene*	26	30	0.9	8.2*	7.8	1.1	6.2*	1.4	4.3
1,1,1-Trichloroethane	24	29	0.8	7.9*	4.0	2.0	4.2*	2.1	2.0
Benzene	18	17	1.1	4.8*	2.9	1.7	3.6*	1.6	2.3
o-*Xylene*	11	11	1.0	2.6	2.1	1.2	2.2*	0.5	4.7
Ethylbenzene	9.7	11	0.9	2.2	2.0	1.1	1.8*	0.6	2.8
Tetrachloroethylene	8.9	7.4	1.2	1.7	1.3	1.3	2.1*	0.2	8.4
Styrene	3.6	4.2	0.9	0.6	0.6	1.0	0.4	0.3	1.5
α-Pinene	3.4*	0.8	4.2	1.4*	0.3	5.5	1.4*	0.05	29.0
n-*Octane*	4.6	4.3	1.1	1.6*	0.9	1.7	1.4*	0.4	3.9
n-*Decane*	1.9	2.6	0.8	0.9*	0.5	1.9	0.6	2.0	0.3
n-*Undecane*	2.9*	2.0	1.5	1.0	0.5	2.0	0.9*	0.1	9.0
n-*Dodecane*	1.4*	0.7	2.1	0.6	0.6	1.0	0.6*	0.1	4.8
p-*Dichlorobenzene*	2.8*	1.8	1.6	1.0*	0.7	1.4	0.4	0.2	1.8
Chloroform	1.6*	0.6	2.5	0.8*	0.03	25.0	0.4	0.6	0.7
Trichloroethylene	1.2*	0.7	1.8	0.5*	0.1	4.8	0.4	0.1	3.2
Carbon tetrachloride	0.6	0.6	1.0	0.7	0.6	1.1	0.7	0.3	2.2

Table 29. ***(continued)***

	Los Angeles						Contra Costa		
	January 1984 (N=24)			May 1984 (N=23)			June 1984 (N=10)		
	In	Out	Ratio	In	Out	Ratio	In	Out	Ratio
1,2-Dichloroethane	0.2	0.2	1.0	0.03	0.02	1.1	0.1	0.03	4.7
1,4-Dioxane	0.3	0.3	1.0	0.02	0.02	1.0	0.07	0.03	2.9
o-Dichlorobenzene	0.12	0.2*	0.6	0.03	0.03	1.0	0.03	0.02	1.0

*Significantly higher ($p < 0.05$) by Wilcoxon signed rank test.

Figure 31. *p-Dichlorobenzene: Estimated frequency distributions of personal air exposures, outdoor air concentrations, and exhaled breath values for the target population of 330,000 residents in the South Bay section of Los Angeles. All air values are 10-14 hr integrated samples. The breath values were taken following the daytime air sample (6:00 am-6:00 pm). All outdoor air samples were taken in the vicinity of the participants' homes. (May 1984)*



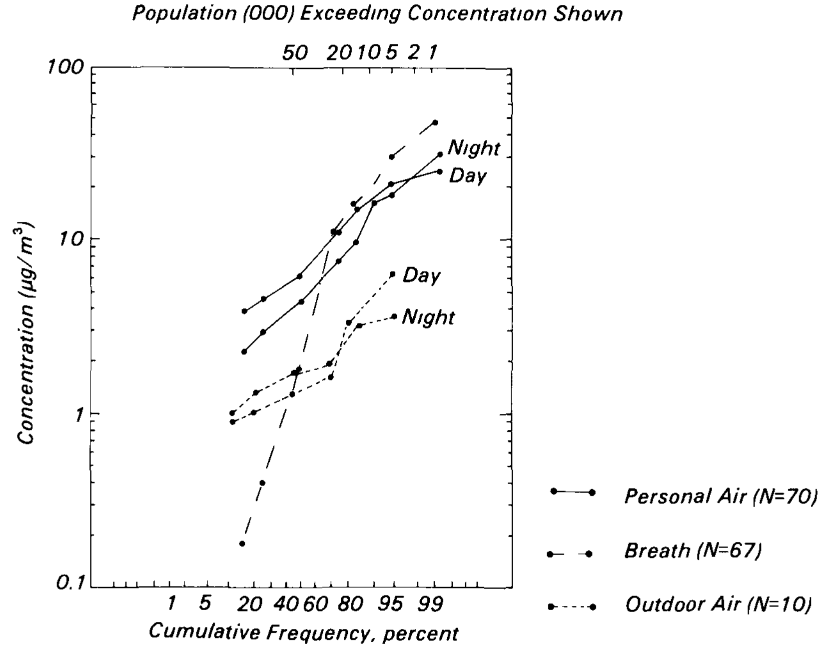
time history of air concentrations over the 12-hour monitoring period, high correlation coefficients related to a single 12-hour integrated concentration were not expected. However, the fact that significant correlations of breath values with previous exposures in air or water were observed for every one of the eleven prevalent chemicals in the first and largest of the field trips suggests that breath measurements may be capable of providing rough estimates of preceding exposures.

These correlations continued to be significant for some chemicals (xylenes, trichloroethylene, 1,1,1-trichloroethane, tetrachloroethylene, and *p*-dichlorobenzene) at most or all TEAM Study sites.

In California, correlations between breath concentrations and preceding personal air exposures were again significant for many chemicals (Table 31) although the magnitudes were not large. Correlations with outdoor air concentrations were almost never significant. In drinking water only chloroform showed occasional significant correlations with breath concentrations.

Intramedium Correlations. Spearman rank correlations were calculated for all possible pairs of the prevalent target chemicals for the New Jersey personal air, outdoor air, and breath samples. Correlations were high for certain chemicals in all media. For example, the xylene isomers and

Figure 32. ***Benzene: Estimated frequency distributions of personal air exposures, outdoor air concentrations, and breath values for 91,000 residents of Antioch and Pittsburg, California. All air values are 10-14 hr integrated samples. Breath values were taken following the daytime air sample (6:00 am-6:00 pm). All outdoor air samples were taken in the vicinity of the participants' homes. (June 1984)***



ethylbenzene had correlation coefficients exceeding 0.9 in virtually all cases (Table 32). On the other hand, chloroform and *p*-dichlorobenzene showed little correlation with any of the other chemicals or with each other.

Statistical Analysis of Questionnaire Data

Two questionnaires were administered to each participant. The household questionnaire included questions on age, sex, occupations, household characteristics, and customary activities of the participant and also of other members of the household. The 24-hour recall questionnaire, administered immediately following the end of the 24-hour monitoring period, included questions on the participant's activities. Information on more than 100 items were collected for each person. Of these, about 60 items were selected for statistical analysis (Table 33). Two approaches were adopted: pairwide comparisons (t-tests) followed by stepwise regressions. The logarithms of the chemical concentrations were used in both approaches because of the approximately log-normal distributions observed for all chemicals in air and breath.

Pairwise Comparisons (t-tests). The 60 questionnaire items were examined for possible associations with increased exposure to each of 12 chemicals in New Jersey and 16 in California. All three measures of personal exposures (daytime air, overnight air, and breath) were examined in each of the three New Jersey and three California visits. For example, in the

Figure 33. ***p-Dichlorobenzene: Estimated frequency distributions of personal air exposures, outdoor air concentrations, and breath values for 91,000 residents of Antioch and Pittsburg, California. All air values are 10-14-hour integrated samples. Breath values were taken following the daytime air sample (6:00 am - 6:00 pm). All outdoor air samples were taken in the vicinity of the participants' home.***

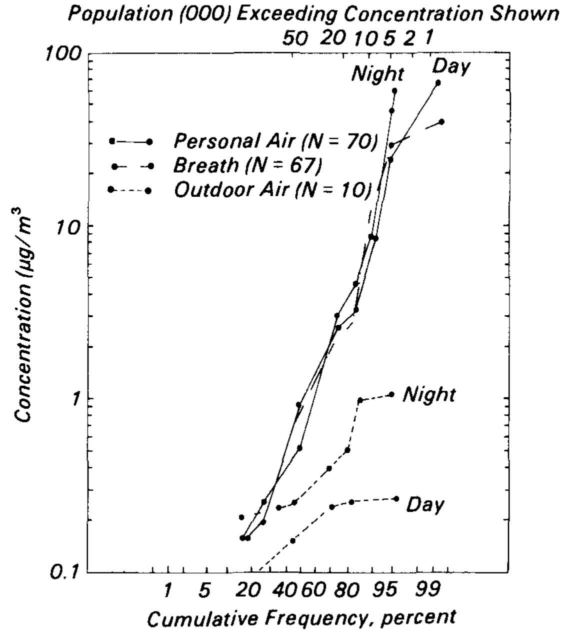


Figure 34. ***Octane, Decane, Undecane, and Dodecane: Estimated frequency distributions of overnight concentrations in participants' homes compared to overnight outdoor air concentrations. (June 19884)***

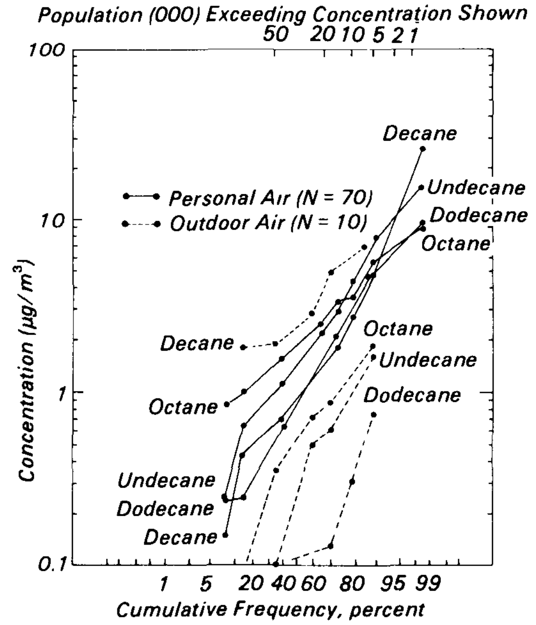


Table 30. ***Spearman Correlations Between Breath Concentrations and Preceding Daytime 12-Hour Personal Exposures to Eleven Compounds in New Jersey, North Carolina, and North Dakota***

Compound	NJ1[a] (N=330)	NJ2[b] (N=130)	NJ3[c] (N=47)	ND[d] (N=23)	NC[e] (N=23)
Chloroform	.07	−.11	−.03	−.01	.45*
1,1,1-Trichloroethane	.28*	.28*	.32*	.71*	—
Benzene	.21*	—[f]	—	—	.22
Carbon tetrachloride	.24*	−.01	—	−.23	−.53*
Trichloroethylene	.38*	.10	.35*	.26	.38
Tetrachloroethylene	.46*	.23*	.37*	.53*	.58*
Styrene	.19*	.20*	.19	—	.32
m,p-Dichlorobenzene	.54*	.38*	.61*	.63*	.68*
Ethylbenzene	.33*	.22*	.44*	.12	−.01
o-Xylene	.26*	.22*	.45*	.21	.28
m,p-Xylene	.32*	.27*	.48*	.19	.08

[a] *Fall 1981.*
[b] *Summer 1982.*
[c] *Winter 1983.*
[d] *Fall 1982.*
[e] *Spring 1982.*
[f] *Data uncertain based on quality assurance results.*
**Significant at* $p < .05$ *level.*

first New Jersey visit (Fall 1981) 11 questionnaire items had one or more associations significant at $p < 0.0001$, and an additional six variables had one or more associations significant at $p < 0.001$ (Table 34). These 17 variables accounted for a total of 47 t-tests significant at $p < 0.001$, compared to only two expected to occur by chance at that level. Chemicals appearing most often were three aromatic compounds: ethylbenzene (12 times), *m,p*-xylene (9), and *o*-xylene (8). Chemicals never appearing were chloroform and carbon tetrachloride.

Of the 60-70 questionnaire variables, about half appeared to have considerable influence on personal exposure to one or more of the target chemicals. These are ranked in order of the number of significant associations observed during the six visits to New Jersey and California (Table 35). As can be seen, variables related to smoking, occupation, home characteristics, activities, and automobile travel were the most important determinants of exposure.

Exposure to Active Smokers. The breath concentrations of all prevalent chemicals were compared for smokers and nonsmokers (Table 36). Since the distributions were skewed to the right, significance tests were performed using the logarithms of the concentrations. Five aromatic chemicals (and also octane, measured only in California) were significantly higher in the breath of persons who had smoked tobacco the day they were monitored; six chlorinated compounds and three other straight-chain hydrocarbons

Table 31. Spearman Correlations Between Breath and Preceding Air Concentrations (Measurable Amounts Only)

Compound	*Breath* vs. *Daytime Personal Air*			*Breath* vs. *Daytime Outdoor Air*		
	LA1[a] *(N=11-112)*	*LA2*[b] *(13-49)*	*CC*[c] *(10-58)*	*LA1*[a] *(N=8-24)*	*LA2*[b] *(7-24)*	*CC*[c] *(7)*
Trichloroethylene	*0.74**	*0.84**	*0.72**	*−0.05*	*NC*[d]	*NC*
m,p-*Dichlorobenzene*	*0.71**	*0.40**	*0.46**	*0.54**	*0.60**	*NC*
Tetrachloroethylene	*0.32**	*0.36**	*0.44**	*0.11*	*−0.09*	*NC*
1,1,1-Trichloroethane	*0.57**	*0.62**	*0.11*	*−0.17*	*0.19*	*NC*
Ethylbenzene	*0.31**	*0.45**	*0.13*	*−0.12*	*0.29*	*NC*
o-*Xylene*	*0.39**	*0.51**	*0.03*	*0.14*	*−0.22*	*NC*
m,p-*Xylene*	*0.42**	*0.44**	*0.16*	*0.02*	*0.14*	*−0.29*
Benzene	*0.25**	*0.25*	*0.07*	*−0.04*	*0.11*	*NC*
Styrene	*0.31**	*0.12*	*0.06*	*0.08*	*0.23*	*NC*
n-*Octane*	*0.31**	*0.38**	*0.25*	*−0.07*	*0.53*	*NC*
n-*Decane*	*0.22*	*0.63**	*0.01*	*−0.09*	*NC*	*NC*
n-*Undecane*	*0.10*	*0.34*	*0.09*	*0.22*	*0.56*	*NC*
n-*Dodecane*	*0.23*	*0.66*	*NC*	*0.33*	*NC*	*NC*
Chloroform	*−0.06*	*0.17*	*NC*	*NC*	*NC*	*NC*
Carbon tetrachloride	*−0.32*	*NC*	*0.05*	*NC*	*NC*	*NC*
α-Pinene	*0.21**	*0.10*	*0.10*	*−0.15*	*−0.15*	*NC*

[a] *Los Angeles—First trip—February 1984.*
[b] *Los Angeles—Second trip—May 1984.*
[c] *Contra Costa (Antioch/Pittsburg)—June 1984.*
[d] *Not calculated—$N \leq 5$.*
**Significant at $p < 0.05$.*

showed no consistent differences. The magnitude of the increase was considerable—smokers had 2-10 times higher geometric mean concentrations of benzene, styrene, ethylbenzene, and xylenes in their breath than nonsmokers. Benzene concentrations in the breath of smokers and nonsmokers in the fall visit to New Jersey are compared in Figure 35.

Exposure in Homes of Smokers. Overnight indoor air concentrations in homes with smokers were compared to concentrations in homes with no smokers for all six visits (Table 37). The fall 1981 visit to New Jersey (Figure 36) and the winter 1984 visit to Los Angeles showed significant increases ranging from 50-100% for all five aromatics in the indoor air of homes with smokers; however, the spring and early summer visits to Los Angeles and Antioch/Pittsburg, California and the summer and winter visits to New Jersey showed no difference. It was not possible to determine from the questionnaire whether the homes with resident smokers actually experienced smoking during the 12-hour overnight period (which included the sleeping period). Such homes would be misclassified as smoking homes, which would tend to obscure differences. Similarly, homes classified as nonsmoking may have had a smoking guest on the day of monitoring. Therefore, the true increases

Table 32. **Spearman Correlations ≥0.5 Between Prevalent Compounds in Air and Breath: TEAM Study, New Jersey, Fall 1981; Summer 1982; Winter 1983**

						Personal Air						Outdoor Air					
	Compound 1	Compound II	Breath			Night			Day			Night			Day		
		Fall:	(N = 29-312)			(N = 82-325)			(N = 52-314)			(N = 18-72)			(N = 7-72)		
		Summer:	(N = 20-92)			(N = 50-149)			(N = 50-133)			(N = 18-60)			(N = 14-53)		
		Winter:	(N = 15-49)			(N = 36-49)			(N = 33-47)			(N = 7-8)			(N = 7-8)		
			S	F	W	S	F	W	S	F	W	S	F	W	S	F	W
1.	m,p-Xylene	o-Xylene	.90	.91	.96	.91	.94	.95	.92	.96	.98	.91	.92	.92	.86	.96	.79
2.	Ethylbenzene	o-Xylene	.89	.93	.92	.86	.93	.96	.93	.95	.98	.95	.94	.89	.95	.94	.83
3.	Ethylbenzene	m,p-Xylene	.97	.93	.96	.86	.92	.96	.94	.95	.98	.94	.92	.97	.90	.93	.97
4.	Styrene	Ethylbenzene	.72	.51	.74	.58	.66	.66	.65	.60	.60	.81	.59	.87		.57	
5.	Styrene	o-Xylene	.61		.69	.51	.60	.62	.60	.57	.55	.72	.64	.97			
6.	Styrene	m,p-Xylene	.70		.68	.58	.65	.58	.65	.58	.53	.73	.54	.88			
7.	Benzene	o-Xylene		.52			.57			.50			.55			.52	
8.	Benzene	m,p-Xylene		.58			.60			.55			.58			.56	
9.	Benzene	Ethylbenzene		.63			.62			.55			.65			.57	
10.	Benzene	Styrene		.56									.56				
11.	Tetrachloroethylene	Ethylbenzene			.52						.58	.71	.63	.82	.60	.59	
12.	Tetrachloroethylene	m,p-Xylene			.50						.56	.69	.60	.89	.59	.61	
13.	Tetrachloroethylene	o-Xylene									.57	.62	.60	.79	.52	.61	
14.	Tetrachloroethylene	Styrene						.55	.54			.56			.56		
15.	Tetrachloroethylene	Trichloroethylene							.56				.60		.52	.54	

Table 32. (continued)

						Personal Air						Outdoor Air					
	Compound 1	Compound II	Breath			Night			Day			Night			Day		
		Fall: Summer: Winter:	(N = 29-312)	(N = 20-92)	(N = 15-49)	(N = 82-325)	(N = 50-149)	(N = 36-49)	(N = 52-314)	(N = 50-133)	(N = 33-47)	(N = 18-72)	(N = 18-60)	(N = 7-8)	(N = 7-72)	(N = 14-53)	(N = 7-8)
16.	Trichloroethylene	1,1,1-Trichloroethane	.51		.53	.62		.70	.66			.84					
17.	Trichloroethylene	Styrene											.51		.58	.60	
18.	Trichloroethylene	m,p-Xylene	.56										.61		.64		
19.	Trichloroethylene	Ethylbenzene											.53		.65		
20.	Trichloroethylene	o-Xylene	.56												.69		
21.	Trichloroethylene	Benzene											.65				
22.	1,1,1-Trichloroethane	Chloroform	.59				.50					.71			.72	.57	
23.	1,1,1-Trichloroethane	Ethylbenzene													.73	.59	
24.	Chloroform	Carbon tetrachloride	.79									.56			.56		

Table 33. Variables Included in Statistical Analysis

Variable Name	*N*[a]	*Description*
Personal Characteristics		
MALE	*183*	
NONWHITE	*107*	*Hispanic (44) + Black (60) + Other (3)*
CHILD	*23*	*Age 5-17*
YOUTH	*60*	*Age 18-39*
ADULT	*148*	*Age 40-65*
OLD	*40*	*Age 65-85*
WEIGHTY	*33*	*Weighs over 200 lbs*
Occupation		
EMPLOYED	*203*	
JPAINTER	*9*	*Occupation: painter*
JGARAGE	*12*	*Occupation: garage/service station*
JHOSPIT	*6*	*Occupation: hospital worker*
JMETAL	*7*	*Occupation: metal worker*
JDRIVER	*15*	*Occupation: taxi/bus/truck driver*
HPAINTER	*10*	*Painter in household*
HCHEMIC	*14*	*Chemical worker in household*
HGARAGE	*9*	*Garage/service station worker in household*
HMETAL	*21*	*Metal worker in household*
HDRIVER	*11*	*Taxi/bus/truck driver in household*
Activities		
HOBFURN	*15*	*Hobby: furniture refinishing*
HOBPAIN	*51*	*Hobby: painting*
HOBMOD	*7*	*Hobby: scale models*
HOBGAR	*68*	*Hobby: gardening*
HOBFURNO	*37*	*Other household members' hobby: furniture refinishing*
HOBPAINO	*15*	*OHMH: painting*
HOBMODO	*7*	*OHMH: scale models*
HOBGARO	*68*	*OHMH: gardening*
PEST	*47*	*Often use pesticides*
NUM_PEST	*162*	*House is treated regularly for pesticides*
PUMPGAS	*9*	*Pumped gas on day of monitoring*
PEST24	*20*	*Exposed to pesticides that day*
SMOKED24	*161*	*Smoked that day*
HOMESMOK	*258*	*Smoker in household*
Household Characteristics		
OLDHOUSE	*121*	*House older than 10 years*
CENT_A_C	*14*	*Central air conditioning*
WIND_A_C	*267*	*Window air conditioner*
FAN_OUT	*113*	*Window fan or ceiling exhaust fan*
CIRCFAN	*72*	*Circulating fan*
ELECSTOV	*17*	*Electric stove*
GASHEAT	*161*	*Gas furnace*
Occupation-Related		Worked at or in on day of monitoring:
XPAINT24	*27*	*Paint store*
XDRYCI24	*13*	*Dry cleaners*
XCHEM24	*21*	*Chemical plant*
XPETRO24	*9*	*Petroleum plant*
XGARAG24	*67*	*Garage/service station*
XFURN24	*7*	*Furniture refinishing shop*

Table 33. (continued)

Variable Name	N[a]	Description
XPLAS24	11	Plastics plant
XTEXT24	5	Textiles plant
XWOOD24	6	Wood processing plant
XPRINT24	9	Printing shop
XLAB24	14	Scientific laboratory
XDYE24	4	Dye plant
XHPSP24	13	Hospital
XMETAL24	17	Metal work
XNONE24	124	None of the above
Activity/Occupation-Related		Exposed to on day of monitoring:
XSOLV24	37	Solvents
XODOR24	83	Odorous chemicals
XPEST24	27	Pesticides
XDUST24	63	High dust levels
XEXHAU24	62	Auto/truck exhaust
XCLEAN24	94	Household cleaners
XGREAS24	19	Degreasing chemicals
XOTHER24	19	Other chemicals or mixtures

[a] Number of persons in category during first New Jersey visit (Total number of respondents: 362)

Table 34. Questionnaire Items Associated with Significantly Increased Exposures ($p < 0.001$): New Jersey, Fall 1981

	Geometric Means ($\mu g/m^3$)					
	Breath		Personal Air			
Questionnaire Item/			Day		Night	
Chemical	Yes	No	Yes	No	Yes	No
Employed (N=188-194)						
1,1,1-Trichloroethane	6.7	3.5	31	12		
Tetrachloroethylene	9.7	5.5				
Ethylbenzene	3.4	1.9	12	6.1		
o-Xylene	2.6	1.6	8.9	5.3		
m,p-Xylene	7.1	4.5	29	15		
Smoked (N=144-154)						
Benzene	21	5.3	18	11		
Styrene	1.3	0.6				
Ethylbenzene	3.9	2.0				
m,p-Xylene	7.9	4.5				
Smoker in Home (N=223-245)						
Benzene	13	4.9	14	8.1		
Styrene	1.0	0.5	2.1	1.1		

Table 34. (continued)

	Geometric Means ($\mu g/m^3$)					
	Breath		Personal Air			
			Day		Night	
	Yes	No	Yes	No	Yes	No
Ethylbenzene			7.7	5.2		
m,p-Xylene			19	12		
High Potential Exposure* (N=238)						
Tetrachloroethylene	8.8	5.7				
Ethylbenzene			10.7	5.9		
o-Xylene			8.7	4.9		
m,p-Xylene			26	15		
Male (N=172-173)						
Ethylbenzene			11	6.9		
o-Xylene			8.9	5.7		
m,p-Xylene			29	17		
Service Station/Garage Worker (N=11)						
Ethylbenzene			55	8.3		
m,p-Xylene			132	21		
Hospital Worker (N=6)						
p-Dichlorobenzene			84	4.0	120	4.5
Paint (N=24-25)						
Tetrachloroethylene	13	7.3				
Ethylbenzene	6.1	2.5				
o-Xylene	4.4	2.0				
Chemical Plant (N=20)						
Styrene	1.9	0.8				
Furniture Repair Plant (N=7)						
o-Xylene			35	6.9		
Textile Plant (N=5)						
1,1,1-Trichloroethane			320	20		
Wood Processing Plant (N=6)						
Trichloroethylene			22	3.1		
Chlorobenzene						

Table 34. (continued)

	Geometric Means ($\mu g/m^3$)					
	Breath		*Personal Air*			
			Day		*Night*	
	Yes	*No*	*Yes*	*No*	*Yes*	*No*
Dye Plant (N=4)						
Ethylbenzene			42	8.6		
Solvents (N=33)						
Ethylbenzene	6.2	2.4				
o-*Xylene*	4.2	2.0				
m,p-*Xylene*	12.1	5.2				
Odorous Chemicals (N=78)						
Ethylbenzene			15	7.5		
o-*Xylene*			12	6.1		
High Dust/Particulate Exp. (N=56)						
Ethylbenzene			18	7.6		
m,p-*Xylene*			44	19		

* *All those who were employed in or exposed to at least one of the 14 listed occupations/activities on the day of monitoring; the inverse of the XNONE24 variable (See previous table).*

in homes that experienced smoking on the day of monitoring may exceed the values in the table.

Occupational Exposure. About 85 of the 350 participants were classified as having potential occupational exposures to some of the target compounds Certain occupations showed significant ($p < .05$, Mann-Whitney nonparametric test) increases in breath concentrations or personal air exposures to some chemicals, whereas other occupations showed no increased exposures. Figures 37 to 41 compare unweighted median breath values for workers in several occupations (chemicals, paint, plastics, petroleum, and printing) to persons not engaged in those occupations. In these pairwise comparisons, no attempt is made to control for confounding factors; however, stepwise regressions (see below) confirmed most of the pairwise results.

Effects of Activities and Potential Sources on Exposures

All participants were asked if they had been exposed to potential sources of target chemicals on the day they were monitored or within the previous week. Sources included industrial plants, auto exhaust, and paint. For ten of the twelve sources, at least one (and as many as six) of the eleven most prevalent chemicals appeared at significantly higher levels in the breath of persons exposed during the day or week compared to those not exposed to the source. In most cases, the chemicals that were elevated were those expected to be associated with a given source, such as tetrachloroethylene with dry cleaners (Figure 42) and benzene with service stations (Figure 43)

Table 35. ***Variables Ranked by Number of Pairwise Associations with Significantly Increased or Decreased Exposures ($p < 0.05$) (All New Jersey and California Visits)***

	Variable	*General Category*	*N*[a] *($p < 0.05$)*
1.	*Employed*	*Occupation*	*76*
2.	*Adult (21-65)*	*Age/Occup.*	*65*
3.	*Student*	*Age/Occup.*	*62*
4.	*Smoke free*	*Smoking*	*62*
5.	*Smoked*	*Smoking*	*61*
6.	*Smoker in home*	*Smoking*	*58*
7.	*Never smoked*	*Smoking*	*58*
8.	*High potential exposure (24-hr)*	*Occupation*	*40*
9.	*Exposed to solvents (24-hr)*	*Occupation*	*40*
10.	*Hispanic*	*Race*	*40*
11.	*Exposed to dust/particles (24-hr)*	*Occupation*	*38*
12.	*Circulating fan*	*Home*	*38*
13.	*Hazardous job worker in home*	*Occupation/home*	*38*
14.	*Hazardous job*	*Occupation*	*37*
15.	*Old (> 65)*	*Age*	*36*
16.	*Fan in window/ceiling exhaust*	*Home*	*36*
17.	*Child (< 12)*	*Age*	*35*
18.	*Exposed to solvents (wk)*	*Occupation*	*32*
19.	*High potential exposure (wk)*	*Occupation*	*30*
20.	*Visited garage/service station (wk)*	*Auto*	*29*
21.	*Exposed to degreasers*	*Occupation*	*29*
22.	*Exposed to tobacco smoke*	*Smoking*	*28*
23.	*Pumped gasoline*	*Auto*	*27*
24.	*Gardened*	*Hobby*	*26*
25.	*Exposed to auto exhaust*	*Auto*	*24*
26.	*Exposed to odorous chemicals*	*Occupation*	*24*
27.	*Youth (12-20)*	*Age*	*20*
28.	*Gas heat*	*Home*	*20*
29.	*Auto exhaust (wk)*	*Auto*	*17*
30.	*Visited garage/service station (24-hr)*	*Auto*	*17*
31.	*Printing shop*	*Occupation*	*12*
32.	*Pesticide Exposure*	*Activity*	*12*

[a] *The maximum possible number of significant associations is 243: 11 chemicals x 3 media x 3 New Jersey trips + 16 chemicals x 3 media x 3 California trips*

Table 36. **Breath Concentrations ($\mu g/m^3$) of Selected Chemicals: Smokers Vs. Non-Smokers. Unweighted Geometric Means.**

	Sample size		Benzene**		Styrene**		Ethylbenzene**		o-Xylene*		m,p-Xylene**		Octane**	
Location	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
NJ (Fall)[a]	150	188	21	5.3	1.3	0.6	3.9	2.0	2.4	1.9	7.9	4.4	—[c]	—
NJ (Summer)	66	76	NR[b]	NR	1.0	0.3	2.0	0.5	1.2	0.6	3.5	—	—	—
NJ (Winter)	26	23	NR	NR	0.6	0.2	2.3	1.1	1.6	1.0	4.9	2.8	—	—
LA (Winter)	29	85	15	2.4	0.8	0.2	2.4	0.6	1.5	0.6	5.7	1.9	1.0	0.4
LA (Spring)	11	40	14	1.6	1.9	0.1	3.2	0.5	1.6	0.4	6.7	1.6	1.8	0.7
CC (Spring)	19	49	14	0.8	1.1	0.2	2.0	0.3	1.0	0.3	4.3	0.7	0.6	0.2

[a] All values during this visit may be elevated due to permeation of exhaust fumes into van-mounted spirometer.

[b] Not reported — blank contamination.

[c] Not measured in New Jersey.

* All differences significant at $p < 0.05$.

** All differences significant at $p < 0.001$.

Table 37. **Overnight Indoor Air Concentrations ($\mu g/m^3$) in Homes With and Without Smokers: Weighted Geometric Means.**

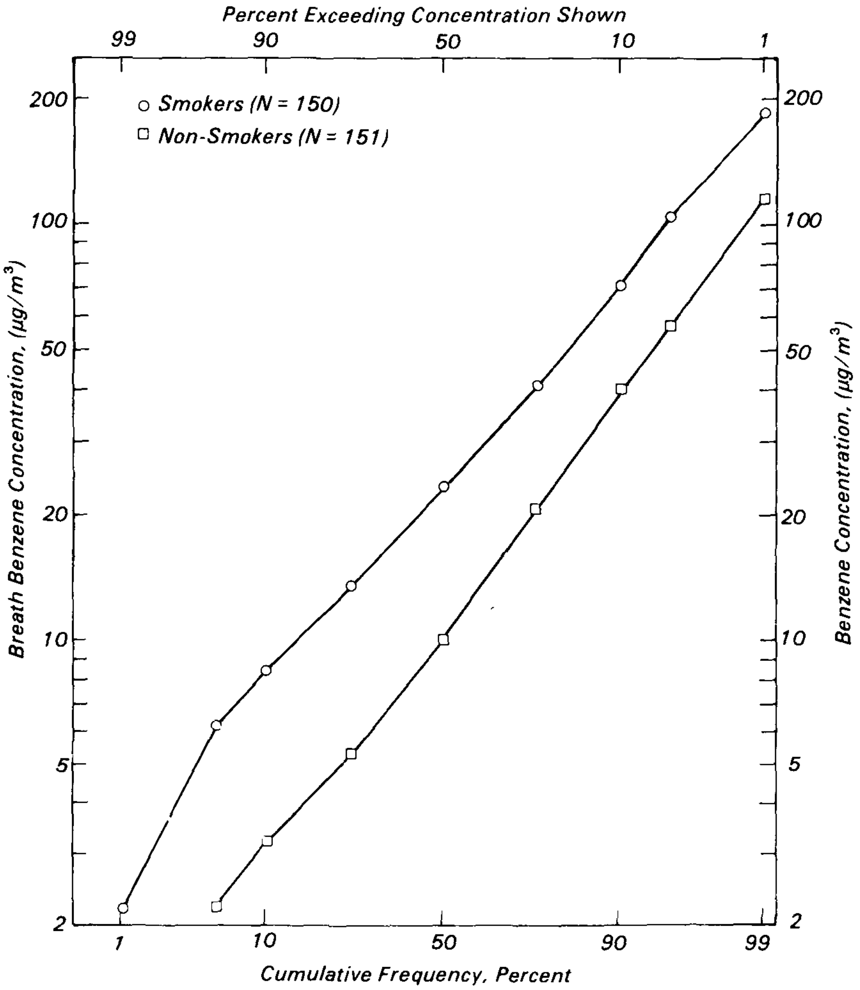
	Sample size		Benzene		Styrene		Ethylbenzene		o-Xylene		m,p-Xylene		Octane	
Location	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
NJ (Fall)	252	94	16*	8.4	1.9*	1.0	7.9*	4.5	6.3*	3.8	19*	11	—[b]	—
NJ (Summer)	111	44	NR[a]	NR	1.4	1.2	3.9	4.8	4.6	5.5	11	13	—	—
NJ (Winter)	37	12	NR	NR	1.5	1.0	5.6	7.5	6.1	7.2	17	21	—	—
LA (Winter)	56	58	17*	11	3.4*	1.7	9.1*	5.6	11*	7.5	25*	17	4.7*	3.1
LA (Spring)	23	28	4.8	4.5	0.4	0.6	2.8	3.1	2.8	2.7	11	11	1.8	1.8
CC (Spring)	35	33	4.9	4.4	0.6	0.5	1.8	2.1	2.2	2.8	6.3	7.2	1.3	1.6

[a] Not reported — blank contamination.

[b] Not measured in New Jersey.

*Difference significant at $p < 0.05$.

Figure 35. Unweighted cumulative frequency distributions of benzene concentrations in the breath of current smokers vs. non-smokers (New Jersey, Fall 1981).



