SECTION 8

STATISTICAL ANALYSIS

8.1 OVERVIEW OF DATA ANALYSIS

A number of different types of data were available for analysis from this chemical characterization substudy and the PTEAM main study. These included:

- Indoor and outdoor air concentrations for the PAHs and phthalates.
- Indoor and outdoor concentrations for PM_{10} and $PM_{2.5}$.
- Indoor and outdoor concentrations for selected elements including lead, nickel, arsenic, cadmium, chromium, beryllium, and manganese.
- Air exchange rate measurements.
- Results from the time/activity survey.

Except for the air samples for PAHs and phthalates, sample collection was performed at each of 178 homes for both daytime and nighttime monitoring periods. Indoor air samples for PAHs and phthalates were collected from a subset of ~125 homes, while outdoor air samples were collected from about half of these.

Using these data, various types of statistical analysis were conducted to meet the specific objectives of this substudy listed in Table 8-1. The types of analyses used to address these objectives are also described briefly. To estimate frequency distributions for residential indoor and outdoor air concentrations of PAHs and phthalates (Objectives 1 and 2), weighted univariate statistics were calculated. These included the percentages of compound concentrations above the method quantifiable limit, arithmetic and geometric mean concentrations in air samples and their standard errors, and percentiles of the population with distributions of the concentrations.

TABLE 8-1. RELATIONSHIP OF STATISTICAL ANALYSIS TO OBJECTIVES

Analysis Objective	Primary Type of Statistical Models/Analysis
1. To estimate frequency distributions for residential indoor concentrations of PAHs and phthalates in the selected study area during a single season (Fall, 1990).	Weighted univariate statistics[a] on indoor air concentrations.
2. To estimate frequency distributions for residential outdoor concentrations of PAHs and phthalates in the selected study area during a single season (Fall, 1990).	Weighted univariate statistics on outdoor air concentrations.
3. To evaluate whether PAH and phthalate exposures are principally from indoor or outdoor microenvironments in the selected study area during a single season (Fall, 1990).	Unweighted univariate statistics on indoor/outdoor air concentration ratios. Unweighted correlations between indoor and outdoor air concentrations. Calculation of source strength in each home. Unweighted univariate statistics on source strength.
4. To estimate the contribution of outdoor levels of PAHs and phthalates to indoor levels in the selected study area during a single season (Fall, 1990).	Calculation of outdoor contribution to indoor concentration in each home using simple indoor air model. Unweighted univariate statistics on results.
5. To correlate PAH and phthalate concentration values with other pollutant data collected on PTEAM.	Unweighted correlations among compound concentrations.
6. To investigate the possible sources and activities contributing to residential indoor levels of PAHs and phthalates in the selected study area during a single season (Fall, 1990).	Mean concentrations calculated for homes with various sources. Differences tested for significance.
7. To examine the contribution of environmental tobacco smoke to indoor levels of PAHs and phthalates for the selected study area during that season.	Mean concentrations calculated for homes with various sources. Differences tested for significance. Calculated and compared indoor/outdoor concentration ratios in homes with smoking compared to other homes.

[a] Univariate statistics include estimates of the mean and standard deviation, selected percentiles (including median), and proportions of the population with levels falling into certain ranges.

To study the relationships between indoor and outdoor air levels (Objective 3) and to evaluate whether PAH and phthalate exposures are principally from indoor or outdoor microenvironments, unweighted Spearman's rank correlations between indoor and outdoor samples were calculated. Univariate statistics (like those indicated above) were also calculated for the ratio of indoor to outdoor air concentrations. In addition, indoor source strengths for PAHs and phthalates were calculated for each home using a simple indoor air model and the monitoring results for indoor air concentrations, outdoor air concentrations, and air exchange rates. Summary statistics were generated for the resulting source strength values to determine if strong indoor sources were present for the target chemicals.

A simple indoor air quality model was also used to estimate the contribution of outdoor air levels of PAHs and phthalates (Objective 4) to indoor air concentrations for each home where both indoor and outdoor air monitoring data were available. Unweighted univariate statistics were then calculated for these estimates.

To study the relationship between different compounds (Objective 5), unweighted Spearman's rank correlations were calculated for all four sample types (indoor/night, indoor/day, outdoor/night, and outdoor/day). Correlations were performed for the PAH and phthalate concentrations measured in this substudy as well as the particulate and metal concentrations measured as part of the main study. Similar correlations were calculated for indoor air concentrations of PAHs in homes with tobacco smoking during the monitoring period.

To investigate the possible sources and activities contributing to residential indoor levels of PAHs and phthalates (Objectives 6 and 7), exposed and nonexposed groups were defined based on the answers to selected questions in the time/activity survey. Unweighted arithmetic and geometric mean concentrations for indoor and outdoor air samples were calculated for each group and then tested (using a t-test) to determine if the exposed and nonexposed groups had significantly different mean concentrations. Indoor/outdoor air concentration ratios were also calculated and compared for homes with and without smoking.

Weighted statistical analysis was performed using SUDAAN, special-purpose software developed for analysis of sample survey data (30). This software allows robust statistical inferences to be made based on the sampling distribution of survey statistics generated by the known probability sampling design. Statistical analysis weights were used to weight the observations inversely to their probabilities of selection and were adjusted to partially compensate for survey non-response. Using these procedures, sampling weights were adjusted to sum to an estimated 61,520 households in the targeted area of Riverside containing at least one non-smoker age 10 or older. Details of the weighting procedures are given in Volume 1 of the PTEAM final report (25).

8.2 METHOD QUANTIFIABLE LIMITS

The method quantifiable limit (MQL) is the minimum concentration at which a chemical can be quantitatively measured in a sample with acceptable accuracy and precision. Factors that effect the MQL value are the sensitivity and precision of the analytical measurement system, the variability of the sample collection and processing method, the volume of air collected, and the fraction of the air sample that is analyzed. During this study, MQLs for most of the PAHs and phthalates were calculated using the approach outlined by EPA (29) and used during previous TEAM projects. As described in Section 7, most of the MQLs are estimated for this study based on the variability of measured concentrations for low levels of target chemicals spiked onto control samples and are intended to reflect overall method performance. For some of the higher molecular weight PAHs, MQL values were estimated based on the lowest calibration samples.

For the analysis of PAHs and phthalates, the MQL was defined as a mass (ng) of target analyte per sample. The MQL as an air concentration for each sample was then calculated as

$$\text{MQL (ng/m}^3\text{)} = \frac{\text{MQL mass (ng)}}{\text{sample volume (m}^3\text{)}} \tag{8-1}$$

MQL values will therefore vary due to differences in collected air volumes. Table 8-2 summarizes MQL values by compound for the samples collected and analyzed during this study.

Since the range of collected sample volumes was small, the MQL values show little variability within each compound. This is shown by the small differences between the 10th, median, and 90th percentile values reported in the table. Occasionally, sample pumps would shut off during monitoring to give smaller sample volumes and correspondingly higher MQLs. The maximum MQL values represent this worst case scenario which occurred in less than 5% of the samples.

GC/MS results for field samples showed a large closely eluting peak that interfered with the analysis of benzo(k)fluoranthene (BkF). Although not confirmed, this peak is probably a mixture of benzo(j)fluoranthene and benzo(b)fluoranthene. Only when BkF was at fairly high concentrations could the two peaks be resolved and quantitation performed. As a result of this problem, the MQLs reported in Table 8-2 for BkF are considerably lower than the MQLs experienced for actual field samples. Because the size of the interfering peak varied between samples, revised MQLs could not be estimated. As a consequence, weighted statistics have not been calculated for BkF; rather, unweighted statistics using measured

TABLE 8-2. SUMMARY STATISTICS FOR METHOD QUANTIFIABLE LIMITS (MQL) FOR PAHS AND PHTHALATES

Compound	n[a]	MQL (ng/m^3)			
		10th percentile	median	90th percentile	maximum
PAHs					
3-Rings					
Acenaphthylene	339	0.89	1.0	1.3	2.0
Phenanthrene	339	2.4	2.8	3.6	5.3
Anthracene	339	0.15	0.18	0.23	0.34
4-Rings					
Fluoranthene	339	0.91	1.1	1.4	2.0
Pyrene	339	0.48	0.57	0.72	1.1
Benzo[a]anthracene	339	0.09	0.11	0.13	0.20
Chrysene	339	0.08	0.09	0.12	0.17
5-Rings					
Benzo[k]fluoranthene	339	0.07	0.08	0.11	0.16
Benzo[e]pyrene	339	0.07	0.08	0.11	0.16
Benzo[a]pyrene	339	0.07	0.08	0.11	0.16
6-Rings					
Indeno[1,2,3-cd]pyrene	339	0.19	0.22	0.29	0.42
Benzo[ghi]perylene	339	0.13	0.15	0.19	0.29
7-Rings					
Coronene	339	0.21	0.24	0.31	0.46
PHTHALATES					
Diethylphthalate	339	68	80	100	150
Di-n-butylphthalate	339	12	14	18	27
Butylbenzylphthalate	339	4.3	5.1	6.4	9.6
Di-2-ethylhexylphthalate	339	21	24	31	46
Di-n-octylphthalate	339	2.8	3.2	4.1	6.1

[a] n = number of samples.

concentrations only have been reported. In addition, compound prevalence was not calculated.

All sample concentrations including those measured below the MQL were calculated, entered into the data file, and used during statistical analysis. However, only when the resulting statistic was above the MQL has it been reported. When there was no instrumental signal during analysis, the measured air concentration was reported as zero and this zero value was used for statistical analysis. As a single exception to this approach, one eighth of the MQL value was substituted for zero during calculation of the geometric mean. This was done since the logarithm of zero is undefined.

8.3 COMPOUND PREVALENCE

The percentage of samples with air concentrations above the MQL (percent quantifiable) was calculated by sample type (indoor/day, indoor/night, outdoor/day, and outdoor/night) and compound. With the exception of BkF, sample weights were used for all analyses. Results are given in Table 8-3.

For the PAHs excluding B[k]F, percent quantifiable values ranged from a high of 100% for phenanthrene in indoor/daytime samples and benzo[ghi]perylene in outdoor/nighttime samples to a low of 44.8% for benzo[a]anthracene, in outdoor/daytime samples. With the exception of benzo[a]anthracene, all of the 3- and 4-ringed PAHs had high percent quantifiable values (>65%) and showed a similar pattern between sample types. On the other hand, most of the 5- to 7-ringed PAHs tended to show slightly lower percent measurable values. For these latter chemicals, outdoor/nighttime air samples generally gave the highest percent measurable values, whereas outdoor/daytime samples showed the lowest.

TABLE 8-3. WEIGHTED PERCENT OF SAMPLES WITH REPORTED AIR CONCENTRATIONS ABOVE THE METHOD QUANTIFIABLE LIMIT

Compound	Percent Quantifiable			
	Indoor		Outdoor	
	Night	Day	Night	Day
PAHs				
3-Rings				
Acenaphthylene	76.3	77.9	86.8	67.5
Phenanthrene	98.9	100	90.1	92.7
Anthracene	87.6	86.4	73.2	69.5
4-Rings				
Fluoranthene	81.0	80.8	90.3	73.0
Pyrene	98.9	98.4	95.3	92.7
Benzo[a]anthracene	56.3	49.1	56.4	44.8
Chrysene	84.7	80.3	88.7	89.7
5-Rings				
Benzo[k]fluoranthene[a]	33.9	39.4	38.6	23.5
Benzo[e]pyrene	74.3	72.8	88.2	69.5
Benzo[a]pyrene	75.0	68.1	81.7	49.2
6-Rings				
Indeno[1,2,3-cd]pyrene	68.6	68.5	53.4	48.4
Benzo[ghi]perylene	87.7	89.4	100	79.9
7-Rings				
Coronene	77.4	77.5	84.6	60.1
PHTHALATES				
Diethylphthalate	98.4	94.9	17.0	14.2
Di-n-butylphthalate	99.0	100	61.5	52.6
Butylbenzylphthalate	95.7	93.8	11.0	11.9
Di-2-ethylhexylphthalate	99.0	100.0	25.8	61.0
Di-n-octylphthalate	30.5	36.1	1.8	1.8
Sample Size	113	115	53	42

[a] Unweighted estimate.

In evaluating the percent measurable results, it should be kept in mind that all of the target PAHs are generated as a suite of chemicals during the combustion of fossil fuels. Thus, theoretically when one PAH is found in a sample, all of the other target PAHs should also be present. During the combustion process, the volatile 3- and 4-ringed PAHs are formed at much higher concentrations than the less volatile 5- to 7-ringed species (18). Differences in percent quantifiable values among chemicals found in this study may be due to differences in the relative concentrations for the MQL values estimated here compared to the relative concentrations found in air samples. Differences in percent quantifiable values may also be due to different source strengths or mechanisms for decay or removal between different chemical species.

With the exception of di-n-octylphthalate, all of the phthalates were ubiquitous in indoor air samples with percent quantifiable values greater than 90%. Percent quantifiable values for phthalates in outdoor air samples were much lower ranging from a high value of 61.4% for di-n-butylphthalate in nighttime samples to a low value of 1.8% for di-n-octylphthalate in both daytime and nighttime samples. These data suggest that indoor phthalate concentrations arise primarily from indoor sources and that most of the exposure to airborne phthalates will occur indoors.

