Personal Exposures, Outdoor Concentrations, and Breath Levels of Toxic Air Pollutants Measured for 425 Persons in Urban, Surburban and Rural Areas

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PERSONAL EXPOSURES, OUTDOOR CONCENTRATIONS, AND BREATH LEVELS OF TOXIC AIR POLLUTANTS MEASURED FOR 425 PERSONS IN URBAN, SUBURBAN, AND RURAL AREAS, L. Wallace, U.S. Environmental Protection Agency, Washington, DC 20460, E. Pellizzari, T. Hartwell, C. Sparacino, L. Sheldon, and H. Zelon, Research Triangle Institute, Research Triangle Park, NC 27709.

EPA's TEAM Study has measured exposures to 20 volatile organic compounds in personal air, outdoor air, drinking water, and breath of 370 persons in NJ, 25 in ND, and 30 in NC during 1980-1982. The NJ residents were selected by a probability sampling scheme to represent 120,000 inhabitants of Elizabeth and Bayonne. Participants carried a personal monitor to collect two 12-hour air samples and gave a breath sample at the end of the day. Two consecutive 12-hour outdoor air samples were also collected on identical Tenax cartridges in the back yards of 90 of the participants. About 3000 samples were collected, of which 1000 were quality control samples. Eleven compounds were often present in air. Personal exposures were invariably higher than outdoor concentrations for these chemicals, and were sometimes 10 times the outdoor concentrations. Indoor sources appeared responsible for much of the difference. Breath concentrations also usually exceeded outdoor concentrations, and correlated more strongly with personal exposures than with outdoor concentrations.

Introduction

The TEAM (Total Exposure Assessment Methodology) Study was designed to develop and demonstrate methods to measure human exposure to toxic substances in air and drinking water. A first phase to field-test the methods was completed in 1981[1,2]. Methods developed or demonstrated in Phase I included:

- o A personal monitor employing Tenax cartridges
- o A spirometer for collecting expired air on Tenax cartridges
- o A statistical design and OMB-approved questionnaires for Phase II.

Preliminary results from Phase I, which included pilot studies of 17 students at Lamar University in Beaumont, Texas and the University of North Carolina and 12 persons in New Jersey and North Carolina included:

- o About a dozen volatile organic compounds were often or always found in personal air samples of all subjects
- o Exposures were highly variable, ranging from 1 to 1000 ug/m^3 for some chemicals
- o Breath values were correlated with personal exposures for several chemicals

The objective of the second phase was to estimate the distribution of exposures to target substances for the entire population of an industrial/chemical manufacturing area. A total of 20 toxic, carcinogenic, or mutagenic organic compounds were measured in the air and drinking water of 350 residents of Bayonne and Elizabeth, New Jersey, in the fall of 1981. The participants were selected from over 10,000 residents screened by a probability sampling technique to represent 120,000 persons (over the age of seven) who live in the two neighboring cities.

100 geographic areas throughout the two cities were selected for monitoring. Each participant carried a personal sampler with him during his normal daily activities for two consecutive 12-hour periods. (One resident in each of the 100 areas had an identical sampler operating in the back yard for the same two 12-hour periods.) All participants also collected two drinking water samples. At the end of the 24-hour sampling period, all participants gave a sample of exhaled breath, which was analyzed for the same compounds. All participants also completed a questionnaire on their occupations and activities during the sampling period. An extensive quality assurance program was carried out on all sampling/analysis activities.

Measurement Methods

Air. Personal and outdoor air samples were collected on Tenax cartridges for 12-hour periods. A Dupont pump pulled air at 30 mL/min (.22L sampling

volume) across the 1.5 cm i.d. cartridge, which contained 6 cm (2 g) of Tenax. Cartridges were analyzed by GC-MS.

Breath. Breath samples were collected by a spirometer consisting of a humidified supply of pure air, a Tedlar bag to collect the pure air, a 2-way Douglas mouthpiece, a second Tedlar bag to collect expired air, and two Nutech pumps to pull the expired air across two Tenax cartridges. The subject uses the two-way mouthpiece to breathe pure air from the first Tedlar bag and exhale into the second bag. Analysis was by GC-MS.