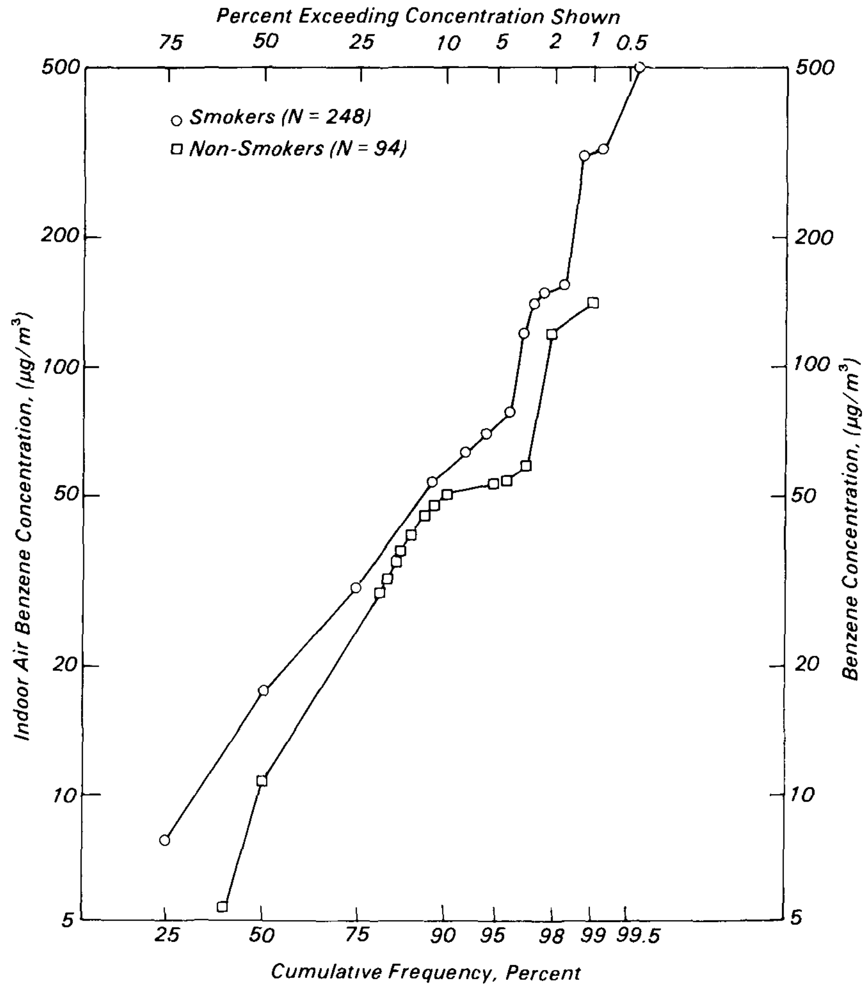
or with auto exhaust (Figure 44). Table 38 summarizes the chemicals with significantly elevated breath concentrations in people exposed to potential sources.

A second series of questions concerned direct exposure to chemical groups or mixtures. These chemical mixtures included solvents, pesticides, and tobacco smoke. Again, certain chemicals appeared at significantly higher levels in the breath of exposed persons compared to those not exposed (Figures 45-46).

Thus, breath analysis was effective in detecting increased exposures due to specific sources or chemical mixtures. The magnitude of the increase ranged from 30-50% up to factors of three or higher.

Personal air exposures to certain chemicals were also significantly elevated for persons recently exposed to potential sources compared to persons not exposed to that source. Chemicals for which both personal air *and* breath levels of exposed persons were significantly elevated over persons not

Figure 36. ***Unweighted cumulative frequency distributions of benzene concentrations in the air in homes with at least one smoker vs. homes with no smokers (New Jersey, Fall 1981).***



exposed to that source are listed in Table 39. A complete set of comparisons of breath and personal air concentrations is presented in Appendix Y of Vol. II.

Since many chemicals have multiple sources, some members of the so-called "unexposed" groups in the above analyses may have been exposed to the same chemical through a different source, thus blurring the distinction between exposed and unexposed groups. Therefore, the breath and personal air levels of groups exposed to each source were compared to the group of persons who responded that they were not exposed to *any* source. As could be expected, the number of chemicals showing significant differences increased considerably. The number showing simultaneously elevated air and breath values doubled (Table 40).

Caution in interpreting these results is indicated because of the small numbers of persons in some of the exposed groups and the possibility of confounding variables (such as smoking, which may be more prevalent in

Figure 37. **Median breath concentrations of 21 chemical plant workers vs. 330 other participants (NJ, Fall, 1981). Asterisks indicate significant ($p < .05$) differences using Mann-Whitney nonparametric test.**

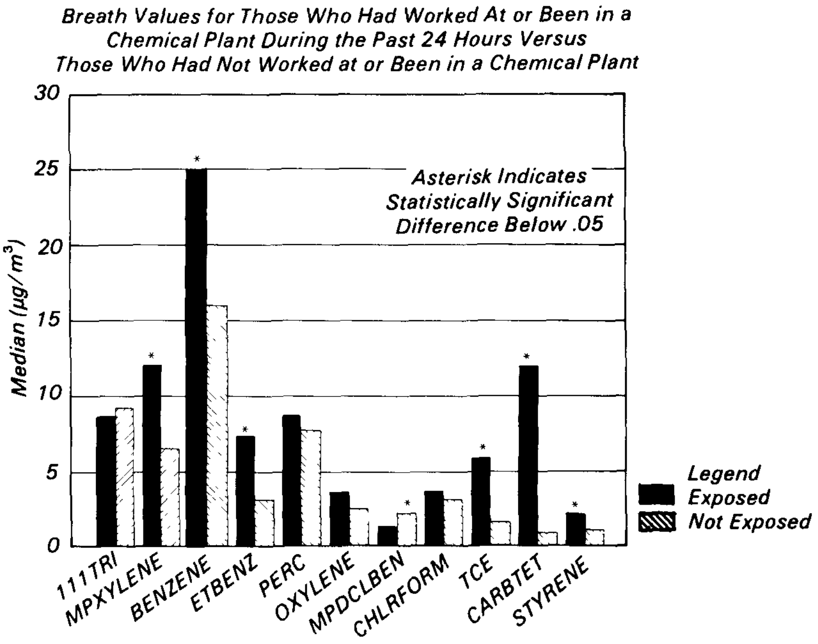

Breath Values for Those Who Had Worked At or Been in a Chemical Plant During the Past 24 Hours Versus Those Who Had Not Worked at or Been in a Chemical Plant

Figure 38. **Median breath values for 28 paint plant workers vs. 320 other participants (NJ, Fall, 1981). Asterisks indicate significant ($p < .05$) differences using Mann-Whitney nonparametric test.**

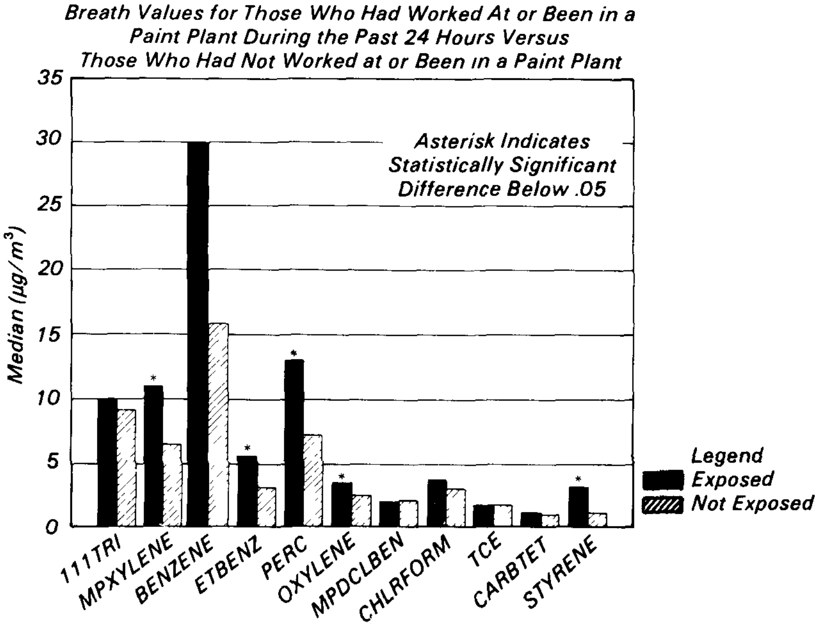

Breath Values for Those Who Had Worked At or Been in a Paint Plant During the Past 24 Hours Versus Those Who Had Not Worked at or Been in a Paint Plant

Figure 39. ***Median breath values for 11 plastics manufacturing workers vs. 340 other participants (NJ, Fall, 1981). Asterisks indicate significant (p < .05) differences using Mann-Whitney nonparametric test.***

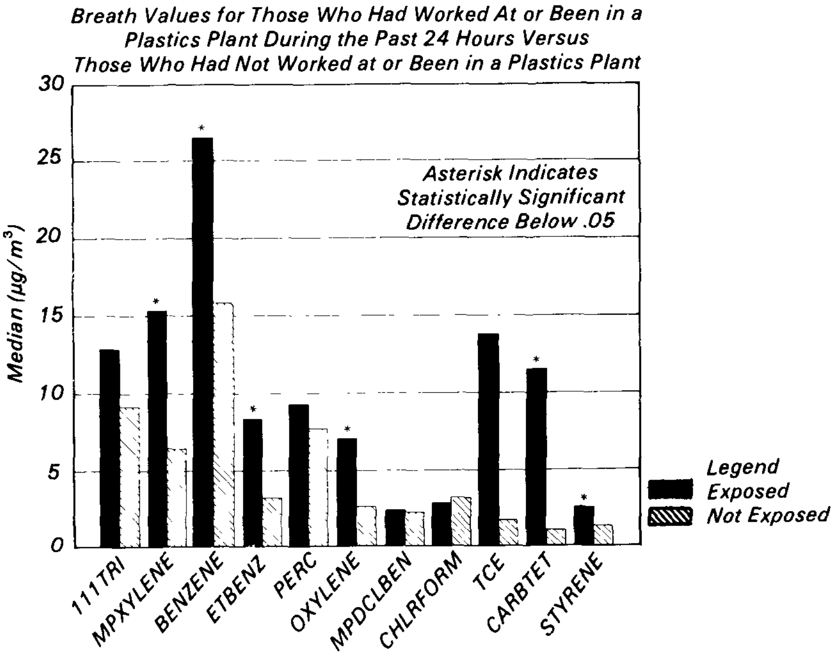


Figure 40. ***Median breath values for 19 petroleum plant workers vs. 330 other participants (NJ, Fall, 1981). Asterisks indicate significant (p < .05) differences using Mann-Whitney nonparametric test.***

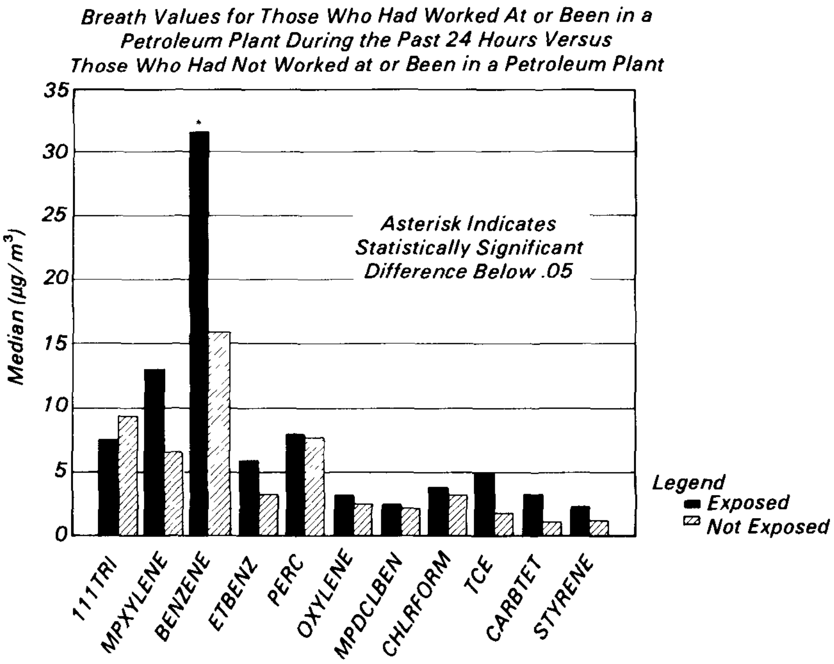


Figure 41. **Median breath values for 9 printing plant workers vs. 340 other participants (NJ, Fall, 1981). Asterisks indicate significant ($p < .05$) differences using Mann-Whitney nonparametric test.**

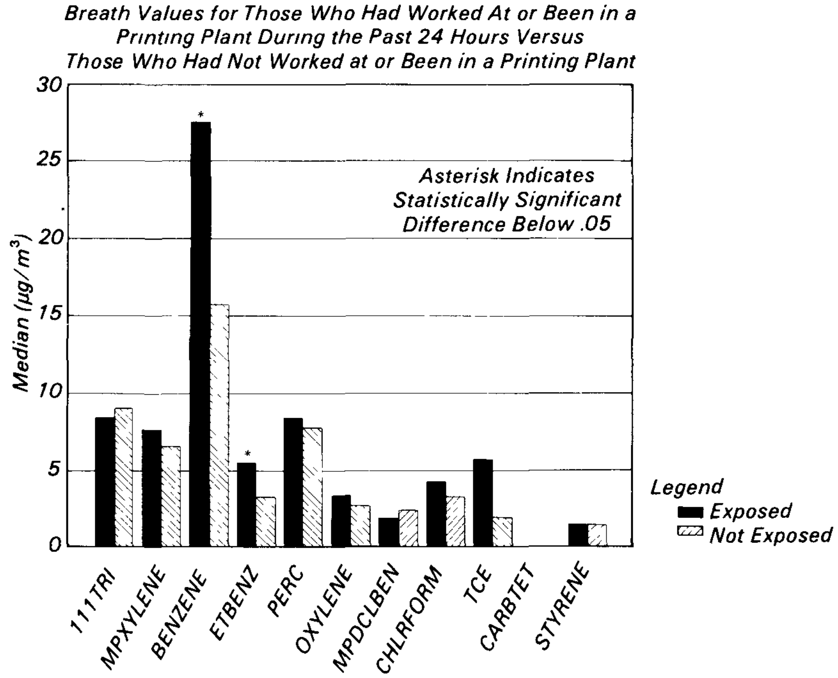


Figure 42. **Median breath values for 11 persons visiting dry cleaning shops on the day they were sampled vs. 340 other participants (NJ, Fall, 1981). Asterisk indicates significantly ($p < .05$) higher exposure to tetrachloroethylene (Mann-Whitney test).**

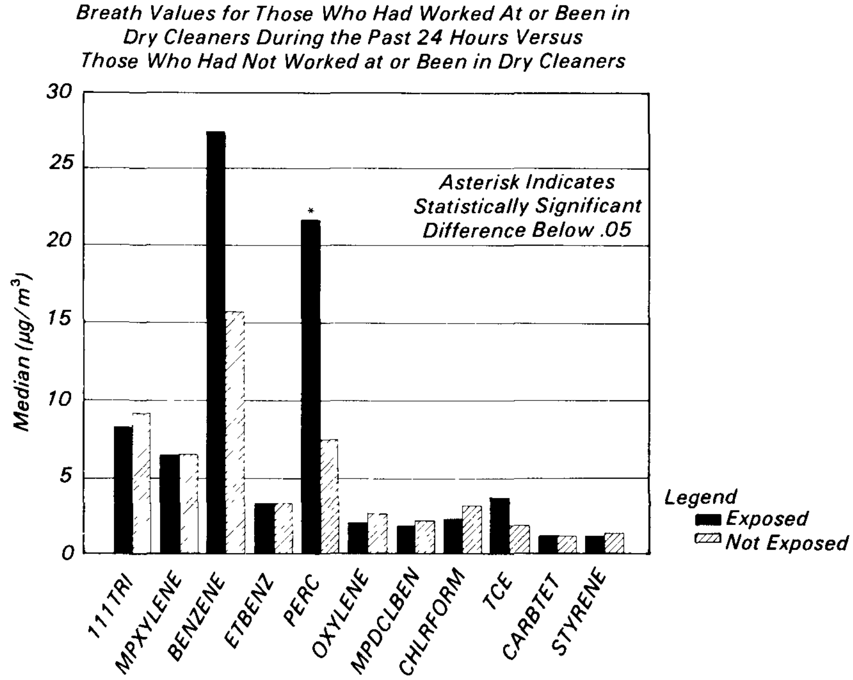


Figure 43. ***Median breath values for 67 persons visiting a service station the day they were sampled vs. 270 other participants (NJ, Fall, 1981). Asterisk indicates significantly (p < .05) higher levels of benzene (Mann-Whitney test).***

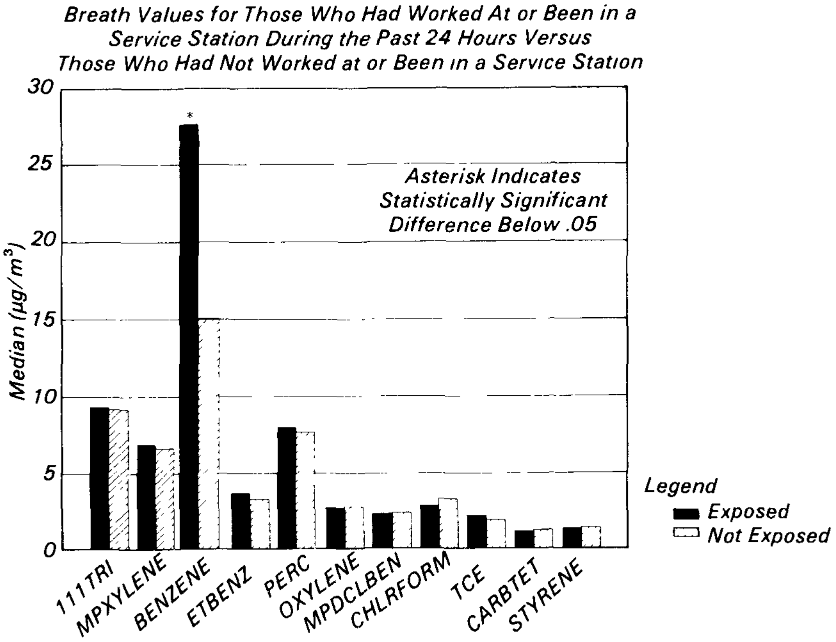


Figure 44. ***Median breath values for 62 persons exposed to automobile or truck exhaust on the day they were sampled vs. ~280 other participants (NJ, Fall, 1981). Asterisk indicates significantly (p < .05) higher levels of benzene (Mann-Whitney test).***

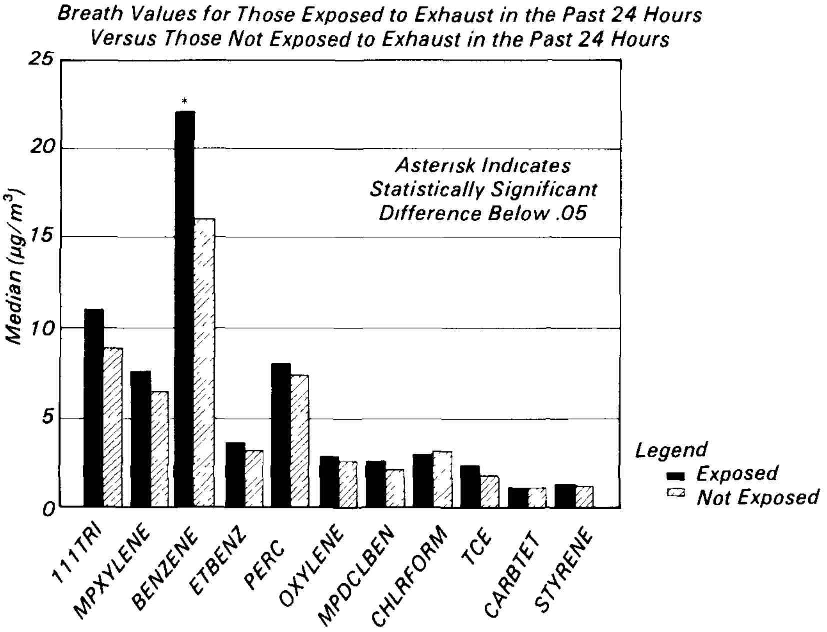


Figure 45. ***Median breath concentrations of 150 smokers compared to 150 nonsmokers (NJ, Fall, 1981). Benzene and other aromatic compounds were elevated..***

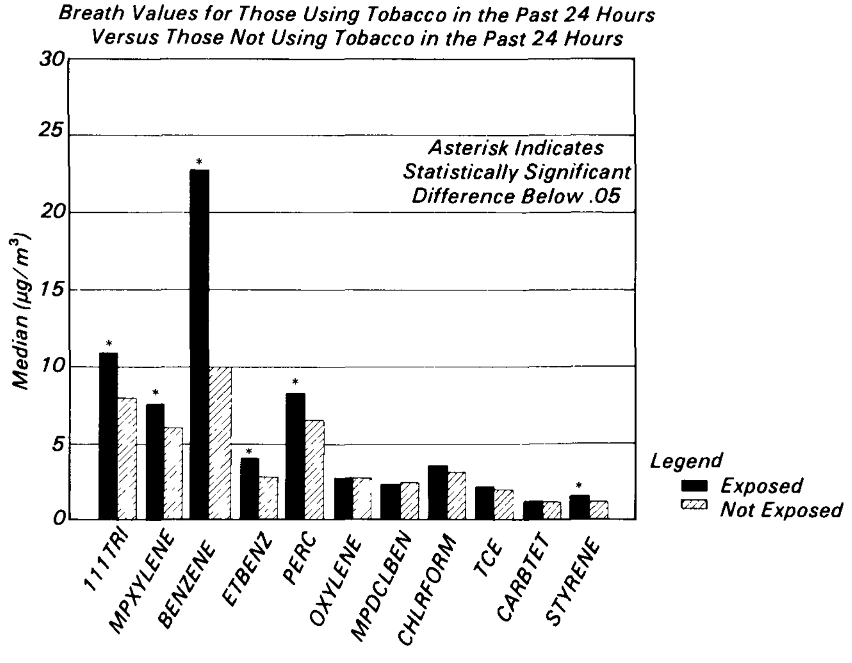

Breath Values for Those Using Tobacco in the Past 24 Hours Versus Those Not Using Tobacco in the Past 24 Hours

Figure 46. ***Median breath concentrations for 20 persons using pesticides vs. 330 other participants (NJ, Fall, 1981). No compounds were signigicantly different.***

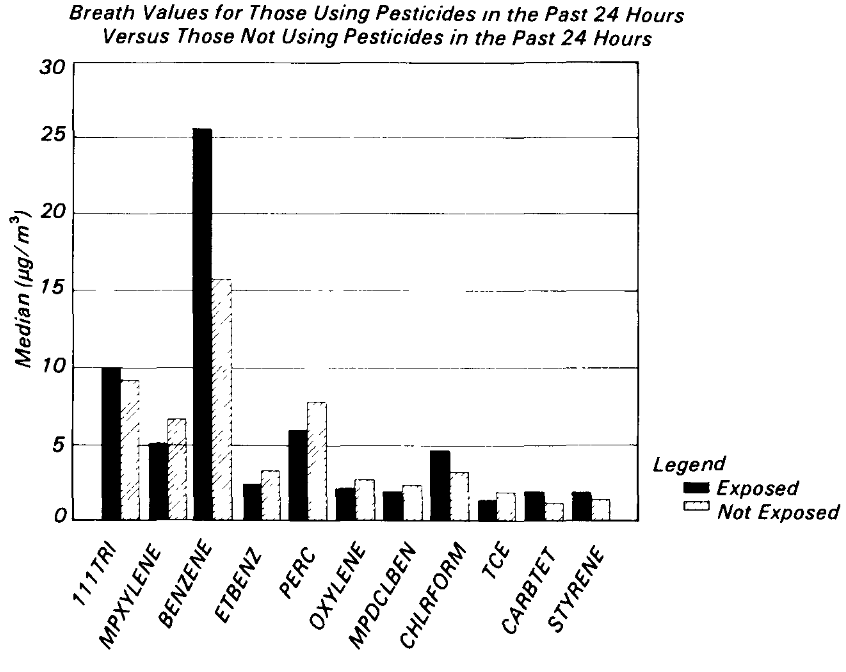

Breath Values for Those Using Pesticides in the Past 24 Hours Versus Those Not Using Pesticides in the Past 24 Hours

Table 38. Median Concentrations ($\mu g/m^3$) of Chemicals Significantly ($p < .05$) Higher in Breath of Persons Exposed to Potential Sources During The Day (Week) They Were Monitored

	N	a	b	c	d	e	f	g	h	i	j	k
All Subjects	350	16	3.2	2.6	6.6	1.3	7.8	1.9	9.1	1.1	3.2	2.3
Chemical plants	21 (37)	25* (25)*	7.4*		12	2.3 (2.3)*		6 (5.7)		12 (3.3)		
Plastics	11 (15)	27* (22)	8.4* (7.2)	7.1* (5.8)*	16* (12)	2.4 (2)		(9.8)		12*		
Paint	28 (58)	30*	5.7* (5.1)*	3.6 (3.4)	11* (10)*	3.3* (2)	13* (10)					
Petroleum plants	9 (19)	32 (27)				2.3 (2.4)						
Printing	9 (17)	28	5.5									
Auto exhaust	62 (93)	22										
Gas station	67 (154)	28* (20)*										
Science lab	14 (18)	32										
Metal working	17 (22)					(10)			17			
Dry cleaners	13 (37)						22 (15)*					

Table 38. **(continued)**

	N	a	b	c	d	e	f	g	h	i	j	k
All Subjects	350	16	3.2	2.6	6.6	1.3	7.8	1.9	9.1	1.1	3.2	2.3
Hospitals	13 (38)											
Furniture refinishing	7 (10)											
None	124											

*$p < 0.005$.

a = Benzene, b = Ethylbenzene, c = o-Xylene, d = m,p-Xylene, e = Styrene, f = Tetrachloroethylene, g = Trichloroethylene, h = 1,1,1-Trichloroethane, i = Carbon tetrachloride, j = Chloroform, k = m,p-Dichlorobenzene.

Table 39. Chemicals Showing Significantly ($p < .05$) Higher Concentrations in Air and Breath of Persons Recently Exposed to Potential Sources Compared to Persons not Exposed to That Source

Potential Source	No. of Persons Exposed	Ratio of Median Concentrations Breath	 Air
Dry Cleaners	37		
Tetrachloroethylene		2.8	2.0 (.01)[a]
Paint	28		
Styrene		2.6	1.6 (.002)
Ethylbenzene		1.8	1.8 (.0009)
o-Xylene		1.4	1.9 (.006)
m,p-Xylene		1.8	2.1 (.0003)
Auto Exhaust	62		
None			
Tobacco Smokers	161		
Styrene		1.4	1.4 (.0002)
Chemical Plant	21		
Styrene		1.8	1.8 (.02)
Ethylbenzene		2.3	1.5 (.008)
m,p-Xylene		1.8	1.6 (.01)
Pesticides	20		
None			
Furniture Refinishing	7		
None			
Printing Shop	9		
None			
Petroleum Plant	19		
None			
Science Laboratory	14		
None			
Service Station	67		
Benzene		1.9	1.2 (.03)

Table 39. (continued)

		Ratio of Median Concentrations	
Potential Source	*No. of Persons Exposed*	*Breath*	*Air*
Plastics Manufacturing	*11*		
Styrene		*2.0*	*2.4 (.04)*
Hospital	*13*		
None			
Solvents	*37*		
Styrene		*1.7*	*1.5 (.03)*
Ethylbenzene		*1.9*	*1.5 (.01)*
o-*Xylene*		*1.7*	*2.2 (.002)*
m,p-*Xylene*		*2.0*	*1.5 (.005)*
Odorus Chemicals	*83*		
Tetrachloroethylene		*1.1*	*1.2 (.02)*
Benzene		*1.3*	*1.5 (.003)*
Ethylbenzene		*1.2*	*1.6 (.0001)*
o-*Xylene*		*1.2*	*1.8 (.0000)*
m,p-*Xylene*		*1.2*	*1.5 (.0001)*
Degreasing Compounds	*19*		
None			
Dust	*63*		
m,p-*Xylene*		*1.1*	*1.2 (.002)*
Tobacco Smoke (non-smokers only)	*99*		
None			
Cleaning Solutions	*94*		
None			
Toxic Chemicals	*27*		
None			

[a] *Probability that the ratio is due to chance (Wilcoxon rank-sum test).*

Table 40. Chemicals with Significantly ($p < .05$) Higher Concentrations in Air and Breath of Persons Recently Exposed to Potential Sources Compared to Persons Not Exposed to Any Source

		Ratio of Median Concentrations: Exposed vs Unexposed Groups	
Potential Source	No. of Persons Exposed	Breath	Air
Paint	28		
Benzene		2.3 (.0002)[a]	1.3 (.03)
Tetrachloroethylene		2.0 (.0000)	2.7 (.02)
Styrene		2.8 (.0004)	1.8 (.0005)
Ethylbenzene		1.9 (.0004)	2.1 (.0001)
o-Xylene		1.4 (.009)	2.5 (.0003)
m,p-Xylene		1.7 (.002)	2.5 (.0000)
Chemical Plant	21		
Styrene		1.9 (.02)	2.0 (.004)
Ethylbenzene		2.5 (.0008)	1.8 (.0006)
o-Xylene		1.4 (.05)	2.3 (.0003)
m,p-Xylene		1.9 (.004)	1.9 (.0006)
Plastics Manufacturing	11		
Styrene		2.0 (.01)	2.6 (.02)
Ethylbenzene		2.8 (.003)	1.8 (.03)
o-Xylene		3.4 (.0006)	2.3 (.02)
m,p-Xylene		2.5 (.001)	2.1 (.02)
Dry Cleaning	37		
Tetrachloroethylene		2.3 (.0000)	2.2 (.003)
Benzene		2.2 (.02)	1.7 (.03)
Petroleum Plant	19		
None			
Service Station	67		
Benzene		2.2 (.0000)	1.3 (.02)
Printing	9		
Ethylbenzene		1.8 (.02)	1.6 (.03)
o-Xylene		1.3 (.03)	2.2 (.02)

Table 40. (continued)

Potential Source	No. of Persons Exposed	Ratio of Median Concentrations: Exposed vs Unexposed Groups	
		Breath	Air
Metal Working	17		
Tetrachloroethylene		1.4 (.01)	1.8 (.03)
Ethylbenzene		1.8 (.05)	3.7 (.0000)
o-Xylene		1.8 (.05)	4.4 (.0000)
Science Laboratory	14		
Ethylbenzene		1.7 (.03)	2.2 (.002)
o-Xylene		1.4 (.05)	2.7 (.001)
Furniture Refinishing	7		
Ethylbenzene		2.8 (.03)	2.2 (.02)
o-Xylene		2.5 (.04)	2.4 (.006)
Hospital	13		
None			

[a]Probability of no difference between exposed and unexposed groups — Wilcoxon Rank-Sum Test.

occupationally exposed groups). To account for such confounding variables, a set of stepwise regressions were performed.

Stepwise Regressions. Stepwise regressions were performed using the model:

$$y = a + \Sigma b_i q_i$$

where y = ln concentration

q_i = questionnaire index variable

Because of the large number of variables on the two questionnaires, an extensive investigation of collinearity was carried out. The methods of Belsley, Kuh, and Welsh (1) were employed to identify collinearities. In most cases, it was possible to reduce collinearities without eliminating questions or otherwise losing data. The final matrix of variates and eigenvalues seldom included variables associated with a condition number higher than 20. (The threshold value for seriously degraded estimates is considered by Belsley et al. to be about 30.)

The SAS (Statistical Analysis System) STEPWISE procedure (combined forward and backward selection) was employed with criteria of $p < 0.15$ for inclusion. The final model included only variables for which $p < 0.05$.

The results of the stepwise regressions of all six New Jersey and California sites are presented in Appendix A.

Three major sources of increased exposures were identified. Smoking, employment, and auto-related activities were all significantly related to increased exposures to many of the 11 prevalent chemicals in New Jersey and the 16 in California.

Smoking was responsible for greatly elevated breath concentrations of benzene and styrene, and significantly elevated breath concentrations of ethylbenzene, xylenes, and octane Table 41 summarizes the effects of smoking on breath concentrations of smokers during all six trips. Benzene concentrations in smokers' breath increased six-fold, styrene four-fold, and four other compounds more than doubled compared to nonsmokers' breath concentrations. Having a smoker in the home resulted in increased overnight personal air exposures to the same group of hydrocarbons during the fall season in New Jersey and the winter season in California.

Employment in many occupations was associated with increased exposures to one or more of the chemicals. Self-reported exposures to solvents, odorous chemicals, dust and particulates, degreasers, and other mixtures were repeatedly associated with increased exposures to the target chemicals.

Auto-related activities (driving, pumping gas, visiting service stations) were associated with increased exposures to many aromatics and straight-chain hydrocarbons in all California trips.

Other important variables included age, race, and sex. Adults showed consistently elevated exposures, while children and old people showed depressed exposures. Occasionally Hispanics showed elevated exposures. Males often had higher exposures to aromatics, but females sometimes showed higher exposures to trichloroethylene.

Household characteristics were sometimes associated with increased indoor air levels. In fall and winter, homes with gas furnaces often were associated with increased overnight indoor air concentrations of the aromatics compared to homes with oil furnaces. Ventilation characteristics, however, showed inconsistent effects. Window air conditioners and circulating fans were usually associated with increased indoor concentrations, as might be expected if their use leads to decreased outdoor ventilation, but sometimes circulating fans were associated with reduced exposures.

Certain variables were associated with increased exposures to one chemical only One example is visiting a dry cleaners (tetrachloroethylene).

Table 41. Effects of Smoking on Breath Concentrations of Benzene and Other Hydrocarbons

	New Jersey			*California*			*Grand*
Compound	*Fall*	*Summer*	*Winter*	*Winter*	*Spring*	*Summer*	*Mean*
Benzene	*1.38*[a]	*2.38*	*1.19*	*1.85*	*1.67*	*2.70*	*1.86*[b] ± *0.58*
Styrene	*0.81*	*1.16*	*1.20*	*1.56*	*2.59*	*1.14*	*1.41* ± *0.63*
Ethylbenzene	*0.56*	*1.46*	*0.66*	*1.37*	*1.75*	*1.48*	*1.2* ± *0.49*
m,p-*Xylene*	*0.53*	*1.25*	*0.49*	*1.02*	*1.27*	*1.32*	*0.98* ± *0.38*
o-*Xylene*	*NS*[c]	*NS*	*0.58*	*0.82*	*1.19*	*1.03*	*0.90* ± *0.26*
Octane	*NM*[d]	*NM*	*NM*	*0.83*	*1.10*	*1.00*	*0.98* ± *0.14*

[a] *Coefficient of SMOKER variable in stepwise regression; thus smokers had* $e^{1\ 38} \approx 4$ *times as much benzene in their breath as nonsmokers. All listed coefficients were significant at* $p < 0.05$.

[b] *Arithmetic mean of all six trips, unweighted; thus on average, smokers had* $e^{1\ 86} = 6.4$ *times as much benzene on their breath as nonsmokers.*

[c] *Not significant.*

[d] *Not measured.*

Although the questionnaires were successful in identifying major sources of exposure for some chemicals, they were unsuccessful for other chemicals. For example, the sources of the elevated indoor air levels of chloroform, *m,p*-dichlorobenzene, trichloroethylene, 1,1,1-trichloroethane, carbon tetrachloride, decane, undecane, dodecane, and α-pinene were not determined by the questionnaire.

Effect of Outdoor Concentrations on Exposures

Stepwise regressions were run to determine the effect of outdoor concentrations on personal exposures of the New Jersey and California subjects who had outdoor measurements in their backyards. A reduced set of approximately 20 independent questionnaire variables was selected for the New Jersey subjects (85 persons in the fall and 71 in the summer) based on their frequencies and importance in previous stepwise regressions. Because of the smaller number of persons in California with outdoor measurements (25 in Los Angeles each season and 10 in Contra Costa), only six questionnaire variables in Los Angeles and three in Contra Costa were included in the regressions.

The model was of the form·

$$\ln C_{in} = a + b \ln C_{out} + \Sigma c_i q_i$$

where C_{in} = indoor concentration (or, for New Jersey only, breath concentration or daytime personal air concentration)

C_{out} = outdoor concentration

q_i = questionnaire variables (occupation, household characteristics, etc.) generally indexed to 0 or 1

c_i = coefficients of the q_i

The natural logarithms of the concentration variables were employed because their distributions are closer to being log-normal than normal.