8.4 CONCENTRATION STATISTICS

Based on the relativity high percent quantifiable values calculated above, weighted descriptive statistics for measured air concentrations were calculated for all of the target PAHs and the phthalates (except BkF). Weighted univariate statistics for measured air concentrations are given in Tables 8-4 to 8-9. These include arithmetic and geometric means and their standard errors, percentiles, and maximum values. Results are provided separately

TABLE 8-4. WEIGHTED DESCRIPTIVE STATISTICS FOR NIGHTTIME OUTDOOR AIR CONCENTRATIONS (ng/m^3)

Compound	n[a]	Median MQL	Arithmetic Mean	Arithmetic S.E.[b]	Geometric Mean	Geometric S.E.	Percentiles 10th	Percentiles 25th	Percentiles 50th	Percentiles 75th	Percentiles 90th	Maximum[c]
PAHs												
3-Rings												
Acenaphthylene	52	1.0	13	2.4	5.8	1.8	NQ[d]	1.8	6.9	19	35	54
Phenanthrene	53	2.8	13	1.4	10	1.8	4.1	7.5	12	16	22	39
Anthracene	53	0.18	0.71	0.10	0.43	0.09	NQ	NQ	0.57	1.0	1.6	2.7
4-Rings												
Fluoranthene	53	1.1	2.4	0.21	2.0	0.23	NQ	1.6	2.3	2.9	4.1	6.3
Pyrene	53	0.57	2.3	0.20	1.9	0.20	0.59	1.5	2.0	2.8	4.0	6.6
Benzo[a]anthracene	53	0.11	0.21	0.03	0.12	0.02	NQ	NQ	0.13	0.36	0.56	0.90
Chrysene	53	0.09	0.41	0.05	0.27	0.03	NQ	0.14	0.21	0.64	1.0	1.5
5-Rings												
Benzo[e]pyrene	53	0.08	0.35	0.04	0.23	0.03	NQ	0.10	0.22	0.55	0.85	1.3
Benzo[a]pyrene	53	0.08	0.44	0.07	0.23	0.04	NQ	0.08	0.19	0.66	1.4	2.4
6-Rings												
Indeno[1,2,3-cd]pyrene	52	0.22	0.67	0.09	0.34	0.07	NQ	NQ	0.34	1.1	1.6	3.5
Benzo[ghi]perylene	53	0.15	1.4	0.19	0.81	0.12	0.24	0.33	0.83	2.1	3.1	7.9
7-Rings												
Coronene	53	0.24	1.2	0.17	0.69	0.10	NQ	0.31	0.55	1.9	2.9	6.9
PHTHALATES												
Diethylphthalate	53	80	99	56	NQ	-	NQ	NQ	NQ	NQ	140	3300
Di-n-butylphthalate	53	14	37	13	16	3.2	NQ	NQ	18	38	57	630
Butylbenzylphthalate	53	5.1	NQ	-	NQ	-	NQ	NQ	NQ	NQ	6.7	47
Di-2-ethylhexylphthalate	53	24	NQ	-	NQ	-	NQ	NQ	NQ	26	38	95
Di-n-octylphthalate	53	3.2	NQ	-	NQ	-	NQ	NQ	NQ	NQ	NQ	3.4

[a] n = Number of observations.
[b] S.E. = Standard Error.
[c] Sample maximum, not weighted.
[d] NQ = Not quantifiable (below the method quantifiable limit).

TABLE 8-5. WEIGHTED DESCRIPTIVE STATISTICS FOR DAYTIME OUTDOOR AIR CONCENTRATIONS (ng/m^3)

Compound	n[a]	Median MQL	Arithmetic Mean	Arithmetic S.E.[b]	Geometric Mean	Geometric S.E.	Percentiles 10th	25th	50th	75th	90th	Maximum[c]
PAHs												
<u>3-Ringed</u>												
Acenaphthylene	41	1.0	3.8	0.93	2.3	0.59	NQ[d]	1.1	1.8	4.8	12	18
Phenanthrene	42	2.8	10	1.5	8.3	1.5	3.0	5.0	8.8	13	20	32
Anthracene	42	0.18	0.42	0.06	0.32	0.07	NQ	0.18	0.36	0.59	0.85	1.2
<u>4-Ringed</u>												
Fluoranthene	42	1.1	2.6	0.40	2.1	0.39	NQ	1.3	2.2	3.3	4.8	8.8
Pyrene	42	0.57	2.1	0.33	1.7	0.32	0.68	0.99	1.8	2.8	4.1	6.3
Benzo(a)anthracene	42	0.11	0.15	0.03	NQ	-	NQ	NQ	NQ	0.26	0.37	0.50
Chrysene	42	0.09	0.36	0.07	0.27	0.05	0.10	0.15	0.24	0.48	0.84	1.4
<u>5-Ringed</u>												
Benzo(e)pyrene	42	0.08	0.22	0.04	0.16	0.03	NQ	0.08	0.13	0.33	0.59	0.69
Benzo(a)pyrene	42	0.08	0.17	0.04	0.11	0.02	NQ	NQ	0.09	0.22	0.35	0.94
<u>6-Ringed</u>												
Indeno(1,2,3-cd)pyrene	39	0.22	0.40	0.09	NQ	-	NQ	NQ	NQ	0.54	1.2	1.5
Benzo(ghi)perylene	41	0.15	0.72	0.14	0.42	0.10	NQ	0.17	0.36	1.1	1.5	2.9
<u>7-Ringed</u>												
Coronene	42	0.24	0.57	0.12	0.34	0.08	NQ	NQ	0.36	0.94	1.2	2.3
PHTHALATES												
Diethylphthalate	42	80	NQ	-	NQ	-	NQ	NQ	NQ	NQ	110	660
Di-<u>n</u>-butylphthalate	42	14	19	4.2	NQ	-	NQ	NQ	16	24	33	110
Butylbenzylphthalate	42	5.1	NQ	-	NQ	-	NQ	NQ	NQ	NQ	5.3	11
Di-2-ethylhexylphthalate	42	24	42	9.8	28	3.8	NQ	NQ	28	51	65	570
Di-<u>n</u>-octylphthalate	42	3.2	NQ	-	NQ	-	NQ	NQ	NQ	NQ	NQ	4.1

[a] n = Number of observations.
[b] S.E. = Standard Error.
[c] Sample maximum, not weighted.
[d] NQ = Not quantifiable (below the method quantifiable limit).

TABLE 8-6 WEIGHTED DESCRIPTIVE STATISTICS FOR NIGHTTIME INDOOR AIR CONCENTRATIONS (ng/m^3)

			Arithmetic		Geometric		Percentiles					
Compound	n[a]	Median MQL	Mean	S.E.[b]	Mean	S.E.	10th	25th	50th	75th	90th	Maximum[c]
PAHs												
3-Rings												
Acenaphthylene	109	1.0	31	24	2.9	0.80	NQ[d]	NQ	3.8	8.9	16	2900
Phenanthrene	113	2.8	17	1.5	15	1.1	8.1	11	15	20	28	140
Anthracene	111	0.18	1.2	0.47	0.44	0.06	NQ	0.28	0.47	0.75	1.2	30
4-Rings												
Fluoranthene	113	1.1	2.0	0.30	1.6	0.13	NQ	1.1	1.6	2.3	2.8	34
Pyrene	113	0.57	2.6	0.66	1.7	0.13	0.83	1.2	1.6	2.2	2.7	79
Benzo[a]anthracene	103	0.11	0.16	0.02	NQ	-	NQ	NQ	0.11	0.15	0.32	2.3
Chrysene	106	0.09	0.29	0.03	0.18	0.02	NQ	0.11	0.17	0.30	0.61	3.0
5-Rings												
Benzo[e]pyrene	110	0.08	0.38	0.15	0.14	0.02	NQ	NQ	0.15	0.31	0.47	19
Benzo[a]pyrene	112	0.08	0.77	0.45	0.17	0.02	NQ	NQ	0.20	0.40	0.70	56
6-Rings												
Indeno[1,2,3-cd]pyrene	110	0.22	1.1	0.51	0.31	0.06	NQ	NQ	0.39	0.78	1.4	64
Benzo[ghi]perylene	111	0.15	2.4	1.4	0.62	0.10	NQ	0.28	0.61	1.5	2.3	170
7-Rings												
Coronene	113	0.24	1.7	0.75	0.58	0.09	NQ	0.30	0.61	1.3	2.3	96
PHTHALATES												
Diethylphthalate	113	80	420	38	320	31	140	190	340	510	810	2100
Di-n-butylphthalate	113	14	580	110	410	64	160	260	390	640	1500	2200
Butylbenzylphthalate	113	5.1	51	4.4	30	3.8	8.7	17	35	69	120	250
Di-2-ethylhexylphthalate	113	24	100	7.4	91	6.3	51	68	93	120	170	330
Di-n-octylphthalate	110	3.2	7.0	NQ	-	NQ	NQ	NQ	NQ	NQ	4.6	180

[a] n = Number of observations.
[b] S.E. = Standard Error.
[c] Sample maximum, not weighted.
[d] NQ = Not quantifiable (below the method quantifiable limit).

TABLE 8-7 WEIGHTED DESCRIPTIVE STATISTICS FOR DAYTIME INDOOR AIR CONCENTRATIONS (ng/m^3)

Compound	n[a]	Median MQL	Arithmetic Mean	Arithmetic S.E.[b]	Geometric Mean	Geometric S.E.	Percentiles 10th	25th	50th	75th	90th	Maximum[c]
PAHs												
<u>3-Rings</u>												
Acenaphthylene	113	1.0	11	4.4	2.7	0.77	NQ[d]	NQ	3.5	7.6	15	530
Phenanthrene	114	2.8	19	1.7	16	1.3	8.5	12	16	21	32	150
Anthracene	111	0.18	0.86	0.23	0.38	0.05	NQ	0.25	0.41	0.68	1.0	24
<u>4-Rings</u>												
Fluoranthene	113	1.1	2.3	0.38	1.8	0.18	NQ	1.3	1.7	2.5	3.1	40
Pyrene	114	0.57	2.9	0.75	1.9	0.16	0.93	1.3	1.8	2.3	3.6	92
Benzo[a]anthracene	109	0.11	0.16	0.03	NQ	-	NQ	NQ	NQ	0.17	0.38	2.3
Chrysene	107	0.09	0.28	0.04	0.18	0.02	NQ	0.11	0.16	0.27	0.63	2.9
<u>5-Rings</u>												
Benzo[e]pyrene	110	0.08	0.37	0.12	0.16	0.02	NQ	0.08	0.17	0.32	0.60	15
Benzo[a]pyrene	110	0.08	0.52	0.24	0.14	0.02	NQ	NQ	0.14	0.32	0.77	30
<u>6-Rings</u>												
Indeno[1,2,3-cd]pyrene	107	0.22	1.1	0.39	0.32	0.08	NQ	NQ	0.42	0.87	1.7	49
Benzo[ghi]perylene	115	0.15	2.1	0.89	0.69	0.11	0.16	0.31	0.74	1.6	3.5	120
<u>7-Rings</u>												
Coronene	115	0.24	1.5	0.47	0.64	0.09	NQ	0.28	0.68	1.6	2.3	63
PHTHALATES												
Diethylphthalate	114	80	450	47	340	32	130	200	340	530	840	2800
Di-<u>n</u>-butylphthalate	114	14	630	97	460	56	190	260	420	740	1300	3100
Butylbenzylphthalate	115	5.1	62	7.8	36	4.5	8.5	17	34	85	140	390
Di-2-ethylhexylphthalate	115	24	140	12	110	8.6	59	71	110	170	240	1000
Di-<u>n</u>-octylphthalate	110	3.2	16	5.7	NQ	-	NQ	NQ	NQ	5.1	9.7	560

[a] n = Number of observations.
[b] S.E. = Standard Error.
[c] Sample Maximum, not weighted.
[d] NQ = Not quantifiable (below the method quantifiable limit).

TABLE 8-8. WEIGHTED DESCRIPTIVE STATISTICS FOR COMBINED DAYTIME/NIGHTTIME OUTDOOR AIR CONCENTRATIONS (ng/m^3)

Compound	n[a]	Median MQL	Arithmetic Mean	Arithmetic S.E.[b]	Geometric Mean	Geometric S.E.	Percentiles 10th	Percentiles 25th	Percentiles 50th	Percentiles 75th	Percentiles 90th
PAHS											
3-Rings											
Acenapthylene	34	1.0	7.7	2.1	4.2	1.6	NQ[c]	2.0	4.4	9.9	21
Phenanthrene	36	2.8	11	1.8	9.4	2.1	3.4	6.4	11	15	18
Anthracene	36	0.18	0.55	0.10	0.41	0.11	NQ	0.21	0.55	0.74	1.0
4-Rings											
Fluoranthene	36	1.1	2.5	0.36	2.1	0.37	NQ	1.5	2.2	3.2	4.5
Pyrene	36	0.57	2.2	0.31	1.9	0.31	0.98	1.4	2.0	2.5	3.9
Benzo[a]anthracene	36	0.11	0.18	0.35	0.12	0.03	NQ	NQ	NQ	0.26	0.46
Chrysene	36	0.09	0.39	0.06	0.28	0.05	0.12	0.16	0.22	0.56	0.95
5-Rings											
Benzo[e]pyrene	36	0.08	0.28	0.05	0.20	0.03	NQ	0.11	0.18	0.42	0.60
Benzo[a]pyrene	36	0.08	0.30	0.06	0.18	0.04	NQ	0.09	0.16	0.49	0.84
6-Rings											
Indeno[1,2,3-cd]pyrene	32	0.22	0.51	0.11	0.29	0.09	NQ	NQ	0.30	0.68	1.2
Benzo[ghi]perylene	35	0.15	1.0	0.20	0.66	0.14	0.20	0.30	0.69	1.3	2.0
7-Rings											
Coronene	36	0.24	0.83	0.10	0.54	0.10	NQ	0.29	0.46	1.2	2.0
PHTHALATES											
Diethylphthalate	36	80	80	43	NQ	-	NQ	NQ	NQ	NQ	120
Di-n-butylphthalate	36	14	34	12	19	4.5	NQ	NQ	18	33	47
Butylbenzylphthalate	36	5.1	NQ	-	NQ	-	NQ	NQ	NQ	NQ	NQ
Di-2-ethylhexylphthalate	36	24	30	5.4	NQ	-	NQ	NQ	NQ	39	45
Di-n-octylphthalate	36	3.2	NQ	-	NQ	-	NQ	NQ	NQ	NQ	NQ

[a] n = Number of observations.
[b] S.E. = Standard Error.
[c] NQ = Not quantifiable (below the method quantifiable limit).