Water. Drinking water samples were collected in the morning and evening from the kitchen tap in 40 mL vials containing sodium thiosulfate. For analysis, purgable organics were swept onto a Tenax cartridge and were analyzed by GC-FID (aromatics) and GC-ECD (halocarbons).

Quality Assurance

Blank samples and control (spiked) samples were kept at the laboratory and shipped to the field to determine background contamination levels and recovery efficiencies. Duplicate air, water and breath samples were collected and analyzed at the primary and QA laboratories to determine intralaboratory and interlaboratory precision.

Results

About 4,400 of the 5,200 target households were contacted and provided information on 11,414 household residents. These data were employed in the second stage to select a weighted samples of participants. About 58% of the eligible residents in each city agreed to participate fully in the study (Table I). Limited follow-up studies on nonrespondents showed no outstanding differences from respondents.

About 1950 air, breath, and water samples were collected and chemically analyzed (Table II). An additional 980 quality control samples (duplicates, spikes, and blanks) were analyzed.

Quality Assurance Results

Air and Breath. Results from 76 field and 79 laboratory blanks (Table III) showed low backgrounds (corresponding to < 2 ug/m^3) except for benzene (5 $\pm$ 3 ug/m^3). Mean backgrounds for each batch of Tenax cartridges were subtracted from the measured amounts on field cartridges from that batch. The results from 110 field and 91 laboratory control cartridges showed typical recovery efficiencies of 90-100%.

Results from 134 pairs of duplicate personal air samples and 34 duplicate outdoor air samples analyzed at the primary laboratory showed typical relative standard deviations (RSD) of 20-30%, except for benzene (45-50%). Thirty deplicate breath samples had typical RSD's of 30-40%. QA samples analyzed at different laboratories had slightly larger typical RSD's of 30-40% (90 air samples) and 30-50% (49 breath samples).

Spearman correlations between duplicates analyzed at the primary laboratory were significant for ten of eleven prevalent compounds in personal air and five of eight prevalent compounds in outdoor air. Interlaboratory correlations were significant for nine of ten compounds in personal air, five of seven compounds in outdoor air, and seven of nine prevalent compounds in breath.

Percent Detected

For each of the 19-20 target chemicals in each of the sample types (breath, water, personal and outdoor air) the weighted percent of quantifiable concentrations is shown in Table IV.

Air and Breath. We may sort the target chemicals into four classes based on their presence in air and breath samples (Table V). The first class, ubiquitous chemicals that are present in 60-98% of all air and breath samples, included two common solvents (1,1,1-trichloroethane and tetrachloroethylene) and four aromatic components of gasoline, paints, and other petrochemical products (benzene, two xylene isomers, and ethylbenzene).

The second class, compounds often but not always present in all sample types, included two additional solvents (carbon tetrachloride and trichloroethylene); a compound whose main source is drinking water (chloroform); and two components of common consumer products (styrene, used in insulation and plastics; and para-dichlorobenzene, used in moth crystals and deodorants). The probable source of the last two compounds is in the home, judging by the much greater frequencies of detection in personal air samples (70-80%) compared to outdoor air samples (10-30%).

The third class of substances were only occasionally found (<10% detected in most sample types). This class includes vinylidene chloride, a component of paints and plastics; ethylene dichloride, a common component of many products; chlorobenzene and o-dichlorobenzene.

Finally, four brominated substances not found in air or breath included three trihalomethanes and dibromochloropropane. However, previous work (Phase I of the TEAM Study) showed that levels of bromodichloromethane increased sufficiently in summer to become readily detectable in the personal air and exhaled breath of selected Elizabeth and Bayonne residents. Thus, the present negative findings for bromodichloromethane in air and breath should not be extrapolated to apply to all seasons.