The results (displayed in Appendix B) indicated that outdoor concentrations were sometimes significantly associated with personal exposures to some chemicals but seldom on a consistent basis. For example, in New Jersey overnight indoor air levels of carbon tetrachloride and trichloroethylene were significantly associated with outdoor air levels in both summer and winter; but eight other chemicals showed no significant association in the fall and three showed none in the summer. Breath levels were significantly associated with daytime outdoor air levels of seven chemicals in the fall but none in the summer. Daytime personal air exposures were significantly related to daytime outdoor air concentrations of five chemicals. The observed slopes of the log-log regressions usually lie between 0.2 and 0.4, indicating a weakly positive relationship (Table 42). Partial R^2 values for the significant associations range from 0.03 to 0.35. Other important determinants of personal exposure in these subsets were smoking, having a smoker in the home, certain occupations (particularly those involving paints, solvents, and odorous chemicals), and activities (particularly auto exhaust exposure and visiting a dry cleaners or service station).

In California, only overnight personal air exposures were compared to outdoor levels (Table 43). Only tetrachloroethylene showed a significant ($p < 0.10$) dependence on outdoor levels on all three trips. Six of 16 chemicals never displayed a significant association with outdoor levels in California

Discussion

Comparison of New Jersey and California Results

Quality Control. Considerable improvements were evident in comparing field blanks collected in the first trip to Los Angeles with those collected

Table 42. Effect of Outdoor Air Concentrations on Measures of Personal Exposure (NJ): Coefficients of Stepwise Regressions

			Personal Air			
	Breath		Day		Night	
Chemical	*Fall*	*Summer*	*Fall*	*Summer*	*Fall*	*Summer*
Chloroform	*NS*[a]	*NS*	*NS*	*−0.16*	*NS*	*NS*
Benzene	*0.21*[b]	*NS*	*NS*	*NS*	*0.44*	*NS*
Carbontetrachloride	*NS*	*NS*	*0.22*	*NS*	*0.30*	*0.28*
1,1,1-Trichloroethane	*0.24*	*NS*	*0.21*	*NS*	*NS*	*NS*
Trichloroethylene	*0.17*	*NS*	*0.41*	*NS*	*0.26*	*0.26*
Tetrachloroethylene	*0.21*	*NS*	*0.58*	*0.41*	*NS*	*0.36*
Styrene	*NS*	*NS*	*NS*	*NS*	*NS*	*0.28*
m,p-*Dichlorobenzene*	*0.40*	*NS*	*0.42*	*NS*	*NS*	*0.82*
Ethylbenzene	*0.19*	*NS*	*NS*	*0.31*	*NS*	*0.26*
o-*Xylene*	*0.28*	*NS*	*NS*	*NS*	*NS*	*0.21*
m,p-*Xylene*	*NS*	*NS*	*NS*	*NS*	*NS*	*0.19*

[a] *Not significant ($p < 0.05$) in stepwise regression.*

[b] *The model is: ln (Exposure) = a ln (Outdoor concentration) + b. Thus ln (benzene in breath) = 0.21 ln (benzene in daytime outdoor air) + b or benzene in breath = $\alpha(\text{benzene in air})^{0.21}$*

in New Jersey (Table 44). Benzene blank values improved from 97 ng/cartridge to 26; 1,1,1-trichloroethane from 33 to 5; and chloroform and *p*-xylene from 22 to 3 each. Recoveries of most chemicals were similar in both locations, although the recoveries in the Los Angeles trip of highly volatile components were somewhat higher.

A similar marked improvement was displayed in measurement precision of the duplicate samples (Table 45). The largest improvement was for benzene (36% RSD reduced to 13%). Three of eleven chemicals had worse precision.

Several chemicals showed higher blank values and worse duplicate precision on the second California trip as compared to the first, but overall the California results were an improvement over the New Jersey results.

Response Rates. Response rates also improved (from 43% to 57%). Although low by survey design standards, these response rates may be acceptable for exposure monitoring studies, considering the heavy burden of carrying monitoring instruments 24 hours a day. Nonresponse may be related to socio-economic status, place of employment, etc., which may be related to personal exposures. Further study is needed of the effect of nonresponse on estimates of population exposure.

Prevalence. In New Jersey, North Carolina, and North Dakota, 20 target chemicals were selected for study; 11 were prevalent in air and breath (>25% of samples measurable), and 3 of 4 trihalomethanes were prevalent in drinking water. In California, 26 chemicals were selected, including 9 that had not been measured in New Jersey Of these, 19 were prevalent in air and breath, and all 4 trihalomethanes were prevalent in drinking water. (The 19 prevalent CA chemicals included all 11 of the prevalent New Jersey chemicals.)

Table 43. Effect of Overnight Outdoor Air Concentrations on Indoor Air Concentrations (CA): Coefficients of Stepwise Regressions

	Los Angeles		*Antioch/Pittsburg*
Chemical	*February*	*May*	*June*
Aromatic Hydrocarbons			
Benzene	*NS*[a]	*NS*	*NS*
Styrene	*NS*	*NS*	*NS*
Ethylbenzene	*0.19*[b]	*NS*	*NS*
o-*Xylene*	*NS*	*NS*	*NS*
m,p-*Xylene*	*NS*	*0.52*	*NS*
Chlorinated Hydrocarbons			
Chloroform	*NS*	*NS*	*NS*
1,1,1-Trichloroethane	*0.38*	*0.71*	*NS*
Carbon tetrachloride	*NS*	*NS*	*NS*
Trichloroethylene	*NS*	*NS*	*NS*
Tetrachloroethylene	*0.23*	*0.51*	*0.39*
m,p-*Dichlorobenzene*	*0.98*	*NS*	*NS*
Aliphatic Hydrocarbons			
Decane	*0.42*	*NS*	*NS*
Dodecane	*NS*	*NS*	*NS*
Octane	*NS*	*0.33*	*NS*
Undecane	*0.26*	*NS*	*NS*
α-Pinene	*NS*	*−0.61*	*NS*

[a] *Not significant ($p < 0.05$) in stepwise regression.*

[b] *Coefficient of ln (outdoor concentration). Thus ethylbenzene indoors = α(ethylbenzene outdoors)$^{0.19}$. (See also footnote to Table 42.)*

Concentrations. For the concentrations in air and breath described above, several observations are evident:

1. *Exposures were highly variable.* For many chemicals, the range in personal air exposures exceeded a factor of 1000 or even 10,000. This was far greater than for typical criteria pollutants such as carbon monoxide and suspended particulates. The range in breath concentrations was almost equally variable, indicating that the higher exposures may have been producing a higher body burden.

2. *All eleven chemicals had higher personal air concentrations than outdoor air concentrations.* This is the case even for overnight exposures, when participants were normally at home for the entire 12 hours.

3. *Breath levels were also often higher than outdoor levels.* Since levels in exhaled breath are often only 20-40% of total intake, the remainder being metabolized or excreted through other pathways, the breath levels imply exposures several times greater. This is further indication that

Table 44. Control and Blank Data for Tenax Cartridges Used in New Jersey and California: TEAM Study

	Field Controls Recovery[a] (%)		Field Blanks Background, ng	
Target Compound	NJ (N=110)	LA (N=18)	NJ (N=76)	LA (N=18)
Chloroform	89	110	22	3
1,2-Dichloroethane	100	120	1	ND[b]
1,1,1-Trichloroethane	87	125	33	5
Benzene	86	115	97	26
Carbon tetrachloride	80	95	2	ND
Bromodichloromethane	86	NA[c]	ND	NA
Trichloroethylene	95	110	3	ND
p-Dioxane	NA	95	NA	ND
Chlorodibromomethane	95	NA	ND	NA
1,2-Dibromoethane	NA	80	NA	ND
n-Octane	NA	105	NA	ND
Tetrachloroethylene	108	105	11	ND
Chlorobenzene	110	95	1	ND
Ethylbenzene	95	100	12	ND
Bromoform	96	NA	ND	NA
p-Xylene	100	100	22	3
Styrene	104	85	2	6
o-Xylene	100	105	8	2
1,1,2,2-Tetrachloroethane	NA	110	NA	ND
α-Pinene	NA	95	NA	ND
p-Dichlorobenzene	101	90	3	8
n-Decane	NA	90	NA	ND
o-Dichlorobenzene	96	105	1	4
n-Undecane	NA	95	NA	4
n-Dodecane	NA	100	NA	3

[a] Corrected for background.
[b] ND = not detected.
[c] NA = not analyzed.

Table 45. Median Coefficients of Variation (%) for Duplicate Personal Air Samples in New Jersey and California: TEAM Study

Target Compound	*NJ*[a]	*CA*[b]
Chloroform	*20*	*28*
1,1,1-Trichloroethane	*27*	*8*
Benzene	*36*	*13*
Carbon tetrachloride	*24*	*15*
Trichloroethylene	*14*	*12*
Tetrachloroethylene	*21*	*12*
Styrene	*18*	*28*
p-*Dichlorobenzene*	*23*	*30*
Ethylbenzene	*20*	*13*
o-*Xylene*	*19*	*13*
m,p-*Xylene*	*24*	*15*
n-*Decane*	*NM*[c]	*12*
n-*Dodecane*	*NM*	*13*
1,4-Dioxane	*NM*	*20*
n-*Octane*	*NM*	*11*
n-*Undecane*	*NM*	*15*
α-Pinene	*NM*	*13*
o-*Dichlorobenzene*	*NM*	*12*

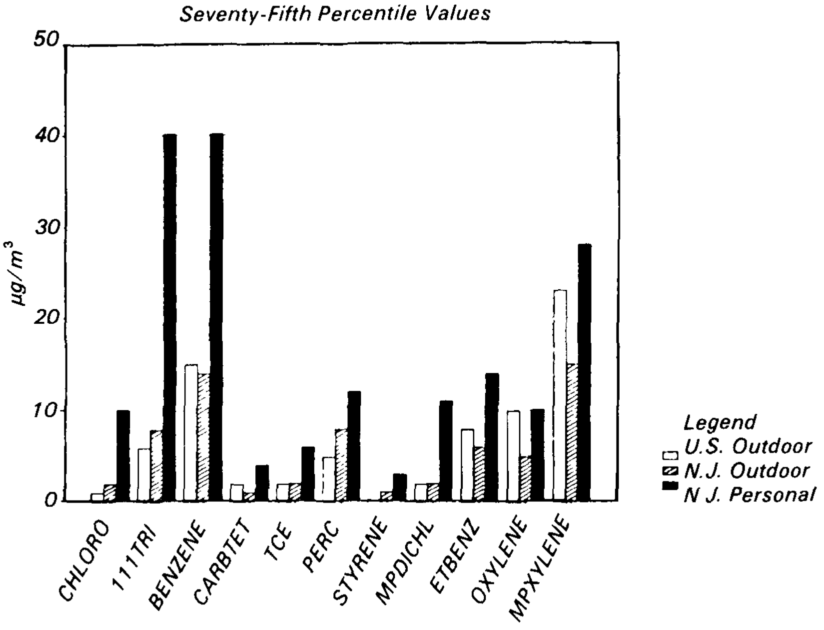
[a] *Bayonne and Elizabeth, NJ, Fall 1981, N = 134.*
[b] *Los Angeles, CA, Winter 1984, N = 24.*
[c] *NM = not measured.*

exposures are higher than would be expected from observed outdoor concentrations.

4. *The ratio of personal exposures to outdoor levels increased with higher exposures.* This can be illustrated by comparing indoor overnight exposures (when persons were almost invariably inside their homes) to outdoor overnight concentrations for the 75th percentile and the 99th percentile of each distribution. The ratios increased from 2-5 at the 75th percentile up to 10-20 at the 99th percentile for most of the target chemicals (Figures 47 and 48).

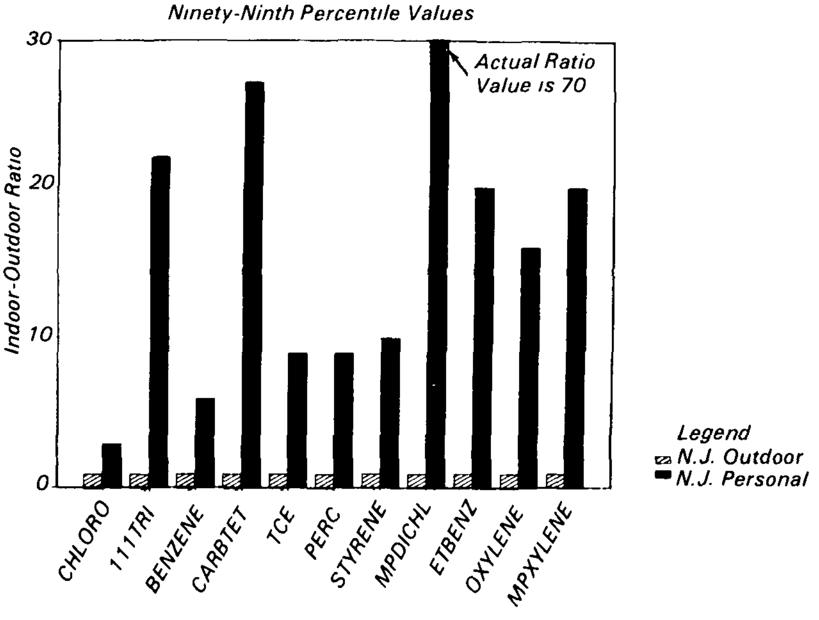
5. *The higher overnight personal exposures appear to implicate the home or personal activities within the home as the major source of exposure to these eleven compounds.* The daytime personal air exposures were usually the highest, as expected since this time period included the commuting and occupational activities. However, the overnight personal air exposures, when people were normally sleeping, were nearly as high. In fact, all eleven prevalent chemicals had much higher overnight indoor concentrations than overnight outdoor concentrations, sometimes 100 times higher for individual paired observations.

Figure 47. ***Comparison of unweighted 75th percentile concentrations of 11 prevalent chemicals in overnight outdoor and personal air in New Jersey (Fall 1981) with outdoor air measured in a number of U.S. cities between 1970-1980 (Brodzinsky 1982).***



Seventy-Fifth Percentile Values

Figure 48. ***Comparison of unweighted 99th percentile concentrations of 11 prevalent chemicals in overnight outdoor air and overnight personal air in New Jersey (Fall 1981).***



Ninety-Ninth Percentile Values

6. *The presence or absence of a source is a far stronger determinant of indoor air concentrations than the air exchange rate.* Although air exchange rates were not measured, several studies indicate that the range of rates is quite small (less than a factor of 10). Yet homes often differed by a factor of 100 in concentration. The most likely reason for such high concentrations is the presence of a powerful source.

7. *Only chloroform and possibly bromodichloromethane were important contributors to total exposure from drinking water in the study areas.* The median value for chloroform in drinking water in New Jersey (Fall 1981) was 67 μg/L; in air, 3.2 μg/m^3. Assuming 2L of water intake per day and 20 cubic meters of air intake per day, the median intake of chloroform in water (134 μg) was about twice that in air (64 μg). (However, if the water was boiled for tea or coffee, it would lose its chloroform—thus the water intake may be overestimated.) Drinking water also accounted for most exposure to bromodichloromethane, since the chemical was detected in only 3% of the personal air samples.

8. *Breath levels and personal air exposures to certain toxic and carcinogenic chemicals are significantly elevated in persons exposed to potential sources (consumer products, activities, and workplaces).*

Indoor versus Outdoor Air Concentrations

Concentrations in overnight indoor and outdoor air are compared for New Jersey and California in Tables 46 and 47 For indoor air, no obvious differences between the two sites appear. However, for outdoor air, the February overnight concentrations in Los Angeles stand out—six chemicals (benzene, 1,1,1-trichloroethane, tetrachloroethylene, *p*-xylene, *o*-xylene, and ethylbenzene) exceeded the highest New Jersey values by a factor of 2 or more, whether medians or 90th percentile concentrations are compared. The May Los Angeles results are more comparable with the New Jersey values. Once again personal air and indoor air concentrations were observed to be higher than outdoor concentrations for nearly all chemicals. As in New Jersey, maximum indoor concentrations usually far exceeded maximum outdoor concentrations measured at the same homes (Table 48).

Personal exposures and concentrations were compared for persons who were inside their homes for the entire overnight period, and for all but 20 minutes or less of the daytime monitoring period. For each of the six trips to New Jersey and California, the median and mean indoor-outdoor differences were calculated. Median differences (Table 49) were normally positive (i.e., indoor levels were greater than outdoor levels), and usually less than 5 μg/m^3. Mean differences (Table 50) were larger, often exceeding 10 μg/m^3.

The findings of higher indoor concentrations are paralleled by recent studies in Europe and the U.S., some using different adsorbents than Tenax. Seven other studies of volatile organics in ten or more homes have been reported since 1979. Mølhave (2) found elevated levels of benzene and toluene in 39 Danish dwellings. Jarke (3) found more complex chromatograms and increased concentrations of organics in 34 Chicago homes Lebret (4) found that all 35 organics analyzed displayed mean indoor/outdoor ratios exceeding unity in 134 Dutch homes, with seven mean indoor/outdoor ratios exceeding 10. Tobacco smoking was correlated with increased levels of ten organics. Factor analysis identified certain clusters of compounds as petroleum distillate-based. Seifert (5) reported that 15 homes in Berlin displayed

Table 46. *Volatile Organic Compounds in Overnight Indoor Air in New Jersey and California: TEAM Study, 1981-84*

Target Compound	Median (μg/m^3)						90th Percentile					
	NJ1[a] (N=347)	NJ2[b] (157)	NJ3[c] (49)	LA1[d] (112)	LA2[e] (50)	CC[f] (71)	NJ1	NJ2	NJ3	LA1	LA2	CC
Chloroform	3.3	0.88	2.2	1.5	0.67	0.03	16	13	12	5.0	5.2	2.4
1,1,1-Trichloroethane	17	12	18	26	7.2	4.3	78	58	86	85	17	12
Benzene	15	NC	NC	15	4.4	4.4	54	NC	NC	30	25	16
Carbon tetrachloride	1.5	1.3	—	0.65	0.65	0.71	5.8	1.9	NC	1.1	0.9	3.8
Trichloroethylene	2.2	2.7	1.5	1.1	0.34	0.25	12	12	5.4	6.9	2.5	2.1
Tetrachloroethylene	6.4	5.5	6.6	8.3	1.9	1.8	26	19	36	22	4.2	8.5
Styrene	1.8	1.4	1.3	2.8	0.84	0.71	4.6	4.0	4.5	6.7	2.8	2.0
m,p-Dichlorobenzene	3.8	3.2	4.2	2.6	0.84	0.53	82	63	140	54	23	8.4
Ethylbenzene	6.3	4.9	5.3	7.9	2.5	1.9	22	13	27	16	23	6.5
o-Xylene	4.9	5.4	6.0	9.7	2.0	2.2	15	12	22	19	25	7.1
m,p-Xylene	14	13	19	22	8.7	6.1	47	33	63	40	75	18
Octane	—	—	—	3.7	2.0	1.6	—	—	—	8.4	9.9	3.6
Decane	—	—	—	2.0	1.1	0.71	—	—	—	5.9	5.3	2.6
Undecane	—	—	—	2.3	1.2	1.1	—	—	—	7.1	4.1	4.4
Dodecane	—	—	—	1.3	0.6	0.63	—	—	—	4.4	3.0	3.7
α-Pinene	—	—	—	3.4	1.8	1.4	—	—	—	12	17	5.6
1,4-Dioxane	—	—	—	0.24	0.03	0.03	—	—	—	1.4	3.0	0.36

[a] Sept-Nov 1981. [b] July-Aug 1982. [c] Jan-Feb 1983. [d] Feb 1984. [e] May 1984. [f] June 1984.

Table 47. **Volatile Organic Compounds in Overnight Outdoor Air in New Jersey and California: TEAM Study, 1981-84**

	Median (µg/m³)						90th Percentile					
Target Compound	NJ1[a] (N=86)	NJ2[b] (71)	NJ3[c] (8)	LA1[d] (24)	LA2[e] (23)	CC[f] (10)	NJ1	NJ2	NJ3	LA1	LA2	CC
Chloroform	0.66	0.08	0.04	0.62	0.03	0.62	2.9	44	0.06	1.9	1.1	1.0
1,1,1-Trichloroethane	4.5	4.7	1.4	29	4.6	2.1	11	32	1.9	67	8.2	3.9
Benzene	6.7	NC	NC	19	2.5	1.7	15	NC	NC	32	5.8	3.2
Carbon tetrachloride	0.81	0.61	NC	0.65	0.65	0.33	2.1	2.5	NC	1.2	0.96	0.47
Trichloroethylene	1.3	1.4	0.06	0.72	0.03	0.12	3.9	27	0.39	2.0	0.13	0.14
Tetrachloroethylene	2.6	1.8	1.3	7.4	1.3	0.25	6.9	11	3.3	24	4.1	0.61
Styrene	0.61	0.41	0.53	4.2	0.57	0.23	1.7	1.3	1.0	8.3	1.3	1.9
m,p-Dichlorobenzene	1.2	1.3	0.65	1.7	0.50	0.25	2.5	2.5	1.3	5.9	1.6	1.0
Ethylbenzene	2.9	2.5	4.0	11	1.8	0.66	6.9	7.4	5.2	20	5.0	1.6
o-Xylene	2.9	3.4	3.2	13	1.9	0.39	7.9	10	4.3	22	4.8	1.5
m,p-Xylene	9.9	9.2	11	30	7.3	1.3	21	24	12	48	15	3.8
Octane	—	—	—	4.3	0.71	0.36	—	—	—	9.8	1.4	1.9
Decane	—	—	—	2.6	0.48	1.9	—	—	—	5.9	1.6	7.0
Undecane	—	—	—	2.2	0.51	0.10	—	—	—	4.9	2.1	1.6
Dodecane	—	—	—	0.76	0.56	0.12	—	—	—	1.6	1.0	0.75
α-Pinene	—	—	—	0.83	0.26	0.05	—	—	—	2.9	1.1	0.75
1,4-Dioxane	—	—	—	0.26	0.02	0.3	—	—	—	1.4	0.76	0.53

[a] Sept-Nov 1981. [b] July-Aug 1982. [c] Jan-Feb 1983. [d] Feb 1984. [e] May 1984. [f] June 1984.

Table 48. **Maximum Overnight Concentrations Indoors and Outdoors for Homes With Outdoor Monitors: TEAM Study, 1981-84**

	New Jersey						California					
							Los Angeles				Contra Costa	
	Sept-Nov 1981 (N=85)		July-Aug 1982 (N=71)		Feb 1983 (N=8)		Feb 1984 (N=25)		May 1984 (N=25)		June 1984 (N=10)	
Chemical	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
m,p-*Dichlorobenzene*	920	13	1600	8	120	5	210	21	170	2	8	1
1,1,1-Trichloroethane	880	40	120	51	170	10	200	190	94	20	14	10
Tetrachloroethylene	250	27	98	26	72	5	94	34	56	5	9	6
Benzene	120	91	NC[a]	NC	NC	NC	43	33	29	8	22	4
m,p-*Xylene*	120	70	150	65	63	14	58	52	94	26	26	4
Ethylbenzene	320	20	180	28	32	5	29	26	35	13	9	2
o-*Xylene*	46	27	100	31	24	5	34	28	29	6	11	2
Chloroform	220	22	35	130	16	1	6	6	20	2	6	2
Trichloroethylene	47	15	59	61	7	0.7	50	3	11	2	4	0.3
Styrene	54	11	10	11	11	1	9	9	5	3	4	2
Carbon tetrachloride	14	14	6	5	NC	NC	3	2	1	1	3	2
Octane	—[b]	—	—	—	—	—	38	12	20	2	2	2
Decane	—	—	—	—	—	—	11	27	17	2	26	7
Undecane	—	—	—	—	—	—	11	19	76	6	16	2

Table 48. **(continued)**

	New Jersey						California					
							Los Angeles				Contra Costa	
	Sept-Nov 1981 (N=85)		July-Aug 1982 (N=71)		Feb 1983 (N=8)		Feb 1984 (N=25)		May 1984 (N=25)		June 1984 (N=10)	
Chemical	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Dodecane	—	—	—	—	—	—	10	4	57	3	5	1
α-Pinene	—	—	—	—	—	—	44	5	29	2	3	1
1,4-Dioxane	—	—	—	—	—	—	4	5	4	2	1	1

[a] Not calculated.

[b] Not measured.

Table 49. Median Indoor-Outdoor Differences ($\mu g/m^3$) for Persons Who Did Not Leave Their Homes During the 12-hour Monitoring Period

	NJ1		NJ2		NJ3	LA1		LA2		CC
	N[a]	D[b]	N	D	N	N	D	N	D	N
Chemical	(N=66)	(48)	(48)	(20)	(5)	(18)	(9)	(18)	(12)	(18)
Aromatic Hydrocarbons										
Benzene	4.8	5.1	0.4	0.6	14	0.5	7.0	3.2	1.4	0.3
m,p-*Xylene*	4.0	5.4	5.6	3.9	43	−2.8	7.7	1.0	1.1	2.8
o-*Xylene*	1.7	2.0	2.0	3.0	17	−0.1	3.8	0.3	−0.1	1.1
Ethylbenzene	2.5	2.7	2.0	2.0	18	−1.4	2.4	0.4	0.3	1.0
Styrene	1.0	0.6	1.0	0.4	1.9	−0.0	2.5	0.3	0.5	−0.0
Subtotal	14.0	15.8	11.0	9.9	93.9	−3.8	23.4	5.2	3.2	5.2
Chlorinated Hydrocarbons										
1,1,1-Trichloroethane	11	6.6	4.8	0.4	12	6.8	12	4.6	2.9	1.1
m,p-*Dichlorobenzene*	2.4	2.4	1.2	2.2	1.6	0.6	1.2	0.7	0.1	0.1
Tetrachloroethylene	2.8	2.0	2.2	1.6	1.0	0.3	3.0	0.0	0.9	2.3
Chloroform	2.6	2.5	0.6	0.7	6.4	1.1	1.6	0.7	0.3	−0.1
Trichloroethylene	0.4	0.9	0.4	2.2	1.1	0.3	0.5	0.5	0.3	0.3
Carbon tetrachloride	0.4	0.2	0.2	0.3	0.0	0.0	0.3	−0.0	−0.0	0.5
Subtotal	19.6	14.6	9.4	7.4	22.1	9.1	18.6	6.5	4.5	4.2

[a] Night (6 PM-6 AM).

[b] Day (6 AM-6 PM).

Table 50. **Mean Indoor-Outdoor Differences ($\mu g/m^3$) for Persons Who Did Not Leave Their Homes During the 12-hour Monitoring Period**

Chemical	NJ1 N[a] (N=66)	NJ1 D[b] (48)	NJ2 N (48)	NJ2 D (20)	NJ3 N (5)	LA1 N (18)	LA1 D (9)	LA2 N (18)	LA2 D (12)	CC N (18)
Aromatic Hydrocarbons										
Benzene	10	12	2.5	1.5	19	1.1	10	4.5	1.6	2.2
m,p-*Xylene*	8.6	55	6.6	1.5	27	−0.7	15	6	3.6	4.6
o-*Xylene*	3.3	24	3.9	1.4	11	0.0	9.5	1.7	0.5	1.9
Ethylbenzene	10	13	5.8	0.1	14	−0.5	8.8	1.7	1.0	1.5
Styrene	2.2	2.9	1.6	0.1	3.1	0.4	1.9	0.4	1.4	−0.1
Subtotal	35	107	20	5	74	0.3	45	14	8	10
Chlorinated Hydrocarbons										
1,1,1-Trichloroethane	39	35	51	21	25	13	3.3	18	20	0.9
m,p-*Dichlorobenzene*	47	36	10	2.6	20	6.2	52	10	130	1.6
Tetrachloroethylene	8	8.3	7	5.9	14	4.4	12	0.8	15	1.8
Chloroform	7.8	6.1	4.1	6.3	7.0	1.2	1.4	2.1	0.4	−0.1
Trichloroethylene	0.8	2.5	−1.0	4.2	1.9	12	7.9	1.2	2.8	0.5
Carbon tetrachloride	0.6	0.8	0.2	0.6	0.5	0.1	1.3	−0.0	−0.1	0.7
Subtotal	103	89	71	40	68	37	78	32	168	5

[a] *Night (6 PM-6 AM).*
[b] *Day (6 AM-6 PM).*

increased levels of toluene and xylene attributed to printed material. De Bortoli (6) found that all of 32 organics measured in 15 northern Italian homes had indoor/outdoor ratios exceeding unity. Gammage (7) detected gasoline vapors in 40 east Tennessee homes, most with attached garages. Monteith (8) found increased levels of ten volatile organic compounds in 44 mobile homes in Texas.

These eight studies of more than 800 homes show remarkable agreement on the following points:

1. Essentially every one of the 40 or so organics studied has higher indoor levels than outdoor, often 10 times higher.

2. Sources are numerous, including building materials, furnishings, dry cleaned clothes, cigarettes, gasoline, cleansers, moth crystals, hot showers, and printed material.

3. Ranges of concentrations are great, often two or more orders of magnitude.

It seems clear that many indoor sources of toxic organics exist; however, few have been unequivocally identified and fewer still have had their source emission rates estimated (9). Identification of indoor sources from among thousands of consumer products and building materials is required to allow a better estimate of possible risks to public health and corrective actions that can be taken.

Although occupational exposures did not account for most of the observed differences between personal and outdoor concentrations, they did account for the very highest exposures. For example, the person with the highest exposure to vinylidene chloride and 1,1,1-trichloroethane was a painter. Commuting was also implicated in increased exposures to benzene and xylenes.

Outdoor Air. Reliance on outdoor monitors to estimate exposure is contraindicated by this study. Correlations with personal exposures were poor, even in Los Angeles where outdoor levels were the most nearly comparable with personal exposures. However, outdoor air concentrations of two chemicals, trichloroethylene and carbon tetrachloride, were significantly associated with indoor concentrations in New Jersey. These outdoor levels are similar to those measured by all techniques (Tenax, cryogenic trapping, evacuated cylinder) in urban and suburban areas throughout the U.S. between 1970 and 1980 (10).

Drinking Water. Drinking water was a main source of exposure for the trihalomethanes. In California, groundwater supplies provided increased levels of bromoform and dibromochloromethane. Assuming 2 L/day water intake and 20 m^3/day air intake, the daily intake of chloroform through water generally exceeded the air intake. However, for the common chlorinated solvents (trichloroethylene, tetrachloroethylene, 1,1,1-trichloroethane), drinking water usually supplied less than 1% of the total daily intake.

Breath. Breath is an important mode of intake and excretion for many volatile compounds (11). The compounds measured in the exhaled breath of persons breathing pure air have been supplied by the bloodstream as it passed through the lungs. The advantages of measuring breath rather than blood are (1) the technique is noninvasive and therefore preferable for use in studies requiring reasonable response rates from general public volunteers; and (2) the measurement technique employed (Tenax, GC/MS analysis) is more sensitive than the corresponding technique for blood employed in the first phase of the TEAM Study. In fact, scores of compounds were quantified in breath using this technique but only one (chloroform) was quantified regularly in blood during Phase I.

However, before these breath measurements can be used as an indicator of exposure, an adequate model relating exposures at environmental concentrations to body burden must be available.

Simple comparisons of exposure to breath concentrations do not take into account the dependence of breath levels on pre-existing concentrations in the body and also on the effective biological residence times of each chemical. A simple two-parameter time-dependent model has been developed that accounts for the effect of the initial breath concentration and the effective residence time in the body (12). The model was tested in the TEAM Pilot Study for 27 cases in which two breath samples and three intervening 8-hour air samples were collected; the model predicted an effective half-life of 21 hours for tetrachloroethylene and 9 hours for 1,1,1-trichloroethane. A later "washout" study (13) performed over a 10-hour period in a pure air chamber on an adult male exposed for 1 hour to tetrachloroethylene vapors in a dry cleaning shop interior resulted in a measured effective half-life of 21 hours.

Breath concentrations reflected personal exposures more closely than outdoor concentrations. Spearman correlations between breath and preceding personal exposure were significant (although low in magnitude) for 10 of 11 prevalent chemicals in New Jersey, and for about 10 of 19 prevalent chemicals in Los Angeles, but correlations between breath and preceding outdoor levels were significant for only three chemicals in New Jersey and one in Los Angeles. A concurrent study of personal exposures and breath concentrations of halogenated organics for 146 residents of three other U.S. cities has recently reported similar findings (14, 15). Thus, the feasibility of using breath measurements to estimate exposure to these compounds has been demonstrated. This approach may be useful in cases of spills or releases that have disappeared from the atmosphere before they could be monitored—immediate breath measurements could determine the approximate extent of population exposure. Similarly, breath measurements of persons living near hazardous waste sites could be used to detect current or recent exposure.

Sources of Exposure

Smoking. Benzene concentrations in air and breath were significantly different for smokers and nonsmokers Three other aromatics (*p*-xylene, ethylbenzene, and styrene) also showed significantly elevated levels in the breath of smokers compared to nonsmokers during all six visits to New Jersey and California. (The fifth aromatic, *o*-xylene, was elevated, but not always significantly.) Octane, measured only in California, was significantly elevated in the breath of smokers on all three visits. Two laboratory studies have identified the five aromatic components in sidestream (16) and mainstream smoke (17).

Benzene levels in the homes containing smokers were 30-50% higher than in nonsmoking households. Since about 60% of U.S. children live in homes with smokers, it appears possible that a large number of children have increased exposure to benzene, a known leukemogen, during their early years. A recent study by Sandler (18) comparing lifetime cancer mortality rates of persons who were exposed or were not exposed as children to parental smoking showed significant increases in hematopoietic (leukemia, lymphomas, etc.) mortality rates in the exposed group. The odds ratio increased from 1.7 with one parent smoking to 4.6 with both parents smoking.

A second study by Stjernfeldt (19) in Sweden has also shown increased leukemia rates in children of smoking mothers Odds ratios were 1.3 for mothers smoking <10 cigarettes/day, 2.0 for mothers smoking ≥10 cigarettes/day.

Proximity to Point Sources. In New Jersey, census tracts were classified as high and low exposure strata depending on whether they were within 1.5 km of suspected point sources or not. Those strata bordering the high exposure strata and containing major highways as well were classified as moderate exposure. In general, few differences in percent measurable or concentrations in air and breath were seen between the high, moderate, and low proximity strata Wind directions were measured, with some chemicals displaying increases when the wind was from the east.

Uncertainty of Estimates

The uncertainty in the estimates of personal exposures of the target population consists of two parts: survey sampling uncertainty and measurement errors. For a simple random sample size of 350 persons, assuming a log-normal distribution, standard sampling theory states that the estimate of the median will be 95% certain to lie between the 44th and 56th percentiles (20). Since our sample is clustered, the design effect will broaden these ranges of uncertainty by a small amount. The corresponding range for the summer group of 160 persons is 41-59%; and for the winter group of 40 persons, 35-65%.

The second source of uncertainty is measurement error. Analysis of the duplicate measurements for all three seasons using a method developed by the author and based on observations in Evans et al. (21) resulted in estimated frequency distributions of exposures that had geometric standard deviations that were 5-20% less than the sample geometric standard deviations. This is explained in detail in Appendix D.