TABLE 8-9. WEIGHTED DESCRIPTIVE STATISTICS FOR COMBINED DAYTIME-NIGHTTIME INDOOR AIR CONCENTRATIONS (ng/m^3)

Compound	n[a]	Median MQL	Arithmetic Mean	Arithmetic S.E.[b]	Geometric Mean	Geometric S.E.	Percentiles 10th	Percentiles 25th	Percentiles 50th	Percentiles 75th	Percentiles 90th
PAHS											
3-Rings											
Acenapthylene	101	1.0	2.2	16	3.2	0.81	NQ[c]	1.4	3.9	8.0	11
Phenanthrene	104	2.8	18	1.7	16	1.2	8.5	11	15	20	30
Anthracene	100	0.18	0.1	0.32	0.47	0.62	NQ	0.30	0.49	0.66	1.1
4-Rings											
Fluoranthene	103	1.1	2.2	0.37	1.7	0.16	NQ	1.3	1.6	2.2	2.8
Pyrene	104	0.57	2.8	0.78	1.8	0.15	0.90	1.3	1.8	2.2	2.8
Benzo[a]anthracene	91	0.11	0.16	0.02	0.11	0.01	NQ	NQ	0.11	0.18	0.30
Chrysene	93	0.09	0.30	0.03	0.20	0.02	NQ	0.12	0.18	0.33	0.58
5-Rings											
Benzo[e]pyrene	98	0.08	0.39	0.15	0.17	0.02	NQ	0.08	0.15	0.32	0.51
Benzo[a]pyrene	100	0.08	0.70	0.40	0.18	0.03	NQ	0.08	0.19	0.36	0.65
6-Rings											
Indeno[1,2,3-cd]pyrene	97	0.22	1.1	0.52	0.39	0.07	NQ	0.20	0.39	0.82	1.4
Benzo[ghi]perylene	103	0.15	2.4	1.3	0.72	0.11	0.19	0.35	0.84	1.4	2.3
7-Rings											
Coronene	105	0.24	1.7	0.68	0.65	0.10	NQ	0.31	0.75	1.3	2.0
PHTHALATES											
Diethylphthalate	104	80	430	41	350	30	150	210	350	540	850
Di-n-butylphthalate	104	14	620	110	470	64	180	300	410	720	1500
Butylbenzylphthalate	105	5.1	56	56	37	3.9	9.8	18	35	73	140
Di-2-ethylhexylphthalate	105	24	120	11	110	7.9	59	75	103	150	215
Di-n-octylphthalate	102	3.2	11	4.6	NQ	NQ	NQ	NQ	NQ	4.1	6.7

[a] n = Number of observations.
[b] S.E. = Standard Error.

for outdoor/nighttime (Table 8-4), outdoor/daytime (Table 8-5), indoor/nighttime (Table 8-6), and indoor/daytime (Table 8-7) samples. Indoor and outdoor air concentrations combined over the daytime and nighttime samples are also given (Tables 8-8 and 8-9). Unweighted statistics for benzo[k]fluoranthene are given in Table 8-10 using quantifiable concentrations only. Results are compared between sample types in Table 8-11 using weighted median concentration values. Results for benzo[a]pyrene are summarized graphically in Figure 8-1 which shows estimated air concentrations in each of the four sample types.

PAH data show several interesting trends. First, relative air concentrations for the individual PAH species in all four sample types generally show highest concentrations for the more volatile, 3- and 4-ringed species and lowest concentrations for the particulate-phase 5-, 6-, and 7-ringed species. Highest median air concentrations were found for phenanthrene (8.8 to 16 ng/m^3) followed by acenaphthylene (1.8 to 6.9 ng/m^3), fluoranthene (1.6 to 2.3 ng/m^3), and pyrene (1.6 to 2.0 ng/m^3). Lowest median concentrations for the particulate phase 5- to 7-ringed species were an order of magnitude lower than highest median concentrations for other species with lowest median air concentrations reported for benzo[a]pyrene (0.09 to 0.20 ng/m^3) and benzo[e]pyrene (0.13 to 0.22 ng/m^3).

Second, indoor air samples showed little or no difference in median or mean air concentrations compared to outdoor concentrations. This is not an unexpected result since field monitoring was performed in the fall in southern California. The weather was generally moderate so homes were open. Based on answers to the study questionnaire, there was little use of indoor heating appliances including woodstoves and fireplaces which are considered one of the primary sources of indoor air PAHs. In addition, less than 30% of the homes reported any smoking.

TABLE 8-10. UNWEIGHTED AIR CONCENTRATION STATISTICS FOR BENZO[k]FLUORANTHENE - QUANTIFIABLE VALUES ONLY

Statistic	Concentration (ng/m^3)[a] Indoor	Outdoor
Arithmetic Mean	1.7	1.2
Standard Deviation	4.8	0.99
Percentiles		
10th	0.22	0.26
25th	0.32	0.41
50th	0.62	0.76
75th	1.1	1.9
90th	3.0	2.8
Range	0.09 - 3.5	0.14 - 3.4
Number of samples	90	33

[a] Day and night concentration data combined.

TABLE 8-11. WEIGHTED MEDIAN AIR CONCENTRATIONS (ng/m^3) FOR PAHs AND PHTHALATES

Compound	Indoor-Day	Indoor-Night	Outdoor-Day	Outdoor-Night
PAHs				
<u>3-Rings</u>				
Acenaphthylene	3.5	3.8	1.8	6.9
Phenanthrene	16	15	8.8	12
Anthracene	0.41	0.47	0.36	0.57
<u>4-Rings</u>				
Fluoranthene	1.7	1.6	2.2	2.3
Pyrene	1.8	1.6	1.8	2.0
Benzo[a]anthracene	NQ[a]	0.11	NQ	0.13
Chrysene	0.16	0.17	0.24	0.21
<u>5-Rings</u>				
Benzo[e]pyrene	0.17	0.15	0.13	0.22
Benzo[a]pyrene	0.14	0.20	0.09	0.19
<u>6-Rings</u>				
Indeno[1,2,3-cd]pyrene	0.42	0.39	NQ	0.34
Benzo[ghi]perylene	0.74	0.61	0.36	0.83
<u>7-Rings</u>				
Coronene	0.68	0.61	0.36	0.55
PHTHALATES				
Diethylphthalate	340	340	NQ	NQ
Di-<u>n</u>-butylphthalate	420	390	16	18
Butylbenzylphthalate	34	35	NQ	NQ
Di-2-ethylhexylphthalate	110	93	28	NQ
Di-<u>n</u>-octylphthalate	NQ	NQ	NQ	NQ

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

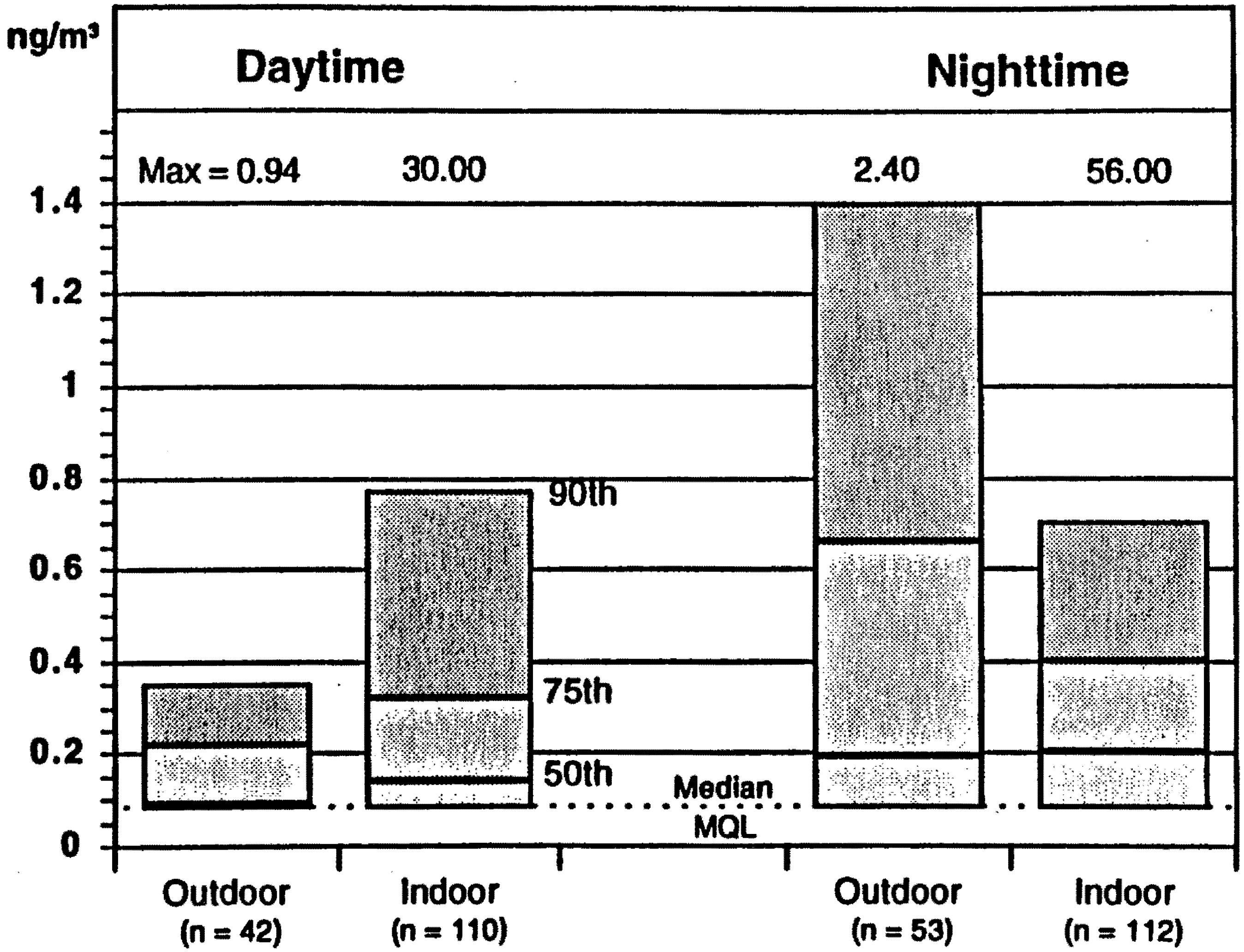

Figure 8-1. Weighted Distributions for Benzo[a]pyrene Concentrations in Indoor and Outdoor Air

The most striking trend in the concentration data is the considerably higher nighttime concentrations reported for outdoor samples compared to the daytime samples. For example, the median nighttime/outdoor air concentration for BaP was 0.19 ng/m^3 while the corresponding daytime concentration was less than half that value at 0.09 ng/m^3. This trend was seen for all of the particulate phase 5- to 7-ringed PAHs as well as the more volatile 3-ringed species.

Daytime/nighttime air concentration ratios were calculated to further examine this trend. Table 8-12 gives data for daytime/nighttime air concentration ratios calculated using the weighted statistical results (i.e. the ratio for the geometric mean was calculated as the daytime geometric mean air concentration divided by the nighttime geometric mean air concentration). Ratios were calculated only if both daytime and nighttime statistics had quantifiable concentrations. Results for daytime/nighttime concentration ratios are given for both indoor and outdoor air samples. Generally, PAH concentration ratios of indoor samples are close to one. Ratios for the geometric means ranged from 0.82 to 1.1, with only BaP (0.82) anthracene (0.86), and acenaphthylene (0.92) showing ratios less than 1.0. For outdoor samples, only the 4-ringed PAH fluoranthene showed a geometric mean ratio greater than 0.90 with many compounds giving low daytime/nighttime ratios. Acenaphthylene gave the lowest mean (arithmetic -0.25, geometric 0.39) and median (0.26) ratios. Arithmetic mean, geometric mean, and median ratios for BaP were 0.38, 0.48, and 0.50 indicating that the nighttime outdoor concentration was approximately twice as high as the daytime concentration. For the phthalates, median daytime/nighttime concentration ratios indoors were generally greater than one in all cases. Di-2-ethylhexylphthalate showed the highest median ratio (1.2). Phthalates were detected in only a few outdoor samples; thus no conclusions should be drawn from these data.

TABLE 8-12. THE RATIO OF DAYTIME TO NIGHTTIME AIR CONCENTRATIONS FOR WEIGHTED DESCRIPTIVE STATISTICS

Compound	Mean		Percentiles				
	Arithmetric	Geometric	10th	25th	50th	75th	90th
INDOORS							
PAHs							
<u>3-Rings</u>							
Acenaphthylene	0.35	0.93	NQ[a]	NQ	0.92	0.85	0.94
Phenanthrene	1.1	1.1	1.0	1.1	1.1	1.1	1.1
Anthracene	0.72	0.86	NQ	0.89	0.87	0.91	0.83
<u>4-Rings</u>							
Fluoranthene	1.2	1.1	NQ	1.2	1.1	1.1	1.1
Pyrene	1.1	1.1	1.1	1.1	1.1	1.0	1.3
Benzo[a]anthracene	1.0	NQ	NQ	NQ	NQ	1.1	1.2
Chrysene	0.97	1.0	NQ	1.0	0.94	0.90	1.0
<u>5-Rings</u>							
Benzo[e]pyrene	0.97	1.1	NQ	NQ	1.1	1.0	1.3
Benzo[a]pyrene	0.68	0.82	NQ	NQ	0.70	0.8	1.1
<u>6-Rings</u>							
Indeno[1,2,3-cd]pyrene	1.0	1.0	NQ	NQ	1.1	1.1	1.2
Benzo[ghi]perylene	0.88	1.1	NQ	1.1	1.2	1.1	1.5
<u>7-Rings</u>							
Coronene	0.88	1.1	NQ	0.93	1.1	1.2	1.0
PHTHALATES							
Diethylphthalate	1.1	1.1	0.93	1.1	1.0	1.0	1.0
Di-<u>n</u>-butylphthalate	1.1	1.1	1.2	1.0	1.1	1.2	0.87
Butylbenzylphthalate	1.2	1.2	0.98	1.7	0.97	1.2	1.2
Di-2-ethylhexylphthalate	1.4	1.2	1.2	1.0	1.2	1.4	1.4
Di-<u>n</u>-octylphthalate	2.2	NQ	NQ	NQ	NQ	NQ	2.1

(continued)

TABLE 8-12. (continued)

Compound	Mean		Percentiles				
	Arithmetric	Geometric	10th	25th	50th	75th	90th
OUTDOORS							
PAHs							
<u>3-Rings</u>							
Acenaphthylene	0.29	0.39	NQ	0.61	0.26	0.25	0.34
Phenanthrene	0.76	0.83	0.73	0.66	0.93	0.81	0.91
Anthracene	0.59	0.74	NQ	NQ	0.63	0.59	0.53
<u>4-Rings</u>							
Fluoranthene	1.1	1.1	NQ	0.81	0.96	1.1	1.2
Pyrene	0.91	0.90	1.2	0.66	0.90	1.0	1.0
Benzo[a]anthracene	0.71	NQ	NQ	NQ	NQ	0.72	0.66
Chrysene	0.87	1.0	NQ	1.1	1.1	0.75	0.84
<u>5-Rings</u>							
Benzo[e]pyrene	0.63	0.70	NQ	0.80	0.59	0.66	0.69
Benzo[a]pyrene	0.38	0.48	NQ	NQ	0.47	0.33	0.25
<u>6-Rings</u>							
Indeno[1,2,3-cd]pyrene	0.59	NQ	NQ	NQ	NQ	0.49	0.75
Benzo[ghi]perylene	0.51	0.52	NQ	0.51	0.43	0.52	0.48
<u>7-Rings</u>							
Coronene	0.48	0.49	NQ	NQ	0.65	0.49	0.41
PHTHALATES							
Diethylphthalate	NQ	NQ	NQ	NQ	NQ	NQ	0.79
Di-n-butylphthalate	0.51	NQ	NQ	NQ	0.88	0.63	0.58
Butylbenzylphthalate	NQ	NQ	NQ	NQ	NQ	NQ	0.79
Di-2-ethylhexylphthalate	NQ	NQ	NQ	NQ	NQ	2.0	1.7

[a] Values for indoor or outdoor concentration statistic below the MQL.