Drinking Water. In drinking water, a different set of the target chemicals were present. All of the four trihalomethanes except bromoform were present in >99% of all samples from both Bayonne and Elizabeth. In Bayonne, no other target chemicals appeared often in the water. In Elizabeth, four other chemicals often appeared, but their levels were generally so low that they made no appreciable contributions to the exposures of the participants.

Observed Concentrations

Air and Breath. Weighted mean values for personal air samples range

from 1-100 ug/m^3 at night, and from 2-870 ug/m^3 in the daytime for the 12 most prevalent compounds (Table VI). Outdoor air mean levels fall well below the personal air levels for almost every chemical. Breath concentrations are also higher than outdoor concentrations for most chemicals.

Maximum concentrations show even more marked differences between personal and outdoor air (Table VII). Personal air maxima are often 10-100 times larger than outdoor maxima. Breath maxima always exceed outdoor air maxima, sometimes by a factor of 10.

Since the overnight personal air samples are taken in the subject's homes, they may be considered esentially indoor samples. Thus, indoor-outdoor ratios can be calculated for corresponding percentiles of each distribution. These ratios are always greater than one, indicating indoor sources for all 11 prevalent chemicals. At median concentrations, indoor-outdoor ratios range from 1.5 to 4.9, but at the 99th percentile (Figure 1) many chemicals display indoor-outdoor ratios of 10 or 20, indicating very strong indoor sources.

Day-night differences are minimal for most chemicals -- only tetrachloroethylene appears to have significantly larger concentrations in both personal and outdoor daytime air samples.

Drinking Water. Weighted mean concentrations of ten target chemicals in drinking water showed only three trihalomethanes exceeding 1 ug/L: chloroform (70 ug/L); bromodichloromethane (14); and dibromochloromethane (2.5).

Correlations in Air

Spearman correlations were calculated for all possible pairs of the target chemicals within the overnight and daytime personal air and outdoor air samples. Correlations were high between certain groups of associated chemicals. For example, the xylene isomers and ethylbenzene, found in gasoline and paints in about the same relative proportions, had correlation coefficients exceeding .9 in all cases. On the other hand, chloroform and paradichlorobenzene showed little correlation with any of the other chemicals or with each other.

Correlations Between Breath and Air

Correlations of breath levels with preceding personal air exposures were usually significant at the $p < .0001$ level; however, correlations with preceding outdoor concentrations were always weak and seldom significant (Table VIII). The chemicals most highly correlated with previous exposures were paradichlorobenzene and tetrachloroethylene. The weakest correlation was with chloroform -- this is to be expected, since the main route of exposure for chloroform was not air, but drinking water.

Ratios of breath concentrations to previous 12-hour air exposures were also calculated for ten prevalent chemicals. These ratios give a rough indication of the fraction of each compound excreted through the breath. Two compounds -- benzene and tetrachloroethylene -- appear to be excreted largely

through the breath, having ratios of 76-80%. Breath-air ratios for the other chemicals ranged between 33-43%. The comparisons above do not take into account the dependence of breath levels on pre-existing concentrations in the body and also on the effective residence times of each chemical. A simple two-parameter time-dependent model has been developed that accounts for the effect of the initial breath concentration and the effective residence time in the body[2]. The model was tested in the TEAM Pilot Study for 27 cases in which two breath samples and three intervening 8-hour air samples were collected; the model predicted an effective half-life of 21 hours for tetrachloroethylene. A later "washout" study[3] performed over a 10-hour period in a pure air chamber on an adult male exposed for one hour to tetrachloroethylene vapors in a dry cleaning shop interior resulted in a measured effective half-life of 21 hours.

Effects of Residence, Occupation, and Activities on Exposure

City. Few differences between Bayonne and Elizabeth were noted for unweighted outdoor air concentrations, using Mann-Whitney/Wilcoxon nonparametric tests. Unweighted personal exposures were significantly higher for eight chemicals in Elizabeth and two in Bayonne. Student t-tests on the geometric mean of the weighted data indicated that only 2-4 of the chemicals showed significant ($p < .05$) differences between cities, with Elizabeth generally slightly higher on personal air and breath samples.