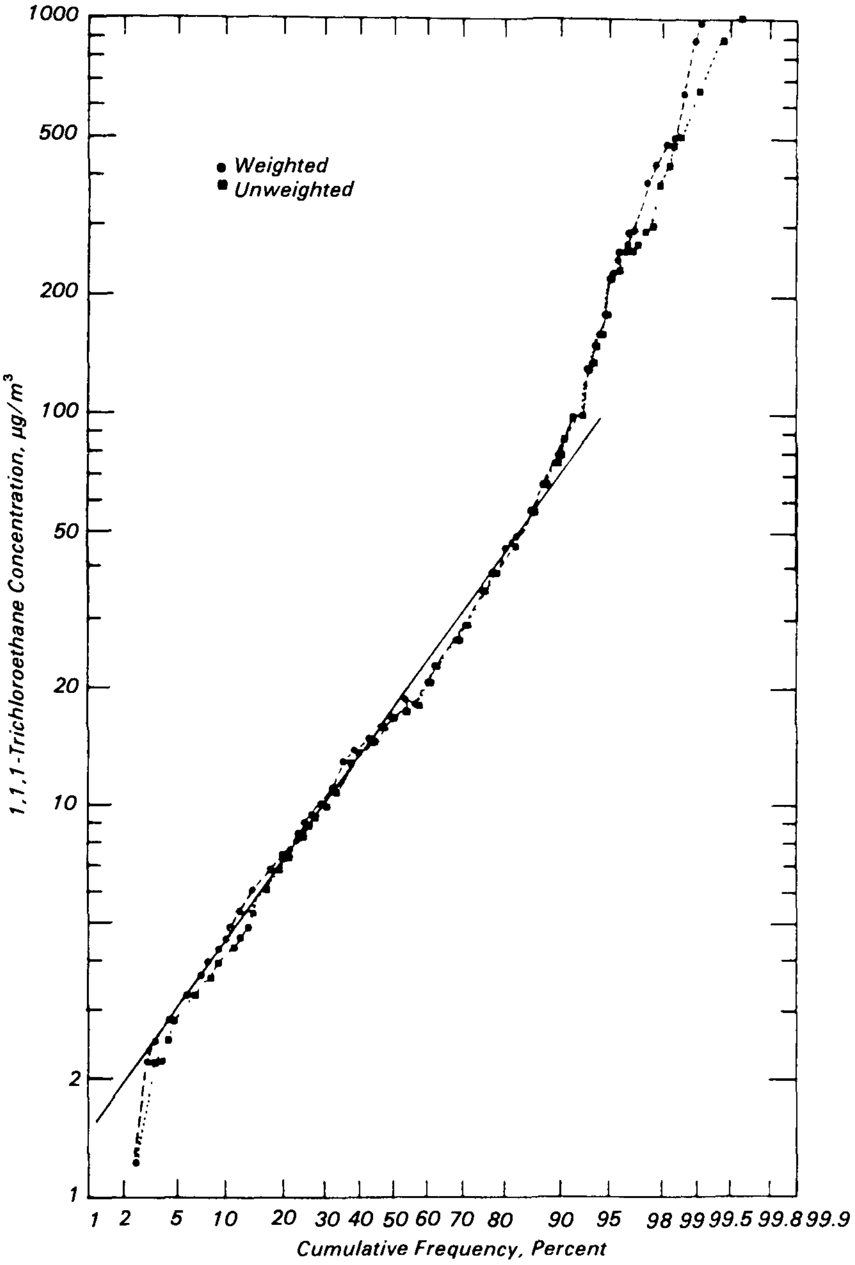
Comparison of Weighted and Unweighted Frequency Distributions

In an effort to better characterize relatively rare high exposures, the TEAM Study selected potentially highly exposed persons with higher probabilities than persons with low potential exposures. The known selection probabilities of the sample members can be used to compute unbiased estimates of the population distributions of exposures by weighting each observation inversely to its selection probability; the observed ("unweighted") frequency distributions of exposures are not a proper basis for inferences from the sample to the target population.

If the initial hypotheses as to the main causes of exposures were correct, the observed values would contain relatively more high exposures than actually occur in the general population, represented by the weighted curve. Thus, the unweighted curve should lie *above* the weighted curve, at least at the higher exposures, on a log-normal probability graph. If, however, the unweighted curve lies *below* the weighted curve at the higher exposures, unsuspected causes of high exposures may be predominant.

By graphing both frequency distributions on one set of axes, one can gauge the relative impact of the weighting process. A sample graph is displayed as Figure 49. It will be noted that the unweighted curve lies *below*, instead of above, the weighted curve, indicating that a preponderance of persons who were expected to have low exposures in fact had high ones. This was the case for three of the five chemicals compared in this way (see Appendix

Figure 49. ***Weighted vs. unweighted frequency distributions for 1,1,1-trichloroethane. The straight line is a log-normal curve with the same geometric mean and geometric standard deviation as the observed distribution.***



E). The reason for "guessing wrong" about the high exposures may be that the importance of indoor sources was not well understood when the study was designed, and such potential sources were therefore not used to stratify the sample.

Health Effects

Although this study is concerned only with documenting exposures and identifying possible sources, some discussion of health effects may be appropriate, since these are the ultimate reasons for our interest in these compounds. Two broad types of health effects may be distinguished: chronic and acute.

Chronic Effects. The chronic effect of greatest interest is cancer. One of the TEAM target compounds (benzene) is generally considered a known human carcinogen. Five others are considered animal carcinogens and therefore possible human carcinogens—carbon tetrachloride, chloroform, trichloroethylene, tetrachloroethylene, and *p*-dichlorobenzene. Risk assessments of human exposure to these six compounds have been made using the TEAM exposure measurements and potency estimates from EPA and other organizations, with an estimated range of 1000-5000 excess cancer cases per year nationwide (22). These numbers far exceed the estimates of 5-27 cases per year that have been used to regulate hazardous air pollutants (NESHAPS).

Other TEAM target compounds are mutagens and therefore possible carcinogens. These include styrene, 1,1,1-trichloroethane, and α-pinene. Still others are promoters (co-carcinogens)—octane, decane, and undecane. Others are presently being tested for carcinogenicity (xylenes, ethylbenzene). Risk assessments of these chemicals are at present highly speculative; however, it is possible that their effects on cancer incidence are not negligible (23).

A second chronic effect of interest is chemical sensitivity. This is an ill-defined condition marked by progressively more debilitating severe reactions to various consumer products such as perfumes, soaps, tobacco smoke, plastics, etc. The incidence of this syndrome is unknown; however, anecdotal accounts indicate that it may be increasing sharply. The effects on productivity of affected persons can be severe.

Acute Effects. A second ill-defined group of symptoms, sometimes known as "Sick Building Syndrome," affects a number of office workers. The symptoms include sleepiness, nausea, eye irritation, irritability, forgetfulness, and a number of other respiratory and central nervous system disorders. One experiment has determined that the symptoms are unlikely to be related to mass psychology or otherwise psychosomatic (24). A second experiment has shown that mixtures of common organic pollutants (mostly xylenes) at levels similar to those in new buildings can cause both subjective and objective symptoms in a group of sensitive individuals (25). The lowest experimental concentration was 5 mg/m^3; effects were still apparent, leading the experimenter to hypothesize that effects may appear at levels as low as 1 mg/m^3. Thus, the indoor air levels measured in the TEAM Study, which exceeded 1 mg/m^3(sum of 11 organics) in ~3% of New Jersey homes, may have some potential of being associated with frank acute health effects, although no attempt was made to observe such effects.

Standard Operating Procedures

To make the methods developed in the TEAM Study more widely available, detailed descriptions of all procedures have been compiled. These Standard

Operating Procedures (SOPs) are included as Volume IV of this publication. The list of SOPs is included as Table 51.

TEAM Study Publications

A number of EPA reports and journal articles have been published on various aspects of the TEAM Study. All of these publications are listed in Table 52.

Validity of TEAM Data

At present, no standard methods exist for measuring volatile organic compounds at environmental concentrations. Without such reference methods, it is not possible to confirm the accuracy of any measurement methods. The use of blanks, controls, deuterated compounds, duplicates, external laboratories, and performance audits can serve to protect against many errors, but not against all. For example, artifact formation during or after sampling might not be detected by standard QA precautions (26). Side-by-side sampling using completely different methods would be desirable, and was performed to a limited extent in the California TEAM Study. In that comparison Tenax cartridges and Tedlar bags agreed for 11 of 12 compounds in three 24-hour outdoor samples. A recent experiment (27) compared Tenax cartridges collected at four widely different flow rates to stainless steel evacuated canisters. Ten experiments were carried out in an experimental home under controlled conditions. The two methods agreed very closely for all ten target chemicals.

Although these results are encouraging, the number of samples is small. In the absence of direct methods for determining accuracy, indirect methods must be employed. Several different ways to assess the validity of the TEAM data are discussed below.

1. Agreement with Other Methods.

Although few side-by-side studies comparing Tenax and other methods have been carried out, results of ambient monitoring in the same city during the same time period may be an approximate test of agreement between two monitoring methods, provided that concentrations do not vary widely between the sampling locations. Since 1983, the California Air Resources Board (CARB) has operated a four-station ambient monitoring network in Los Angeles. The method employed is 24-hour bag sampling followed by gas chromatography analysis with electron capture or flame ionization detection. Thus no sorbent is employed and artifacts peculiar to Tenax would not be expected to occur.

The CARB network collected 25 samples during February 1984 and 30 during May 1984 at the four Los Angeles sites; concurrently, the TEAM Study collected two consecutive 12-hour samples at 24 locations each month. After averaging the two 12-hour samples, the TEAM concentrations were compared to the CARB values (Table 53 and Figures 50 and 51).

Both methods found six chemicals to be generally below detectable limits. Median values of six additional chemicals agreed to within one standard deviation of each method except for trichloroethylene, which agreed to within two standard deviations. The TEAM concentrations were higher for three chemicals; lower for the other three. Both methods agreed in finding a sharp decrease in concentration between February and May for four chemicals but little change for the remaining two. Thus, the two methods appear to agree to within their limits of precision, with no evidence indicating a consistent bias.

Table 51. Approved SOPs for Phase III TEAM Study

RTI/ACS-SOP No.	*SOP Title*
321-001	*Tenax Cleanup and Preparation*
322-001	*Cleanup of Water Collection Bottles*
331-001	*Collection of Personal Air Samples*
331-002	*Collection of Fixed Site Air Samples*
332-001	*Collection of Water Samples*
337-001	*Collection of Breath Samples*
340-001	*Shipment of Field Sampling Equipment*
350-001	*Site Workroom Procedures and Rules*
350-002	*Maintenance and Use of the Van*
361-001	*Calibration of Dupont P-125A Constant Flow Samples*
367-002	*Calibration of Nutech Model 221 Gas Sampler with a Dry Gas Meter*
410-001	*Using Sampling Protocol/Chain-of-Custody Sheet in the Field*
431-001 (Air)	*Storage of Samples at the Field Sampling Site*
432-001 (Water)	
437-001 (Breath)	
461-001 (Air)	*Shipment of Samples from the Field to RTI*
432-001 (Water)	
467-001 (Breath)	
470-001	*Receipt of Air, Breath, and Water Samples at RTI*
482-001	*Storage of Water Samples at RTI*
481-001 (Air)	*Storage of Tenax Samples at RTI*
487-001 (Breath)	
512-001	*Analysis of Drinking Water by Purge Trap Gas Chromatography*
533-001	*Analysis of Organic Compounds Collected on Tenax Using the Finnigan 3300 GC/MS/COMP System*
533-002	*Analysis of Organic Compounds Collected on Tenax Using the Finnigan 4021 GC/MS/COMP System*
612-001	*Preparation of Purge and Trap Calibration Solutions*
630-001	*Preparing Relative Molar Response Tenax Cartridges Using a Permeation System*
630-002	*Preparing Relative Molar Response and Column Performance Evaluation Tenax Cartridges Using a Flash Evaporation System*
630-003	*Loading External Standards on Tenax Cartridges Via Injection Using a Permeation System*
630-004	*Loading Deuterium Standards on Tenax Cartridges Using a Permeation System*
712-001	*Quantitation of Volatile Organic Compounds in Water*
711-001 (Air)	*Quantitation of Volatile Organic Compounds in Tenax Samples*
717-001 (Breath)	
790-001	*Preparation and Submission of Data Summary Sheets to the Center for Computer Application/Data Entry (CCA/DE)*

Table 51. (continued)

RTI/ACS-SOP No.	*SOP Title*
810-001	*Preparation and Handling of QA Performance Audit Samples on Tenax for GC/MS Analysis*
812-001	*Conducting a QA System Audit of Sample and Data Collection in the Field*
860-001	*Preparing Quality Control Samples on Tenax Cartridges*
862-001	*Preparation of Water Blanks and Controls*
861-002 (Air) *862-002 (Water)* *867-002 (Breath)*	*Shipment of QC Samples to the Field Sampling Site*
861-003 (Air) *862-003 (Water)* *867-003 (Breath)*	*Exposure of QC Samples*
881-001 (Air) *882-001 (Water)* *887-001 (Breath)*	*Submission of QA Samples to and Receipt of Data from a QA Laboratory*

2. Confirmation by Other Studies.

The major finding of the TEAM Study was the higher indoor concentrations of eleven prevalent chemicals. A total of eight studies (2-8, 15) some using methods quite different from those employed in the TEAM Study, have also found higher indoor concentrations of these and other chemicals in other countries and other areas in the United States.

3. Internal Consistency.

If chemical reactions or other random errors were affecting an appreciable proportion of samples in a major way, correlations between, for example, breath and air samples would not be expected. In fact, however, ten of eleven chemicals showed significant correlations between breath concentrations and the preceding personal air concentrations. At the same time, few of these chemicals showed correlations between breath and outdoor air samples. The most natural conclusion from these observations is that exhaled breath concentrations are closely related to inhaled concentrations and less closely related to outdoor concentrations. It is difficult to imagine any explanation attributing such a pattern of correlations to chance.

4. Ability to Predict Measurable Phenomena.

A number of hypotheses have been generated by the TEAM findings, some of which have now been tested and confirmed to varying degrees. Some of these hypotheses are listed below.

a. A Main Source of Exposure to Aromatics is Tobacco Smoke

As noted, on all six trips to New Jersey and California, smokers had significantly elevated breath levels of benzene, styrene, ethylbenzene, and *m,p*-xylene. A recent study of mainstream cigarette smoke has confirmed that these components are present in significant amounts

Table 52. TEAM Study Publications

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Table 53. Comparison of Outdoor Measurements of Toxics by TEAM Study and by California Air Resources Board

Chemical	February CARB[a] (N=25)[b]	February TEAM (N=25)	May CARB (N≈32)[b]	May TEAM (N=25)[c]
Benzene	20[d] ± 6.4[e]	16 ± 7.8	9.3 ± 3.2	3.6 ± 3.0
1,1,1-Trichloroethane	13 ± 8.1	33 ± 35	5.1 ± 2.9	5.9 ± 0.6
Tetrachloroethylene	12 ± 6.8	8 ± 8.7	3.2 ± 1.9	1.5 ± 1.5
Trichloroethylene	2 ± 0.7	0.6 ± 1.9	0.6 ± 0.3	0.2 ± 1.0
Carbon tetrachloride	0.4 ± 0.1	0.6 ± 0.2	0.5 ± 0.1	0.7 ± 0.2
Chloroform	0.3 ± 0.1	0.7 ± 1.0	0.2 ± 0.1	0.3 ± 0.6

[a] *California Air Resources Board.*

[b] *Total number of 24-hour measurements made at four sites in Los Angeles.*

[c] *Mean of two consecutive 12-hour measurements made at 25 sites in South Bay section of Los Angeles.*

[d] *Arithmetic mean (μg/m³).*

[e] *Standard deviation (μg/m³).*

(17). The elevated benzene levels observed in indoor air are consistent with a sidestream concentration 5-10 times that in mainstream smoke. Such an increased sidestream concentration of benzene (250 μg/cigarette compared to 35 μg in mainstream smoke) has recently been observed (28).

b. Use of Hot Water is the Main Source of Airborne Chloroform in Homes

This hypothesis is based on the fact that the median indoor level of chloroform was four times the median outdoor level in New Jersey in the fall of 1981. Assuming a typical air exchange rate of 0.5 ach

Figure 50. ***Comparison of outdoor air measurements in Los Angeles by the California Air Resources Board (CARB) and the TEAM Study. The CARB measurements employed a Tedlar-bag collection with GC-ECD analysis; the TEAM measurements employed a Tenax collector with GC-MS analysis. CARB measurements were 24-hour samples collected in four locations in the Los Angeles basin; TEAM measurements were two consecutive 12-hour samples collected at 25 homes in the South Bay section of Los Angeles. (The two 12-hour values at each home were combined into a single 24-hour value.) A total of 25 measurements were made by both CARB and TEAM in February; and 30 by CARB and 25 by TEAM in May. Not shown are six toxic chemicals for which both methods found no detectable amounts. Units are µg/m^3. Arithmetic means for all but one case (trichloroethylene in May) were within one standard deviation associated with each method.***

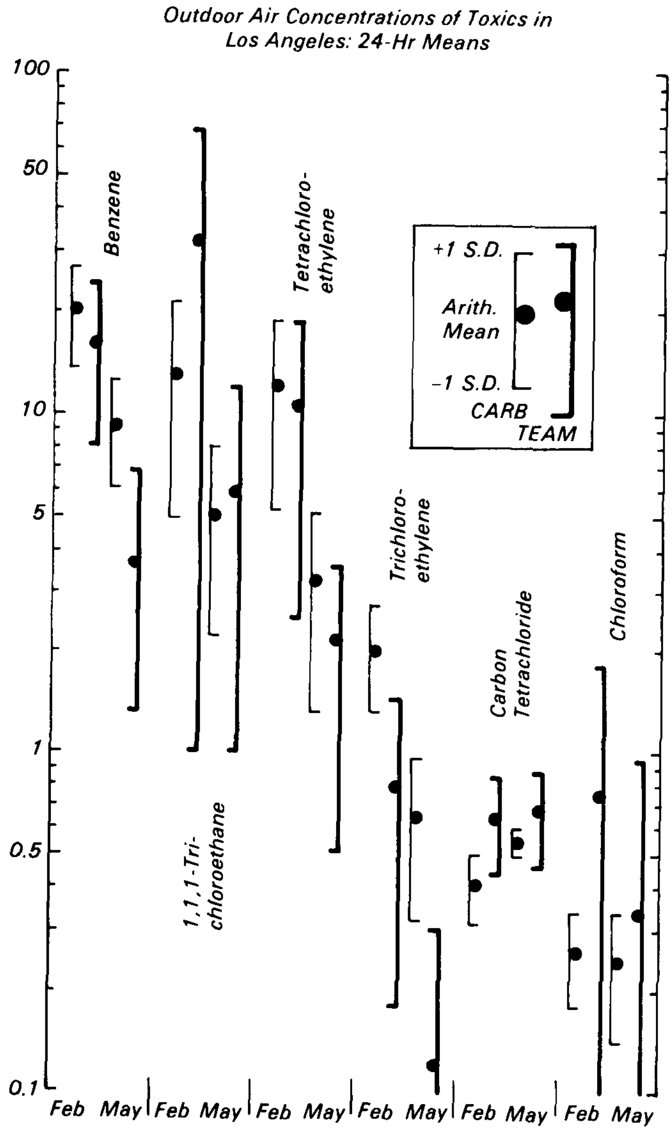
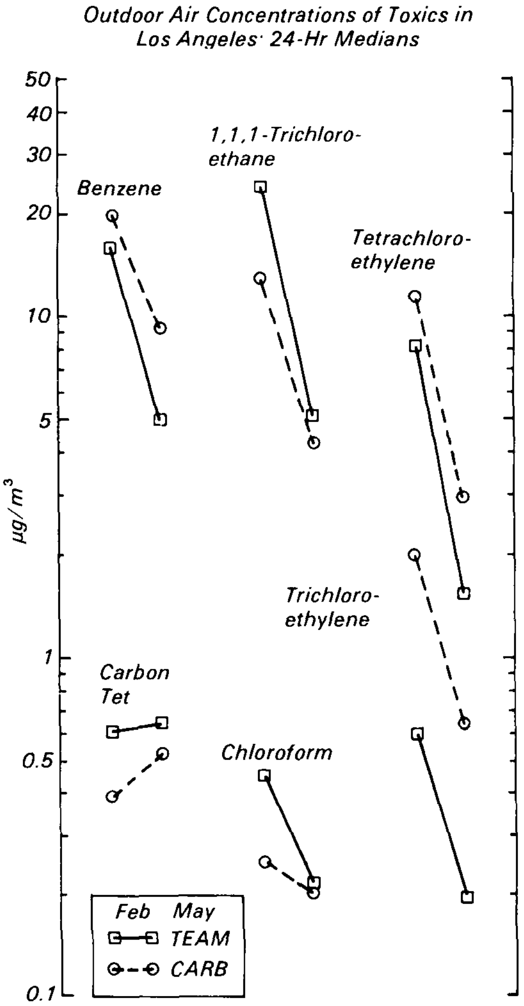

Outdoor Air Concentrations of Toxics in Los Angeles: 24-Hr Means

Figure 51. Comparison of median outdoor air concentrations. (See caption for Figure 50.)



and a typical home volume of 300 m^3, a total of 150 μg of chloroform would have to be liberated each hour to achieve a steady-state concentration of 1 μg/m^3 above background (outdoor) levels. Assuming a concentration of 50 μg chloroform per liter of water, at least 3 L/hr or ~70 L/day would be required to liberate all contained chloroform to achieve this indoor concentration. Common large-scale uses of hot water in most homes include showers, baths, and washing clothes or dishes. Since this speculation was first made, a study funded by EPA has reported such liberation of trichloroethylene from spiked water sources during model showers under controlled conditions (29). Similar studies using chloroform have also supported the hypothesis (30).

c. *Tetrachloroethylene Levels in Dry Cleaning Shops Sometimes Exceed 1000 μg/m^3*

From the fact that persons who reported visiting a dry cleaning shop showed twice as much tetrachloroethylene in their breath as the other persons (median values) and assuming a 5-minute exposure in the shop, one can calculate that the concentration in the shop must have been about 12h/5m=140 times the typical ambient level of 10 μg/m^3, or more than 1000 μg/m^3. A special study of dry cleaning shops (31) showed that tetrachloroethylene levels up to 10,000 μg/m^3 were observed.

d. *The Effective Half-Life of Tetrachloroethylene in Breath is ~21 Hours*

By using the TEAM pilot study measurements of tetrachloroethylene in breath and personal air of 12 persons and assuming a common half-life in the body, a value of 21 hours was calculated (12). This estimate was confirmed by direct measurement of breath values of a volunteer over a 10-hour period in a clean-air chamber (13).

e. *Benzene Exposures While Filling Gas Tanks May Exceed 1000 μg/m^3*

Persons who reported filling their tanks with gasoline had twice as much benzene on their breath as persons who did not. The same calculation as above for tetrachloroethylene indicates that concentrations at the breathing zone may exceed 1000 μg/m^3 (100 times the ambient level). A recent study (32) has measured benzene levels during refueling of ~1 ppm (3000 μg/m^3).

Other hypotheses regarding indoor sources have also been generated but not yet tested. These include·

a. *Moth Crystals and Room Air Deodorizers are Important Sources of* p-*Dichlorobenzene Exposures in Homes*

This hypothesis is suggested by the fact that *p*-dichlorobenzene was prevalent in ~80% of homes and that its main uses include the two uses described above. The greatly elevated indoor concentrations of *p*-dichlorobenzene are consistent with the main purpose of both uses, which is to supply a long-lasting continuous source of elevated levels of *p*-dichlorobenzene in the home. The observed steep geometric standard deviation may be explained by the fact that homes with such sources will have high concentrations while homes without sources will have background levels; thus a great dynamic range in concentrations and correspondingly large geometric standard deviations will be achieved.

b. Tetrachloroethylene Exposures are Elevated by Wearing or Storing Dry-Cleaned Clothes

The evidence for this comes from observed higher levels in the breath of persons visiting dry cleaning shops; higher exposures of persons working in textile plants; and higher exposures of persons visiting dry cleaning shops. Also, one study has measured increased concentrations in a home for up to one week after placing newly dry cleaned clothes in a closet (33).

c. Employment Leads to Increased Exposures to Some Toxic Chemicals

More than 50 significant relationships with increased exposures or breath concentrations were observed for 19 employment-related variables.

d. Common Activities Lead to Increased Exposures to Some Toxic Chemicals

Among the activities identified with increased exposures were: pumping gasoline, visiting service stations, visiting dry cleaners, traveling in a car, furniture refinishing, painting, scale model building, pesticide use, and smoking. More than 20 such activities were identified (34).

e. Household and Personal Characteristics are Associated with Significantly Increased or Decreased Exposures to Some Toxic Chemicals

Age, race, and sex were personal characteristics occasionally associated with significantly higher or lower exposures. Significant household variables included age of the house, type of heat, ventilation, and the presence in the home of hobbyists, smokers, and persons with certain types of occupations (particularly chemical, plastics, and paint plant workers).

Several other hypotheses may be generated by these findings. For example, the higher exposures of females to trichloroethylene may be due to the chemical's use in cosmetics as a solvent and in opaquing fluids used in offices.

The occasional finding of increased indoor air concentrations associated with the presence of a chemical worker in the home suggests that some transport of pollutants from the workplace may be occurring.

The reduced exposures associated with gardening are consistent with the greater amount of time likely to be spent outdoors, where concentrations are nearly always lower.

If in fact indoor concentrations normally exceed outdoor levels, it will be important to consider these indoor exposures as part of any regulatory process dealing with traditional sources. For example, if mean indoor levels are normally 2-4 times the outdoor concentrations (as observed in this study) a 50% decrease in outdoor levels will produce a decrease in human exposure of only 12-25%. Some attention to reducing indoor concentrations (by removing sources, substituting innocuous chemicals in products, establishing standards for building materials, increasing ventilation, etc.) may provide more cost-effective reductions of human exposure than traditional environmental regulations of emissions from major point sources

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Appendix A
Sources of Exposure to Volatile Organic Chemicals: An Analysis of Personal Exposures in the TEAM Study

Stepwise regression results for personal air and breath concentrations of 11 prevalent chemicals in the three New Jersey trips and 16 chemicals in the three California trips are summarized below.

New Jersey—Fall 1981

A total of 33 stepwise regressions were run for eleven chemicals in three media: day and night personal air and breath.

The best models for each of the eleven prevalent chemicals are summarized for daytime personal air (Table A-1): overnight personal air (Table A-2); and breath (Table A-3). Listed in the tables are the number of persons in each category; the slope (b) and its associated standard error (SE) of the linear regression; the F and p-values associated with each relationship; and the total R^2 (or percent of variance) explained by the "best" model. In general, the variances of the aromatic compounds were best explained by the questionnaire variables (R^2 values as high as 32%), while those of the chlorinated compounds were not well explained (R^2 values normally less than 10%). As an additional check of the stepwise regression, comparisons with the t-tests were performed. In more than 80% of the cases, the two approaches agreed in identifying significant variables. The best models identified by the stepwise regression contain only eight (out of 108) variables (identified by asterisks in Tables A-1 - A-3) that were not also significant by the t-test.

Of 14 specific occupations selected as having potential for exposures, 11 had at least one positive significant relationship with air or breath levels of the 11 prevalent chemicals. Similarly 16 of 29 activities and 9 of 17 personal or household characteristics were identified with significantly increased (occasionally decreased) exposures.

The results of this first set of stepwise regressions clearly show that common daily activities such as filling one's gas tank, visiting the dry cleaners, or smoking can lead to significantly increased breath concentrations of toxic chemicals. A number of occupations (paint, chemicals, plastics, textiles, metal work, wood processing, service stations, etc.) were implicated in increased exposure to some chemicals during the day. Household characteristics were sometimes selected as significant variables on the overnight air samples—for example, a smoker or chemical worker in the home was associated with significantly increased exposures to some aromatics.

The strength of the association can be quantified by calculating the value of e^b: this is the *ratio* of the geometric mean concentration for persons having the characteristic compared to those not having the characteristic. Thus, a value of $b = 0.69$ indicates a two-fold increase, a value of $b = 2\ 3$ indicates an order of magnitude increase. (For a few variables with multiple categories, such as travel time or frequency of pesticide treatments, the value of e^b is the ratio of the geometric mean of each category to the next lower category.)

Breath. Smoking was the single strongest predictor for increased breath levels of four of the five aromatics: benzene, styrene, ethylbenzene, and

Table A-1. Stepwise Regression Results[a]: Daytime Personal Air—New Jersey, Fall 1981

Chemical	Variable	N[b]	c_i[c]	S.E.[d]	F[e]	p[f]
Aromatic Hydrocarbons						
Benzene (0.03)[g]	*Smoker in home*	*258*	*0.68*	*0.20*	*12*	*0.0006*
Styrene (0.17)	**Plastics plant exp.*	*11*	*1.32*	*0.37*	*13*	*0.0005*
	Paint exposure	*27*	*0.78*	*0.26*	*9.2*	*0.002*
	Smoker	*161*	*0.40*	*0.13*	*9.6*	*0.002*
	Scale models	*7*	*1.24*	*0.46*	*7.4*	*0.007*
	Painting as a hobby	*10*	*−0.49*	*0.19*	*6.9*	*0.009*
	Degreasers exp.	*9*	*0.64*	*0.30*	*4.6*	*0.03*
	Metal work exp.	*17*	*0.78*	*0.32*	*5.8*	*0.02*
	Dyeplant exp.	*4*	*1.23*	*0.60*	*4.2*	*0.04*
Ethylbenzene (0.25)	*Wood proc. plant exp.*	*6*	*2.08*	*0.50*	*18*	*0.001*
	Garage worker	*12*	*1.41*	*0.37*	*14*	*0.002*
	Employed	*192*	*0.41*	*0.13*	*9.8*	*0.002*
	Sci. lab exp.	*14*	*1.01*	*0.36*	*7.9*	*0.005*
	Metal work exp.	*14*	*0.89*	*0.32*	*7.9*	*0.005*
	Dye plant exp.	*17*	*1.46*	*0.58*	*6.3*	*0.01*
	Odorous chem. exp.	*4*	*0.37*	*0.16*	*5.4*	*0.02*
m,p-*Xylene (0.32)*	*Wood proc. plant exp.*	*6*	*2.33*	*0.44*	*28*	*0.0001*
	Employed	*192*	*0.56*	*0.11*	*24*	*0.0001*
	Garage worker	*12*	*1.35*	*0.33*	*17*	*0.0001*
	Metal work exposure	*17*	*0.76*	*0.28*	*7.2*	*0.008*
	Solvent exp.	*37*	*0.50*	*0.19*	*6.9*	*0.009*
	Gardener in home	*68*	*−0.32*	*0.14*	*5.0*	*0.03*
	Furn. ref. exp.	*7*	*0.87*	*0.40*	*4.8*	*0.03*

Table A-1. ***(continued)***

Chemical	*Variable*	*N*	c_i	*S.E.*	*F*	*p*
o-*Xylene* *(0.25)*	*Wood proc. plant exp.*	*6*	*2.24*	*0.47*	*23*	*0.0001*
	Odorous chemicals	*83*	*0.47*	*0.14*	*11*	*0.001*
	Metal plant exp.	*17*	*0.90*	*0.30*	*9.2*	*0.003*
	Employed	*188*	*0.29*	*0.12*	*5.5*	*0.02*
	Furn. ref. exp.	*7*	*0.99*	*0.42*	*5.5*	*0.02*
	Solvent exp.	*37*	*0.43*	*0.20*	*4.8*	*0.03*
	Adult (40-65)	*148*	*0.27*	*0.12*	*4.9*	*0.03*
Chlorinated Hydrocarbons						
1,1,1-Trichloroethane *(0.16)*	*Wood proc. plant*	*6*	*3.90*	*0.75*	*28*	*0.0001*
	Employed	*191*	*0.91*	*0.19*	*23*	*0.0001*
	Textile plant exp.	*5*	*2.16*	*0.79*	*7.4*	*0.007*
	Chem. worker in home	*14*	*1.25*	*0.47*	*6.9*	*0.009*
Trichloroethylene *(0.10)*	*Wood proc. plant exp.*	*6*	*1.72*	*0.56*	*9.5*	*0.002*
	Plastics plant exp.	*11*	*1.23*	*0.42*	*8.7*	*0.003*
	Sci. lab exp.	*14*	*0.99*	*0.40*	*6.2*	*0.01*
Tetrachloroethylene *(0.04)*	*Wood proc. plant exp.*	*6*	*2.11*	*0.55*	*15*	*0.0002*
Carbon Tetrachloride *(0.07)*	**Metal worker*	*7*	*1.32*	*0.48*	*7.6*	*0.006*
	**Painter*	*9*	*0.95*	*0.42*	*6.9*	*0.02*
	**Furn. ref. exp.*	*7*	*1.00*	*0.45*	*5.1*	*0.03*
	Over 65 yrs. old	*40*	*−0.41*	*0.20*	*4.5*	*0.04*
Chloroform *(0.02)*	*Garage worker*	*12*	*−1.14*	*0.42*	*7.5*	*0.006*

Table A-1. **(continued)**

Chemical	Variable	N	c_i	S.E.	F	p
m,p-*Dichlorobenzene* (0.11)	Hospital worker	6	2.96	0.72	17	0.0001
	Central air cond.	14	1.21	0.49	6.0	0.02
	Garage worker	12	−1.18	0.54	4.9	0.03
	Home pesticide treat.	162	0.38	0.19	4.0	0.05
	Car travel (daytime)	174	−0.32	0.16	3.9	0.05
	Taxi/truck driver	15	−0.87	0.46	3.5	0.06

[a] The model is: $y = a + \Sigma c_i q_i$ where the q_i are the questionnaire variables and y is the natural logarithm of the daytime exposure.

[b] sample size.

[c] The logarithm of the concentration is regressed on the variables—thus daytime personal air benzene exposures of smokers and those who live with smokers are likely to be $e^{0.68} \approx 2$ times as much as nonsmokers who do not live with smokers.

[d] Standard error.

[e] F-value of the comparison of the two groups.

[f] Probability that there is no difference in geometric means of the two groups.

[g] Proportion of the variance explained by the model.

*Not significant by t-test comparing geometric means of indexed variable. All other unstarred variables in table continued to show significant differences under pairwise t-test of geometric means.