This outdoor daytime/nighttime concentration effect could have occurred for several reasons. First, since automobiles may be the primary source of PAHs in Riverside, elevated nighttime PAH levels in air samples could result from increased traffic during that period. However, casual observations of traffic patterns by the field monitoring teams suggest that there should be little bias toward heavier traffic during either the daytime (~ 8 am to 6 pm) or the nighttime (~ 6 pm to 8 am) sampling periods. Alternatively, weather conditions during the monitoring period were substantially different during the day and at night. Winds were much higher during the daytime which could have dispersed and, hence, diluted PAH concentrations in daytime air samples. However, the outdoor concentrations reported for PM_{10} and $PM_{2.5}$ collected at each home during the PTEAM study did not show this effect (23). Finally, several of the chemicals may be sensitive to photodegradation. Under these conditions, PAHs that are generated at the same rate over a 24-hour period, may react with sunlight during the day to effectively reduce daytime concentrations. This phenomenon has been reported by other researchers. Atkinson et al. (19) estimated atmospheric lifetimes of approximately 1 to 12 hours in the presence of the hydroxy radical. Wehry et al. (20) showed that for the particulate phase PAH photoreactivity is influenced by the chemical and physical properties of the particulate.

Although most of the homes had low PAH concentrations in indoor air samples, two homes had substantially elevated levels relative to the other homes in the study. Both of these homes had very high indoor air concentrations for all of the target PAHs in both daytime and nighttime samples. Indoor air concentration data from these two homes are given in Table 8-13. Indoor PAH air concentrations in the home with the next highest values were approximately an order of magnitude lower than the results reported for the two highest homes. The data for the two highest homes are presented to show the "worst" case

TABLE 8-13. MEASURED INDOOR AIR CONCENTRATIONS (ng/m^3) TWO HIGHEST HOMES

	House 116		House 167	
Compound	Day	Night	Day	Night
PAHs				
3-Rings				
Acenaphthylene	530	2900	200	130
Phenanthrene	150	140	45	44
Anthracene	18	19	6.0	5.5
4-Rings				
Fluoranthene	40	34	11	13
Pyrene	92	79	22	23
Benzo[a]anthracene	2.3	2.3	0.9	0.86
Chrysene	2.9	3.0	1.2	1.4
5-Rings				
Benzo[k]fluoranthracene	26	35	6.7	5.8
Benzo[e]pyrene	15	19	3.7	2.9
Benzo[a]pyrene	30	56	7.9	4.9
6-Rings				
Indeno[1,2,3-cd]pyrene	49	64	7.5	7.0
Benzo[ghi]perylene	124	170	17	15
7-Rings				
Coronene	63	96	12	8.4
PHTHALATES				
Diethylphthalate	320	320	160	120
Di-n-butylphthalate	340	220	150	97
Butylbenzylphthalate	17	16	15	12
Di-2-ethylhexylphthalate	62	65	79	84
Di-n-octylphthalate	NQ[a]	NQ	NQ	4.9
PM_{10}[b] (µg/m^3)	150	150	124	81
$PM_{2.5}$[b] (µg/m^3)	83	84	63	53

[a] NQ = Not quantifiable (below the method quantifiable limit).
[b] Measured as part of the PTEAM main study.

concentrations found in Riverside during field monitoring. Home 167 reported moderate smoking (~10 cigarettes) during each of the two monitoring periods. No other obvious combustion activities or sources were reported for either home that would serve as a major source for PAHs. An evaluation of indoor particulate levels for these two homes showed values for both homes that are at approximately the 85th percentile compared to other homes monitored on the PTEAM study. Outdoor PAH air concentrations for these homes were also an order of magnitude lower than the measured indoor air concentrations.

Table 8-14 compares PAH concentration data generated during previous field monitoring studies to those reported here. Ranges reported for the 10th and 90th percentile on this study were somewhat lower than concentrations reported by Wilson and Chuang (5) and Offerman et al. (4). However, this study was intended to represent all homes in Riverside while the other two studies selected homes where suspected sources of PAHs might be present.

BaP concentrations were further analyzed as a final evaluation of the reported PAH air concentration data. BaP is a carcinogen and is currently under consideration by ARB as a toxic air contaminant. It has been estimated that an air concentration of 0.3 ng/m^3 over a 70-year exposure period will result in a 10^{-6} excess cancer risk (4). The California Office of Environmental Health Hazard Assessment has set a preliminary unit risk for BaP as 1.1×10^{-3} $(ng/m^3)^{-1}$. This unit risk value implies that exposure to an air concentration of 0.9 ng/m^3 of BaP over 70 years would give 10^{-6} excess cancer risk.

Table 8-15 shows the weighted percentage of air samples of each type that exceed the 0.3 ng/m^3 concentration. Percentages of samples that exceed 2 times (0.6 ng/m^3), 5 times

TABLE 8-14. PAH AIR CONCENTRATIONS REPORTED ON THIS STUDY AND COMPARED TO PREVIOUS STUDIES

	Reported Concentration Range (ng/m^3)					
	Riverside		Wilson (5)		Offerman (15)	
Compound	Outdoor	Indoor	Outdoor	Indoor	Outdoor	Indoor
Acenaphthylene	NQ[b] - 35	NQ - 16	1.5 - 22	41 - 23	4.1 - 19	12 - 46
Phenanthrene	3.0 - 22	8.1 - 32	18 - 70	17 - 69	5.4 - 51	29 - 81
Anthracene	NQ - 1.6	NQ - 1.2	0.47 - 3.3	0.5 - 2.6	0.3 - 6.1	2 - 52
Fluoranthene	NQ - 4.8	NQ - 3.1	4.6 - 15	2.6 - 17	1.3 - 22	1.9 - 19.9
Pyrene	0.68 - 4.1	0.8 - 3.6	1.9 - 11	1.5 - 7.5	0.9 - 11	1.0 - 29
Benzo[a]anthracene	NQ - 0.56	NQ - 2.3	0.18 - 1.7	0.14 - 0.76	NQ - 2.8	0.19 - 6.4
Chrysene	NQ - 1.0	NQ - 2.9	0.38 - 2.4	0.24 - 1.1	0.03 - 4.6	0.08 - 3.6
Benzo[e]pyrene	NQ - 0.85	NQ - 0.60	0.33 - 5	0.22 - 1.1	NQ - 0.60	0.21 - 2.2
Benzo[a]pyrene	NQ - 1.4	NQ - 0.77	0.12 - 1.6	0.097 - 1.2	0.02 - 0.43	NQ - 5.1
Indeno[1,2,3-cd]pyrene	NQ - 1.6	NQ - 1.7	0.15 - 2.3	0.86 - 1.4	NQ - 0.38	0.07 - 4.0
Benzo[ghi]perylene	NQ - 3.1	NQ - 3.5	0.31 - 8.1	0.34 - 4.5	NQ - 0.80	0.13 - 10
Coronene	NQ - 2.9	0.3 - 2.3	0.33 - 6.3	0.24 - 3.7	NQ - 1.1	NQ - 3.1

[a] For this study, range is reported as 10th to 90th percentile.
[b] NQ = below the quantifiable limit.

TABLE 8-15. WEIGHTED PERCENTILE OF AIR SAMPLES WITH BaP CONCENTRATION EXCEEDING SELECTED LEVELS

	Percentage			
Sample Type	≥ 0.3 ng/m^3	≥ 0.6 ng/m^3	≥ 1.5 ng/m^3	≥ 30 ng/m^3
Indoor-day	25.2	12.4	1.7	1.3
Indoor-night	39.7	12.0	1.9	1.3
Indoor-24 hr	29.3	13.4	1.5	1.5
Outdoor-day	15.8	3.91	0	0
Outdoor-night	37.6	25.2	7.6	0
Outdoor-24 hr	26.7	13.8	0	0

(1.5 ng/m^3), and 10 times (3.0 ng/m$^{3)}$ this level have also been given. Results show that a substantial fraction of the population may be exposed to BaP concentrations above the 0.3 ng/m^3 level. The home with the highest BaP levels had indoor air concentrations that are approximately two orders of magnitude higher than the 0.3 ng/m^3 risk level.

Evaluation of the air concentration data for the phthalates is straightforward. With the exception of di-n-octylphthalate, all of the phthalates showed high indoor concentrations and low outdoor air concentrations. Diethylphthalate and di-n-butylphthalate showed the highest indoor air concentrations with median daytime concentrations of 340 and 420 ng/m^3, respectively. Median outdoor air levels for the phthalates were at least an order of magnitude lower than the corresponding indoor levels. Di-n-octylphthalate showed median concentration levels below the quantifiable limit (3.2 ng/m^3) for all four sample types. Since phthalates are plasticizers, all plastic materials in a home could be potential sources.

8.5 INDOOR/OUTDOOR RELATIONSHIPS

8.5.1 Indoor/Outdoor Air Concentration Ratios

As a first step in studying the relationship of the target PAHs and phthalates between indoor and outdoor samples, indoor/outdoor air concentration ratios were calculated for sample collected at the same home during the same time period and summary statistics generated for these ratios. Unweighted data on indoor/outdoor air concentration ratios are provided in Table 8-16. Ratios were calculated only if both concentrations were quantifiable. Results are given for both daytime and nighttime samples.

For the PAHs, the highest geometric mean ratios for indoor/outdoor air concentrations were calculated for acenaphthene (2.6), phenanthrene (2.0), and benzo[a]pyrene (1.8) in daytime samples. The highest median indoor/outdoor air concentration ratios were calculated for phenanthrene (1.9) and benzo[a]anthracene (1.9) in

TABLE 8-16. UNWEIGHTED SUMMARY STATISTICS FOR THE INDOOR/OUTDOOR AIR CONCENTRATION RATIO - QUANTIFIABLE AMOUNT ONLY

		Indoor/Outdoor Air Concentration Ratio							
		Geometric		Percentiles					
Compound	n[a]	Mean	S.E.	10th	25th	50th	75th	90th	Maximum
NIGHTTIME									
PAHs									
3-Rings									
Acenaphthylene	28	0.62	1.3	0.17	0.30	0.45	1.2	4.2	74
Phenanthrene	42	1.2*[b]	1.1	0.69	0.86	1.3	1.7	2.4	6.4
Anthracene	32	0.91	1.2	0.30	0.39	0.66	1.7	3.4	23
4-Rings									
Fluoranthene	34	0.82	1.1	0.42	0.56	0.75	1.1	1.5	8.3
Pyrene	44	0.85	1.1	0.36	0.50	0.79	1.3	1.7	16
Benzo[a]anthracene	17	0.85	1.3	0.26	0.52	0.65	2.3	4.3	6.9
Chrysene	36	0.71*	1.2	0.23	0.46	0.66	1.0	2.1	5.5
5-Rings									
Benzo[e]pyrene	32	0.77	1.2	0.28	0.41	0.67	1.0	1.8	43
Benzo[a]pyrene	32	0.87	1.3	0.26	0.39	0.64	1.3	3.7	53
6-Rings									
Indeno[1,2,3-cd]pyrene	25	0.93	1.3	0.29	0.53	0.83	1.1	2.5	36
Benzo[ghi]perylene	40	0.82	1.2	0.37	0.47	0.68	1.2	1.7	22
7-Rings									
Coronene	31	0.89	1.2	0.37	0.53	0.85	1.3	1.7	24
PHTHALATES									
Diethylphthalate	8	2.3	1.6	0.15	1.6	3.2	5	8.4	8.4
Di-n-butylphthalate	27	15*	1.2	4.5	8.5	15	28	72	110
Butylbenzylphthalate	5	5.5*	1.8	0.85	2.4	8.9	14	19	19
Di-2-ethylhexylphthalate	12	2.8*	1.1	1.7	2.1	3.1	3.8	4.2	5.1
Di-n-octylphthalate	1	0.85	-	0.85	0.85	0.85	0.85	0.85	0.85

(continued)

TABLE 8-16. (continued)

Compound	n[a]	Geometric Mean	Geometric S.E.[b]	Percentiles 10th	25th	50th	75th	90th	Maximum
		Indoor/Outdoor Air Concentration Ratio							
DAYTIME									
PAHs									
<u>3-Rings</u>									
Acenaphthylene	22	2.6[*,b]	1.3	0.72	1.0	1.5	4.3	25	92
Phenanthrene	37	2.0[*]	1.1	1.0	1.3	1.9	2.7	3.6	9.0
Anthracene	22	1.4	1.2	0.55	0.69	1.1	2.2	5.0	19
<u>4-Ringed</u>									
Fluoranthene	30	0.88	1.1	0.48	0.57	0.76	1.2	2.2	7.8
Pyrene	37	1.2	1.1	0.52	0.70	1.1	1.5	2.9	18
Benzo[a]anthracene	9	1.7	1.3	0.70	0.92	1.9	2.4	6.2	6.2
Chrysene	23	0.79	1.2	0.33	0.50	0.72	1.5	1.9	4.0
<u>5-Ringed</u>									
Benzo[e]pyrene	21	1.3	1.3	0.43	0.76	1.1	1.5	4.5	25
Benzo[a]pyrene	15	1.8	1.4	0.43	0.70	1.2	3.6	8.9	86
<u>6-Ringed</u>									
Indeno[1,2,3-cd]pyrene	13	1.6	1.3	0.77	0.80	1.2	1.7	5.4	33
Benzo[ghi]perylene	29	1.4	1.2	0.55	0.77	1.3	1.4	7.1	41
<u>7-Ringed</u>									
Coronene	23	1.4	2	0.64	0.78	1.4	1.9	2.4	27
PHTHALATES									
Diethylphthalate	6	3.0[*]	1.5	0.86	1.1	4.3	5.7	7.4	7.4
Di-<u>n</u>-butylphthalate	19	16[*]	1.2	5.3	8.8	14	34	56	100
Butylbenzylphthalate	5	4.6[*]	1.2	3.0	3.5	4.3	5.1	8.7	8.7
Di-2-ethylhexylphthalate	19	2.2[*]	1.2	1.0	1.4	1.7	4.4	5.7	15
Di-<u>n</u>-octylphthalate	1	1.4	-	1.4	1.4	1.4	1.4	1.4	1.4

[a] n = number of sample pairs.
[b] Significantly different from one at the 0.05 level.

daytime samples. As with the concentration data, a daytime/nighttime trend is seen for these calculated indoor/outdoor concentration ratios. For daytime samples, all the target PAHs except fluoranthene and chrysene had median and geometric mean indoor/outdoor air concentration ratios greater than one indicating higher indoor air concentrations during the day. For the nighttime samples, both mean and median indoor/outdoor air concentration ratios for all target PAHs except phenanthrene were less than one indicating higher outdoor concentrations. Since indoor air concentrations were fairly uniform (Table 8-11) between the daytime and nighttime monitoring periods, then these results reflect the substantially lower daytime air concentrations measured in outdoor samples. The very high indoor/outdoor air concentration ratios (maximum and 90th percentile) indicate that in some homes very high concentrations are measured, whereas the range of outdoor air concentration range is narrower.