Proximity to Point Sources. Census tracts were classified as high and low exposure strata by whether they were within 1.5 km of any major point sources or not. Those strata bordering the high exposure strata and containing major highways were classified as moderate exposure. In general, no differences in percent measurable were seen between the high and low proximity strata. However, the moderate strata in Bayonne and Elizabeth occasionally showed significantly higher percentages measurable for scattered compounds in breath, personal air, or outdoor air samples. This indicates a possible greater influence on exposure due to mobile sources than to stationary sources.

Occupational Exposure. About 85 of the 350 participants were classified as having potential occupational exposure to some of the target compounds. Median breath values of aromatic compounds associated with gasoline and auto exhaust (benzene, xylenes, and ethylbenzene) were 40-70% higher for the occupationally exposed groups. Other differences due to occupation are being investigated.

Activities on the Day Monitored. The data collected on the 24-hour exposure screeners proved useful in identifying the probable sources of high exposures. For example, persons pumping their own gas on the day they were monitored showed the expected higher levels of benzene and xylene isomers (but not other chemicals) in personal air and breath samples. Similarly, those visiting a dry cleaner showed higher levels of tetrachloroethylene in air and breath. Persons exposed to tobacco showed significantly higher levels of benzene, xylene, styrene, and ethylbenzene in air and breath. Persons exposed to solvents had higher levels of 1,1,1-trichloroethane in their breath and personal air samples. Persons exposed to auto/truck exhausts

showed significantly higher levels of benzene in air and breath. Persons exposed to degreasing compounds had higher levels of trichloroethylene in air and breath. Persons exposed to paint had higher levels of benzene, styrene and xylene isomers in air and breath.

Discussion

Personal air exposures to all eleven of the most prevalent chemicals were greater -- often much greater -- than would have been predicted from outdoor monitoring alone. The major cause of these higher exposures appears to be in the home, since overnight concentrations in the home were consistently greater than in the adjoining backyard.

Two particularly clear examples of indoor chemicals were paradichlorobenzene, used in moth crystals and deodorants; and styrene, used in plastics, foam rubber, and insulation. Tetrachloroethylene (and sometimes 1,1,1-trichloroethane) are used in dry cleaning. Paints may contain vinylidene chloride, styrene, and xylenes. Gasoline contains benzene, ethylbenzene, and xylenes. Tap water contains chloroform, and heated water (particularly hot showers) will give up most of its chloroform to the indoor air. Benzene was more prevalent in smokers' homes than in nonsmokers'; and smokers' breath levels were about double those of nonsmokers (mean value of 33 ug/m^3 vs. 17 ug/m^3).

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

Reliance on outdoor monitors to estimate exposure is contraindicted by this study. Mean outdoor levels of the 11 chemicals ranged from 1-12 ug/m^3, but mean personal exposures ranged from 3-870 ug/m^3. Maximum outdoor levels ranged from 5-470 ug/m^3 while maximum personal exposures ranged from 76-330,000 ug/m^3. These outdoor levels are similar to those measured by all techniques (Tenax, cryogenic trapping, evacuated cylinder) in urban and suburban areas throughout the U.S. between 1970 and 1980 (Table IX).

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

Breath concentrations reflected personal exposures more closely than outdoor concentrations. Spearman correlations between breath and preceding

personal exposure were significant for ten of 11 prevalent chemicals, but correlations between breath and preceding outdoor levels were significant for only five chemicals. The ratio of median breath concentrations to median daytime air exposures ranged from 33-43% for nine chemicals, and 75-80% for two others. Thus, the feasibility of using breath measurements to estimate exposure to these compounds has been demonstrated. This approach may be useful in cases of spills or releases that have disappeared from the atmosphere before they could be monitored -- immediate breath measurements could determine the approximate extent of population exposure. Similarly, breath measurements of persons living near hazardous waste sites could be used to detect current or recent exposure.