Table A-2. *Stepwise Regression Results[a]: Overnight Personal Air—New Jersey, Fall 1981*

Chemical	Variable	N	c_i	S.E.	F	p
Aromatic Hydrocarbons						
Benzene	*Smoker in home*	258	0.52	0.19	7.6	0.006
(0.04)	*Gardener in home*	68	−0.48	0.22	5.0	0.03
Styrene	*Smoker in home*	258	0.54	0.13	19	0.0001
(0.06)						
Ethylbenzene	*Smoker in home*	258	0.37	0.11	11	0.001
(0.19)	*Chem. worker in home*	14	0.83	0.26	10	0.002
	High dust levels	63	0.41	0.13	10	0.002
	Old home (>10 yrs)	121	0.32	0.11	9.2	0.003
	Pumped gas	9	0.81	0.32	8.4	0.01
	Furn. ref. hobby	15	0.64	0.26	5.8	0.02
	**Nonwhite*	104	0.28	0.11	5.8	0.02
	Metal worker in home	7	0.46	0.22	4.5	0.03
	Gas furnace	151	0.21	0.10	4.3	0.04
	Furn ref. in home/other	37	0.55	0.27	4.1	0.04
m,p-*Xylene*	*Chem. worker in home*	14	1.01	0.25	16	0.0001
(0.18)	*Smoker in home*	258	0.37	0.11	12	0.0008
	Old home (>10 yrs)	121	0.33	0.11	9.8	0.002
	Pumped gas	9	0.97	0.31	9.6	0.002
	Lived in home <1 yr	47	0.45	0.16	8.4	0.004
	High dust exp.	63	0.38	0.13	8.2	0.004
	Furn. ref. hobby in home	37	0.61	0.25	5.9	0.02
	**Solvent exposure*	33	0.35	0.17	4.3	0.04

Table A-2. ***(continued)***

Chemical	*Variable*	*N*	c_i	*S.E.*	*F*	*p*
o-*Xylene*	*Pumped gas*	*9*	*1.01*	*0.32*	*10*	*0.002*
(0.13)	*Chem. worker in home*	*14*	*0.79*	*0.26*	*9.4*	*0.002*
	Smoker in home	*258*	*0.32*	*0.11*	*8.1*	*0.005*
	High dust exp.	*63*	*0.36*	*0.13*	*7.4*	*0.007*
	Old home (>10 yrs)	*121*	*0.28*	*0.11*	*7.2*	*0.008*
	Furn. ref. in home	*37*	*0.67*	*0.26*	*6.8*	*0.01*
Chlorinated Hydrocarbons						
1,1,1-Trichloroethane	**Metal worker in home*	*7*	*0.79*	*0.29*	*7.2*	*0.008*
(0.05)	**Metal work exp.*	*17*	*0.88*	*0.32*	*7.6*	*0.006*
Trichloroethylene	*Outdoor concentration*	*84*	*0.21*	*0.06*	*10*	*0.002*
(0.01)	*Sci. lab exp.*	*14*	*0.71*	*0.33*	*4.4*	*0.04*
Tetrachloroethylene	*Male*	*177*	*0.28*	*0.12*	*5.8*	*0.02*
(0.10)	*Textile plant exp.*	*5*	*1.18*	*0.50*	*5.6*	*0.02*
	Old house (>10 yrs)	*120*	*0.28*	*0.12*	*5.2*	*0.02*
	Furn. ref. hobbyist in home	*14*	*0.67*	*0.30*	*5.0*	*0.03*
	Outdoor concentration	*84*	*0.11*	*0.06*	*4.2*	*0.04*
Carbon Tetrachloride	*Child (<17 yrs)*	*23*	*1.02*	*0.26*	*16*	*0.0001*
(0.09)	*White*	*248*	*0.44*	*0.13*	*11*	*0.0009*
Chloroform	*Pesticide use*	*47*	*0.47*	*0.20*	*5.3*	*0.02*
(0.02)						

Table A-2. (continued)

Chemical	Variable	N	c_i	S.E.	F	p
m,p-*Dichlorobenzene* (0.09)	Job at hospital	6	3.49	0.77	21	0.0001
	Central air cond.	14	1.35	0.53	6.6	0.01
	Soda consumption	106	0.24	0.10	5.2	0.02

[a] The model is: $y = a + bx + \Sigma c_i q_i$ where the y is the natural logarithm of the overnight personal exposure, x is the natural logarithm of the outdoor concentration, and the q_i are the questionnaire variables.

[b] The logarithm of the concentration is regressed on the variables—thus overnight indoor air in a home with a smoker is likely to have $e^{0.52} \approx 1.7$ times as much benzene as in a home with no smokers.

See footnotes to Table A-1 for explanation of other headings.

Table A-3. **Stepwise Regression Results[a]: Breath (daily exposures)—New Jersey, Fall 1981**

Chemical	Variable	N	c_i	S.E.	F	p
Aromatic Hydrocarbons						
Benzene	*Smoker*	161	1.46[b]	0.17	72	0.0001
(0.16)	*Paint plant/store*	27	0.77	0.33	5.4	0.02
Styrene	*Smoker*	161	0.81	0.10	65	0.0001
(0.24)	*Paint plant*	27	0.55	0.20	7.9	0.005
	Chem. plant	21	0.57	0.21	7.5	0.007
	Nonwhite	92	0.28	0.11	6.4	0.01
Ethylbenzene	*Smoker*	161	0.56	0.14	17	0.0001
(0.13)	*Solvent exp.*	37	0.75	0.23	11	0.001
	Employed	192	0.41	0.14	9.1	0.003
m,p-*Xylene*	*Smoker*	161	0.53	0.12	20	0.0001
(0.10)	*Solvent exp.*	37	0.72	0.20	13	0.0003
o-*Xylene*	*Employed*	188	0.46	0.11	16	0.0001
(0.09)	*Solvent exp.*	37	0.64	0.19	12	0.0008
Chlorinated Hydrocarbons						
1,1,1-Trichloroethane	*Employed*	191	0.66	0.18	13	0.0004
(0.04)						
Trichloroethylene	*Gas heat*	161	0.32	0.12	6.6	0.01
(0.02)						
Tetrachloroethylene	*Employed*	193	0.57	0.10	30	0.0001
(0.10)	*Dry cleaners exp.*	24	0.87	0.29	9.1	0.003

Table A-3. (continued)

Chemical	Variable	N	c_i	S.E.	F	p
Carbon Tetrachloride (0.02)	High potential exp.	224	0.27	0.12	4.8	0.03
Chloroform (0.02)	Paint plant/store	27	0.97	0.35	7.4	0.007
m,p-Dichlorobenzene (0.03)	Central air cond.	14	1.43	0.49	8.5	0.004

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[a] The model is: $y = a + \Sigma c_i q_i$ where the q_i are the questionnaire variables and y is the natural logarithm of the breath concentration.

[b] The logarithm of the concentration is regressed on the variables—thus a smoker is likely to have $e^{1.46} \approx 4$ times as much benzene on his breath as a nonsmoker.

See footnotes to Table A-1 for explanation of other headings.

m,p-xylene. Employment was the strongest factor for 1,1,1-trichloroethane, tetrachloroethylene, and *o*-xylene.

Daytime air. The daytime personal air exposures reflect the working and commuting period. Employment in plastics, wood processing, service station/garages, painting, textiles, metals, scientific laboratories, dye plants, and hospitals was associated with significantly increased exposures to nine of the eleven chemicals. Close contact with smokers was the strongest explanatory variable for daytime exposures to benzene.

Overnight air. Overnight personal air exposures were essentially indoor samples. A smoker in the home was the strongest determinant of indoor concentrations of benzene, styrene, ethylbenzene, and *m,p*-xylene.

New Jersey—Summer 1982

A second trip to New Jersey took place in July-August 1982. A subset of 160 of the original participants was monitored.

Breath. Again, smoking was the strongest determinant of breath values of benzene, styrene, ethylbenzene, and *m,p*-xylene (Table A-4). Dry cleaners exposure led to a ten-fold ($e^{2\,39}$) increase in geometric mean breath levels of tetrachloroethylene for those exposed.

Overnight personal air. Homes with window air conditioning and circulating fans (which tend to reduce outdoor ventilation) had significantly higher levels of five chemicals, and homes with window fans had lower levels of another chemical (Table A-5). Self-reported exposure to auto exhaust was also associated with increased exposure to aromatics.

Daytime personal air Employment-related exposures—particularly metalwork and chemical plant exposures were associated with sharp (up to $e^{2\,9}$ = 18-fold) increases in daytime exposure (Table A-6). Auto-related activities (travel time, visits to service stations) were associated with increased exposure to aromatics associated with gasoline.

New Jersey—Winter 1983

A subset of 49 participants were monitored in the third season (February 1983) in New Jersey.

Breath. Smoking was again most strongly correlated with breath levels of benzene and styrene, and was second in importance to solvent exposure for the xylenes (Table A-7). Other important variables for aromatics exposure were race (whites having higher values); exposure to dust and particulates; living in a house for more than 10 years; and, for styrene only, having a gas furnace.

Chlorinated compounds again had few variables associated with higher breath levels. Females showed higher exposure to trichloroethylene.

Overnight Personal Air. Gas furnaces were associated with increased levels of aromatics in homes (Table A-8). Employment, sex (male), and smoking were also associated with significantly elevated exposures.

Daytime Personal Air. Occupational exposure was implicated in increased daytime exposure to four aromatic compounds (Table A-9). Solvent exposure was specifically identified by the regression. Again, gas furnaces were associated with increased exposures to aromatics. Persons reporting exposure to auto exhaust showed higher exposures to benzene.

Los Angeles—February 1984

Three visits to California were carried out in 1984. In the first visit, 117 participants were monitored in Los Angeles. Five new chemicals (octane, decane, undecane, dodecane, and α-pinene) were observed in greater than 25% of all samples.

Table A-4. Stepwise Regression Results: Breath—New Jersey, Summer 1982

Chemical	*Variable*	*b^a*	*S.E.^{b}*	*F^c*	*p^d*
Aromatic Hydrocarbons					
Benzene	*Smoked*	2.38	0.61	15	0.0002
(R^2 = 0.16)	*Home pesticide treatment*	1.03	0.39	7.1	0.009
	Over 200 lbs	2.18	1.01	4.6	0.03
Styrene	*Smoked*	1.16	0.29	16	0.0001
(0.10)					
Ethylbenzene	*Smoked*	1.46	0.38	15	0.0002
(0.14)	*Exposed to chemicals*	2.04	0.70	8.4	0.004
o-*Xylene*	*Adult*	1.02	0.41	6.1	0.02
(0.09)	*Exposed to chemicals*	1.81	0.74	6.0	0.02
m,p-*Xylene*	*Smoked*	1.25	0.41	9.5	0.002
(0.14)	*Employed*	1.15	0.42	7.4	0.007
	Paint exposure	1.72	0.83	4.3	0.04
Chlorinated Hydrocarbons					
Chloroform	*Home pesticide treatment*	0.78	0.30	6.6	0.01
(0.08)					
1,1,1-Trichloroethane	*Auto travel (day)*	0.54	0.15	13	0.0003
(0.14)	*Nonwhite*	0.94	0.39	5.8	0.02
Carbon Tetrachloride	*None*				
Trichloroethylene	*Auto travel*	0.52	0.16	10	0.002
(0.13)	*Dust/particulate exp.*	1.48	0.61	6.0	0.02
	Nonwhite	1.00	0.44	5.2	0.02

Table A-4. (continued)

Chemical	Variable	b[a]	S.E.[b]	F[c]	p[d]
Tetrachloroethylene (0.15)	*Dry cleaner exposure*	2.39	0.91	6.9	0.01
	Adult	0.76	0.32	5.6	0.02
m,p-*Dichlorobenzene* (0.03)	*Child*	−1.55	0.71	4.7	0.03

[a] Coefficient of the questionnaire variable, e.g., persons who smoked had $e^{2.38}$ = 10.8 times as much benzene in their breath as persons who did not smoke.

[b] Standard error.

[c] F-value of the comparison of the two groups.

[d] Probability that there is no difference in geometric means of the two groups.

Table A-5. Stepwise Regression Results: Overnight Personal Air—New Jersey, Summer 1982

Chemical	Variable	b	S.E.	F	p
Aromatic Hydrocarbons					
Benzene	*None*				
Styrene (R^2 = 0.11)	*Window air conditioner*	0.62	0.21	8.8	0.003
	Auto exhaust	0.58	0.24	5.6	0.02
	Toxics exposure	0.67	0.32	4.4	0.04
Ethylbenzene (0.05)	*Window air conditioner*	0.71	0.25	8.0	0.005

Table A-5. ***(continued)***

Chemical	*Variable*	*b*	*S.E.*	*F*	*p*
o-*Xylene*	*Window air conditioner*	*0.80*	*0.22*	*7.3*	*0.008*
(0.07)	*Gas stove*	*0.74*	*0.37*	*4.0*	*0.05*
m,p-*Xylene*	*Window air conditioner*	*0.75*	*0.25*	*9.0*	*0.003*
(0.08)	*Auto exhaust*	*0.64*	*0.30*	*4.7*	*0.03*
Chloroform	*Degreasers exposure*	*2.05*	*0.76*	*7.2*	*0.008*
(0.07)	*Window fan*	*−0.64*	*0.32*	*4.1*	*0.05*
Chlorinated Hydrocarbons					
1,1,1-Trichloroethane	*None*				
Carbon Tetrachloride	*Gardening*	*0.41*	*0.17*	*6.0*	*0.02*
(0.06)	*Over 65 years old*	*−0.47*	*0.22*	*4.7*	*0.03*
Trichloroethylene *(0.04)*	*Employed*	*0.64*	*0.26*	*6.2*	*0.01*
Tetrachloroethylene *(0.04)*	*Circulating fan*	*0.73*	*0.28*	*6.6*	*0.01*
m,p-*Dichlorobenzene*	*None*				

See footnotes to Table A-4 for explanation of headings.

Table A-6. Stepwise Regression Results: Daytime Personal Air—New Jersey, Summer 1982

Chemical	Variable	b	S.E.	F	p
Aromatic Hydrocarbons					
Benzene	*Chemical exposure*	2.48	0.71	12	0.0006
$(R^2 = 0.13)$	*Window fan*	−1.22	0.41	9	0.003
Styrene	*Toxics exposure*	0.97	0.41	5.7	0.02
(0.07)	*Garage/serv. sta. exp.*	0.64	0.28	5.1	0.03
Ethylbenzene	*Metalwork*	2.90	0.82	12	0.0006
(0.18)	*Auto travel*	0.38	0.12	10	0.002
	Window air conditioner	0.70	0.33	4.5	0.04
o-*Xylene*	*Auto travel*	0.41	0.11	13	0.0004
(0.25)	*Metalwork*	2.52	0.76	11	0.001
	Window air conditioner	0.83	0.31	7.4	0.007
	Employed	0.64	0.26	6.0	0.02
m,p-*Xylene*	*Auto travel*	0.50	0.13	15	0.0001
(0.19)	*Window air conditioner*	1.01	0.36	7.8	0.006
	Metalwork	2.33	0.89	6.8	0.01
Chloroform	*Degreasers exposure*	2.13	0.83	6.6	0.01
(0.04)					
Chlorinated Hydrocarbons					
1,1,1-Trichloroethane	*Metalwork*	2.83	1.16	6.0	0.02
(0.04)					
Carbon Tetrachloride	*Chemical exposure*	0.62	0.23	7.0	0.01
(0.05)					

Table A-6. (continued)

Chemical	Variable	b	S.E.	F	p
Trichloroethylene (0.05)	Dust/particle exposure	1.18	0.44	7.2	0.008
Tetrachloroethylene (0.04)	Dust/particle exposure	1.09	0.45	5.8	0.02
m,p-Dichlorobenzene (0.04)	Smoked	0.73	0.29	6.2	0.01

See footnotes to Table A-4 for explanation of headings

Table A-7. Stepwise Regression Results: Breath—New Jersey, (Winter 1983)

Chemical	*Variable*	*b*	*S.E.*	*F*	*p*
Aromatic Hydrocarbons					
Benzene	*Smoker*	1.19	0.33	13	0.0007
(R^2 = 0.32)	*White*	1.06	0.42	4.6	0.01
	Solvents	1.01	0.48	4.4	0.04
Styrene	*Smoker*	1.20	0.23	27	0.0001
(0.42)	*Gas furnace*	0.60	0.23	6.6	0.01
	White	0.69	0.31	5.1	0.03
Ethylbenzene	*Old house*	−0.70	0.21	11	0.002
(0.52)	*Smoker*	0.66	0.21	9.7	0.003
	White	0.76	0.28	7.6	0.009
	Dust exposure	0.68	0.28	5.8	0.02
	Solvents	0.75	0.31	5.7	0.02
o-*Xylene*	*Solvents*	0.96	0.30	10	0.002
(0.42)	*Smoker*	0.58	0.20	8.4	0.006
	Old house	−0.57	0.21	7.4	0.009
	White	0.69	0.27	6.6	0.01
m,p-*Xylene*	*Old house*	−0.65	0.20	11	0.002
(0.48)	*Solvents*	0.76	0.30	6.5	0.01
	Smoker	0.49	0.20	5.8	0.02
	Dust exposure	0.59	0.27	4.8	0.03
Chlorinated Hydrocarbons					
1,1,1-Trichloroethane (0.18)	*Dust exposure*	2.00	0.62	10	0.002
Carbon tetrachloride (0.28)	*No occup. exposure*	0.21	0.05	18	0.0001
Trichloroethylene	*Dust exposure*	1.24	0.48	6.6	0.01
(0.17)	*Female*	0.88	0.38	5.4	0.02
Tetrachloroethylene (0.14)	*Old house*	−0.81	0.29	7.6	0.008
Chloroform	*None*				
m,p-*Dichlorobenzene*	*None*				

See footnotes to Table A-4 for explanation of headings.

Table A-8. Stepwise Regression Results: Overnight Personal Air—New Jersey, (Feb. 1983)

Chemical	*Variable*	*b*	*S.E.*	*F*	*p*
Aromatic Hydrocarbons					
Benzene	*Gas furnace*	*0.68*	*0.27*	*6.5*	*0.01*
$(R^2 = 0.28)$	*Male*	*0.62*	*0.28*	*4.8*	*0.03*
	Smoker	*0.58*	*0.27*	*4.6*	*0.04*
Styrene	*No occ. exposure*	*1.19*	*0.42*	*8.2*	*0.006*
(0.25)	*Male*	*0.67*	*0.30*	*5.1*	*0.03*
	Employed	*0.66*	*0.30*	*4.7*	*0.04*
Ethylbenzene	*Gas furnace*	*0.73*	*0.27*	*7.1*	*0.01*
(0.14)					
o-*Xylene*	*Gas furnace*	*0.65*	*0.24*	*7.6*	*0.008*
(0.25)	*Employed*	*0.59*	*0.25*	*5.8*	*0.02*
m,p-*Xylene*	*Gas furnace*	*0.70*	*0.24*	*8.4*	*0.006*
(0.15)					
Chlorinated Hydrocarbons					
1,1,1-Trichloroethane	*None*				
Tetrachloroethylene	*None*				
Carbon tetrachloride	*Employed*	*0.64*	*0.22*	*8.7*	*0.005*
(0.20)	*Nonwhite*	*0.65*	*0.27*	*5.8*	*0.02*
m,p-*Dichlorobenzene*	*None*				
Chloroform	*None*				
Trichloroethylene	*No occ exposure*	*2.14*	*0.54*	*16*	*0.0003*
(0.27)	*Male*	*0.91*	*0.40*	*5.2*	*0.03*

See footnotes to Table A-4 for explanation of headings.

Table A-9. Stepwise Regression Results: Daytime Personal Air—New Jersey, (Feb. 1983)

Chemical	*Variable*	*b*	*S.E.*	*F*	*p*
Aromatic Hydrocarbons					
Benzene	*Auto exhaust*	*0.68*	*0.30*	*5.2*	*0.03*
$(R^2 = 0.11)$					
Styrene	*Occup. exp.*	*0.79*	*0.33*	*5.8*	*0.02*
(0.12)					
Ethylbenzene	*Occup. exp.*	*0.99*	*0.29*	*12*	*0.001*
(0.51)	*Solvent exp.*	*1.35*	*0.41*	*11*	*0.002*
	Gas furnace	*0.69*	*0.26*	*5.7*	*0.02*
o-*Xylene*	*Occup. exp.*	*1.06*	*0.28*	*15*	*0.0004*
(0.54)	*Solvent exp.*	*1.32*	*0.40*	*11*	*0.002*
	Gas furnace	*0.65*	*0.25*	*6.9*	*0.01*

Table A-9. (continued)

Chemical	*Variable*	*b*	*S.E*	*F*	*p*
m,p-*Xylene* *(0.50)*	*Solvent exp.*	*1.28*	*0.39*	*11*	*0.002*
	Occup. exp.	*0.85*	*0.27*	*10*	*0.003*
	Gas furnace	*0.68*	*0.24*	*7.7*	*0.008*
Chlorinated Hydrocarbons					
1,1,1-Trichloroethane	*None*				
Tetrachloroethylene	*None*				
Carbon tetrachloride	*None*				
m,p-*Dichlorobenzene*	*None*				
Chloroform	*None*				
Trichloroethylene *(0.12)*	*No exposure*	*1.46*	*0.59*	*6.2*	*0.02*

See footnotes to Table A-4 for explanation of headings.

Breath. Auto-related variables (exposure to auto exhaust, pumping gasoline, and visiting a service station) were associated with significantly increased breath concentrations of benzene, ethylbenzene, *o*-xylene, *m,p*-xylene, decane, and undecane (Table A-10) Smoking continued to be the most important determinant of breath concentrations of benzene, styrene, ethylbenzene, *o*-xylene, and *m,p*-xylene; among the new chemicals monitored in California, only octane appeared to be strongly related to smoking. Employment was associated with increased exposures to carbon tetrachloride, trichloroethylene, styrene, and ethylbenzene.

Overnight personal air. Once again a smoker in the home was the most important determinant of indoor air concentrations of benzene, styrene, ethylbenzene, and *m,p*-xylene (Table A-11). Undecane and dodecane also showed smoking-related increases, as did 1,1,1-trichloroethane and α-pinene. Homes with circulating fans rather than air conditioning or exhaust fans showed elevated levels of six chemicals. Pesticide exposures were associated with increased indoor air concentrations of five chemicals. Self-reported exposures to solvents were associated with increased indoor air concentrations of three chemicals. Gardening (which requires extended outdoor activity) was associated with significantly *reduced* overnight personal exposures to two chemicals.

Daytime personal air. Employment, smoking, and auto-related activities continued to be significantly related to increased daytime personal exposures (Table A-12) Females appeared to have increased exposure to trichloroethylene.

Los Angeles—May 1984

A subset of 52 of the 117 February participants were monitored in May.

Breath. Smoking-related variables continued to significantly increase breath concentrations of all five aromatics, and also octane, decane, and undecane (Table A-13) Auto travel continued to be important for several chemicals, as did employment.

Overnight personal air Age (over 65) and race (Hispanic) appeared a number of times in connection with decreased and increased overnight exposures, respectively (Table A-14). Smoking in the home was *not* related to increased concentrations of any of the aromatics or other hydrocarbons, perhaps due to more open homes in May with increased air exchange.

Daytime personal air. Auto-related activities and employment were most important in increased daytime exposures to eight chemicals (Table A-15). Age (over 65) and gardening again had "protective" effects

Contra Costa—June 1984

The final TEAM trip recruited 71 residents of Antioch and Pittsburg in Contra Costa County, California

Breath Smoking was again the strongest determinant of breath concentrations of the five aromatics and octane (Table A-16) Employment increased exposures to five chemicals Once again females were associated with higher exposures to trichloroethylene. Children (under 12) were less exposed, and males more highly exposed, to several chemicals

Overnight personal air. Night-time auto travel resulted in increased exposures to benzene, ethylbenzene, and the xylenes (Table A-17) Children under 12 and gardeners had reduced exposures

Daytime personal air. Auto-related activities were most prominent in increased exposures (Table A-18).

Table A-10. Stepwise Regression Results: Breath—Los Angeles (Feb. 1984)

Chemical	*Variable*	*b*	*S.E.*	*F*	*p*
Aromatic Hydrocarbons					
Benzene	*Smoked*	*1.85*	*0.27*	*47*	*0.0001*
(R^2 = 0.32)	*Auto exhaust*	*0.63*	*0.32*	*3.9*	*0.05*
Styrene	*Smoked*	*1.56*	*0.34*	*21*	*0.0001*
(0.28)	*Dust/part. exp.*	*1.55*	*0.45*	*12*	*0.0008*
	Occup. exp.	*0.92*	*0.37*	*6.1*	*0.02*
Ethylbenzene	*Smoked*	*1.37*	*0.21*	*43*	*0.0001*
(0.42)	*Dust/part. exp.*	*0.81*	*0.28*	*8.3*	*0.005*
	Pumped gas	*0.88*	*0.32*	*7.8*	*0.006*
	Paint exp.	*0.68*	*0.29*	*5.4*	*0.02*
o-*Xylene*	*Smoked*	*0.82*	*0.15*	*28*	*0.0001*
(0.24)	*Garage/serv. station exp.*	*0.50*	*0.18*	*6.8*	*0.006*
m,p-*Xylene*	*Smoked*	*1.02*	*0.16*	*40*	*0.0001*
(0.33)	*Garage/serv. station exp.*	*0.67*	*0.19*	*12*	*0.0007*
	Clean. material	*0.53*	*0.23*	*5.3*	*0.02*
	Dust/part. exp.	*0.45*	*0.22*	*4.3*	*0.04*
Other Hydrocarbons					
Octane	*Smoked*	*0.83*	*0.24*	*12*	*0.0009*
(0.10)					

Table A-10. (continued)

Chemical	*Variable*	*b*	*S.E.*	*F*	*p*
Decane *(0.07)*	*Clean. material*	*1.09*	*0.44*	*6.2*	*0.01*
	Garage/serv. station exp.	*0.83*	*0.35*	*5.6*	*0.02*
Undecane *(0.23)*	*Unexposed nonsmoker*	*-0.89*	*0.27*	*11*	*0.001*
	Dust/part. exp.	*1.13*	*0.35*	*11*	*0.001*
	Garage/serv. station exp.	*0.74*	*0.30*	*6.2*	*0.01*
	Employed	*-0.63*	*0.27*	*5.4*	*0.02*
	Auto exhaust	*-0.72*	*0.31*	*5.3*	*0.02*
	Gas stove	*0.54*	*0.26*	*4.3*	*0.04*
Dodecane *(0.11)*	*Window fan*	*0.48*	*0.15*	*11*	*0.002*
	Dust/part. exp.	*0.43*	*0.18*	*5.8*	*0.02*
α-Pinene	*None*				
Chlorinated Hydrocarbons					
Chloroform *(0.17)*	*Auto exhaust*	*1.04*	*0.40*	*6.8*	*0.01*
	Adult	*0.86*	*0.33*	*6.8*	*0.01*
	Pesticide exp.	*-1.72*	*0.69*	*6.3*	*0.01*
1,1,1-Trichloroethane *(0.20)*	*Adult*	*0.77*	*0.25*	*9.6*	*0.002*
	Smoked	*0.77*	*0.26*	*9.0*	*0.003*
Carbon tetrachloride *(0.04)*	*Painter*	*0.45*	*0.22*	*4.1*	*0.04*
Trichloroethylene *(0.06)*	*Employed*	*0.91*	*0.34*	*7.1*	*0.009*
Tetrachloroethylene *(0.19)*	*Smoked*	*0.63*	*0.17*	*14*	*0.0003*
	Gas stove	*-0.53*	*0.17*	*9.5*	*0.003*
p-*Dichlorobenzene*	*None*				

See footnotes to Table A-4 for explanation of headings.

Table A-11. Stepwise Regression Results: Overnight Personal Air— Los Angeles (Feb. 1984)

Chemical	*Variable*	*b*	*S.E.*	*F*	*p*
Aromatic Hydrocarbons					
Benzene *(R^2 = 0.18)*	*Smoker in home*	*0.41*	*0.12*	*11*	*0.001*
	Exposed/daytime	*-0.46*	*0.15*	*10*	*0.002*
	Circulating fan	*0.31*	*0.13*	*5.9*	*0.02*
Styrene *(0.17)*	*Smoker in home*	*0.70*	*0.19*	*13*	*0.0004*
	Circulating fan	*0.61*	*0.20*	*9.0*	*0.003*
	Hispanic	*-0.65*	*0.26*	*6.0*	*0.02*
Ethylbenzene *(0.21)*	*Smoker in home*	*0.42*	*0.12*	*12*	*0.0009*
	Circulating fan	*0.42*	*0.13*	*10*	*0.002*
	Exposed/daytime	*-0.39*	*0.15*	*7.0*	*0.01*
	Solvent exp.	*0.43*	*0.20*	*4.6*	*0.03*

Table A-11. (continued)

Chemical	Variable	b	S.E.	F	p
o-*Xylene*	*Circulating fan*	0.38	0.12	9.8	0.002
(0.19)	*Smoker in home*	0.34	0.12	8.6	0.004
	Exposed/daytime	0.35	0.14	6.6	0.01
	Solvent exp.	0.40	0.18	4.8	0.03
m,p-*Xylene*	*Smoker in home*	0.32	0.11	9.1	0.003
(0.12)	*Pesticide exp.*	0.65	0.26	6.3	0.01
Other Hydrocarbons					
Octane	*Circulating fan*	0.48	0.17	8.2	0.005
(0.10)	*Solvent exp.*	0.61	0.25	5.9	0.02
Decane	*Dust/part. exp.*	0.99	0.41	5.7	0.02
(0.05)					
Undecane	*Smoker in home*	0.38	0.16	5.5	0.02
(0.12)	*Gardening*	-0.44	0.19	5.1	0.03
	Pesticide exp.	0.86	0.40	4.8	0.03
Dodecane	*Gardening*	-0.78	0.20	15	0.0002
(0.17)	*Pesticide exp.*	1.14	0.42	7.3	0.008
	Smoked at night	0.41	0.20	4.1	0.04
α-Pinene	*Circulating fan*	0.47	0.20	5.7	0.02
(0.10)	*Hispanic*	-0.58	0.26	5.1	0.03
	Smoker in home	0.39	0.19	4.4	0.04
Chlorinated Hydrocarbons					
Chloroform	*Pesticide exp.*	0.92	0.39	5.4	0.02
(0.05)					
1,1,1-Trichloroethane	*Smoker in home*	0.59	0.19	9.5	0.002
(0.08)					
Carbon tetrachloride	*None*				
Trichloroethylene	*Pesticide exp.*	2.23	0.69	10	0.002
(0.09)					
Tetrachloroethylene	*Solvent exp.*	0.58	0.25	5.2	0.02
(0.05)					
p-*Dichlorobenzene*	*None*				

See footnotes to Table A-4 for explanation of headings.

Table A-12. Stepwise Regression Results: Daytime Personal Air—Los Angeles (Feb. 1984)

Chemical	Variable	b	S.E.	F	p
Aromatic Hydrocarbons					
Benzene	*Auto travel*	0.0026	0.0012	4.6	0.03
(R^2 = 0.04)					

Table A-12. (continued)

Chemical	*Variable*	*b*	*S.E.*	*F*	*p*
Styrene	*Toxics. exp.*	*1.16*	*0.35*	*11*	*0.001*
(0.16)	*Smoked/daytime*	*0.55*	*0.18*	*9.1*	*0.003*
Ethylbenzene	*Clean. materials*	*0.67*	*0.23*	*8.7*	*0.004*
(0.18)	*Smoked/daytime*	*0.42*	*0.18*	*5.8*	*0.02*
	Travel time	*0.0036*	*0.0015*	*5.6*	*0.02*
	Hispanic	*−0.43*	*0.21*	*4.0*	*0.05*
o-*Xylene*	*Female*	*0.40*	*0.16*	*5.8*	*0.02*
(0.18)	*Smoked/daytime*	*0.45*	*0.19*	*5.5*	*0.02*
	Employed	*0.41*	*0.18*	*5.4*	*0.02*
	Solvent exp.	*0.52*	*0.25*	*4.4*	*0.04*
m,p-*Xylene*	*Paint exp.*	*0.53*	*0.19*	*7.4*	*0.008*
(0.15)	*Hispanic*	*−0.41*	*0.18*	*5.4*	*0.02*
	Smoker in home	*0.28*	*0.13*	*5.0*	*0.03*
Other Hydrocarbons					
Octane	*None*				
Decane	*Employed*	*0.77*	*0.27*	*8.2*	*0.005*
(0.20)	*Paint exp.*	*1.11*	*0.39*	*8.0*	*0.006*
	Pumped gas	*1.03*	*0.41*	*6.4*	*0.01*
Undecane	*Pumped gas*	*1.02*	*0.33*	*10*	*0.002*
(0.13)	*Paint exp.*	*0.82*	*0.31*	*6.9*	*0.01*
Dodecane	*None*				
α-Pinene *(0.06)*	*Gas stove*	*−0.58*	*0.22*	*6.6*	*0.01*
Chlorinated Hydrocarbons					
Chloroform	*None*				
1,1,1-Trichloroethane	*Smoked/daytime*	*0.88*	*0.26*	*11*	*0.001*
(0.16)	*Toxics exp.*	*1.59*	*0.52*	*9.5*	*0.003*
Carbon Tetrachloride *(0.09)*	*Toxics exp.*	*0.98*	*0.30*	*11*	*0.001*
Trichloroethylene *(0.06)*	*Female*	*0.96*	*0.36*	*7.2*	*0.008*
Tetrachloroethylene	*Hispanic*	*−0.71*	*0.24*	*8.9*	*0.004*
(0.13)	*Toxics exp.*	*1.05*	*0.38*	*7.6*	*0.007*
p-*Dichlorobenzene*	*None*				

See footnotes to Table A-4 for explanation of headings.

Table A-13. Stepwise Regression Results: Breath—Los Angeles (May 1984)

Chemical	Variable	b	S.E.	F	p
Aromatic Hydrocarbons					
Benzene	*Employed*	2.55	0.62	17	0.0001
(R^2 = 0.34)	*Smoked*	1.67	0.70	5.7	0.02
Styrene	*Smoked*	2.59	0.51	26	0.0001
(0.40)	*Old*	−1.27	0.60	4.4	0.04
Ethylbenzene	*Smoked*	1.75	0.31	31	0.0001
(0.50)	*Employed*	0.81	0.27	9.0	0.004
o-*Xylene*	*Smoked*	1.19	0.34	12	0.001
(0.35)	*Employed*	0.88	0.29	9.1	0.004
m,p-*Xylene*	*Smoked*	1.27	0.26	24	0.0001
(0.46)	*Employed*	0.69	0.22	9.5	0.004
Other Hydrocarbons					
Octane	*Smoker in home*	1.10	0.28	16	0.0002
(0.28)	*Male*	0.58	0.28	4.3	0.04
Decane (0.10)	*Smoker in home*	0.72	0.30	5.6	0.02
Undecane	*Pesticide exp.*	1.42	0.58	6.1	0.02
(0.21)	*Smoker in home*	0.78	0.36	4.6	0.04
	Auto travel	0.007	0.003	4.2	0.05
Dodecane (0.14)	*Auto travel*	0.006	0.002	7.8	0.007
α-Pinene (0.09)	*Auto exhaust*	−0.91	0.41	5.0	0.03
Chlorinated Hydrocarbons					
Chloroform	*None*				
1,1,1-Trichloroethane	*High exp.*	1.59	0.53	9.0	0.004
(0.22)	*Old*	−1.46	0.74	3.9	0.05
Carbon Tetrachloride	*None*				
Trichloroethylene	*None*				
Tetrachloroethylene (0.13)	*Employed*	0.76	0.29	7.0	0.01
p-*Dichlorobenzene*	*None*				

See footnotes to Table A-4 for explanation of headings.

Table A-14. ***Stepwise Regression Results: Overnight Personal Air— Los Angeles (May 1984)***

Chemical	*Variable*	*b*	*S.E.*	*F*	*p*
Aromatic Hydrocarbons					
Benzene	*None*				
Styrene	*Circulating fan*	*1.08*	*0.44*	*6.1*	*0.02*
(R^2 = 0.18)	*High exp. act.*	*−0.99*	*0.43*	*5.2*	*0.03*
Ethylbenzene	*Hispanic*	*1.04*	*0.41*	*6.4*	*0.01*
(0.20)	*Old*	*−1.08*	*0.47*	*5.2*	*0.03*
o-*Xylene*	*Old*	*−1.85*	*0.50*	*14*	*0.0005*
(0.32)	*Hispanic*	*1.15*	*0.43*	*7.1*	*0.01*
m,p-*Xylene*	*Hispanic*	*0.95*	*0.34*	*8.0*	*0.007*
(0.25)	*Old*	*−1.03*	*0.39*	*7.0*	*0.01*
Other Hydrocarbons					
Octane *(0.14)*	*Hispanic*	*0.90*	*0.32*	*8.2*	*0.006*
Decane *(0.17)*	*Hispanic*	*1.42*	*0.46*	*9.6*	*0.003*
Undecane	*Hispanic*	*1.07*	*0.46*	*5.5*	*0.02*
(0.19)	*Pesticide exp.*	*1.10*	*0.50*	*4.8*	*0.03*
Dodecane	*Pesticide exp.*	*1.31*	*0.45*	*8.4*	*0.006*
(0.27)	*Old*	*−0.97*	*0.48*	*4.2*	*0.05*
α-Pinene	*None*				
Chlorinated Hydrocarbons					
Chloroform	*High exp. act.*	*1.46*	*0.40*	*13*	*0.0008*
(0.27)	*Smoker in home*	*1.07*	*0.40*	*7.1*	*0.01*
	Employed	*−0.89*	*0.43*	*4.2*	*0.05*
1,1,1-Trichloroethane	*None*				
Carbon tetrachloride *(0.12)*	*Old*	*−0.45*	*0.17*	*7.0*	*0.01*
Trichloroethylene	*None*				
Tetrachloroethylene	*None*				
m,p-*Dichlorobenzene*	*None*				

See footnotes to Table A-4 for explanation of headings.