The phthalates showed indoor/outdoor concentration ratios greater than one suggesting relatively strong indoor sources. Highest ratios were calculated for di-n-butylphthalate (14-16). No conclusions can be drawn about di-n-octylphthalate because it was quantified in so few samples.

8.5.2 Indoor/Outdoor Correlations

To further investigate the relationship between indoor and outdoor air samples, Spearman's rank correlations were calculated for the target PAHs and phthalates. Correlation is a measure of the linear relationship between two variables (in this case indoor and outdoor air concentration), with 1.00 showing a perfect direct correlation and -1.00 showing a perfect inverse relationship. If there is no relationship between the two variables, then the correlation will be close to 0.00. Spearman's rank correlation uses the ranks of the concentrations rather than the concentration values. This tends to counteract the effects of extreme concentration values or a skewed distribution.

Table 8-17 shows Spearman's rank correlations between indoor and outdoor air concentrations measured for samples collected at the same home during the same time period. Data are provided separately for daytime and nighttime samples. The table also shows which correlations are significant (i.e., judged to be nonzero) at the 0.05 level. There appears to be little difference in the indoor/outdoor correlations for either the daytime or nighttime monitoring period. Highest correlations are seen for the 5-, 6-, and 7-ringed particulate-bound PAHs. The highest indoor/outdoor correlation was found for benzo[ghi]perylene in daytime samples whereas the lowest indoor/outdoor correlation was found for anthracene in daytime samples.

These indoor/outdoor correlations for PAHs are generally higher than those reported previously for volatile organic chemicals (21, 22). They are also considerably higher than the correlations reported for the phthalates. The strong correlations for PAHs suggests that outdoor PAHs may have made a substantial contribution to measured indoor concentrations. On the other hand, the high indoor/outdoor concentration ratios for the phthalates and the low indoor/outdoor correlations suggests again that indoor phthalates are coming primarily from indoor sources and that outdoor sources do not provide a substantial contribution to indoor phthalate concentrations.

8.5.3 Indoor Air Models

A simple indoor air model was used to evaluate whether indoor exposures to PAHs and phthalates were primarily from indoor or outdoor sources. The model was also used to estimate the relative contribution to indoor air concentrations from both of these sources. It should be stressed that due to the many assumptions that must be made and the uncertainty

TABLE 8-17. SPEARMAN'S RANK CORRELATION BETWEEN INDOOR AND OUTDOOR AIR SAMPLES[a]

Compound	Daytime Samples		Nighttime Samples	
	n[b]	Correlation	n	Correlation
PAHs				
3-Rings				
Acenaphthylene	39	0.58[c]	47	0.51[c]
Phenanthrene	40	0.54[c]	48	0.60[c]
Anthracene	39	0.30	47	0.37
4-Rings				
Fluoranthene	40	0.55[c]	48	0.59[c]
Pyrene	40	0.52	48	0.44
Benzo[a]anthracene	38	0.51	46	0.52[c]
Chrysene	35	0.62[c]	45	0.59[c]
5-Rings				
Benzo[e]pyrene	39	0.71[c]	47	0.66[c]
Benzo[a]pyrene	38	0.72[c]	48	0.69[c]
6-Rings				
Indeno(1,2,3-cd)pyrene	34	0.69[c]	48	0.79[c]
Benzo(ghi)perylene	39	0.82[c]	45	0.78[c]
7-Rings				
Coronene	40	0.80[c]	47	0.76[c]
PHTHALATES				
Diethylphthalate	40	0.55	48	0.52[c]
Di-n-butylphthalate	40	-0.20	47	0.11
Butylbenzylphthalate	40	0.16	48	0.16
Di-2-ethylhexylphthalate	40	0.16	48	0.28
Di-n-octylphthalate	40	0.28	46	0.31

[a] Computed using all samples.
[b] Number of sample pairs.
[c] Significantly different from zero at the 0.05 level.

associated using a simple indoor air model, the analysis performed here was not intended to be a rigorous treatment of the data. Rather, it was intended to be a preliminary assessment that might be used to evaluate trends in the measured air concentration data.

As a first step, indoor source strength values were computed for each home where both indoor and outdoor air monitoring was performed. The relationship between indoor and outdoor air concentrations was defined as (31)

$$SS = mV\ (a + k)\ C_i - mVfaC_o \tag{8-2}$$

where:

- SS = source strength, µg/h
- V = house volume, m^3
- m = air mixing between zones
- a = air exchange rate, h^{-1}
- k = pollutant decay rate, h^{-1}
- C_i = indoor concentration, $\mu g/m^3$
- f = fractional penetration of outdoor concentration
- C_o = outdoor concentration, $\mu g/m^3$

For the analysis here, 24-hour time weighted source strength values were computed for each pollutant in each home by using the 24-hour time-weighted arithmetic averages for C_i, C_o, and a. However, these calculations require that assumptions be made about m, k, and f. In the simplest case, m is set equal to one (complete mixing) and k has been set equal to zero (no pollutant decay). Under these conditions equation 8-1 becomes

$$SS = VaC_i - f\ VaC_o \text{ or} \tag{8-3}$$

$$SS = Va\ (C_i - f\ C_o) \tag{8-4}$$

Two approaches have been used to estimate f. For the first approach, f was set equal to 1.0 for the phthalates which are predominately vapor-phase chemicals. For the PAHs f was set equal to 0.5 to reflect their particle-phase distribution. The second approach estimated f for the PAHs from the monitoring data. When there are no sources in the home (SS=0), equation 8-3 rearranges to

$$f = \frac{C_i}{C_o} \tag{8-5}$$

and the penetration factor is equal to the indoor/outdoor air concentration ratio. Although questionnaire data could be used to define homes without indoor sources, indoor/outdoor air concentration ratios calculated for many of these "no source" homes were greater than one suggesting that, in fact, an unidentified indoor source was present. As an alternative, homes with low indoor/outdoor concentration ratios were considered as "no source" homes and f was approximated as the indoor/outdoor concentration ratio for the home at the 25th percentile of the distribution of ratios which seemed a reasonable selection given the range of indoor/outdoor concentration ratios. Table 8-18 lists the penetration factors estimated using this approach. Penetration factors were not estimated for phthalates since it was difficult to identify no source homes. C_i and C_o are the PAH and phthalate air concentrations measured as part of this study. Air exchange rates were measured as part of the PTEAM study. Information on the air exchange rate calculations and the distribution of air exchange rates measured during field monitoring are given in Appendix I. SS was computed using all homes where measurements were performed. When a target chemical was not detected in a

TABLE 8-18. ESTIMATED PENETRATION FACTORS (f) USING INDOOR/OUTDOOR CONCENTRATION RATIOS

Compound	Estimated f[a]
<u>3-Rings</u>	
Acenaphthylene	0.4
Phenanthrene	1.3[b]
Anthracene	0.6
<u>4-Rings</u>	
Fluoranthene	0.6
Pyrene	0.7
Benzo[a]anthracene	0.7
Chrysene	0.5
<u>5-Rings</u>	
Benzo[e]pyrene	0.5
Benza[a]pyrene	0.6
<u>6-Rings</u>	
Indeno[1,2,3-cd]pyrene	0.6
Benzo[ghi]perylene	0.6
<u>7-Rings</u>	
Coronene	0.6

[a] Estimated as the indoor/outdoor air concentration ratios at the 25th percentile.
[b] Indoor/outdoor air concentration ratio was greater than 1; an f value identical to anthracene (0.6) was used for all subsequent calculations since these are similar chemicals.

sample, a concentration equal to one-eight of the MQL was used. Average 24-hour source strength terms were used to minimize the effects caused by differences in measured daytime and nighttime air concentrations measured outdoors. Unweighted univariate statistics for calculated source strength terms are given in Table 8-19.

Results for the PAHs showed low calculated source strengths relative to the phthalates regardless of the f values used in the calculation. Phenanthrene gave the highest median source strength values; lowest values were calculated for the 4-, 5-, and 6-ringed PAHs. There were only small differences in calculated source strengths using the two approaches for estimating f. Results for the phthalates showed much higher calculated source strengths indicating strong indoor sources. Di-n-butylphthalate and diethylphthalate gave the highest values. Again, this should be considered a preliminary assessment of the data; with an understanding that calculated source strength values can change substantially depending upon the assumptions made during the calculations.

Finally, analyses were performed to determine the relative contribution of outdoor sources to indoor air concentrations. The relative contribution of indoor and outdoor sources to the indoor air concentration is also expressed by the indoor air equation. The simple mass indoor air equation can be rearranged where

$$\textit{Indoor Air concentration} = \frac{\textit{contribution}}{\textit{indoor sources}} + \frac{\textit{contribution}}{\textit{outdoor source}} \tag{8-6}$$

$$C_i = \frac{SS}{Va} + f\,C_o$$

TABLE 8-19. 24-HOUR TIME WEIGHTED AVERAGE SOURCE STRENGTH (μg/h) VALUES

Compound	n[a]	f[b]	Source Strength (μg/h) Mean	25th	50th	75th	Maximum
PAHS							
Assumed f Value							
3-Rings							
Acenaphthylene	27	0.5	15	0.00	0.00	0.70	370
Phenanthrene	30	0.5	3.5	1.2	2.0	3.6	27
Anthracene	28	0.5	0.24	0.00	0.04	0.04	3.6
4-Rings							
Fluoranthene	30	0.5	0.45	0.02	0.07	0.24	7.0
Pyrene	30	0.5	0.96	0.05	0.16	0.37	17
Benzo[a]anthracene	26	0.5	0.04	0.00	0.00	0.02	0.42
Chrysene	24	0.5	0.06	0.00	0.00	0.03	0.53
5-Rings							
Benzo[e]pyrene	29	0.5	0.16	0.00	0.00	0.02	3.4
Benzo[a]pyrene	28	0.5	0.40	0.00	0.01	0.03	8.8
6-Rings							
Indeno[1,2,3-cd]pyrene	25	0.5	0.62	0.00	0.00	0.10	11
Benzo[ghi]perylene	27	0.5	1.3	0.00	0.03	0.09	29
7-Rings							
Coronene	30	0.5	0.67	0.00	0.02	0.11	16
PHTHALATES							
Diethylphthalate	30	1.0	84	34	55	130	410
Di-n-butylphthalate	30	1.0	145	65	92	180	530

(continued)

TABLE 8-19. (continued)

Compound	n[a]	f[b]	Source Strength (μg/h) Mean	25th	50th	75th	Maximum
Butylbenzylphthalate	30	1.0	13	3.0	7.0	20	89
Di-2-ethylhexylphthalate	30	1.0	21	12	17	24	110
Di-n-octylphthalate	29	1.0	0.64	0.00	0.24	0.65	8.4
Estimated f Value							
3-Rings							
Acenaphthylene	27	0.4	16	NA[c]	0.07	0.91	370
Phenanthrene	30	0.6	3.2	NA	1.9	3.1	27
Anthracene	28	0.6	0.23	NA	0.03	0.08	3.6
4-Rings							
Fluoranthene	30	0.6	0.34	NA	0.02	0.18	6.9
Pyrene	30	0.7	0.85	NA	0.07	0.28	17
Benzo[a]anthracene	26	0.7	0.03	NA	0.00	0.02	0.40
Chrysene	24	0.5	0.06	NA	0.00	0.03	0.53
5-Rings							
Benzo[e]pyrene	29	0.5	0.16	NA	0.01	0.02	3.4
Benzo[a]pyrene	28	0.6	0.39	NA	0.01	0.03	8.8
6-Rings							
Indeno[1,2,3,cd]pyrene	25	0.6	0.61	NA	0.00	0.08	11
Benzo[ghi]perylene	27	0.6	1.3	NA	0.01	0.06	29
7-Rings							
Coronene	30	0.6	0.65	NA	0.01	0.09	16

[a] = Number of observations.
[b] f = penetration factor.
[c] NA = Not applicable; f was estimated assuming the source strength for the home at the 25th percentile was zero.

fC_o is equal to the contribution of outdoor sources to the indoor air concentration, and the fractional contribution of outdoor sources to indoor air concentration (F_{oi}) may be calculated as

$$F_{oi} = \frac{f\,C_o}{C_i} \tag{8-7}$$

Summary statistics for F_{oi} are given in Table 8-20. As with the source strength calculations, 24-hour time weighted averages were used here. Median F_{oi} values for the PAHs indicate that more than one-half of the indoor air concentrations are generated from outdoor sources. Whereas for the phthalates, only a small fraction of indoor air levels (median F_{oi} <0.25) come from outdoor sources. As discussed above, many assumptions have been made in order to calculate an F_{oi} value. These results should be considered a preliminary assessment of the concentration data used to evaluate trends.

8.6 CORRELATIONS BETWEEN COMPOUNDS

Correlations between compounds in indoor and outdoor air samples were computed to evaluate the degree of association between these compounds. Spearman's rank correlations, using all samples, were computed not only for the PAHs and the phthalates measured as part of this chemical characterization study but also for PM_{10}, $PM_{2.5}$, and selected elements measured as part of the PTEAM study. Only those elements that are identified or considered for identification as toxic air contaminants by ARB have been considered for analysis here. These include arsenic, cadmium, chromium, lead, manganese, mercury, and nickel. Of these seven, only lead and manganese had sufficiently high percentage quantifiable values to be included for analysis. Separate analyses were performed for all four sample types.

TABLE 8-20. FRACTIONAL CONTRIBUTION OF OUTDOOR POLLUTANT SOURCES TO INDOOR AIR CONCENTRATION (F_{oi})

Compound	n[a]	f[b]	Fractional Contribution				
			Min	25th Percentile	50th Percentile	75th Percentile	Maximum
PAHs							
Assumed f Value							
3-Rings							
Acenaphthylene	22	0.5	0.01	0.23	0.97	1.0	1.0
Phenanthrene	30	0.5	0.07	0.20	0.31	0.40	0.75
Anthracene	23	0.5	0.04	0.17	0.52	0.86	1.0
4-Rings							
Fluoranthene	30	0.5	0.06	0.50	0.64	0.83	1.0
Pyrene	30	0.5	0.29	0.39	0.53	0.71	1.0
Benzo[a]anthracene	22	0.5	0.10	0.38	0.47	0.72	1.0
Chrysene	23	0.5	0.13	0.56	0.74	1.0	1.0
5-Rings							
Benzo[e]pyrene	28	0.5	0.03	0.53	0.75	1.0	1.0
Benzo[a]pyrene	26	0.5	0.02	0.37	0.55	0.85	1.0
6-Rings							
Indeno[1,2,3-cd]pyrene	21	1.0	0.02	0.34	0.63	0.81	1.0
Benzo[ghi]perylene	27	0.5	0.02	0.38	0.70	0.83	1.0
7-Rings							
Coronene	29	0.5	0.03	0.36	0.65	0.89	1.0
PHTHALATES							
Diethylphthalate	18	1.0	0.012	0.04	0.11	0.21	1.0
Di-n-buthylphthalate	28	1.0	0.01	0.02	0.04	0.09	0.86
Butylbenzylphthalate	25	1.0	0.08	0.03	0.07	0.19	1.0

Table 8-20. (continued)

Compound	n[a]	f[b]	Fractional Contribution: Min	25th Percentile	50th Percentile	75th Percentile	Maximum
Di-2-ethylhexylphthalate	29	1.0	0.02	0.10	0.25	0.38	1.0
Di-n-octylphthalate	17	1.0	0.01	0.08	0.19	0.28	0.87
Estimated f Value							
3-Rings							
Acenaphthylene	22	0.4	0.01	0.19	0.77	NA	NA
Phenanthrene	30	0.6	0.09	0.24	0.38	NA	NA
Anthracene	23	0.6	0.05	0.20	0.62	NA	NA
4-Rings							
Fluoranthene	30	0.6	0.08	0.60	0.83	NA	NA
Pyrene	30	0.7	0.04	0.56	0.74	NA	NA
Benzo[a]anthracene	22	0.7	0.14	0.54	0.66	NA	NA
Chrysene	23	0.5	0.13	0.56	0.74	NA	NA
5-Rings							
Benzo[e]pyrene	28	0.5	0.03	0.53	0.75	NA	NA
Benzo[a]pyrene	26	0.6	0.02	0.44	0.66	NA	NA
6-Rings							
Indeno[1,2,3,cd]pyrene	21	0.6	0.03	0.41	0.82	NA	NA
Benzo[ghi]perylene	27	0.6	0.02	0.46	0.84	NA	NA
7-Rings							
Coronene	29	0.6	0.04	0.43	0.78	NA	NA

[a] Number of samples.
[b] f = Penetration factor.
[c] Not applicable, estimates for f were made based on the assumption that there was no indoor source therefore F_{oi} would be equal to 1.

Spearman's rank correlations among PAHs in outdoor air samples (Table 8-21) were high in both daytime and nighttime samples. For the outdoor sample sizes used on this study, all correlations greater than 0.30 are significantly greater than zero at the 0.05 level. This would include nearly all correlations computed among PAHs. Highest correlations (>0.85) occurred among the particulate-phase 5- to 7-ringed PAHs. Most of the other compounds showed correlations greater than 0.60. The 3-ringed PAHs, most notably phenanthrene, gave the poorest correlations with the particulate-phase species, although these 3-ringed species correlate fairly well with each other and the 4-ringed congeners.

High correlations may suggest a common source for different chemicals. This is expected to be the case for the PAHs which are generated principally as combustion products of fossil fuels. The reason for the poorer correlation computed for phenanthrene and anthracene is unknown.

Comparison of correlations computed for daytime and nighttime samples showed little difference between samples collected during the two monitoring periods. Generally where there is a difference, nighttime samples tended to exhibit higher correlations. Again, phenanthrene was an exception, with higher correlations for daytime samples.

Table 8-22 gives Spearman's rank correlations among PAHs computed for indoor air samples. For the sample sizes used on this study, all correlations greater than 0.20 are significantly greater than zero at the 0.05 level. Comparison of these results with those generated for outdoor air samples show several interesting trends. First, as with the outdoor samples, the particulate phase 5- to 7-ringed PAHs show strong correlations (0.72 to 0.96) with each other. In contrast, the vapor-phase 3- and 4-ringed species show much poorer

TABLE 8-21. SPEARMAN'S RANK CORRELATIONS AMONG PAHs IN OUTDOOR AIR SAMPLES[b]

	3-rings			4-rings				5-rings		6-rings		7-rings
COMPOUND	Acena-phthylene	Phenan-threne	Anthra-cene	Fluor-anthene	Pyrene	Benzo[a]-anthracene	Chrysene	Benzo[e]-pyrene	Benzo[a]-pyrene	Indeno-[1,2,3-cd]pyrene	Benzo[ghi]-perylene	Coronene
<u>3-rings</u>												
Acenaphthylene		.76	.78	.68	.74	.72	.60	.59	.51	.62	.64	.63
Phenanthrene	.73		.88	.90	.89	.71	.69	.57	.51	.56	.56	.53
Anthracene	.92	.77		.79	.82	.67	.61	.57	.53	.57	.60	.56
<u>4-rings</u>												
Fluoranthene	.81	.79	.87		.97	.85	.85	.73	.70	.71	.75	.69
Pyrene	.80	.73	.87	.91		.86	.83	.73	.70	.71	.75	.69
Benzo[a]anthracene	.80	.52	.78	.76	.69		.97	.89	.89	.74	.81	.78
Chrysene	.72	.45	.70	.74	.67	.97		.91	.91	.73	.81	.78
<u>5-rings</u>												
Benzo[e]pyrene	.73	.48	.74	.70	.72	.91	.92		.95	.83	.91	.88
Benzo[a]pyrene	.80	.51	.80	.71	.71	.94	.90	.94		.78	.86	.85
<u>6-rings</u>												
Indeno[1,2,3-cd]pyrene	.77	.51	.75	.75	.73	.92	.91	.95	.94		.88	.87
Benzo[ghi]perylene	.82	.59	.83	.77	.82	.87	.86	.95	.92	.92		.97
<u>7-rings</u>												
Coronene	.79	.51	.78	.72	.79	.83	.84	.93	.88	.90	.97	

[a] Computed using all samples. For samples sizes used on this study, all correlations greater than 0.30 are significantly greater than zero at the 0.05 level.
[b] Numbers in shaded area are for nighttime samples; other numbers are for daytime samples.
- for daytime samples, n = 38 to 42
- for nighttime samples, n = 52 to 53

TABLE 8-22. SPEARMAN'S RANK CORRELATIONS[a] AMONG PAHS IN INDOOR AIR SAMPLES[b]

COMPOUND	3-rings: Acenaphthylene	3-rings: Phenanthrene	3-rings: Anthracene	4-rings: Fluoranthene	4-rings: Pyrene	4-rings: Benzo[a]anthracene	4-rings: Chrysene	5-rings: Benzo[e]pyrene	5-rings: Benzo[a]pyrene	6-rings: Indeno[1,2,3-cd]pyrene	6-rings: Benzo[ghi]perylene	7-rings: Coronene
3-rings												
Acenaphthylene		.33	.45	.46	.36	.43	.48	.55	.51	.51	.52	.52
Phenanthrene	.25		.45	.72	.69	.28	.25	.26	.28	.28	.23	.23
Anthracene	.40	.54		.52	.48	.47	.38	.34	.31	.27	.36	.26
4-rings												
Fluoranthene	.42	.78	.62		.88	.56	.58	.54	.42	.42	.41	.40
Pyrene	.36	.73	.51	.90		.45	.47	.45	.35	.40	.39	.35
Benzo[a]anthracene	.52	.35	.41	.57	.51		.85	.62	.51	.51	.52	.32
Chrysene	.63	.26	.47	.57	.53	.81		.79	.69	.64	.57	.52
5-rings												
Benzo[e]pyrene	.66	.16	.33	.46	.40	.67	.86		.92	.84	.91	.85
Benzo[a]pyrene	.70	.14	.38	.39	.35	.64	.86	.91		.83	.89	.85
6-rings												
Indeno[1,2,3-cd]pyrene	.66	.16	.29	.43	.37	.57	.76	.90	.81		.83	.80
Benzo[ghi]perylene	.67	.18	.35	.42	.38	.56	.75	.93	.87	.72		.95
7-rings												
Coronene	.63	.19	.28	.40	.34	.51	.69	.90	.83	.90	.96	

[a] Computed using all samples. For samples sizes used on this study, all correlations greater than 0.20 are significantly greater than zero at the 0.05 level.

[b] Numbers in shaded area are for nighttime samples; other numbers are for daytime samples.
- for daytime samples, n = 101 to 114
- for nighttime samples, n = 100 to 113

correlations compared to the outdoor samples. Poorest correlations were computed for phenanthrene.

If outdoor sources provide the primary contribution to indoor PAHs then different penetration factors (f) among compounds could result in poorer correlations. Alternatively, the indoor decay term (k) could be different for different PAHs and thus affect the degree of association. To further investigate this phenomenon, Spearman's rank correlations were computed for indoor air samples in homes with smoking. These homes were selected since they should have a strong indoor source that would minimize the effect of the penetration factors on indoor concentrations. Although data are not given here, results for smoking homes showed little difference in correlations compared to the results for all homes suggesting that different penetration factors are probably not responsible for the observed differences.

As with the outdoor samples, correlations computed for indoor daytime and nighttime samples were generally similar. Where there was a difference, nighttime correlations among compounds tended to be slightly higher.

Although the correlations presented here are Spearman's rank correlations using all samples, several other types of correlations were also computed. These analyses and a brief summary of these results are given in Table 8-23.

Table 8-24 gives Spearman's rank correlations among phthalates computed for both indoor and outdoor air samples. Most of these correlations, especially in indoor air samples, were low. This is not unexpected, since different phthalates would most likely come from different source materials. Highest correlations indoors occurred between diethylphthalate and di-n-butylphthalate and between di-n-octylphthate and di-2-ethylhexylphthalate. Correlations computed for daytime and nighttime samples were generally the same.

TABLE 8-23. ADDITIONAL CORRELATIONS COMPUTED FOR PAHS IN AIR SAMPLES

Correlation	Results
Spearman's rank - samples with quantifiable amount only	Indoor air - similar to results reported here for all samples. Outdoor air - similar to results reported here.
Pearson product moment[a] - all samples	Indoor air - correlations higher than those reported here; for all particulate phase PAHs, correlations were greater than 0.97. Only correlations with phenanthrene and anthracene were less than 0.85. The measured concentrations from the few high homes dominated statistics. Outdoor air - simlar to results reported for Spearman's rank correlations.
Pearson product moment[a] - samples with quantifiable amounts only	Indoor air - results similar to those computed using Pearson correlations - all samples. Outdoor air - similar to results reported for Spearman's rank correlations.

[a] Computed using actual measured concentrations.

TABLE 8-24. SPEARMAN'S RANK CORRELATIONS[a] AMONG PHTHALATES IN INDOOR AND OUTDOOR AIR SAMPLES[b]

Compound	Diethylphthalate	Di-n-butylphthalate	Butylbenzylphthalate	Di-2-ethylhexylphthalate	Di-n-octylphthalate
INDOORS					
Diethylphthalate		.43	.08	.27	.07
Di-n-butylphthalate	.44		.07	.18	.04
Butylbenzylphthalate	.06	.07		.38	.28
Di-2-ethylhexylphthalate	.37	.25	.13		.61
Di-n-octylphthalate	.19	.06	.28	.53	
OUTDOORS					
Diethylphthalate		.42	.31	.19	.30
Di-n-butylphthalate	.82		.74	.54	.46
Butylbenzylphthalate	.63	.68		.67	.64
Di-2-ethylhexylphthalate	.36	.40	.63		.62
Di-n-octylphthalate	.35	.20	.56	.68	

[a] Computed using all samples. For the sample sizes used on this study, all outdoor correlations greater than 0.30 and all indoor correlations greater than 0.20 are significantly greater than zero at the 0.05 level.

[b] Numbers in shaded area are for nighttime samples; other numbers are for daytime samples.
- for indoor/daytime samples, n = 113 to 115
- for indoor/nighttime samples, n = 110 to 113
- for outdoor/daytime samples, n = 42
- for outdoor/nighttime samples, n = 53

Correlations computed for outdoor air samples were higher than those found indoors. Butylbenzylphthalate had high correlations outdoors with all the phthalates except diethylphthalate. Again, fairly strong correlations are seen between di-n-octylphthalate and di-2-ethylthexylphthalate in indoor air samples. Results for the outdoor samples should be viewed with some caution, since only very low levels of the phthalates were measured in outdoor samples. Under these conditions, high correlations could be a result of an experimental artifact such as background contamination generated during sample processing.

Spearman's rank correlations for the phthalates with the PAHs, and PTEAM pollutants were also computed although these data are not shown. For correlations among the phthalates and PAHs, only phenanthrene and diethylphthalate gave correlations greater than 0.50. Fairly high correlations were found between these two compounds in daytime/indoor (0.62), daytime/outdoor (0.60), and nighttime/outdoor (0.52) samples. In contrast, the correlation in daytime/outdoor (0.19) samples was low.

Correlations between the phthalates and PTEAM pollutants were less than 0.50 in all four sample types. The only exception to this was a correlation coefficient of 0.62 computed between butylbenzylphthalate and lead (10 µm fraction) in outdoor/nighttime samples.

Spearman's rank correlations among PAHs and PTEAM pollutants computed for outdoor and indoor air samples are given in Tables 8-25 and 8-26, respectively. Results for outdoor samples show several trends, although the reasons for these correlations are currently unknown.

(1) Correlations between the elements and the PAHs were generally high (> 0.50),

(2) Highest correlations between the elements and PAHs were seen for the less volatile PAHs in nighttime samples and with the 10 µm fraction of the elemental samples.