Table A-15. ***Stepwise Regression Results: Daytime Personal Air—Los Angeles (May 1984)***

Chemical	*Variable*	*b*	*S.E.*	*F*	*p*
Aromatic Hydrocarbons					
Benzene	*Auto travel*	*0.007*	*0.002*	*15*	*0.0003*
(R^2 = 0.45)	*Odor. chem. exp.*	*0.68*	*0.27*	*6.3*	*0.02*
	Pumped gas	*0.72*	*0.36*	*4.0*	*0.05*
Styrene	*Old*	*−1.72*	*0.60*	*8.3*	*0.006*
(0.40)	*Gardening*	*1.34*	*0.50*	*7.2*	*0.01*
	Auto travel	*0.01*	*0.004*	*6.8*	*0.01*
	Smoked	*1.24*	*0.49*	*6.5*	*0.01*
	Gas stove	*−0.92*	*0.44*	*4.3*	*0.04*
Ethylbenzene	*Pumped gas*	*1.66*	*0.51*	*10*	*0.002*
(0.33)	*Employed*	*0.86*	*0.32*	*7.3*	*0.01*
o-*Xylene*	*Pumped gas*	*1.96*	*0.72*	*7.4*	*0.009*
(0.25)	*Auto travel*	*0.009*	*0.004*	*5.8*	*0.02*
m,p-*Xylene*	*Pumped gas*	*1.12*	*0.47*	*5.7*	*0.02*
(0.35)	*Employed*	*0.69*	*0.31*	*5.0*	*0.03*
	Auto travel	*0.005*	*0.003*	*4.1*	*0.05*
Other Hydrocarbons					
Octane *(0.12)*	*Pumped gas*	*1.33*	*0.51*	*6.8*	*0.01*
Decane *(0.13)*	*Old*	*−1.37*	*0.50*	*7.6*	*0.008*
Undecane	*None*				
Dodecane	*Gardening*	*−1.43*	*0.42*	*12*	*0.001*
(0.21)	*Pesticide exp.*	*1.05*	*0.45*	*5.3*	*0.03*
α-Pinene *(0.08)*	*Gas stove*	*−1.03*	*0.49*	*4.4*	*0.04*
Chlorinated Hydrocarbons					
Chloroform	*None*				
1,1,1-Trichloroethane *(0.08)*	*Old*	*−1.23*	*0.59*	*4.3*	*0.04*
Carbon tetrachloride *(0.11)*	*Employed*	*0.42*	*0.17*	*5.8*	*0.02*
Trichloroethylene	*None*				
Tetrachloroethylene *(0.10)*	*Employed*	*0.99*	*0.41*	*5.7*	*0.02*
m,p-*Dichlorobenzene*	*None*				

See footnotes to Table A-4 for explanation of headings.

Table A-16. Stepwise Regression Results: Breath—Contra Costa (June 1984)

Chemical	Variable	b	S.E.	F	p
Aromatic Hydrocarbons					
Benzene	*Smoked*	2.70	0.39	47	0.0001
(0.53)	*Window fan*	1.44	0.37	15	0.0002
Styrene	*Smoked*	1.14	0.31	13	0.0005
(0.42)	*Male*	0.84	0.29	8.5	0.005
	Child	−1.27	0.47	7.5	0.008
	Gardening	−0.74	0.29	6.7	0.01
Ethylbenzene	*Smoked*	1.48	0.30	25	0.0001
(0.47)	*Male*	1.06	0.27	15	0.0003
	Window fan	0.69	0.28	6.2	0.02
o-*Xylene*	*Male*	1.07	0.26	17	0.0001
(0.43)	*Smoked*	1.03	0.28	14	0.0005
	Window fan	0.76	0.26	8.3	0.005
m,p-*Xylene*	*Smoked*	1.32	0.33	16	0.0001
(0.46)	*Male*	1.13	0.31	14	0.0005
	Window fan	0.73	0.30	5.9	0.02
	Child	−1.08	0.49	4.9	0.03
Other Hydrocarbons					
Octane *(0.16)*	*Smoked*	1.00	0.29	12	0.0009
Decane *(0.07)*	*Employed*	0.56	0.26	4.5	0.04
Undecane *(0.09)*	*Cleanser exp.*	−0.79	0.32	6.1	0.02
Dodecane	*None*				
α-Pinene	*Gas stove*	−1.10	0.43	7.3	0.009
(0.08)	*Circulating fan*	−0.76	0.31	5.9	0.02
Chlorinated Hydrocarbons					
Chloroform	*None*				
1,1,1-Trichloroethane	*Window fan*	1.75	0.61	8.1	0.006
(0.18)	*Solvent exp.*	2.46	1.16	4.5	0.04
Carbon tetrachloride	*Child*	−0.72	0.28	6.8	0.01
(0.17)	*Circulating fan*	−0.44			
Trichloroethylene	*Solvent exp.*	1.91	0.59	10	0.002
(0.18)	*Female*	0.65	0.31	4.4	0.04
Tetrachloroethylene *(0.09)*	*High exp. act.*	1.23	0.47	6.8	0.01
m,p-*Dichlorobenzene* *(0.08)*	*Painter*	4.19	1.54	7.4	0.008

See footnotes to Table A-4 for explanation of headings.

Table A-17. Stepwise Regression Results: Overnight Personal Air—Contra Costa (June 1984)

Chemical	Variable	b	S.E.	F	p
Aromatic Hydrocarbons					
Benzene *(0.53)*	*Auto travel (night)*	0.004	0.002	4.3	0.04
Styrene *(0.13)*	*Hispanic*	1.14	0.53	4.6	0.04
	Smoked/night	0.63	0.31	4.2	0.04
Ethylbenzene *(0.06)*	*Auto travel (night)*	0.004	0.002	4.0	0.05
o-*Xylene* *(0.06)*	*Auto travel (night)*	0.004	0.002	4.4	0.04
m,p-*Xylene* *(0.06)*	*Auto travel (night)*	0.003	0.002	4.4	0.04
Other Hydrocarbons					
Octane *(0.10)*	*Smoker in home*	−0.48	0.21	5.2	0.02
	Auto travel (night)	0.004	0.002	4.6	0.04
Decane *(0.15)*	*Pesticide treatment*	−0.38	0.16	5.6	0.02
	Circulating fan	−0.56	0.25	5.3	0.02
Undecane *(0.12)*	*Circulating fan*	−0.65	0.25	7.1	0.01
	Hobby: models	1.21	0.59	4.3	0.04
Dodecane	*None*				
α-Pinene *(0.09)*	*Smoker in home*	−0.63	0.25	6.5	0.01
Chlorinated Hydrocarbons					
Chloroform	*None*				
1,1,1-Trichloroethane *(0.08)*	*Circulating fan*	1.75	0.61	8.1	0.006
Carbon tetrachloride *(0.09)*	*Gardening*	−0.57	0.22	6.6	0.01
Trichloroethylene *(0.06)*	*Gardening*	−0.69	0.33	4.3	0.04
Tetrachloroethylene *(0.08)*	*Circulating fan*	−0.73	0.29	6.2	0.02
m,p-*Dichlorobenzene* *(0.24)*	*Gas stove*	2.22	0.58	14	0.0003
	Hispanic	2.14	0.73	8.5	0.005
	Child	−1.25	0.61	4.2	0.04

See footnotes to Table A-4 for explanation of headings.

Table A-18. Stepwise Regression Results: Daytime Personal Air—Contra Costa (June 1984)

Chemical	*Variable*	*b*	*S.E.*	*F*	*p*
Aromatic Hydrocarbons					
Benzene	*Window/ceiling fan*	0.56	0.16	13	0.0007
(0.24)	*Auto travel night*	0.003	0.001	6.0	0.02
Styrene	*Employed*	0.57	0.26	4.8	0.03
(0.18)	*Auto exhaust exp.*	0.59	0.29	4.2	0.04
Ethylbenzene	*Window/ceiling fan*	0.77	0.19	16	0.0001
(0.32)	*Service station exp.*	0.62	0.21	8.7	0.004
o-*Xylene*	*Window/ceiling fan*	0.69	0.18	14	0.0004
(0.29)	*Service station exp.*	0.57	0.20	8.0	0.006
m,p-*Xylene*	*Service station exp.*	0.72	0.27	6.9	0.01
(0.17)	*Auto exhaust exp.*	0.57	0.28	4.1	0.05
Other Hydrocarbons					
Octane	*Hispanic*	1.10	0.38	8.3	0.005
(0.19)	*Service station exp.*	0.62	0.22	7.9	0.006
Decane	*Employed*	0.94	0.25	14	0.0004
(0.43)	*Hispanic*	1.43	0.45	10	0.002
	Service station exp.	0.72	0.27	7.2	0.009
Undecane	*Solvent exp.*	2.04	0.52	15	0.0002
(0.30)	*Employed*	0.76	0.29	7.0	0.01
Dodecane *(0.15)*	*Solvent exp.*	2.08	0.62	11	0.001
α-Pinene *(0.06)*	*Dust/part. exp.*	1.02	0.50	4.2	0.05
Chlorinated Hydrocarbons					
Chloroform	*None*				
1,1,1-Trichloroethane *(0.17)*	*Solvent exp.*	2.04	0.55	14	0.0005
Carbon tetrachloride	*None*				
Trichloroethylene *(0.12)*	*Solvent exp.*	2.24	0.77	8.4	0.005
Tetrachloroethylene	*None*				
m,p-*Dichlorobenzene*	*Painter*	5.03	1.54	11	0.002
(0.35)	*Pesticide treat.*	−0.73	0.24	8.9	0.004
	Occup. exp.	1.17	0.44	7.1	0.01
	High dust/part. exp.	1.21	0.49	6.1	0.02

See footnotes to Table A-4 for explanation of headings.

Appendix B
Effect of Outdoor Air on Measures of Personal Exposure in New Jersey and California

As discussed in the text, an analysis was made of the effect of outdoor air on the exposures of New Jersey and California subjects. Only those persons who had outdoor measurements made near their homes were included in the analysis. In New Jersey, the number of persons with outdoor measurements was 85 in the fall of 1981, 71 in the summer of 1982, and 9 in the winter of 1983. (Because of the small number of outdoor measurements in the winter season, no analysis was made of those results.) In Los Angeles, 24 homes had outdoor measurements in both February and May of 1984. In Antioch and Pittsburg, 10 homes had outdoor measurements in June 1984.

The method of analysis was stepwise regression, using the model described in the text:

$$\ln C_{in} = a + b \ln C_{out} + \Sigma c_i q_i$$

where C_{in} = indoor concentration (or breath concentration or daytime personal air concentration)

C_{out} = outdoor air concentration

Q_i = questionnaire variables, generally indexed to 0 or 1

c_i = coefficients of the q_i

Using the rule that the number of variables should not be more than about one-quarter of the number of observations in a stepwise regression, the New Jersey data on 85 and 71 homes allowed about 20 variables to be included in the regression, while the California data allowed only six variables to be included for Los Angeles and only 3 for Antioch/Pittsburg. The larger number of homes in New Jersey made it possible to carry out the regression on all three measures of personal exposure (breath, daytime personal air, and overnight personal air); in California, however, only the overnight personal air in the residences, which is the most likely to be influenced by outdoor air near the residence, was employed in the regression.

As in other stepwise regressions, entry and retention values were set at $p < 0.15$. For the New Jersey data, the final model included only variables for which $p < 0.05$. For the California data, because of the smaller number of homes, a cutoff value of 0.10 was used to allow detection of possibly significant variables. (If the reader desires to use $p < 0.05$, he can of course refer to the listed p-values to identify those variables meeting that criterion.)

The fall 1981 results for New Jersey are summarized in Tables B-1 through B-3. For overnight personal air, which corresponds to indoor air in the residence for most of the subjects, only three chemicals showed a significant influence of outdoor air: benzene, carbon tetrachloride, and trichloroethylene (Table B-1). Five chemicals showed an effect of daytime outdoor air on daytime

Table B-1. ***Stepwise Regression Results For 87 New Jersey Homes with Outdoor Measurements: Overnight Personal Air—Fall 1981***

Chemical	*Variable*	b^a	*S.E.*^{b}	F^c	p^d
Aromatic Hydrocarbons					
Benzene (R^2 = 0.19)	*Outdoor benzene (night)*	*0.44*	*0.10*	*19*	*0.0001*
Styrene (0.04)	*Smoker in home*	*0.59*	*0.27*	*4.7*	*0.03*
Ethylbenzene (0.10)	*Smoker in home*	*0.73*	*0.24*	*9.1*	*0.003*
o-*Xylene (0.15)*	*Smoker in home*	*0.49*	*0.20*	*6.0*	*0.02*
	Gas furnace	*0.44*	*0.19*	*5.4*	*0.02*
m,p-*Xylene (0.12)*	*Smoker in home*	*0.70*	*0.21*	*11*	*0.001*
Chlorinated Hydrocarbons					
Chloroform (0.15)	*Chem. worker in home*	*2.48*	*1.00*	*6.2*	*0.01*
	Auto exhaust	*1.08*	*0.47*	*5.3*	*0.02*
1,1,1-Trichloroethane (0.10)	*Male*	*0.94*	*0.31*	*9.3*	*0.003*
Carbon tetrachloride (0.19)	*Outdoor carbon tetrachloride (night)*	*0.30*	*0.07*	*19*	*0.0001*
Trichloroethylene (0.12)	*Outdoor trichloroethylene (night)*	*0.26*	*0.08*	*13*	*0.0005*
	Electric stove	*0.86*	*0.38*	*4.0*	*0.03*
Tetrachloroethylene (0.12)	*Male*	*0.87*	*0.29*	*9.1*	*0.003*
	Exposed to cleansers	*0.90*	*0.34*	*6.9*	*0.01*
p-*Dichlorobenzene (0.06)*	*Hobby: painting*	*−1.18*	*0.52*	*5.2*	*0.02*

[a] *Coefficient of the questionnaire variable or of the logarithm of the outdoor concentration, e.g., ln (indoor benzene) = a + 0.44 ln (outdoor benzene). Similarly, indoor air in homes of smokers had $e^{0.59} \approx 1.8$ times as much styrene as homes with no smokers.*

[b] *Standard error.*

[c] *F-value of the comparison of the two groups.*

[d] *Probability that there is no difference in geometric means of the two groups.*

personal air exposures (Table B-2). Since many subjects were away from their homes for much of the daytime period, it is somewhat unexpected to have more chemicals showing an effect of outdoor air concentrations on breath levels (Table B-3).

The summer 1982 results for New Jersey are summarized in Tables B-4 through B-6. By contrast to the fall results, eight chemicals showed an effect of outdoor air on overnight indoor concentrations (Table B-4) compared to only three for daytime personal air (Table B-5) and none for breath (Table

Table B-2. Stepwise Regression Results For 87 New Jersey Homes with Outdoor Measurements: Daytime Personal Air—Fall 1981

Chemical	*Variable*	*b*	*S.E.*	*F*	*p*
Aromatic Hydrocarbons					
Benzene	*Employed*	*1.21*	*0.39*	*9.7*	*0.003*
$(R^2 = 0.10)$					
Styrene (0.08)	*Solvent exposure*	*1.52*	*0.57*	*7.0*	*0.01*
Ethylbenzene	*Solvent exposure*	*2.03*	*0.43*	*22*	*0.0001*
(0.25)	*Smoker in home*	*0.63*	*0.28*	*5.2*	*0.02*
o-*Xylene*	*Solvent exposure*	*1.81*	*0.38*	*23*	*0.0001*
(0.33)	*Smoker in home*	*0.60*	*0.24*	*6.5*	*0.01*
	Employed	*0.51*	*0.23*	*4.8*	*0.03*
m,p-*Xylene*	*Solvent exposure*	*1.77*	*0.36*	*24*	*0.0001*
(0.39)	*Employed*	*0.79*	*0.22*	*13*	*0.0006*
	Smoker in home	*0.56*	*0.23*	*6.2*	*0.01*
Chlorinated Hydrocarbons					
Chloroform	*Chem. worker*	*2.36*	*1.01*	*5.5*	*0.02*
(0.06)	*in home*				
1,1,1-Trichloroethane	*Employed*	*1.69*	*0.37*	*21*	*0.0001*
(0.26)	*Daytime outdoor levels*	*0.21*	*0.09*	*4.8*	*0.03*
Carbon tetrachloride	*Daytime outdoor levels*	*0.22*	*0.09*	*6.3*	*0.01*
(0.07)					
Trichloroethylene	*Daytime outdoor levels*	*0.41*	*0.08*	*25*	*0.0001*
(0.31)	*Solvent exposure*	*1.34*	*0.36*	*14*	*0.0004*
	Cleansers exposure	*0.69*	*0.27*	*6.4*	*0.01*
Tetrachloroethylene	*Daytime outdoor levels*	*0.58*	*0.08*	*49*	*0.0001*
(0.43)	*Employed*	*0.86*	*0.25*	*12*	*0.0009*
p-*Dichlorobenzene*	*Daytime outdoor levels*	*0.42*	*0.12*	*13*	*0.0005*
(0.14)					

See footnotes to Table B-1 for explanation of headings.

B-6) The results for the air samples are explainable by the argument above that outdoor air near the residence should have more effect on exposure in the residence than on exposure elsewhere. The larger number of chemicals having an effect of outdoor air concentrations on indoor air concentrations in the summer may be ascribed to increased air exchange in the summer due to opening windows at night. The lack of observable results on breath values may be due to the decreased precision of the summer values resulting from the contamination incident discussed in the text.

The California results are summarized in Tables B-7 through B-9. Six of 16 chemicals showed an effect ($p < 0.10$) of outside air on indoor air during

Table B-3. ***Stepwise Regression Results For 87 New Jersey Homes with Outdoor Measurements: Breath—Fall 1981***

Chemical	*Variable*	*b*	*S.E*	*F*	*p*
Aromatic Hydrocarbons					
Benzene (R^2 = 0.32)	*Smoked*	*1.31*	*0.38*	*12*	*0.0008*
	Dry cleaner exposure	*3.53*	*1.22*	*8.3*	*0.005*
	Auto exhaust exposure	*1.52*	*0.55*	*7.7*	*0.007*
	Daytime outdoor levels	*0.21*	*0.09*	*5.6*	*0.02*
	Paint exposure	*1.60*	*0.70*	*5.1*	*0.03*
	Old (>65)	*−0.99*	*0.49*	*4.1*	*0.05*
Styrene (0.16)	*Smoker in home*	*0.73*	*0.26*	*8.0*	*0.006*
	Paint exposure	*0.97*	*0.44*	*5.0*	*0.03*
Ethylbenzene (0.32)	*Electric stove*	*1.20*	*0.41*	*8.6*	*0.004*
	Smoker in home	*0.66*	*0.23*	*8.0*	*0.006*
	Daytime outdoor levels	*0.19*	*0.07*	*7.7*	*0.007*
	Paint exposure	*1.04*	*0.41*	*6.5*	*0.01*
	Odorous chemical exp	*0.74*	*0.29*	*6.3*	*0.01*
o-*Xylene (0.25)*	*Electric stove*	*1.26*	*0.38*	*11*	*0.001*
	Paint exposure	*1.28*	*0.41*	*9.8*	*0.002*
	Daytime outdoor levels	*0.28*	*0.10*	*7.0*	*0.01*
m,p-*Xylene (0.22)*	*Solvent exposure*	*0.98*	*0.33*	*8.9*	*0.004*
	Smoker in home	*0.58*	*0.21*	*7.6*	*0.007*
	Old house (>10 yrs)	*−0.47*	*0.21*	*4.8*	*0.03*
Chlorinated Hydrocarbons					
Chloroform	*None*				
1,1,1-Trichloroethane (0.26)	*Daytime outdoor levels*	*0.24*	*0.09*	*6.7*	*0.01*
Carbon tetrachloride	*None*				
Trichloroethylene (0.17)	*Smoked*	*0.68*	*0.22*	*9.1*	*0.004*
	Daytime outdoor levels	*0.17*	*0.08*	*4.7*	*0.03*
Tetrachloroethylene (0.18)	*Employed*	*0.68*	*0.21*	*11*	*0.002*
	Daytime outdoor levels	*0.21*	*0.07*	*10*	*0.002*
	Garage/service station exposure	*0.67*	*0.31*	*4.7*	*0.03*
	Dry cleaners exposure	*1.35*	*0.67*	*4.0*	*0.05*
p-*Dichlorobenzene (0.26)*	*Daytime outdoor levels*	*0.40*	*0.08*	*22*	*0.0001*
	Smoker in home	*0.58*	*0.29*	*4.1*	*0.05*

See footnotes to Table B-1 for explanation of headings.

Table B-4. ***Stepwise Regression Results For 71 New Jersey Homes with Outdoor Measurements: Overnight Personal Air—Summer 1982***

Chemical	*Variable*	*b*	*S.E.*	*F*	*p*
Aromatic Hydrocarbons					
Benzene	*None*				
Styrene	*Outdoor level*	*0.28*	*0.08*	*12*	*0.001*
(R^2 = 0.17)	*Male*	*0.56*	*0.24*	*5.6*	*0.02*
Ethylbenzene	*Outdoor level*	*0.26*	*0.07*	*13*	*0.0005*
(0.29)	*High-exposure activity*	*1.34*	*0.50*	*7.2*	*0.009*
	Paint exposure	*−1.34*	*0.50*	*7.0*	*0.01*
	Male	*0.52*	*0.24*	*4.7*	*0.03*
o-*Xylene*	*Outdoor level*	*0.21*	*0.06*	*12*	*0.0009*
(0.27)	*High-exposure activity*	*1.29*	*0.47*	*7.5*	*0.008*
	Gas furnace	*−0.51*	*0.22*	*5.4*	*0.02*
m,p-*Xylene*	*Outdoor level*	*0.19*	*0.06*	*10*	*0.002*
(0.27)	*High-exposure activity*	*1.42*	*0.49*	*8.2*	*0.006*
	Gas furnace	*−0.57*	*0.23*	*6.0*	*0.02*
Chlorinated Hydrocarbons					
Chloroform	*None*				
1,1,1-Trichloroethane (0.08)	*Service station*	*−1.08*	*0.45*	*5.8*	*0.02*
Carbon tetrachloride (0.10)	*Outdoor level*	*0.28*	*0.10*	*7.8*	*0.007*
Trichloroethylene (0.13)	*Outdoor level*	*0.26*	*0.08*	*10*	*0.002*
Tetrachloroethylene	*Outdoor level*	*0.36*	*0.10*	*13*	*0.0007*
(0.19)	*High-exposure activity*	*1.61*	*0.80*	*4.0*	*0.05*
p-*Dichlorobenzene*	*Outdoor level*	*0.82*	*0.23*	*13*	*0.0007*
(0.19)	*Auto exhaust*	*1.36*	*0.60*	*5.2*	*0.03*

See footnotes to Table B-1 for explanation of headings.

the winter of 1984 in Los Angeles (Table B-7) compared to five chemicals in the spring in Los Angeles (Table B-8) Only tetrachloroethylene showed an effect in Antioch/Pittsburg (Table B-9)

Table B-5. ***Stepwise Regression Results For 71 New Jersey Homes with Outdoor Measurements: Daytime Personal Air—Summer 1982***

Chemical	*Variable*	*b*	*S.E.*	*F*	*p*
Aromatic Hydrocarbons					
Benzene	*Gas furnace*	*1.16*	*0.56*	*4.3*	*0.04*
(R^2 = 0.07)					
Styrene	*Paint*	*1.88*	*0.65*	*8.4*	*0.005*
(0.12)					
Ethylbenzene	*Outdoor level*	*0.31*	*0.09*	*10*	*0.002*
(0.31)	*Gas furnace*	*1.07*	*0.34*	*9.6*	*0.003*
	Employed	*0.85*	*0.38*	*5.0*	*0.03*
	Auto travel time	*0.33*	*0.16*	*4.3*	*0.04*
o-*Xylene*	*Auto travel time*	*0.42*	*0.16*	*7.2*	*0.009*
(0.19)	*Solvents*	*1.30*	*0.50*	*6.7*	*0.01*
m,p-*Xylene*	*Solvents*	*1.85*	*0.54*	*12*	*0.001*
(0.27)	*Auto travel time*	*0.57*	*0.17*	*11*	*0.001*
	High-exposure activity	*2.14*	*0.74*	*8.3*	*0.005*
	Pesticide exposure	*1.32*	*0.54*	*5.9*	*0.02*
Chlorinated Hydrocarbons					
Chloroform	*Outdoor level*	*−0.16*	*0.05*	*12*	*0.001*
(0.26)	*Old house (>10 yrs.)*	*−1.00*	*0.38*	*6.8*	*0.01*
	Hobby: gardening	*0.97*	*0.46*	*4.5*	*0.04*
1,1,1-Trichloroethane	*Employed*	*1.35*	*0.51*	*7.1*	*0.01*
(0.15)	*Gas furnace*	*0.99*	*0.48*	*4.2*	*0.05*
Carbon tetrachloride	*Employed*	*0.41*	*0.19*	*4.8*	*0.03*
(0.13)	*Old house (>10 yrs.)*	*−0.37*	*0.18*	*4.4*	*0.04*
Trichloroethylene	*None*				
Tetrachloroethylene	*Outdoor level*	*0.41*	*0.08*	*24*	*0.0001*
(0.35)	*Dry cleaners exposure*	*2.25*	*0.94*	*5.7*	*0.02*
p-*Dichlorobenzene*	*Employed*	*1.26*	*0.43*	*8.7*	*0.004*
(0.12)					

See footnotes to Table B-1 for explanation of headings.

Table B-6. ***Stepwise Regression Results For 71 New Jersey Homes with Outdoor Measurements: Breath— Summer 1982***

Chemical	*Variable*	*b*	*S.E.*	*F*	*p*
Aromatic Hydrocarbons					
Benzene	*Smoked*	*3.04*	*0.82*	*14*	*0.0006*
(R^2 = 0.29)	*Pesticide treatment*	*1.24*	*0.59*	*4.4*	*0.04*
Styrene	*Smoked*	*1.11*	*0.45*	*6.2*	*0.02*
(0.09)					
Ethylbenzene	*Smoked*	*1.95*	*0.59*	*11*	*0.002*
(0.21)	*Paint exposure*	*3.26*	*1.35*	*5.8*	*0.02*
o-*Xylene*	*Employed*	*1.48*	*0.66*	*5.0*	*0.03*
(0.08)					
m,p-*Xylene*	*Hobby: gardening*	*−1.72*	*0.76*	*5.2*	*0.03*
(0.23)	*Auto travel time*	*0.68*	*0.30*	*5.0*	*0.03*
	Employed	*1.44*	*0.69*	*4.3*	*0.04*
Chlorinated Hydrocarbons					
Chloroform	*None*				
1,1,1-Trichloroethane	*Nonwhite*	*1.41*	*0.59*	*5.6*	*0.02*
(0.14)	*Auto travel time*	*0.55*	*0.24*	*5.2*	*0.03*
Carbon tetrachloride	*None*				
Trichloroethylene	*None*				
Tetrachloroethylene	*Auto travel time*	*0.49*	*0.21*	*5.7*	*0.02*
(0.09)					
p-*Dichlorobenzene*	*None*				

See footnotes to Table B-1 for explanation of headings.

Table B-7. Stepwise Regression Results For 24 Homes with Outdoor Measurements: Overnight Personal Air—Los Angeles (February 1984)

Chemical	Variable	b	S.E.	F	p
Aromatic Hydrocarbons					
Benzene $(R^2 = 0.11)$	*Smoker in home*	0.41	0.24	2.9	0.10
Styrene	*None*				
Ethylbenzene (0.18)	*Outdoor concentration*	0.19	0.08	4.9	0.04
o-*Xylene*	*None*				
m,p-*Xylene* (0.14)	*Smoker in home*	0.41	0.21	3.7	0.07
Chlorinated Hydrocarbons					
Chloroform	*None*				
1,1,1-Trichloroethane (0.24)	*Outdoor concentration*	0.38	0.14	7.1	0.01
Carbon tetrachloride	*None*				
Trichloroethylene	*None*				
Tetrachloroethylene	*Time in car*	0.02	0.01	4.9	0.04
(0.43)	*Outdoor concentration*	0.23	0.11	4.6	0.04
	Smoker in home	0.70	0.36	3.8	0.07
m,p-*Dichlorobenzene* (0.37)	*Outdoor concentration*	0.98	0.27	13	0.002
Aliphatic Hydrocarbons					
Decane (0.17)	*Outdoor concentration*	0.42	0.19	4.7	0.04
Dodecane (0.11)	*No potential high exp.*	0.80	0.40	3.9	0.06
Octane	*None*				
Undecane	*No potential high exp.*	0.69	0.33	4.4	0.05
(0.24)	*Outdoor concentration*	0.26	0.15	3.1	0.09
α-Pinene	*None*				

See footnotes to Table B-1 for explanation of headings.

Table B-8. Stepwise Regression Results For 24 Homes with Outdoor Measurements: Overnight Personal Air—Los Angeles (May 1984)

Chemical	*Variable*	*b*	*S.E.*	*F*	*p*
Aromatic Hydrocarbons					
Benzene	*None*				
Styrene *(R^2 = 0.18)*	*Circulating fan*	*1.4*	*0.66*	*4.5*	*0.05*
Ethylbenzene	*None*				
o-*Xylene*	*None*				
m,p-*Xylene* *(0.15)*	*Outdoor concentration*	*0.52*	*0.27*	*3.6*	*0.07*
Chlorinated Hydrocarbons					
Chloroform *(0.16)*	*No high exposure*	*−1.23*	*0.62*	*3.9*	*0.06*
1,1,1-Trichloroethane *(0.28)*	*Outdoor concentration*	*0.71*	*0.25*	*7.7*	*0.01*
Carbon tetrachloride	*None*				
Trichloroethylene	*None*				
Tetrachloroethylene *(0.34)*	*Outdoor concentration*	*0.51*	*0.30*	*2.9*	*0.10*
m,p-*Dichlorobenzene*	*None*				
Aliphatic Hydrocarbons					
Decane	*None*				
Dodecane	*None*				
Octane *(0.13)*	*Outdoor concentration*	*0.33*	*0.19*	*3.0*	*0.10*
Undecane	*None*				
α-Pinene	*Circulating fan*	*1.76*	*0.57*	*9.6*	*0.006*
(0.45)	*Gardening*	*1.54*	*0.58*	*7.0*	*0.02*
	Outdoor concentration	*−0.61*	*0.26*	*5.5*	*0.03*

See footnotes to Table B-1 for explanation of headings.

Table B-9. Stepwise Regression Results For 10 Homes with Outdoor Measurements: Overnight Personal Air—Contra Costa (June 1984)

Chemical	*Variable*	*b*	*S.E.*	*F*	*p*
Aromatic Hydrocarbons					
Benzene	*None*				
Styrene *(R^2 = 0.39)*	*Smoker in home*	*1.58*	*0.69*	*5.2*	*0.05*
Ethylbenzene	*None*				
o-*Xylene*	*None*				
m,p-*Xylene*	*None*				
Chlorinated Hydrocarbons					
Chloroform	*None*				
1,1,1-Trichloroethane	*None*				
Carbon tetrachloride	*None*				
Trichloroethylene *(0.31)*	*Employed*	*1.53*	*0.81*	*3.6*	*0.10*
Tetrachloroethylene *(0.31)*	*Outdoor concentration*	*0.39*	*0.19*	*4.1*	*0.08*
m,p-*Dichlorobenzene*	*None*				
Aliphatic Hydrocarbons					
Decane	*None*				
Dodecane *(0.32)*	*Smoker in home*	*1.15*	*0.60*	*3.7*	*0.09*
Octane	*None*				
Undecane	*Smoker in home*	*1.49*	*0.59*	*6.3*	*0.04*
(0.56)	*Employed*	*1.19*	*0.63*	*3.5*	*0.10*
α-Pinene	*None*				

See footnotes to Table B-1 for explanation of headings.

Appendix C
Analysis of Measurement Errors

What are the sources of the measurement errors in the TEAM Study? Two categories of errors can be distinguished: those that affect all chemicals in one sample equally and those that affect specific chemicals. The first category includes errors in measuring flow rates and errors in injecting external standards—in both cases, the error affects every chemical equally. The second category includes background contamination and chemical reactions—in both cases, specific chemicals are affected differently from other chemicals on the same sample.

Errors Affecting All Chemicals Equally

1. *Flow rate during sample collection* Flow rate is measured at the beginning and end of the 12-hour sampling period The two measurements are averaged and multiplied by the sampling time to estimate the volume sampled. Two types of error are involved with this procedure: errors in individual flow rate measurements, and the error involved in estimating the average flow rate by a simple average of the two measurements. The latter error may be larger than the former. (For example, battery-operated pumps have been observed to maintain constant flow for a number of hours and then enter a steep decline in flow rate; in such cases, a simple average, which presumes a linear decline, is likely to underestimate the actual volume sampled.) Both types of errors will cause identical relative errors in estimating the concentrations of all chemicals. Changes in beginning and ending flow rates were usually <10%. Therefore, the error in taking the simple average is likely to be less than 5%. Reproducibility of flow rate measurements was usually <5%. Thus the combined error associated with flow rate measurements is not likely to exceed $\sqrt{5^2 + 5^2} \approx 7\%$.

2. *Injection of external standard.* For each sample cartridge, an external standard (perfluorobenzene or perfluorotoluene) is injected. The response (area counts) of the GC-MS system is then applied to all target compounds based on the amount of standard injected. An error in estimating this amount will affect all target chemicals in the sample in the same way. The magnitude of the error associated with this operation is unknown.

3. *Flow rate of permeation system.* An error in measuring the flow rate of the carrier gas used to load chemicals on the cartridge will cause errors affecting all chemicals equally. (This is not to be confused with the individual permeation tube rates, which are chemical-specific and are described below.) Errors are not expected to exceed 10%.

Errors Affecting Individual Chemicals

4. *Contamination of Tenax during preparation, transport, and storage.* Blank values for most chemicals were consistently below 10 ng (the

equivalent of 0.5 μg/m^3) The chemical with the highest blank levels (the equivalent of 1-5 μg/m^3) was benzene With relative standard deviations of up to 3 μg/m^3 equivalent, errors in estimating low concentrations (<5 μg/m^3) could easily exceed 100%. Other chemicals with relatively high background levels were chloroform and 1,1,1-trichloroethane. For most other chemicals, the error due to blank contamination should have been negligible

5. *Losses (or gains) during transportation and storage (recovery efficiencies).* These are determined by loading known amounts of each target chemical on laboratory and field control cartridges, the difference between the laboratory and field values is the loss (or gain) of the chemical during transportation. The difference between the amount loaded and the amount recovered on the laboratory cartridge is the amount lost (or gained) during storage. The amount of a chemical found on a field cartridge is corrected for the average percent lost (or gained) during transportation and storage, as determined from the control cartridges; thus the magnitude of the error is dependent on the *variability* of the observed loss or gain, and is different for each chemical. These coefficients of variation ranged between 8 and 37% during the three California visits (Table C-1).