TABLE 8-25. SPEARMAN'S RANK CORRELATIONS[a] AMONG PTEAM POLLUTANTS AND PAHS IN OUTDOOR AIR SAMPLES

Compound	Particulates				Lead				Manganese			
	PM_{10}		$PM_{2.5}$		Pb_{10}		$Pb_{2.5}$		Mn_{10}		$Mn_{2.5}$	
	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day
3-rings												
Acenaphthylene	.52	.15	.43	.28	.61	.55	.45	.50	.69	.03	.65	.16
Phenanthrene	.62	.22	.62	.31	.62	.60	.54	.49	.53	.15	.46	.22
Anthracene	.41	.11	.35	.23	.51	.35	.40	.45	.57	.13	.52	.18
4-rings												
Fluoranthene	.58	.22	.56	.21	.66	.53	.50	.40	.49	.18	.47	.21
Pyrene	.43	.21	.42	.18	.54	.53	.41	.42	.48	.17	.49	22
Benzo[a]anthracene	.43	.20	.36	.22	.60	.55	.43	.47	.66	.22	.70	.29
Chrysene	.50	.26	.42	.24	.67	.52	.50	.41	.66	.31	.70	.37
5-rings												
Benzo[e]pyrene	.49	.31	.40	.22	.63	.42	.51	.44	.70	.44	.74	.48
Benzo[a]pyrene	.38	.24	.28	.08	.51	.42	.39	.39	.65	.43	.73	.40
6-rings												
Indeno[1,2,3-cd]pyrene	.50	.14	.40	.07	.63	.51	.48	.43	.66	.21	.76	.33
Benzo[ghi]perylene	.49	.27	.41	.12	.60	.44	.53	.43	.70	.39	.71	.44
7-rings												
Coronene	.48	.25	.39	.14	.59	.41	.50	.38	.62	.36	.70	.41

[a] Computed using all samples. For samples sizes used on this study, all correlations greater than 0.30 are significantly greater than zero at the 0.05 level.
- for daytime samples, n = 40 to 42
- for nighttime samples, n = 46 to 47

TABLE 8-26. SPEARMAN'S RANK CORRELATIONS[a] AMONG PTEAM POLLUTANTS AND PAHS IN INDOOR AIR SAMPLES

Compound	Particulates				Lead				Manganese			
	PM_{10}		$PM_{2.5}$		Pb_{10}		$Pb_{2.5}$		Mn_{10}		$Mn_{2.5}$	
	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day
<u>3-rings</u>												
Acenaphthylene	.34	.06	.40	.19	.42	.27	.33	.17	.51	.15	.49	.18
Phenanthrene	.21	.01	.29	.12	.23	.13	.13	.18	.17	.42	.19	.11
Anthracene	.37	.22	.39	.27	.25	.17	.20	.06	.30	.11	.21	.08
<u>4-rings</u>												
Fluoranthene	.49	.33	.52	.39	.43	.38	.33	.21	.40	.19	.37	.29
Pyrene	.42	.16	.47	.25	.37	.21	.34	.11	.29	.05	.36	.24
Benzo[a]anthracene	.67	.47	.61	.53	.57	.44	.40	.28	.60	.30	.48	.35
Chrysene	.66	.49	.65	.50	.55	.39	.45	.25	.62	.35	.56	.44
<u>5-rings</u>												
Benzo[e]pyrene	.58	.33	.55	.37	.64	.43	.53	.42	.68	.32	.64	.52
Benzo[a]pyrene	.34	.22	.48	.24	.56	.29	.43	.39	.66	.26	.57	.48
<u>6-rings</u>												
Indeno[1,2,3-cd]pyrene	.50	.25	.47	.32	.59	.34	.49	.35	.59	.27	.57	.50
Benzo[ghi]perylene	.48	.45	.48	.19	.63	.31	.53	.36	.61	.25	.65	.47
<u>7-rings</u>												
Coronene	.50	.15	.47	.17	.65	.32	.54	.33	.63	.28	.64	.44

[a] Computed using all samples. For samples sizes used on this study, all correlations greater than 0.20 are significantly greater than zero at the 0.05 level.
- for daytime samples, n = 102 to 111
- for nighttime samples, n = 93 to 104

(3) Few strong correlations were observed between the PAHs and particulate samples. Only phenanthrene in nighttime samples gave correlation coefficients greater than 0.60.

(4) Correlations between PAHs and particulates were generally higher in nighttime samples. Correlation of PAHs with PM_{10} and $PM_{2.5}$ were generally similar.

The same general trends were seen for the correlation among pollutants computed for indoor samples (Table 8-26). Correlation between the PAHs and particulates were slightly higher for indoor samples than outdoor samples, whereas correlations between PAHs and manganese were slightly lower for indoor air samples.

Finally, Spearman's rank correlations among the PTEAM compounds were computed and are given in Table 8-27. These were computed only for those homes associated with this chemical characterization study. For the indoor air samples, most correlations were greater than 0.50 although some of the correlations in the daytime samples were lower. Not surprisingly correlations between PM_{10} and $PM_{2.5}$ were very high (> 0.85). Correlations between the elements and particulates were generally high in nighttime samples. In daytime samples correlation between particulates and manganese were high. However, correlations between lead and these species was low. The reason for the low daytime correlation between lead and other PTEAM pollutants is currently unknown.

8.7 ANALYSIS OF QUESTIONNAIRE DATA

Selected questions from the study questionnaire were analyzed to determine if certain activities were related to elevated levels of PAHs and phthalates in air samples. Table 8-28 lists the questions that were asked to evaluate specific sources for the target PAHs and phthalates. Frequency distributions for these questions are also given. For each potential source category, arithmetic mean air concentrations and their standard errors were

TABLE 8-27. CORRELATION BETWEEN METALS AND PARTICULATES[a,b]

	Particulates		Lead		Manganese	
Compound	PM_{10}	$PM_{2.5}$	Pb_{10}	$Pb_{2.5}$	Mn_{10}	$Mn_{2.5}$
INDOORS						
PM_{10}		.86	.63	.29	.70	.52
$PM_{2.5}$	.90		.56	.41	.42	.47
Pb_{10}	.69	.69		.60	.63	.57
$Pb_{2.5}$	.52	.57	.75		.26	.17
Mn_{10}	.69	.56	.65	.49		.65
$Mn_{2.5}$	.56	.51	.65	.68	.66	
OUTDOORS						
PM_{10}		.81	.29	.05	.67	.65
$PM_{2.5}$	.94		.28	.06	.31	.49
Pb_{10}	.81	.78		.67	.18	.36
$Pb_{2.5}$	.82	.77	.78		.05	.14
Mn_{10}	.67	.53	.58	.61		.75
$Mn_{2.5}$	.53	.42	.63	.49	.77	

[a] Computed using all samples. Only homes associated with the substudy were used for calculation. For the sample sizes used on this study, all outdoor correlations greater than 0.30 and all indoor correlations greater than 0.20 are significantly greater than zero at the 0.05 level.

[b] Numbers in shaded area are for nighttime samples; other numbers are for daytime samples.
- for indoor/daytime samples, n = 107 to 115
- for indoor/nighttime samples, n = 100 to 104
- for outdoor/daytime samples, n = 40 to 42
- for outdoor/nighttime samples, n = 46 to 47

TABLE 8-28. QUESTIONS AND REPORTED FREQUENCIES FOR POTENTIAL POLLUTANT SOURCES

		Number of Homes[a]			
		Day		Night	
Category	Question	Yes	No	Yes	No
Busy Road	Is the house located within 100 yards of a busy roadway?	42	55	39	56
Cooking	Did you do any indoor cooking, grilling or frying while you were at home? Was any cooking, grilling, or frying done in your home by someone else?	46	69	28	85
Smoking	Were any cigarettes, pipefuls of tobacco, and/or cigars smoked in your house during this period?	18	94	22	90
Other Smoke	Were there any other sources of smoke present in the home during this period such as burnt food or candles?	6	107	10	102
Car Start	Was a vehicle started or run in a garage attached to your home during this period?	18	83	5	99
Other[b]	Was natural ventilation open doors or windows used in your home during the period?	96	27	79	45
	Was central air conditioning or heating used in your home during this period?	23	101	19	105
	Was a whole house or attic fan used in your home during this period?	2	122	3	121
	Was an ultrasonic or cool mist humidifier used in your home during this period?	4	120	1	122
	Was a filtration system (including filters, ionizers, and electrostatic precipitators) used in your home during this period?	0	124	0	124
	Was an unvented kerosene heater used in your home during this period?	0	124	0	124
	Was a fireplace used in your home during this period?	1	123	1	123
	Was a wood-burning stove used in your home during this period?	0	124	0	124

[a] Number of homes in each category that had valid data for air concentration measurements and questionnaire response.
[b] Number of homes in each category that had questionnaire response.

determined for the two groups identified from questionnaire responses (i.e., homes with and without potential sources). Arithmetic means were selected because of the small sample sizes for many of the source categories. Data using geometric mean air concentrations are given in Appendix J.

Pairwise t-tests were performed to test for group differences using the arithmetic mean air concentrations. Data for geometric mean air concentrations are given in Appendix J. Because there were very few homes in each source group and because only a small fraction of indoor PAH concentrations appear to be from indoor sources, this analysis should only be expected to show a difference in mean air concentrations between source and nonsource groups when a very strong source is present. Data from the two homes with the very high indoor air concentrations were not used during this analysis since it was felt these data would overwhelm any other effects.

Data relating measured air concentrations to questionnaire results are summarized in Tables 8-29 and 8-30. Mean air concentrations calculated for all homes are given for source and non-source groups for those chemicals that had higher observed air concentrations for the source group in either the daytime or nighttime periods. A compilation of all results is given in Appendix J. Air concentrations that were significantly higher for the source group at the 0.05 level of significance are also indicated in the tables.

Table 8-29 evaluates smoking, cooking, other indoor smoke, and a car starting in the garage of the home as potential sources for elevated indoor air concentrations. Results for smoking show elevated indoor air concentrations for the PAHs in both daytime and nighttime samples. Only phenanthrene and anthracene in nighttime samples are exceptions to this trend. The greatest relative differences in mean air concentrations are seen for the particulate phase 5-, 6-, and 7-ring PAH species. Higher indoor air concentrations for homes

TABLE 8-29. ARITHMETIC MEAN INDOOR AIR CONCENTRATION OF PAHS AND PHTHALATES BY SELECTED QUESTIONNAIRE VARIABLES[a]

Exposure	Chemicals with Higher Concentration for Exposed Group	Arithmetic Mean Air Concentration (ng/m^3) Day Exposed	Day Not Exposed	Night Exposed	Night Not Exposed
Smoking					
day (17/93)[b]	Acenaphthylene	11*[c]	5.3	12	4.4
night (21/85)	Phenanthrene	20	17	-[d]	-
	Anthracene	0.85	0.68	-	-
	Fluoranthene	2.8*	1.8	2.1*	1.6
	Pyrene	2.8	2.0	2.3	1.8
	Benzo[a]anthracene	0.31*	0.11	0.21*	0.12
	Chrysene	0.54*	0.20	0.46*	0.22
	Benzo[e]pyrene	0.46*	0.20	0.28*	0.19
	Benzo[a]pyrene	0.51*	0.20	0.43*	0.25
	Indeno[1,2,3-cd]pyrene	1.1*	0.56	0.75*	0.47
	Benzo[ghi]perylene	1.9*	1.0	1.3	0.88
	Coronene	1.8*	0.87	1.2	0.80
	Diethylphthalate	650	420	430	410
	Di-n-butylphthalate	-	-	-	-
	Di-2-ethylhexylphthalate	220	130	105	104
Car Start	Diethylphthalate	-	-	430	410
day (18/80)	Di-n-butylphthalate	800	580	710	590
night (5/97)	Di-2-ethylhexyphthalate	-	-	110	100
Cooking	Fluoranthene	2.1	1.9	1.8	1.7
day (46/67)	Pyrene	2.2	2.0	2.0	1.8
night (28/83)	Benzo[a]anthracene	0.15	0.13	0.16	0.13
	Chrysene	0.30	0.23	0.30	0.25
	Benzo[e]pyrene	-	-	0.24	0.20
	Benzo[a]pyrene	-	-	0.30	0.28
	Indeno[1,2,3-cd]pyrene	0.71	0.61	0.4	0.52
	Benzo[ghi]perylene	-	-	1.0	0.94
	Coronene	-	-	0.93	0.87
	Di-n-butylphthalate	-	-	40	570
	Butylbenzylphthalate	-	-	60	48
Other Smoke	Acenaphthylene	7.2	6.1	6.1	6.0
day (5/105)	Phenanthrene	2.5	1.7	-	-
night (10/100)	Fluoranthene	2.7	1.9	-	-
	Pyrene	4.0	2.0	-	-
	Indeno[1,2,3-cd]pyrene	0.72	0.64	0.58	0.52
	Benzo[ghi]perylene	1.2	1.1	1.1	1.0
	Coronene	1.1	1.0	1.2	0.86
	Diethylphthaate	460.	450	-	-
	Di-n-butylphthalate	-	-	630	580
	Di-2-ethyl hexylphthalate	180	140	130	100

[a] Two homes with highest levels excluded from analysis.
[b] Number of samples in exposed/not exposed group.
[c] Exposed group had a significantly higher mean concentration at the 0.05 level.
[d] Calculated mean concentration for the exposed group was lower than the not exposed group.

TABLE 8-30. THE EFFECT OF A BUSY ROADWAY ON MEAN AIR CONCENTRATIONS OF PAHS AND PHTHALATES[a]

	Arithmetic Mean Concentration (ng/m^3)[b]							
	Outdoor				Indoor			
	Day		Night		Day		Night	
Compound	Exposed (n=12)[c]	Not Exposed (n=23)	Exposed (n=17)	Not Exposed (n=26)	Exposed (n=42)	Not Exposed (n=54)	Exposed (n=40)	Not Exposed (n=55)
PAHs								
3-Rings								
Acenaphthylene	-[d]	-	17	19	-	-	-	-
Phenanthrene	-	-	14	12	-	-	-	-
Anthracene	-	-	0.83	0.60	-	-	1.9	0.59
4-Rings								
Fluoranthene	2.8	2.5	2.5	2.1	-	-	-	-
Pyrene	-	-	2.4	2.1	2.1	2.2	-	-
Benzo[a]anthracene	-	-	0.26	0.12	0.15	0.14	0.16	0.10
Chrysene	0.42	0.34	0.48	0.31	0.29	0.23	0.32	0.19
5-Rings								
Benzo[e]pyrene	-	-	0.42	0.28	0.29	0.21	0.22	0.19
Benzo[a]pyrene	-	-	0.48	0.38	0.29	0.23	0.31	0.28
6-Rings								
Indeno[1,2,3-cd]pyrene	-	-	0.73	0.53	0.70	0.57	-	-
Benzo[ghi]perylene	-	-	1.6	1.1	1.3	1.1	1.0	1.0
7-Rings								
Coronene	-	-	1.4	0.93	1.1	1.0	0.93	0.95
PHTHALATES								
Diethylphthalate	63	35	205	51	470	440	-	-
Di-n-butylphthalate	-	-	-	-	640	620	-	-
Butylbenzylphthalate	3.0	2.6	-	-	-	-	-	-
Di-2-ethylhexylphthalate	-	-	19	17	160	120	107	104
Di-n-octylphthalate	0.52	0.41	0.36	0.46	23	14	15	2.4

[a] Two homes with highest levels excluded from analysis.
[b] None of the compounds had a significantly higher mean concentration for the exposed group at the 0.05 level.
[c] Number of samples.
[d] Mean concentration for the exposed group was lower than the not exposed group.

where smoking occurred were significant at the 0.05 level for acenaphthylene, fluoranthene, benzo[a]anthracene, chrysene, benzo[e]pyrene, benzo[a]pyrene, and indeno[1,2,3-cd]pyrene in both daytime and nighttime samples. Significantly higher concentrations were also found for benzo[ghi]perylene and coronene in daytime samples. Homes where smoking took place also showed elevated indoor concentrations for diethylphthalate, butylbenzylphthalate, and di-2-ethylhexylphthalate although the difference was not statistically significantly different at the 0.05 level. Homes with cooking and other smoke sources exhibited slightly higher but not significant (at the 0.05 level) air concentrations of some of the PAHs and phthalates. An automobile starting in an attached garage resulted in higher di-n-butylphthalate air concentrations in both daytime and nighttime indoor air samples. No differences in indoor air concentrations were evident for any of the PAHs for this source category.