6 *Calculation of relative response factor* Calculation of concentrations depends on a "relative response factor" (RRF_a) determined for each chemical from a known amount (generally about 200 ng) loaded onto a test cartridge At least seven determinations of the response (peak height or area) of the known chemical compared to the response to an external standard are made and the average ratio is used in all calculations. One error associated with the RRF_a is its variability, as determined from the standard deviation of the observed values. Another source of error connected with the RRF_a is the assumption that the response is linear; if the response is not linear with respect to concentration, then an error will occur. The coefficients of variation of the mean RRF_a calculated for eleven prevalent chemicals varied from 4% to 29% during the three California visits (Table C-1). Although this error is listed under the "chemical-specific" category, it is possible that day-to-day variations in instrumental response affect many chemicals similarly If so, this error would appear under the first category.

7 *Breakthrough volume.* Breakthrough volume of a particular chemical is the volume sampled (from an atmosphere at constant concentration) at which 50% of the chemical is lost through the rear of the cartridge. Breakthrough volumes vary according to chemical, temperature, and the geometry of the sampling system. For the TEAM sampling geometry and nominal volume (~20 L), the only prevalent target chemicals with breakthrough volumes at room temperature less than the 20 L sampling volume are chloroform (15 L) and 1,1,1-trichloroethane (19 L). If the sample volume exceeds the breakthrough volume for a given chemical, the concentration is determined by dividing by the breakthrough volume. Breakthrough volume is determined from previous experiments, and is a steep function of temperature. Thus errors in the published breakthrough volumes or in estimating temperature throughout the sampling period will lead to chemical-specific errors.

   Another potentially significant source of error associated with dividing by the breakthrough volume is the assumption that the concentration

Table C-1. ***Coefficients of Variation (%) of Relative Response Factors and Recovery Efficiencies: California***

	Relative Response Factors (RRF)						Recovery Efficiencies		
	LA1^{a}		LA2^{b}		CC^{c}				
Chemical	Finn^{d} 3300^{e}	Finn 4021	Finn 3300	Finn 4021	Finn 3300	Finn 4021	LA1^{a} (N=18)	LA2^{b} (15)	CC^{ca} (15)
Chloroform	7	5	13	10	7	10	8	12	20
1,1,1-Trichloroethane	5	23	12	11	9	11	10	17	17
Benzene	12	24	8	12	5	12	18	20	16
Carbon tetrachloride	6	23	9	8	4	8	19	14	22
Trichloroethylene	29	18	9	16	7	16	20	18	13
Tetrachloroethylene	11	20	13	9	15	9	18	14	20
Styrene	25	12	18	6	6	6	21	37	8
m,p-*Dichlorobenzene*	6	21	14	8	6	8	16	30	23
Ethylbenzene	13	14	14	10	12	10	16	30	8
o-*Xylene*	9	12	13	9	7	9	16	28	17
m,p-*Xylene*	8	14	14	9	8	9	17	28	7

[a] *Los Angeles—first trip—Feb. 1984.*

[b] *Los Angeles—second trip—May 1984.*

[c] *Contra Costa County—June 1984.*

[d] *Finnegan mass spectrometer.*

[e] *Model number.*

is constant over the sampling period. (This assumption is necessary *to justify dividing by the breakthrough volume rather than the sample volume.)* However, depending on the time-varying profile of the concentration, dividing by the breakthrough volume can yield over- or underestimates. For example, if the concentration is relatively high during the first part of the sampling period, most of the chemical will break through, and the average concentration will be underestimated. If the concentration reaches high values late in the sampling period, little breakthrough will occur, and the average concentration will be overestimated. Since extreme short-term peaks occur for both of these chemicals (chloroform in showers, 1,1,1-trichloroethane in various spray can propellant uses) this error is potentially large in these situations.

8. *Permeation tube rates.* Most of the target chemicals are loaded on control cartridges by permeation tubes. Variations in the permeation rates will lead to chemical-specific errors in estimating recovery efficiencies. However, historical records of permeation-tube variabilities indicate that they are quite stable, with variations ranging from 1-5%.

9. *Chemical reactions.* Artifact formation has been observed on Tenax (Pellizzari, 1984)[1] as have effects of NO_2, O_3, and humidity (Pellizzari, 1984)[2]. The main artifacts observed were benzaldehyde, acetophenone, and phenol, none of which were selected as TEAM target compounds for that reason. However, particularly in California, NO_2 and ozone levels were high, and may have led to errors of unknown magnitude due to chemical reactions occurring during sampling.

10. *Calculation of area of GC/MS peaks.* These areas can be affected by variable background heights, asymmetrical shapes, saturation, and interferences. In most cases, the error should be of small magnitude (<5%).

Table C-2 summarizes these ten types of errors, the chemicals affected, and (when possible) the approximate magnitude of the errors.

To determine the propagation of these errors, we examine the equation for the concentration.

$$C_a = (M_a - M_b)/V\,R_a \tag{1}$$

where M_a = total mass of analyte (ng/cartridge)
M_b = average mass on field blanks (ng/cartridge)
V = volume sampled or breakthrough volume, whichever is smaller (L)
R_a = average recovery efficiency for the given analyte

In turn, M_a is determined from a mean relative response factor (RRF_a) calculated for each analyte for a given mass spectrometer from a minimum of seven cartridges that have been loaded with known amounts of the target chemicals and of the external standards·

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[1] Pellizzari, E D, and Krost, K J (1984) Chemical transformations during ambient air sampling for organic vapors *Analytical Chemistry* 56 1813-1819

[2] Pellizzari, E D, Demian, B, and Krost, K (1984) Sampling of organic compounds in the presence of reactive inorganic gases with Tenax GC *Analytical Chemistry* 56 793-798

Table C-2. Estimated Magnitude of Errors Associated with Air Measurements

Errors Affecting All Chemicals Equally	*Percent Error*
1. Flow rate measurement	*≤7*
2. Injection of external standard	*?*
3. Flow rate of carrier gas for permeation system	*?*

Errors Affecting Individual Chemicals	*Chemicals Affected*	*Range of Error*
4. Blank contamination	*Benzene*	*up to 5 μg/m³*
	1,1,1-Trichloroethane	*up to 2 μg/m³*
	Chloroform	*up to 1 μg/m³*
	m,p-Xylene	*up to 1 μg/m³*
5. Recovery efficiencies	*All*	*8-37%*
6. Relative response factor	*All*	*4-29%*
7. Breakthrough volume	*Chloroform 1,1,1-Trichloroethane*	*Could be large for the two chemicals affected*
8. Permeation tube rates	*All*	*1-5%*
9. Chemical reactions	*Unknown*	*?*
10. Measurement of peak area	*All*	*<5%*

$$\overline{RRF}_a = \frac{1}{n}\sum_{i=1}^{n}\frac{A_{ki}/M_{ki}}{A_{si}M_{si}} \qquad (2)$$

where $A_{k,s}$ = system response (integrated peak area) to the known chemical (k) or the standard (s)

$M_{k,s}$ = mass of known chemical (k) or standard (s)

i = i^{th} of n RRF cartridges

If we assume that the RRF_a determined for the known mass M_k of a particular chemical also applies to any unknown concentration M_a, (that is, that the response is linear with respect to concentration) we may write:

$$\overline{RRF}_a = \frac{A_a/M_a}{A_s/M_s} \qquad (3)$$

where A_a is the system response to the unknown mass of analyte M_a and A_s is the system response on the day of analysis to the mass M_s of the external standard. Solving for M_a, we have·

$$M_a = \frac{A_a/\overline{RRF}_a}{A_s/M_s} \qquad (4)$$

Similarly, the average mass $\overline{M}_b$ for the blank cartridges is calculated from *several determinations at different times (indexed by t) of a set of m blank* cartridges

$$\overline{M}_b = \frac{1}{m}\sum_{t=1}^{m}\frac{A_{bt}/\overline{RRF}_a}{A_{st}\,M_{st}} \qquad (5)$$

Thus, the concentration of an analyte a on a particular field sample is:

$$C_a = \frac{\dfrac{A_a}{RRF_a}\,\dfrac{M_s}{A_s} - 1/m\displaystyle\sum_{t=1}^{m}\dfrac{A_{bt}}{RRF_a}\,\dfrac{M_{st}}{A_{st}}}{V\,R_a} \qquad (6)$$

or

$$C_a = \frac{A_a\dfrac{M_s}{A_s} - \dfrac{\overline{A_b\,M_s}}{A_s}}{RRF_a\,V\,R_a} \qquad (7)$$

where the term $A_a\,M_s/A_s$ refers to the single determination of the analyte area A_a and the system response A_s to the external standard M_s on the sample; the term $\overline{A_b\,M_s}/A_s$ refers to an average of system responses to external standards loaded on m blank cartridges; $\overline{RRF}_a$ is an average relative *response factor determined from at least 7 RRF cartridges; R_a is the average* recovery efficiency from several control cartridges; and V is the sample volume or breakthrough volume of the analyte, whichever is smaller

For those chemicals with negligible blank levels, the equation reduces to

$$C_a = \frac{A_a\,M_s}{A_s\,V\,R_a\,RRF_a} \qquad (8)$$

Of the six factors on the right-hand side, errors in the measurements of the external standard parameters (M_s, A_s) and the sample volume V will affect all chemicals equally, while errors in measuring the peak area of the target chemical and its recovery efficiency are specific to the chemical. (For those cases with sample volumes exceeding the breakthrough volumes of certain chemicals—primarily chloroform and 1,1,1-trichloroethane—the error in the breakthrough volume is of course also specific to the chemical.) Depending on the behavior of the particular mass spectrometer, the daily variation of the relative response factor may or may not affect all chemicals similarly. Since all six quantities are related by multiplication or division, the total error associated with determining the concentration is simply the square root of the sums of the squares of the individual errors, assuming all errors are additive and normally distributed

The coefficients of variances (CVs) of the recovery efficiencies and of the relative response factors are compared for all eleven prevalent chemicals (Table C-3). For every chemical, the average CVs associated with the recovery efficiencies (13-23%) were slightly larger than the average CVs associated with the relative response factors (9-16%). The combined CVs for these two *major sources of error are compared with the observed CVs of all personal*

Table C-3. Coefficients of Variation (%) of Measurement Errors: TEAM-California Study

Chemical	*RRF*[a]	*Recovery Efficiency*[b]	*Combined*[c]	*Observed Precision of Duplicates*[d]
Chloroform	*9*	*13*	*16*	*27*
1,1,1-Trichloroethane	*12*	*15*	*19*	*18*
Benzene	*12*	*18*	*22*	*26*
Carbon tetrachloride	*9*	*18*	*20*	*11*
Trichloroethylene	*16*	*17*	*23*	*32*
Tetrachloroethylene	*13*	*17*	*21*	*16*
Styrene	*10*	*21*	*23*	*30*
m,p-*Dichlorobenzene*	*10*	*23*	*25*	*24*
Ethylbenzene	*10*	*18*	*21*	*14*
o-*Xylene*	*10*	*19*	*21*	*13*
m,p-*Xylene*	*10*	*17*	*20*	*15*

[a] *Mean relative response factor CV averaged for two mass spectrometers during three California visits.*

[b] *Recovery efficiency CVs averaged for 48 air and breath cartridges.*

[c] *Combined error: the square root of the sums of the squares of columns (1) and (2).*

[d] *Mean CVs of personal air and breath samples only (N = 74).*

air and breath samples also in Table C-3 Except for chloroform, trichloroethylene, and styrene, these two sources of error alone appear to account for most of the observed variation.

The errors associated with the area and volume terms are expected to be small (<5%). The error associated with injection of the external standard (M_s) has not been quantitated. However, we may use our knowledge of the different ways in which these errors affect a sample to determine whether the chemical-specific errors or the "constant-multiple" errors are dominant. If most duplicate pairs show consistent ratios among most or all chemicals on a sample, then the dominant errors are of the constant-multiple type (such as M_s and V); if most duplicate pairs show no such consistent bias, then the chemical-specific errors (such as R_a) are dominant.

The relative importance of the two categories of errors was determined by the following scheme: a "typical" ratio R (for example, the median ratio of the eleven prevalent chemicals on one sample to their counterparts on the duplicate) was determined for each pair of duplicates. Then all chemicals on one sample were multiplied by R to remove that part of the variance due to this single multiplicative constant R. The remaining variance represents the chemical-specific variance. If the chemical-specific variance is small compared to the original variance, the importance of background contamination or possible chemical reactions is minimal.

The results of carrying out this calculation for duplicate air and breath samples in New Jersey and two of the three California trips are displayed in Tables C-4 to C-8. As can be seen for the New Jersey data, chemical-specific errors are small (median CVs < 10%) for about six chemicals (styrene,

Table C-4. **Comparison of Total Variance with "Chemical-Specific" Component of All Measurable Duplicate Samples: NJ, Fall 1981**

	Personal Air						Breath			Outdoor Air					
	Night			Day						Night			Day		
Chemical	N[a]	CV[b]	MCV[c]	N	CV	MCV	N	CV	MCV	N	CV	MCV	N	CV	MCV
Chloroform	34	0.13	0.12	13	0.19	0.19	8	0.36	0.07	2	—	—	4	0.21	0.17
1,1,1-Trichloroethane	50	0.26	0.32	30	0.30	0.21	20	0.46	0.24	10	0.29	0.22	13	0.20	0.22
Benzene	51	0.38	0.29	50	0.38	0.27	23	0.41	0.18	11	0.49	0.27	9	0.46	0.25
Carbon Tetrachloride	25	0.09	0.16	7	0.12	0.09	2	—	—	9	0.30	0.19	8	0.10	0.26
Trichloroethylene	40	0.10	0.06	17	0.19	0.06	8	0.28	0.08	7	0.15	0.10	8	0.32	0.10
Tetrachloroethylene	57	0.18	0.08	48	0.17	0.10	24	0.18	0.14	9	0.20	0.12	11	0.18	0.04
Styrene	50	0.22	0.09	36	0.21	0.10	12	0.22	0.13	4	0.14	0.10	3	0.37	0.21
m,p-Dichlorobenzene	49	0.18	0.11	37	0.18	0.10	13	0.16	0.22	5	0.14	0.17	3	0.28	0.23
Ethylbenzene	56	0.18	0.03	47	0.17	0.04	24	0.30	0.11	12	0.20	0.10	12	0.32	0.08
o-Xylene	55	0.14	0.05	45	0.14	0.05	20	0.15	0.06	11	0.20	0.10	11	0.25	0.08
m,p-Xylene	56	0.18	0.06	55	0.18	0.04	26	0.23	0.09	14	0.24	0.03	14	0.24	0.10

[a] Number of duplicate pairs with both values > quantifiable limit.

[b] Median coefficient of variation of original data.

[c] Median coefficient of variation of modified data (constant factor removed): "chemical-specific" CV.

Table C-5. Comparison of Total Variance with "Chemical-Specific" Component of All Measurable Duplicate Samples: NJ, Summer 1982

	Personal Air						Breath			Outdoor Air					
	Night			Day						Night			Day		
Chemical	N^a	CV^b	MCV^c	N	CV	MCV	N	CV	MCV	N	CV	MCV	N	CV	MCV
Chloroform	13	0.38	0.13	12	0.27	0.30	5	0.44	0.14	4	0.77	0.39	2	0.42	0.19
1,1,1-Trichloroethane	26	0.35	0.20	19	0.21	0.14	8	0.50	0.51	9	0.39	0.23	5	0.36	0.11
Benzene	18	0.47	0.36	16	0.43	0.31	5	0.52	0.27	7	0.12	0.19	7	0.54	0.21
Carbon Tetrachloride	4	0.21	0.30	1	—	—	0	—	—	7	0.32	0.18	4	0.05	0.17
Trichloroethylene	18	0.51	0.26	16	0.37	0.19	4	0.40	0.19	6	0.47	0.28	6	0.74	0.40
Tetrachloroethylene	23	0.29	0.07	22	0.27	0.12	10	0.43	0.31	10	0.25	0.05	11	0.44	0.25
Styrene	20	0.15	0.04	19	0.24	0.06	5	0.24	0.04	7	0.24	0.09	4	0.25	0.22
m,p-Dichlorobenzene	27	0.19	0.22	25	0.16	0.12	10	0.25	0.20	12	0.42	0.21	8	0.30	0.19
Ethylbenzene	29	0.24	0.02	30	0.28	0.04	9	0.39	0.10	13	0.59	0.07	7	0.59	0.07
o-Xylene	29	0.22	0.06	30	0.26	0.04	8	0.50	0.17	14	0.52	0.09	8	0.60	0.00
m,p-Xylene	30	0.21	0.03	31	0.24	0.03	7	0.73	0.14	14	0.50	0.08	10	0.55	0.08

[a] Number of duplicate pairs with both values > quantifiable limit.

[b] Median coefficient of variation of original data.

[c] Median coefficient of variation of modified data (constant factor removed): "chemical-specific" CV.

Table C-6. ***Comparison of Total Variance with "Chemical-Specific" Component of All Measurable Duplicate Samples: NJ, Winter 1983***

	Personal Air						*Breath*		
	Night			*Day*					
Chemical	*N*[a]	*CV*[b]	*MCV*[c]	*N*	*CV*	*MCV*	*N*	*CV*	*MCV*
Chloroform	*8*	*0.17*	*0.06*	*8*	*0.44*	*0.16*	*2*	—	—
1,1,1-Trichloroethane	*8*	*0.18*	*0.20*	*9*	*0.55*	*0.43*	*2*	—	—
Benzene	*8*	*0.16*	*0.13*	*9*	*0.34*	*0.07*	*5*	*0.35*	*0.13*
Carbon Tetrachloride	*2.*	—	—	—	—	—	—	—	—
Trichloroethylene	*7*	*0.09*	*0.10*	*6*	*0.34*	*0.15*	*1*	—	—
Tetrachloroethylene	*8*	*0.09*	*0.06*	*9*	*0.25*	*0.08*	*5*	*0.28*	*0.10*
Styrene	*9*	*0.14*	*0.08*	*9*	*0.18*	*0.05*	*4*	*0.19*	*0.05*
m,p-*Dichlorobenzene*	*9*	*0.09*	*0.10*	*9*	*0.18*	*0.13*	*5*	*0.22*	*0.05*
Ethylbenzene	*9*	*0.21*	*0.10*	*9*	*0.21*	*0.03*	*5*	*0.22*	*0.01*
o-*Xylene*	*9*	*0.17*	*0.13*	*9*	*0.17*	*0.04*	*5*	*0.18*	*0.05*
m,p-*Xylene*	*9*	*0.12*	*0.03*	*9*	*0.24*	*0.05*	*5*	*0.22*	*0.04*

[a] *Number of duplicate pairs with both values ½ quantifiable limit.*
[b] *Median coefficient of variation of original data.*
[c] *Median coefficient of variation of modified data (constant factor removed): "chemical-specific" CV.*
Note: Outdoor air duplicate samples too few to calculate statistics.

ethylbenzene, *o*-xylene, *m,p*-xylene, trichloroethylene, and tetrachloroethylene) For these chemicals, it appears likely that multiplicative errors, such as errors in flow rate measurement, injection of standards, or variation of the relative response factor, were the major sources of error Background contamination appeared to be an important source of error for benzene, chloroform, and 1,1,1-trichloroethane

In California, the first Los Angeles visit had very clean Tenax backgrounds and only chloroform and styrene had "chemical-specific" coefficients of variation consistently exceeding 10% (Table C-7) In Contra Costa, 1,1,1-trichloroethane, trichloroethylene, and tetrachloroethylene sometimes exceeded "chemical-specific" coefficients of variation of 20% (Table C-8), however, the number of measurable duplicates was very small

These results indicate that a major portion of the error affects most chemicals similarly. Since the combined errors due to recovery efficiency and relative response factors are large enough to account for most of the observed error, we conclude that the error due to the relative response factor must be of the first category (affecting all chemicals equally) rather than the second

In summary, of the ten sources of error discussed, two have measured ranges of variability considerably larger than most of the rest: recovery efficiencies and relative response factors. These two alone appear capable of causing a significant portion of the observed variation in precision of the duplicate samples. Several other sources of error—blank contamination, breakthrough volume, chemical reaction—could be large on occasion,

Table C-7. Comparison of Total Variance with "Chemical-Specific" Component of All Measurable Duplicate Samples: Los Angeles, Winter 1984

	Personal Air						*Breath*		
	Night			*Day*					
Chemical	*N*[a]	*CV*	*Adj CV*	*N*	*CV*	*Adj CV*	*N*	*CV*	*Adj CV*
Chloroform	*9*	*0.19*	*0.22*	*12*	*0.26*	*0.10*	*3*	*0.25*	*0.11*
1,1,1-Trichloroethane	*11*	*0.05*	*0.08*	*12*	*0.18*	*0.06*	*12*	*0.11*	*0.04*
Benzene	*11*	*0.17*	*0.07*	*12*	*0.15*	*0.05*	*12*	*0.20*	*0.08*
Carbon tetrachloride	*11*	*0.14*	*0.04*	*11*	*0.20*	*0.06*	*2*	*0.07*	*0.11*
Trichloroethylene	*9*	*0.12*	*0.09*	*9*	*0.12*	*0.10*	*7*	*0.10*	*0.06*
Tetrachloroethylene	*11*	*0.10*	*0.02*	*11*	*0.13*	*0.05*	*11*	*0.15*	*0.10*
Styrene	*11*	*0.16*	*0.11*	*11*	*0.36*	*0.14*	*3*	*0.24*	*0.17*
m,p-*Dichlorobenzene*	*11*	*0.11*	*0.06*	*11*	*0.45*	*0.15*	*8*	*0.11*	*0.12*
Ethylbenzene	*11*	*0.11*	*0.05*	*12*	*0.18*	*0.04*	*8*	*0.26*	*0.14*
o-*Xylene*	*11*	*0.13*	*0.04*	*12*	*0.20*	*0.03*	*11*	*0.14*	*0.09*
m,p-*Xylene*	*11*	*0.09*	*0.04*	*11*	*0.22*	*0.06*	*12*	*0.21*	*0.09*

[a] *Number of duplicate pairs with both values greater than the quantifiable limit.*

[b] *Median coefficient of variation.*

[c] *Median coefficient of variation after adjusting for multiplicative errors.*

however, they are unlikely to affect a large portion of the samples because the observed precision of the duplicates (11-32%) appears to allow little room for additional unknown errors.

Table C-8. Comparison of Total Variance with "Chemical-Specific" Component of All Measurable Duplicate Samples: Contra Costa, June 1984

	Personal Air						*Breath*		
	Night			*Day*					
Chemical	*N*[a]	*CV*	*Adj CV*	*N*	*CV*	*Adj CV*	*N*	*CV*	*Adj CV*
Chloroform	2	0.31	0.33	2	0.11	0.09	0	—	—
1,1,1-Trichloroethane	6	0.25	0.20	7	0.13	0.08	4	0.43	0.23
Benzene	7	0.45	0.15	7	0.47	0.13	5	0.18	0.06
Carbon tetrachloride	6	0.20	0.09	6	0.21	0.04	1	—	—
Trichloroethylene	7	0.54	0.46	4	0.34	0.22	0	—	—
Tetrachloroethylene	6	0.15	0.02	7	0.13	0.27	5	0.18	0.64
Styrene	4	0.33	0.13	4	0.45	0.23	5	0.17	0.11
m,p-*Dichlorobenzene*	4	0.22	0.05	3	0.19	0.14	3	0.25	0.01
Ethylbenzene	6	0.17	0.03	7	0.13	0.12	5	0.06	0.05
o-*Xylene*	7	0.12	0.01	7	0.07	0.09	4	0.14	0.17
m,p-*Xylene*	7	0.07	0.02	7	0.11	0.05	6	0.15	0.06

[a] *Number of duplicate pairs with both values greater than the quantifiable limit.*

[b] *Median coefficient of variation.*

[c] *Median coefficient of variation after adjusting for multiplicative errors.*

Appendix D
Corrections to the Estimated Frequency Distributions Due to Measurement Error

Random measurement errors cause increases in the observed variance of any distribution. These increases lead to overestimates of the number of people exposed to concentrations greater than any concentration above the median. For a normal distribution of exposures and a normal distribution of (additive) measurement errors, the variance of the observed distribution equals the sum of the variances of the true distribution and of the measurement errors:

$$\sigma_{\text{obs}}{}^2 = \sigma_{\text{true}}{}^2 + \sigma_{\text{error}}{}^2$$

Similarly, for a log-normal distribution of exposures and a log-normal distribution of (multiplicative) errors, the same formula holds for the logarithms of the quantities. Multiplicative (concentration-dependent) errors are commonly encountered in environmental measurements, particularly those having a dependence on flow rates (Evans, 1984)[1]. Since the observed concentrations (breath, personal air, and outdoor air) are reasonable approximations to log-normal distributions, at least between the 10th and the 90th percentiles (Figures 4 to 14), an attempt has been made to calculate the correction factor associated with the 90th percentile for all air and breath measurements and all prevalent chemicals during all three seasons in New Jersey using the observed quality control data on duplicate measurements. (The duplicate measurements also show evidence of being drawn from distributions whose central regions can be approximated by a log-normal fit: Figures D-1 and D-2.)

A multiplicative measurement error is defined as the ratio of one member (for example, x_1) of a duplicate pair of observations (x_1, x_2) to the geometric mean of the pair

$$E = x_1 / \sqrt{x_1 x_2} = \sqrt{x_1 / x_2}$$

The logarithms of these errors were then calculated for all duplicates collected during the three seasons. For certain chemicals, these errors have been plotted on log-normal probability graph paper (Figures D-3 to D-4). The results indicate that the measurement errors as defined above are in fact reasonable approximations to log-normal distributions, at least between the 10th and 90th percentiles. Thus, by calculating the variance of the measurement errors ($\sigma_E{}^2 = 2s^2$, where s^2 is the variance of the duplicates), the true variance can be estimated:

$$\sigma_T{}^2 = \sigma_{\text{obs}}{}^2 - \sigma_E{}^2$$

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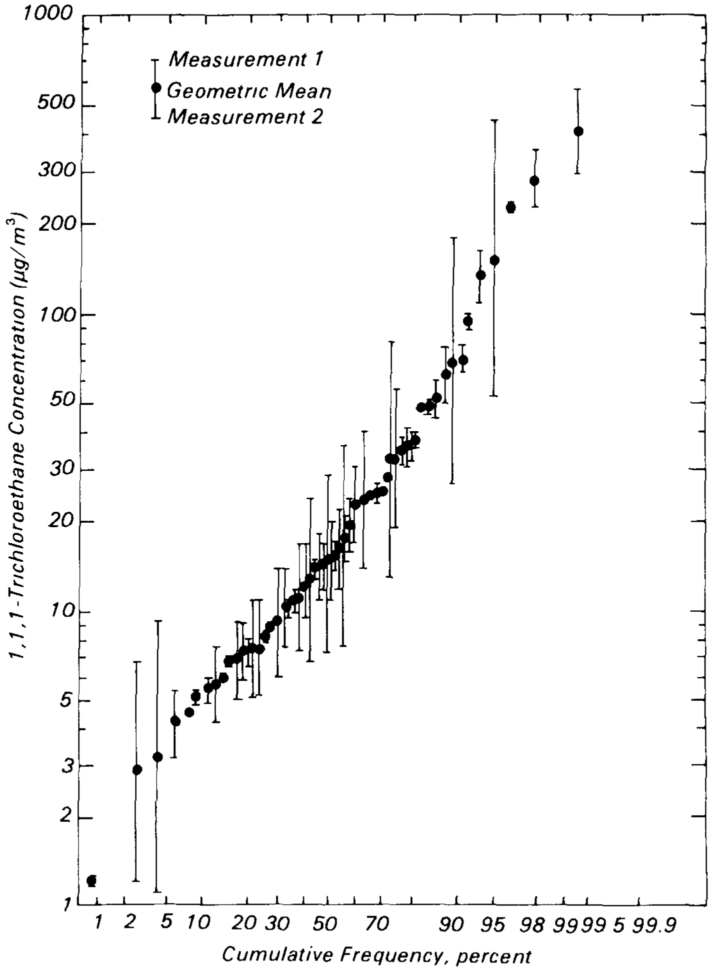
[1] Evans, J S, Cooper, D W, and Kinney, P (1984) On the propagation of error in air pollution measurements *Env Mon & Assess* 4 139-153

Figure D-1. Cumulative frequency distribution of geometric means of 62 pairs of duplicate measurements of overnight personal air exposures to 1,1,1-trichloroethane (New Jersey, Fall 1981).



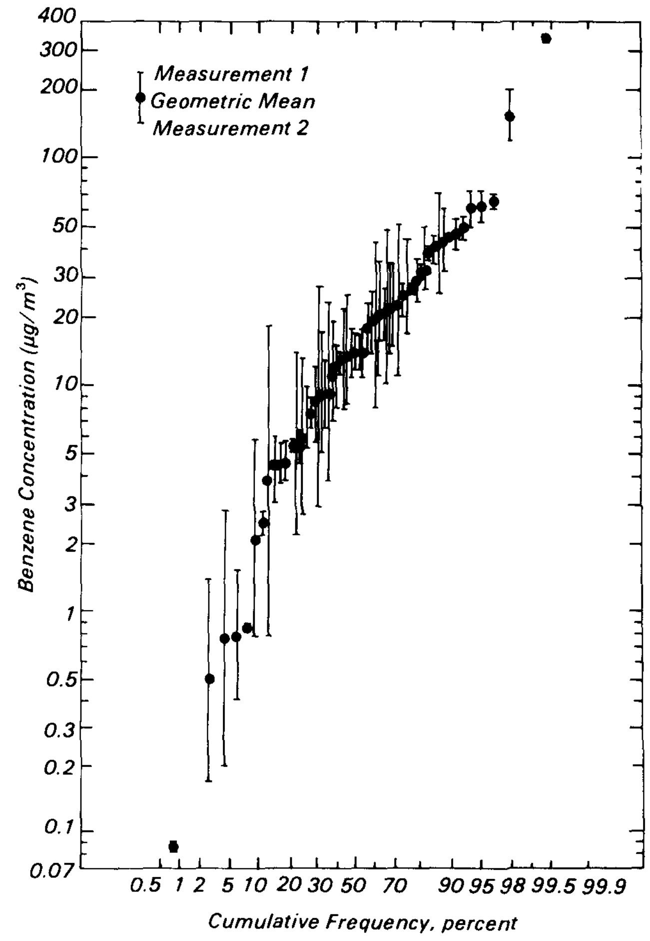
We can then define the correction factor at one standard deviation above the mean (the 84th percentile) as the ratio of the true value $\mu \exp(\sigma_T)$ to the observed value $\mu \exp(\sigma_{obs})$:

$$\text{Correction factor} = \frac{\mu \exp(\sigma_T)}{\mu \exp(\sigma_{obs})} = \exp(\sigma_T - \sigma_{obs})$$

Figure D-5 illustrates the effect of a correction factor of 0.93 on a distribution with an observed geometric standard deviation of $\exp(\sigma_{obs}) = 2.8$. Similar calculations can be employed to determine the correction factor at any percentile of interest.

Since the frequency distributions of both the field and duplicate samples appear to be roughly log-normal between the 10th and 90th percentiles,

Figure D-2. ***Cumulative frequency distribution of geometric means of 62 pairs of duplicate measurements of overnight personal air exposures to benzene (New Jersey, Fall 1981).***



the correction factors due to measurement error have been calculated for these percentiles for the personal air and breath samples collected during the fall of 1981, the summer of 1982, and the winter of 1983. (Due to the smaller number of duplicate samples analyzed for the outdoor air samples, the corresponding correction factors for the 25th and 75th percentiles were calculated.

In the fall of 1981, the error at these percentiles was normally within 20% for most chemicals in most media (Table D-1). The best measured chemical (<5% error in all media) is *p*-dichlorobenzene; the worst (>25% error) is benzene. For all other chemicals, personal air measurements are consistently good. Outdoor air errors are occasionally large for chloroform, styrene, and carbon tetrachloride. Breath values are poor for 1,1,1-trichloroethane and four of the five aromatics. In 6 of 55 cases, measurement errors were large enough to account for all of the observed variance.

Figure D-3. **Cumulative frequency distribution of measurement errors (defined as the ratio of one measurement to the geometric mean of the pair) for 62 pairs of duplicate overnight personal air samples: 1,1,1-trichloroethane (New Jersey, Fall 1981).**

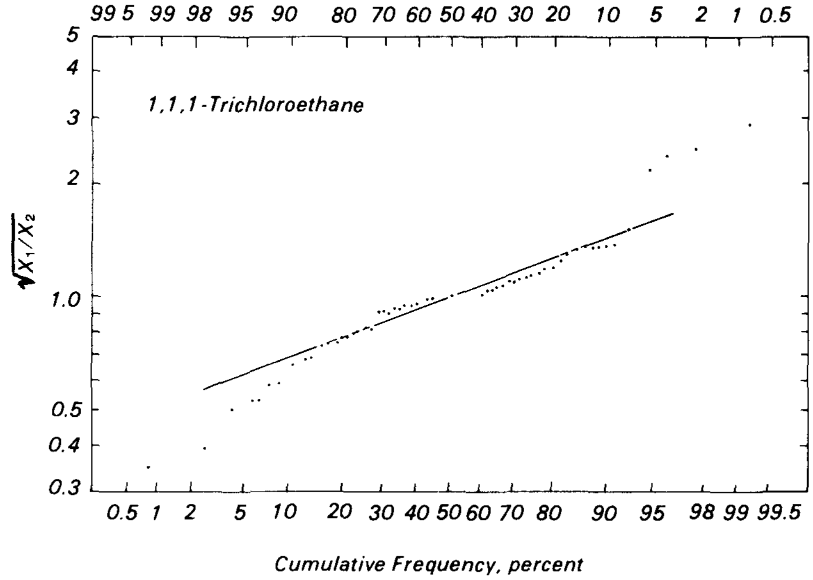


Figure D-4. **Cumulative frequency distribution of measurement errors for 62 pairs of duplicate overnight personal air samples: benzene (New Jersey, Fall 1981).**

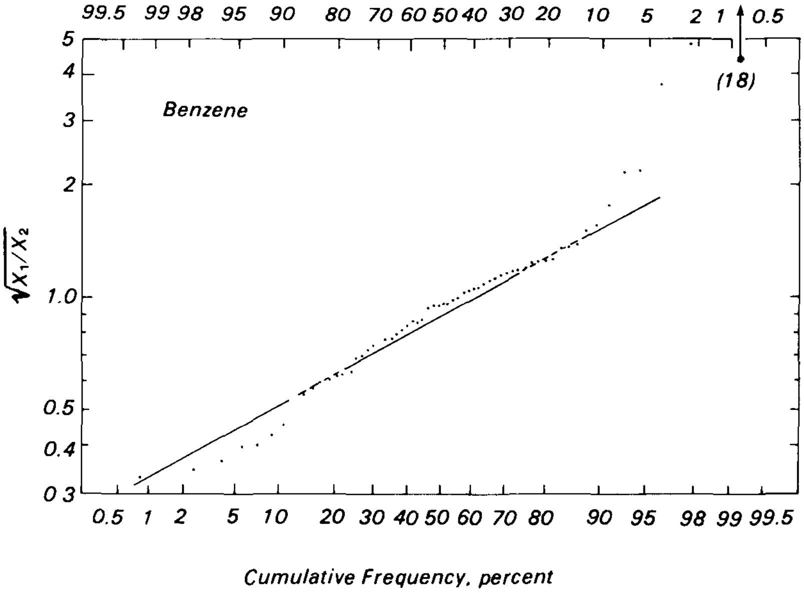


Figure D-5. **Effect of correction factor of 0.93 (Table D-1) on observed cumulative frequency distribution of overnight personal air exposures to tetrachloroethylene for 350 residents of Elizabeth-Bayonne, New Jersey.**

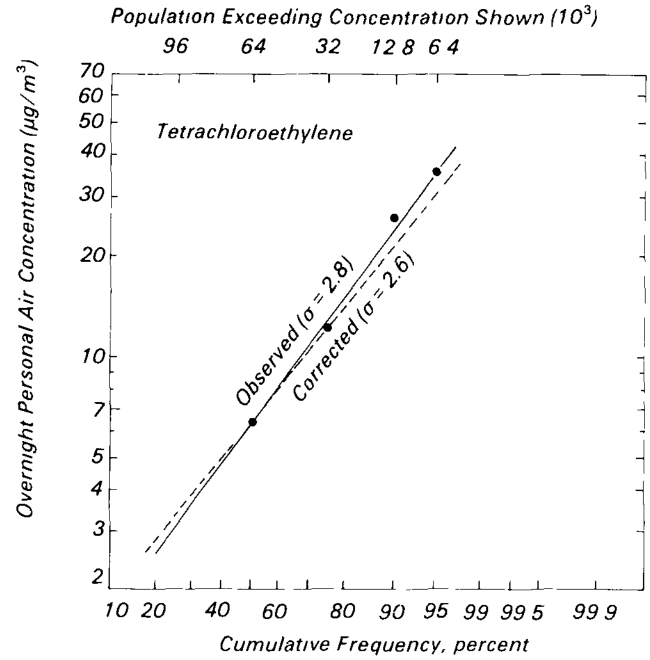


Table D-1. **Correction Factors Due to Measurement Errors—Fall 1981**

		Personal Air		Outdoor Air	
Chemical	Breath[a]	Night[a]	Day[a]	Night[b]	Day[b]
Chloroform	0.70	0.96	0.92	—[c]	0.87
1,1,1-Trichloroethane	0.60	0.93	0.81	0.82	0.91
Benzene	—	0.75	0.62	—	0.66
Carbon tetrachloride	0.97	0.92	0.63	0.95	—
Trichloroethylene	0.84	0.96	0.84	0.98	0.86
Tetrachloroethylene	0.85	0.93	0.96	0.92	0.97
Styrene	0.90	0.89	0.68	—	0.77
m,p-Dichlorobenzene	0.96	0.96	0.92	0.98	0.97
Ethylbenzene	—	0.89	0.92	0.98	0.92
o-Xylene	0.55	0.74	0.92	0.95	0.92
m,p-Xylene	0.50	0.81	0.84	0.93	0.75

[a] Corrected 90th percentile value/observed 90th percentile.