Table 8-30 examines the effect of proximity to a busy roadway to both indoor and outdoor air concentrations at a home. Data are presented for both the daytime and nighttime monitoring periods. Outdoor/nighttime samples showed the greatest concentration differences between source and non-source homes for all PAHs. Both daytime and nighttime samples showed a slightly higher indoor air concentrations for the particulate phase PAHs, although the differences were not significant at the 0.05 level.

To further evaluate the effect of smoking, indoor/outdoor air concentration ratios were calculated for each home where quantifiable values were found in both samples. Geometric mean concentration ratios were then calculated for homes with and without smoking. Results in Table 8-31 compare concentration ratios for those compounds that had higher ratios when smoking was present in the home. Results show only small increases in PAH indoor/outdoor concentration ratios in homes where smoking took place. There were

TABLE 8-31. THE EFFECT OF SMOKING ON GEOMETRIC MEAN INDOOR/OUTDOOR AIR CONCENTRATION RATIOS FOR PAHS AND PHTHALATES

	Geometric Mean Concentration Ratio[a]			
	Day		Night	
Compound	Exposed	Not Exposed	Exposed	Not Exposed
PAHs				
3-Rings				
Acenaphthylene	3.3 (5)[b]	1.8 (25)	0.57 (6)	0.45 (22)
Phenanthrene	-[c] (6)	- (28)	0.6 (6)	- (34)
Anthracene	1.6 (4)	0.1 (16)	0.92 (6)	0.78 (24)
4-Rings				
Fluoranthene	0.87 (6)	0.74 (21)	0.77 (4)	0.73 (3)
Pyrene	- (6)	- (28)	0.77 (7)	0.75 (35)
Benzo[a]anthracene	1.5 (4)	1.3 (3)	0.79 (5)	0.65 (10)
Chrysene	1.1 (6)	0.60 (15)	0.87 (5)	0.61 (29)
5-Rings				
Benzo[e]pyrene	1.4 (6)	0.87 (13)	0.80 (5)	0.58 (25)
Benzo[a]pyrene	2.2 (5)	0.82 (8)	0.78 (5)	0.66 (25)
6-Rings				
Indeno[1,2,3-cd]pyrene	1.3 (4)	.99 (7)	0.83 (5)	0.66 (18)
Benzo[ghi]perylene	1.3 (6)	1.1 (21)	0.88 (7)	0.65 (31)
7-Rings				
Coronene	1.3 (6)	1.1 (15)	0.83 (6)	0.69 (23)
PHTHALATES				
Diethylphthalate	4.5 (1)	3.8 (5)	- (1)	- (7)
Butylbenzylphthalate	- (11)	- (23)	- (13)	- (24)
Di-2-ethylhexylphthalate	11 (2)	2.4 (15)	3.3 (2)	2.7 (10)

[a] Calculated using quantifiable amounts only. Sample sizes were not adequate for tests of significance.
[b] Number of samples; numbers were low because outdoor data were available for less than half the homes; questionnaire data were missing and air concentrations were below the MQL.
[c] Geometric mean concentration for the exposed group was lower than for the not exposed group.

only a very small number of homes in the smoking group that had both indoor and outdoor monitoring data. Although all data were used (including air concentrations below the MQL), no further analyses were performed with the data.

SECTION 9

QUALITY CONTROL/QUALITY ASSURANCE

No formal Quality Assurance Project Plan (QAPP) was prepared for this study; although a program of Quality Assurance and Quality Control activities was included as a part of this research program. A formal QAPP was prepared as part of the EPA PTEAM study that incorporated the monitoring activities performed on this study. The activities specific to this chemical characterization study included:

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

A Quality Assurance Statement which summarizes audits, reviews, and inspections is included in Appendix K. Results for quality control samples and a discussion of performance for the PAH and phthalate monitoring method is given in Section 7.2.2.

SECTION 10

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APPENDIX A

Participant Consent Forms

Expires: June, 1992

THE PERSONAL EXPOSURE STUDY OF AIRBORNE PARTICLES IN RIVERSIDE
Participant Consent Form

I understand that the Research Triangle Institute, (RTI) under contract from the United States Environmental Protection Agency (EPA), is engaged in a study of the potential exposure to certain substances by residents of Southern California living in areas having varying levels of these substances in the environment. I understand that this study is being conducted in order to help measure the levels of exposure to the selected substances in populations environmentally exposed, and is limited to the purpose stated. I further understand that the survey is being conducted in cooperation with and under co-sponsorship of the California Air Resources Board (CARB).

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

I understand that an agent of the Research Triangle Institute will administer the questionnaire in my home, and at the same time make arrangements regarding collection of the environmental samples. I understand that I will receive an incentive payment of one hundred dollars for my complete participation. I understand that a small number of households will be selected for the collection of duplicate samples (to be collected at the same time as the original samples) but that such selection would not entitle me to further compensation.

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

Harvey Zelon, RTI
Michele Hoffman, RTI } Telephone, toll-free 1-800-334-8571, or

Lance Wallace, USEPA Telephone (703) 349-8970, or

Liz Ota, CARB Telephone (916) 323-1503.

Participant Name: ______________________ ______________________
(Print) (Signature)

Participant ID: ______________________ Date: ___/___/___

Chemistry ID: (PLACE LABEL HERE)

Witness: ______________________ Guardian: ______________________

APPENDIX B

Refusal Documentation and Conversion Form

REFUSAL DOCUMENTATION AND CONVERSION FORM

A. Case Identification:

1. Respondent's ID: __ __-__ __ __-__-__-__ __

2. Respondent's Name:______________________

3. Respondent's Address:______________________

4. Telephone Number:______________________

B. Initial Refusal Information:

1. Date of Contact: ___/___/___

2. Time of Contact: ________

3. Reason for Initial Refusal:______________________________

____

4. Strength of initial refusal:

Strong __ Moderate, but firm __ Moderate, not firm __ Mild __

5. Estimate of probability of success of conversion attempt:

High ___ Medium ___ Low___

6. Things to try during recontact:______________________________

____

7. Things to avoid during recontact:______________________________

____

8. Disposition (FS USE ONLY):

__ Recontact by new FI: Assigned to:______________ Date:_______

__ Recontact by FS

__ Recontact by Home Office: Date called to RTI:_________

__ No further contact

C. Recontact Information

1. Date:__/__/__

2. Time:________

3. Result of recontact effort:

___ No contact made after several attempts

___ Firm refusal at door, no further effort suggested

___ Continued refusal after recontact COMPLETE QUESTIONS 4 & 5

___ Conversion COMPLETE QUESTION 4

4. Items discussed and information provided during recontact:_____

____

____

____

5. Reasons for continued refusal [CHECK ALL THAT APPLY. PROBE FOR EACH OF LISTED REASONS IF NOT MENTIONED]:

___ Fixed monitoring equipment in home:____________________

___ Wearing the personal monitor:____________________

___ Multiple Appointments: ____________________

___ Restrictive Scheduling of appointments:____________________

___ Can't carry monitor to work: ____________________

___ Other (Specify): ____________________

____

APPENDIX C

Informational Package

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

September, 1990

OFFICE OF
RESEARCH AND DEVELOPMENT

Dear Riverside Resident,

As you may know, smog and haze in Riverside and other areas in the Los Angeles basin are harmful to the health and well-being of our citizens. We have recently become aware that indoor air pollution can also cause health problems. The U.S. Environmental Protection Agency (EPA) and the California Air Resources Board (ARB) have joined forces to carry out a major study of air pollution in Riverside. This study has the full support of the Riverside City Council.

We are writing to ask for your cooperation in the study. After a brief initial interview, some persons will be invited to take part in a second phase of the study. If you are invited and choose to participate in the second phase, you will receive one hundred dollars ($100) for your help.

Your family has been chosen as one of a small group of families to participate in the first part of the study. Each household in Riverside was given the same chance of being selected. Because you will be representing other families like your own, your participation is vital to the success of the study.

In the next week or two, an interviewer from Research Triangle Institute, which is carrying out the study for us, will visit your home and ask for your cooperation. The interviewer will be wearing an identification badge. This <u>first</u> interview will normally take less than 15 minutes. All of the information you provide will be kept confidential. The interviewer will be glad to answer all your questions.

For the <u>second</u> part of the study, one member of some of the sampled families will be asked to wear a small monitor for 24 hours to measure his or her exposure to air pollution, and will be asked to provide information on his or her activities during that time. In addition, these families will be asked to allow monitors to be placed in their homes to measure pollution levels. The monitors are completely harmless, and all the information obtained will be kept strictly confidential.

We urge you to take part in this important scientific study. Further details of the study are given in the enclosed brochure. If you have any questions, please call one of the numbers given at the end of the brochure.

Erich Bretthauer John R Holmes Terry Frizzel

Erich Bretthauer, Ph.D. Assistant Administrator Office of Research and Development US Environmental Protection Agency	John R. Holmes, Ph.D. Chief, Research Division California Air Resources Board	Terry Frizzel Mayor City of Riverside

WHO IS SPONSORING THE STUDY?

The U.S. EPA and the California ARB contracted with Research Triangle Institute (RTI) and Harvard University School of Public Health to carry out the study. RTI is a not-for-profit research institute in North Carolina that has previously conducted studies of people's exposures to chemicals. The Harvard University School of Public Health is world-renowned for its work on indoor air pollution caused by particles.

WILL MY DATA BE KEPT CONFIDENTIAL?

Yes. The contractors will keep all the information you provide completely confidential. Only you will receive data about yourself and your home. No one else, not even the sponsoring government agencies, will ever know who participated in the study.

WHO DO I CONTACT IF I WANT MORE INFORMATION?

If you would like more information about any part of the study, or have any questions about the study and your participation, please feel free to call:

Mr. Harvey Zelon
Project Manager
Research Triangle Institute
Telephone - Toll free: (800) 334-8571

Dr. Lance Wallace
EPA Project Coordinator
U.S. Environmental Protection Agency
Telephone - (703) 349-8970

Ms. Liz Ota
ARB Project Coordinator
California Air Resources Board
Telephone - (916) 323-1503

The Personal Exposure Study of

Airborne Particles in Riverside

WHAT IS THIS STUDY?

This is a major study of human exposure to environmental pollution. **Its goal is to collect information on people's actual exposures to selected pollutants so that the U.S. Environmental Protection Agency (EPA) and the California Air Resources Board (ARB) can develop the best strategies for protecting public health.** Similar studies have been conducted in cities across the United States, including several in California. This is the first large-scale study to measure the amount and kind of particles that people are breathing as they go about their normal activities.

WHAT PARTICLES ARE BEING MEASURED AND WHY?

The study will measure the tiny particles which are typically present in the air and which can be breathed deep into the lungs. These include dust, smoke, soot, ash, pollen, fungi, and fibers. They may contain various chemicals and metals, and they may cause difficulty breathing, especially for people with asthma, allergies, and other respiratory diseases.

WHY SHOULD I PARTICIPATE?

Because you have been selected to represent many of your fellow Riverside residents, your participation is very important to the success of the study. You will have the satisfaction of knowing you have contributed to an important scientific study—very few people ever have such a chance. Many of our participants in previous studies have said they enjoyed participating and learning about their sources of exposure.

We realize that you will need to spend some time answering our questions and will be carrying a monitor around for 24 hours — therefore, **we will give you $100.00 immediately after you complete the monitoring period.** You will also receive a copy of an EPA publication, *The Inside Story*, which provides many valuable hints about how to improve the quality of the air in your home. After all the samples collected in the study have been analyzed, we will send you the information about the exposures measured for you and your home.

WHAT WILL I BE ASKED TO DO?

PHASE 1

Every household receiving this brochure will be visited by an interviewer from Research Triangle Institute, a scientific research organization. The initial interview will normally take less than 15 minutes. The interviewer may then ask one person in your household to be a participant in the second phase of the study.

PHASE 2

If you or a member of your household is invited to participate in the second phase of the study, you will be asked to wear or carry a small personal monitor for 24 hours, as will 174 other residents of Riverside. Similar monitors will be placed in your living room and outdoors for the same time period. You will also be asked questions about your activities while you were wearing the monitor. One or two days before the monitors are placed in your home, a technician will place a small tube containing a harmless and odorless material in your home to measure the amount of air moving into and out of your home.

WOULD I BE ASKED TO STAY HOME FROM WORK OR TO CHANGE MY ACTIVITIES?

Quite the contrary! It is important to us that you behave exactly as normal on the day you participate. You can wear the monitor or keep it nearby during your work, social, and recreational activities.

WHY DO PEOPLE NEED TO BE MONITORED?

To determine health risks, we must first understand people's exposures to pollutants. Because people are mobile, spending time at home, at work, in their cars, shopping, etc., we can obtain an accurate estimate of people's exposures only by having them wear personal monitors as they move about during the day. In addition, studies have shown that the greatest exposure to many pollutants comes from indoor sources and activities, such as smoking, cooking, and even dusting and vacuuming. Therefore, we want to measure the air inside and outside your home to compare it to your personal air samples.

WHAT ARE THE MONITORS LIKE?

The personal monitor is a small, quiet, battery-operated pump with a small filter attached. You can wear it in the hip pack or small backpack that we provide. It weighs only a few pounds and is perfectly safe. The indoor and outdoor monitors are small boxes with pumps and filters. They will be placed in out-of-the-way places in your living area and yard. Because they are made of harmless materials, no damage will result to you or your home under any circumstances. You are not liable if the monitor stops working or is damaged.