[b] Corrected 75th percentile value/observed 75th percentile.

[c] Corrected value cannot be calculated—measurement errors too large.

In the summer of 1982, contamination of the Tenax cartridges during storage occurred. This caused a general worsening of the measurement errors for most chemicals (Table D-2) However, the majority of observations were not invalidated—only 9 cases out of 50 had to be discarded.

Finally, the corrections due to measurement error are quite small in the winter 1983 season (Table D-3). The Tenax batch was quite clean (with the exception of benzene) and no problems of contamination were encountered in the field. Thus, the overestimates at the 90th percentile are usually 5-15% for all chemicals except 1,1,1-trichloroethane, which is overestimated by a factor of 2 in the personal air determination. All 27 cases gave useful information on the variance of exposures.

Since these calculations rest on criteria that we know to be violated (the distributions of observations and of errors seldom meet the Kolmogorov-Smirnov criterion for log-normality; the errors probably include additive as well as multiplicative components), a numerical simulation was run to determine whether the originally observed distribution could be recovered by convoluting the observed errors with the corrected distribution. At the time of publication, only one set of simulations has been run on one compound—the results indicated that the original distribution could in fact be recovered to within 5% of the observed values over most of the distribution by this method.

Thus, although it is not possible to state that the method has been validated, preliminary indications are encouraging.

Table D-2. Correction Factors Due to Measurement Errors—Summer 1982

		Personal Air		*Outdoor Air*	
Chemical	*Breath*[a]	*Night*[a]	*Day*[a]	*Night*[b]	*Day*[b]
Chloroform	0.64	0.70	0.73	0.95	0.98
1,1,1-Trichloroethane	—[c]	0.72	0.86	0.92	0.66
Carbon Tetrachloride	0.83	—	0.65	0.94	0.93
Trichloroethylene	0.54	0.58	0.76	0.69	0.94
Tetrachloroethylene	0.56	0.69	0.89	0.96	0.74
Styrene	0.44	0.76	0.69	0.87	0.83
m,p-*Dichlorobenzene*	0.87	0.92	0.80	—	0.92
Ethylbenzene	—	0.64	0.53	0.80	—
o-*Xylene*	0.46	—	0.74	—	—
m,p-*Xylene*	—	0.73	0.64	0.88	0.75

[a] *Corrected 90th percentile value/observed 90th percentile.*

[b] *Corrected 75th percentile value/observed 75th percentile.*

[c] *Corrected value cannot be calculated—measurement errors too large.*

Table D-3. Correction Factors[a] for Estimated Frequency Distributions Based on Measurement Errors—Winter 1983

Chemical	*Breath*	*Personal Air* *Overnight*	*Personal Air* *Daytime*
Chloroform	*0.90*	*0.93*	*0.85*
1,1,1-Trichloroethane	*0.87*	*0.42*	*0.69*
Trichloroethylene	*0.89*	*0.93*	*0.70*
Tetrachloroethylene	*0.85*	*0.96*	*0.94*
Styrene	*0.97*	*0.91*	*0.83*
m,p-*Dichlorobenzene*	*0.97*	*0.99*	*0.96*
Ethylbenzene	*0.94*	*0.94*	*0.85*
o-*Xylene*	*0.96*	*0.91*	*0.90*
m,p-*Xylene*	*0.95*	*0.88*	*0.85*

[a] *Corrected 90th percentile value/observed 90th percentile.*

Appendix E
A Method for Comparing Weighted and Unweighted Distributions on Probability Graph Paper, with Examples from the TEAM Study

The TEAM Study employed a three-stage stratified design One purpose was to identify persons with potentially high exposures and to overrepresent them in the sample population to improve the precision of the estimates of these relatively rare high exposures Thus, stratification variables such as occupation, residence near major point sources, and socio-economic status were employed. By selecting persons in these high potential exposure strata with higher probabilities than the rest of the sample, a relatively larger number of high exposures should result Since the probabilities of selection are known for each person, it is straightforward to "weight" the observed values by the reciprocal of the probability of selection to arrive at an estimate of the actual distribution of concentrations for the entire target population The observed distribution is called the unweighted distribution and the corrected distribution is called the weighted distribution

It is useful to compare the two distributions in order to determine the effect of the weighting process For example, did it work as predicted? If so, the higher exposures should have been concentrated among the people selected with higher probabilities (smaller weights). One way to compare the two distributions would be to examine the weights associated with the highest exposures. If most of the small weights are associated with high exposures, the persons expected to have high exposures did If a high proportion of observations with large weights are associated with high exposures, an unsuspected source of high exposures may be operating

These exposures and their associated weights may be sorted and frequencies calculated or they may be compared graphically A graphical comparison has the advantage of displaying the entire distributions at a glance However, before comparing the two distributions, a method must be developed capable of comparing two very different population sizes on the same set of axes

In the first season of the TEAM Study, personal exposures were measured for 350 volunteers representing 128,800 residents of Elizabeth and Bayonne, New Jersey To compare the distribution of exposures of the same population with the target population on the same set of axes, a percentile plotting convention must be adopted For unweighted samples of size N, two popular plotting conventions for the cumulative probability P_k associated with the k^{th} ordered point ($1 \leq k \leq N$) are

$$P_k = k/(N + 1) \qquad (1)$$

$$P_k = (k - ½)/N \qquad (2)$$

As shown by Chernoff and Lieberman (1954)[2] the second convention (P_k = (k-½)/N) leads to better estimates of the standard deviation of a normal

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[2] Chernoff, H and Lieberman, G J (1954), Use of normal probability paper, *J Amer Stat Assoc* 49 778-785

distribution (for $N \geq 10$) than the first convention. Therefore, we shall employ this convention in plotting the unweighted frequency distributions of exposures for the 350-person sample population.

This convention may be visualized as follows: the N observations split the distribution into N percentile ranges. A reasonable choice for the proper plotting percentile of the kth ordered observation is the midpoint of the associated range. $(k-\frac{1}{2})/N$.

For the weighted distributions, we must develop a similar plotting convention For a set of N weighted observations representing a population of P persons, we know that the sum of the weights is the population P·

$$\sum_{i=1}^{N} W_i = P \tag{3}$$

Generalizing our observation on the N equal percentile ranges, we now have N unequal percentile ranges, of "width" W_i. A natural choice for the plotting percentile of the kth observation is the midpoint of the associated width W_k.

$$P_k = \frac{\sum_{i=1}^{k} W_i - W_k/2}{P} \tag{4}$$

For the maximum observation (k = N), this reduces to:

$$P_N = \frac{(P - W_N/2)}{P} \tag{5}$$

This convention has the desired properties. namely,

1 The highest observation will be plotted at the same percentile as on the unweighted curve if the weight W_N equals the "average" weight P/N; at a higher percentile if the weight is less than average; and vice versa.

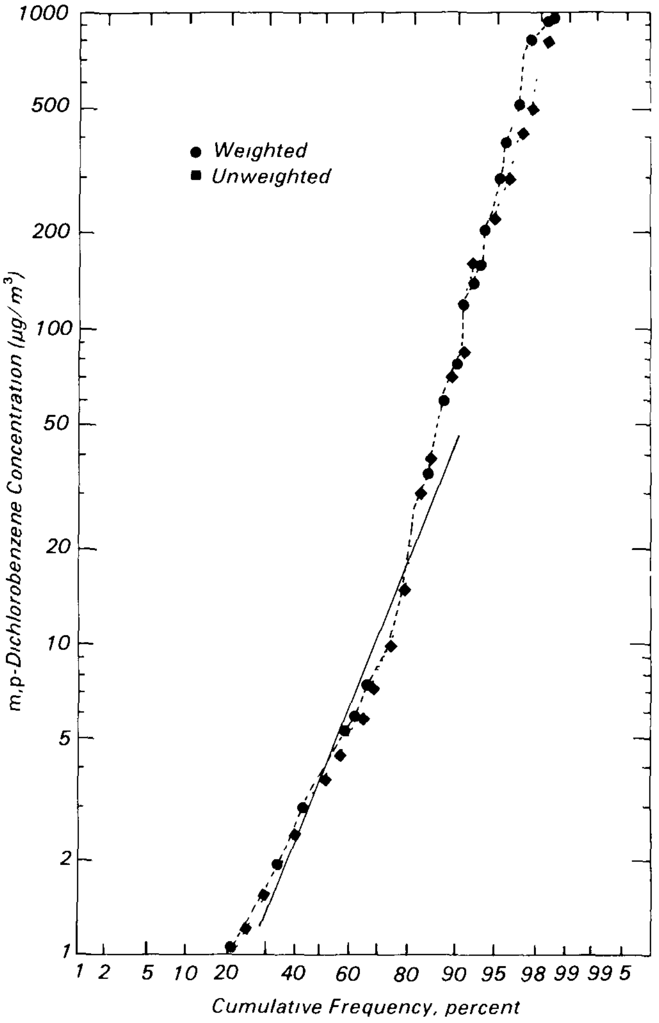
2. The weighted curve will lie below (to the right of) the unweighted curve if the weights have been properly chosen (i.e., higher weights for low levels of exposures).

Conversely, if the weighted curve lies *above* (to the left of) the unweighted curve, a preponderance of persons expected to have low exposures in fact had high exposures, a sign that certain characteristics associated with high exposures may have been overlooked in the sample stratification process.

Applying these considerations to the overnight personal exposures (i.e., indoor air concentrations) in the New Jersey Fall 1981 study, we find that three of five chemicals had weighted curves on the "wrong" side at the higher percentiles (Figures E-1 to E-5). This may be due to the fact that the importance of indoor air sources was not well understood when the study was designed, and therefore potential indoor air sources were not used to stratify the sample.

Of course, one of the stratification variables, occupation, would not be expected to affect night-time exposures. A similar comparison of *daytime* exposures would be required to determine whether the selected occupations indeed had most of the high exposures.

Figure E-1. ***Weighted vs. unweighted frequency distributions for*** m,p-***dichlorobenzene. The straight line is a log-normal curve with the same geometric mean and geometric standard deviation as the observed distribution.***



The "trimmed" geometric standard deviations of the weighted and unweighted curves were approximated by calculating the square root of the ratio of the 84th to the 16th percentile (Table E-1). All but one of the chemicals had "trimmed" geometric standard deviations in this central region very near 3; but the dichlorobenzene isomers were distributed in a much more strongly right-skewed fashion For this chemical, the log-normal approximation was not as good as for the others. For the other chemicals, however, the log-normal approximation using these "trimmed" geometric standard deviations was generally within 5% of the observed values between the 10th and 90th percentiles. Beyond the 90th or 95th percentile, exposures to all chemicals were higher than predicted by the log-normal approximation.

Figure E-2. ***Weighted vs. unweighted frequency distributions for 1,1,1-trichloroethane. The straight line is a log-normal curve with the same geometric mean and geometric standard deviation as the observed distribution.***

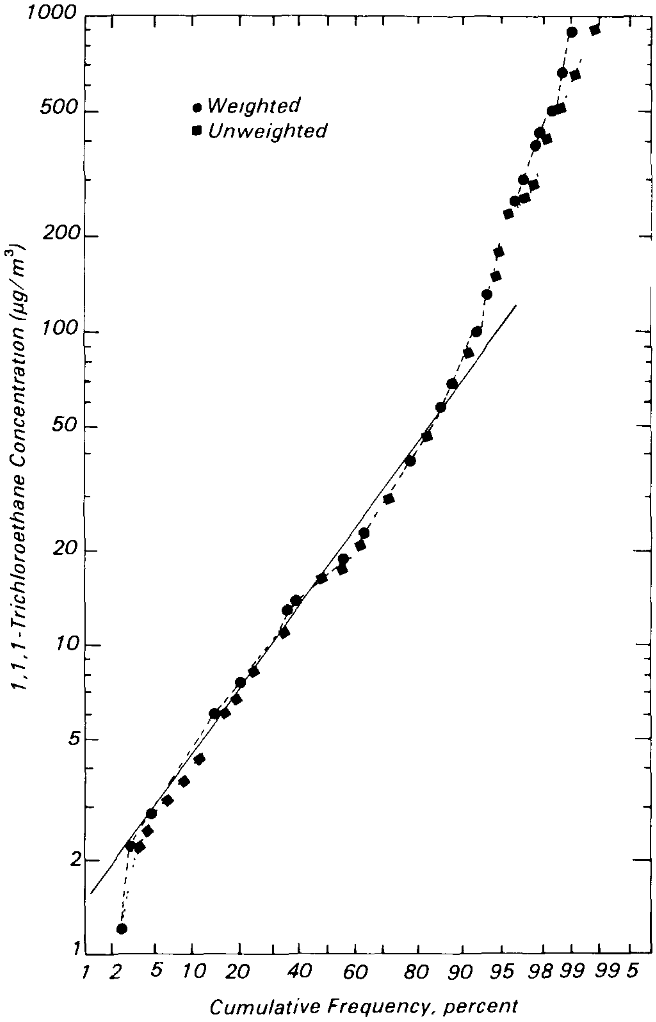


Figure E-3. ***Weighted vs. unweighted frequency distributions for benzene. The straight line is a log-normal curve with the same geometric mean and geometric standard deviation as the observed distribution.***

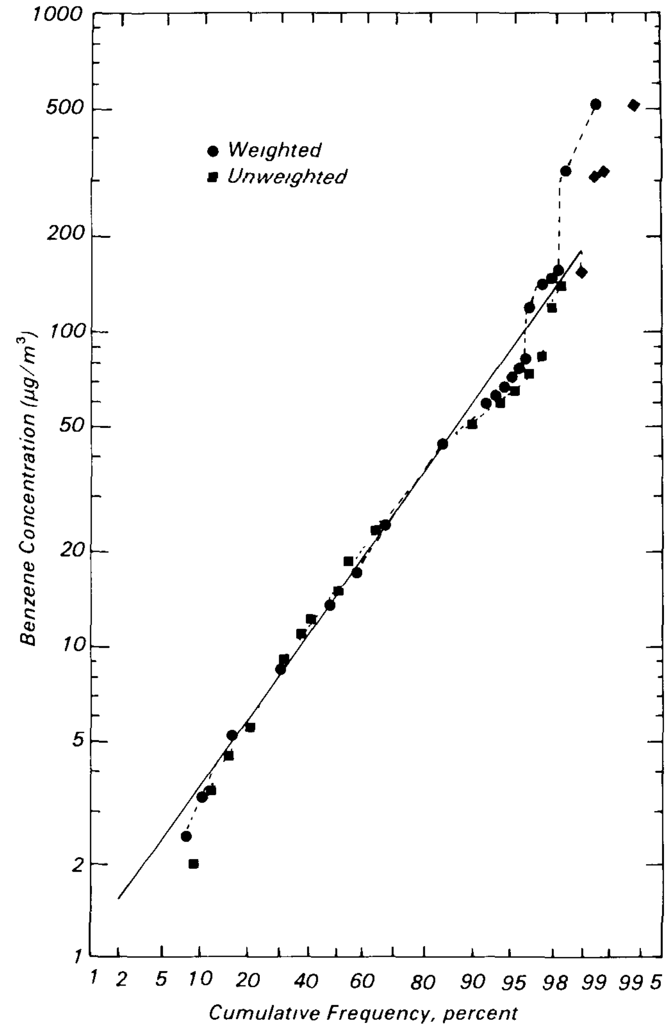


Figure E-4. ***Weighted vs. unweighted frequency distributions for styrene. The straight line is a log-normal curve with the same geometric mean and geometric standard deviation as the observed distribution.***

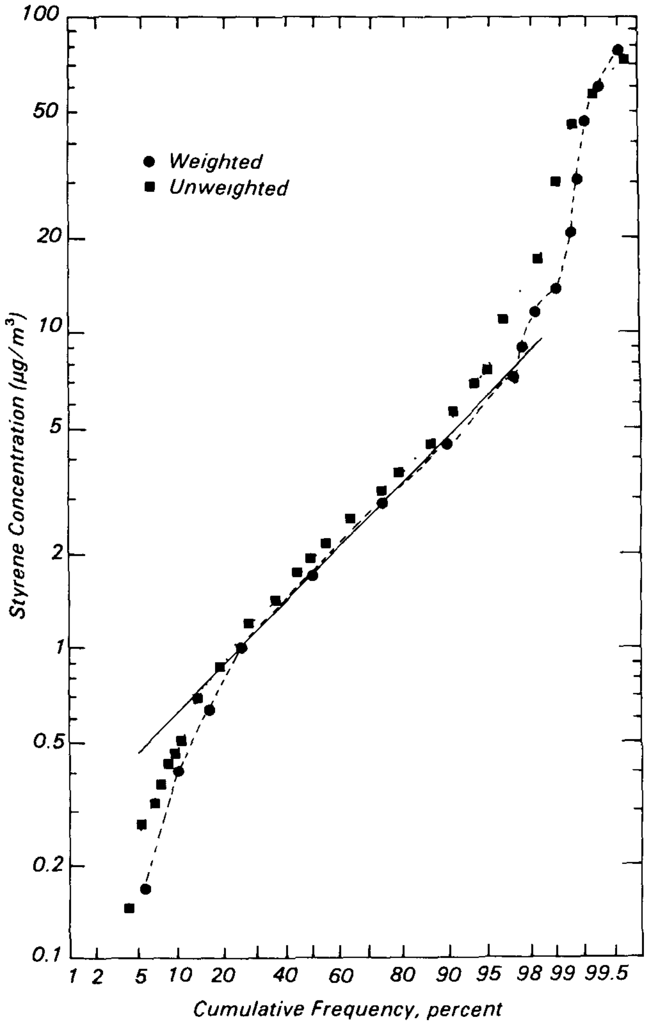


Figure E-5. **Weighted vs. unweighted frequency distributions for tetrachloroethylene. The straight line is a log-normal curve with the same geometric mean and geometric standard deviation as the observed distribution.**

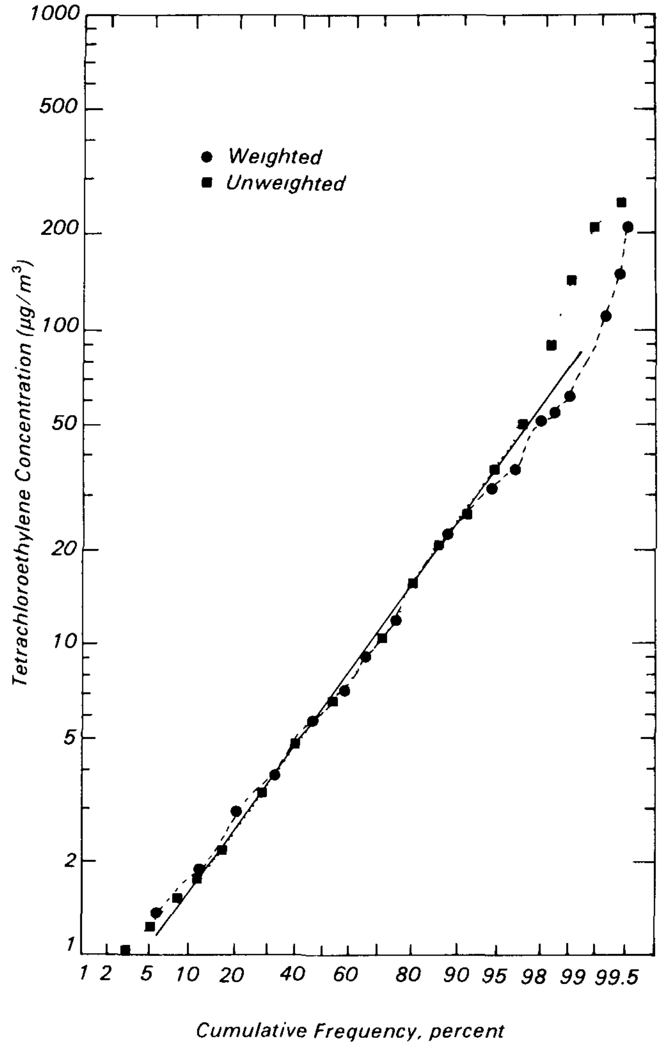


Table E-1. Weighted and Unweighted Overnight Personal Exposures (Indoor Air Concentrations) and Geometric Standard Deviations Calculated for Selected Percentiles

		Percentile			Ratios of Percentiles		
Chemical		*16*	*50*	*84*	$\frac{50}{16}$	$\frac{84}{50}$	$\sqrt{\frac{84}{16}}$
1,1,1-Trichloroethane	*W*[a]	*5.9*[b]	*16.9*[b]	*52*[b]	*2.9*	*3.1*	*3.0*
	U[a]	*6.2*	*16.9*	*50*	*2.7*	*3.0*	*2.8*
Tetrachloroethylene	*W*	*2.2*	*6.3*	*20*	*2.9*	*3.2*	*3.0*
	U	*2.2*	*6.3*	*20*	*2.9*	*3.2*	*3.0*
Benzene	*W*	*5.0*	*15.0*	*46*	*3.0*	*3.1*	*3.0*
	U	*4.7*	*15.0*	*45*	*3.2*	*3.0*	*3.1*
m,p-*Dichlorobenzene*	*W*	*0.9*	*3.8*	*39*	*4.5*	*10.0*	*6.8*
	U	*0.8*	*3.7*	*35*	*4.7*	*9.5*	*6.7*

[a] *W = weighted; U = unweighted.*

[b] *µg/m*^{3}.

Appendix F
Personal Vs. Outdoor Air Comparisons by Season—New Jersey

Daily 24-hour personal exposures and 24-hour outdoor air concentrations of selected chemicals are compared for all three seasons in New Jersey in Figures F-1 through F-5 (see also Figure 26 in text). Because of quality assurance problems, benzene values are available only for the Fall 1981 season (Figure F-5). Personal air exposures exceed outdoor air concentrations at all percentiles for all chemicals in all seasons, with the single exception of chloroform in summer (Figure F-4) Personal exposures to the four chemicals with several seasons of valid data appeared to decrease in summer compared to either fall or winter. However, outdoor concentrations of two chemicals—chloroform and 1,1,1-trichloroethane—were highest in summer Thus, *indoor-outdoor differences were generally smallest in summer and* largest in winter

Figure F-1. ***24-hour personal exposures to 1,1,1-trichloroethane compared to outdoor air in New Jersey-first three seasons.***

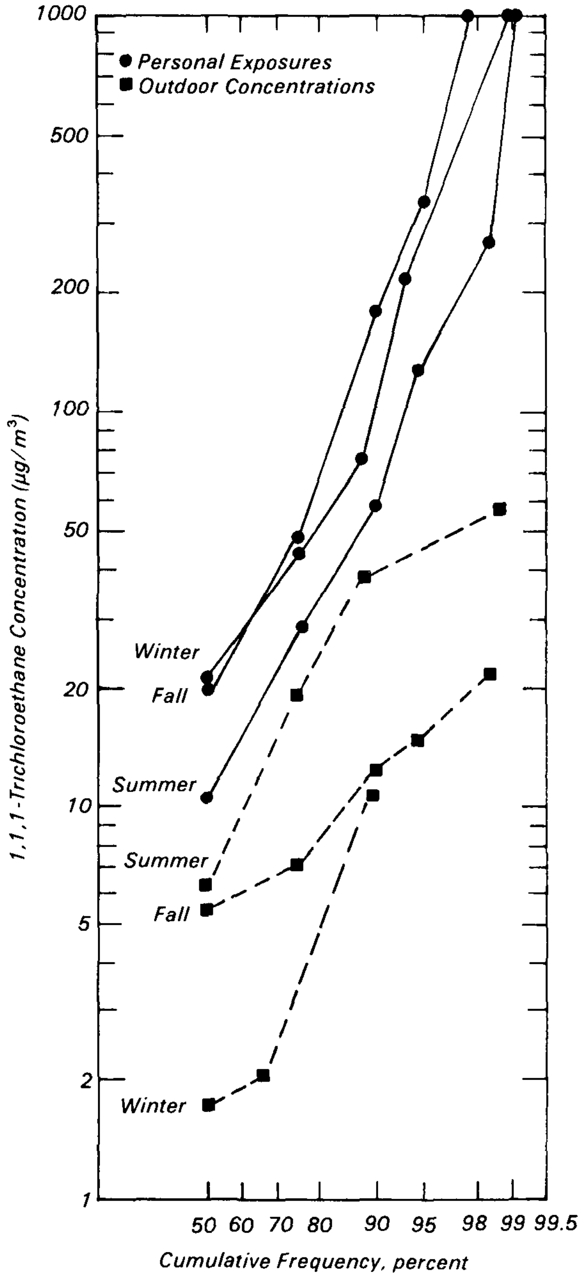


Figure F-2. 24-hour personal exposures to tetrachloroethylene compared to outdoor air in New Jersey-first three seasons.

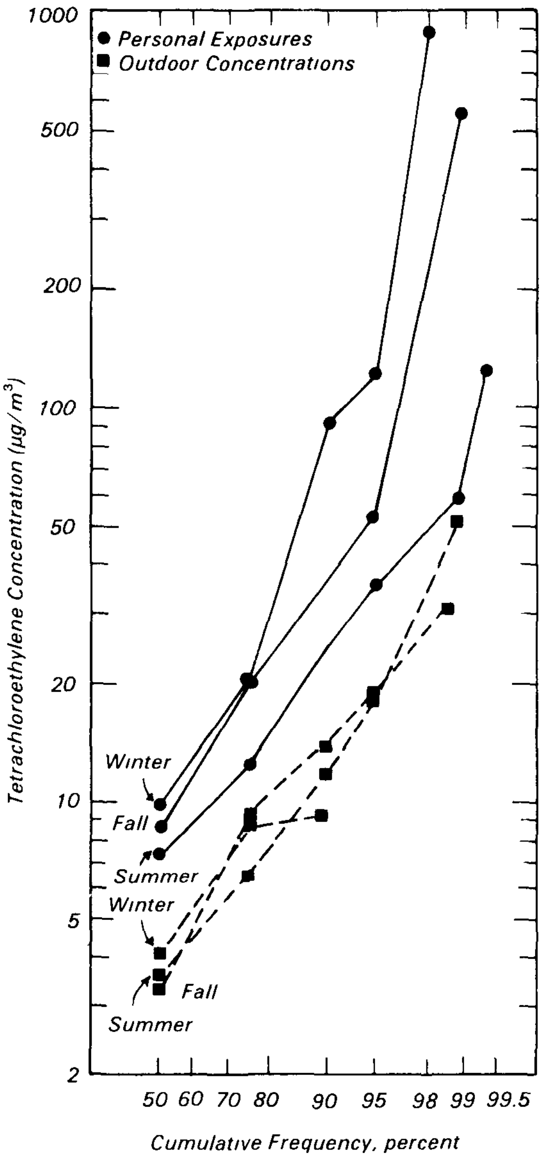


Figure F-3. ***24-hour personal exposures to styrene compared to outdoor air in New Jersey-first three seasons.***

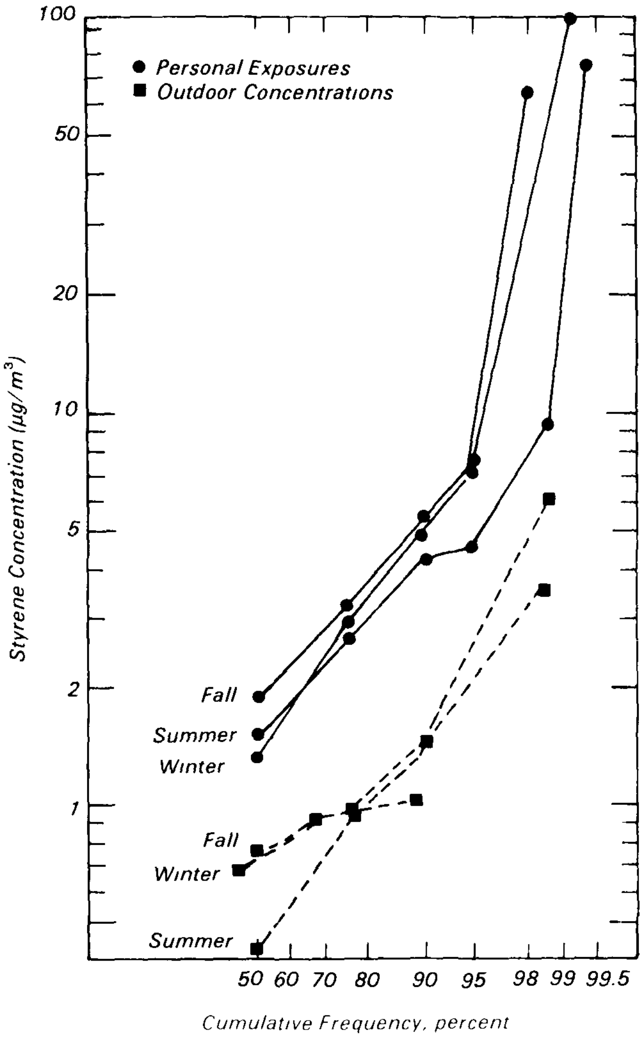


Figure F-4. ***24-hour personal exposures to chloroform compared to outdoor air in New Jersey-first three seasons.***

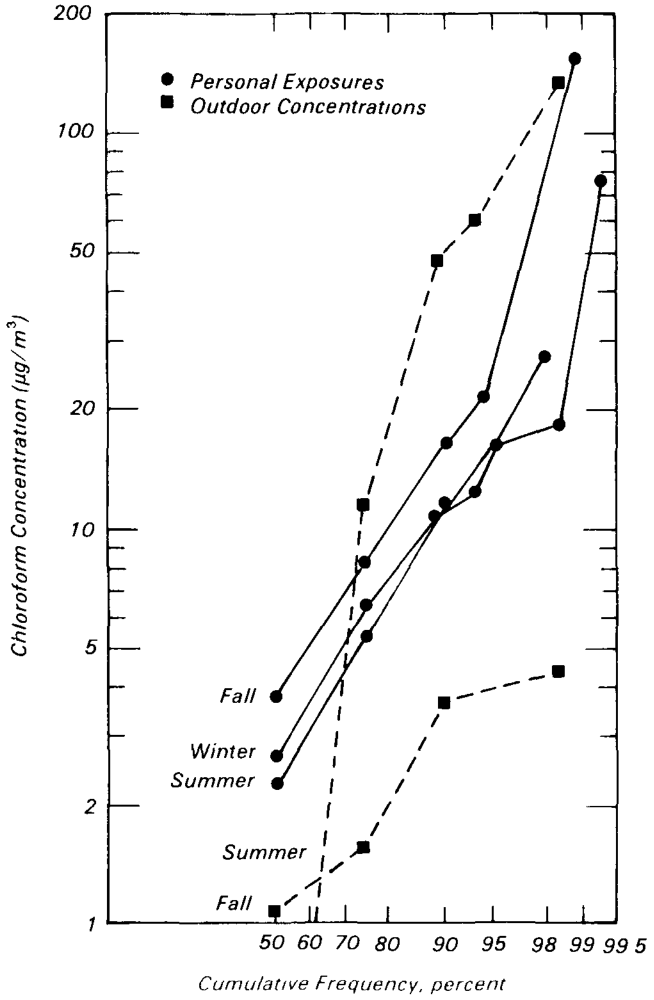
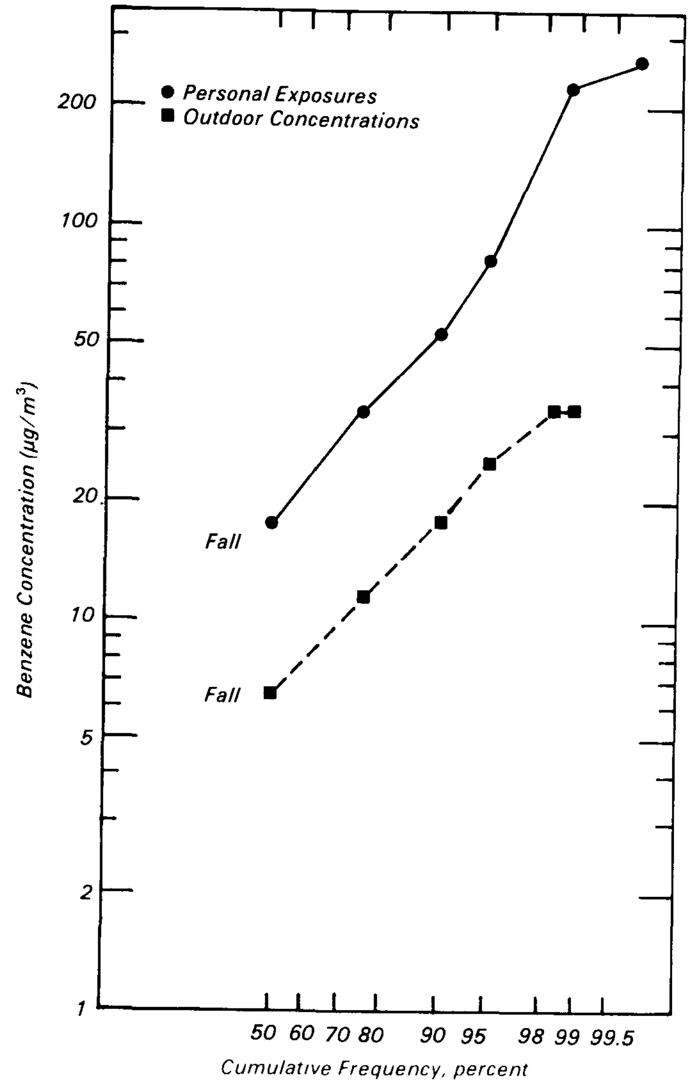


Figure F-5. **24-hour personal exposures to benzene compared to outdoor air in New Jersey-fall season.**



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