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Disclaimer

Opinions expressed are those of the authors and do not reflect official positions of the U.S. Environmental Protection Agency. Mention of products or brand names does not imply endorsement by the government.

Table I. Results of two-stage probability sampling. TEAM Study, Fall, 1981

	Bayonne	Elizabeth
Stage I: Screening		
Households screened	2063	3145
Households completing questionnaire	1788 (87%)	2638 (84%)
Persons providing data	4687	6727
Stage II: Monitoring		
Eligible persons	266	345
Persons completing data collection	154 (57.9%)	201 (58.3%)

Table II. Samples collected. TEAM Study — Fall 1981

	Personal Air	Outdoor Air	Breath	Drinking Water
Field Samples	705	183	358	718
Duplicates	131	32	37	70
Blanks/controls	283	90	185	152
Total	1119	305	580	950

Table III. Blank and control data for air and breath volatiles

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

Table IV. Percentage of population with compound concentrations measurable for Bayonne and Elizabeth[a]: Fall, 1981

	Breath	Overnight Personal Air	Daytime Personal Air	Overnight Outdoor Air	Daytime Outdoor Air	Drinking Water
Minimum Sample Size:	295	346	339	81	86	265
Maximum Sample Size:	339	348	341	86	90	354
Vinylidene chloride	12	3	6	1	0.4	45
Chloroform	60	59	44	47	37	100
1,2-Dichloroethane	2	3	1	3	4	0.4
1,1,1-Trichloroethane	80	80	73	85	81	50
Benzene	89	95	90	89	75	0.1
Carbon tetrachloride	18	30	23	53	50	6
Trichloroethylene	29	52	46	54	46	57
Bromodichloromethane	0.1	2	2	0.1	0	100
Dibromochloromethane	0	0	0	0	0	100
Tetrachloroethylene	93	92	88	80	80	58
Chlorobenzene	3	9	4	2	4	0.9
Bromoform	0	0	0	0	0	3
Dibromochloropropane	0	1	0	0	0	-
Styrene	48	83	77	34	18	0
m,p-Dichlorobenzene	62	82	76	44	23	2
o-Dichlorobenzene	2	7	9	0.6	1	-
Ethylbenzene	93	93	89	87	82	0
o-Xylene	85	87	83	82	74	-
m,p-Xylene	95	99	98	98	90	0

[a] Estimated population: 122,000

Table V. Target compounds sorted by percent measurable in air and breath samples. TEAM Study -- Fall 1981

Compound Class	Range of % Measurable
Ubiquitous	
p-Xylene	86-98
Tetrachloroethylene	70-91
Ethylbenzene	75-89
Benzene	72-89
1,1,1-Trichloroethane	67-79
o-Xylene	60-78
Often present	
Chloroform	23-59
Carbon tetrachloride	10-38
Trichloroethylene	26-36
Styrene	4-79
p-Dichlorobenzene	10-71
Occasionally found	
Vinylidene chloride	0-11
Ethylene dichloride	0- 2
Chlorobenzene	2- 3
o-Dichlorobenzene	0- 7
Never found in air or breath	
Bromoform	0
Bromodichloromethane	0
Dibromochloromethane	0
Dibromochloropropane	0

Table VI. Weighted mean concentrations (ug/m^3) of selected organics in air and breath: TEAM Study, Elizabeth and Bayonne combined, Fall 1981

Chemical	Personal Air		Outdoor Air		Breath
	Night (N=347)	Day (N=340)	Night (N=83)	Day (N=88)	(N=295-339)
1,1,1-Trichloroethane	120	870	5.3	9.1	15
Benzene	31	27	8.6	9.5	19
Carbon tetrachloride	14	4.3	1.1	1.0	1.2
Trichloroethylene	7.7	19	2.1	2.3	1.8
Tetrachloroethylene	11	83	3.6	8.1	13
Styrene	7.7	16	0.9	0.8	1.2
m,p-Dichlorobenzene	55	35	1.5	1.8	8.0
Ethylbenzene	13	26	3.8	4.3	4.6
o-Xylene	16	18	4.0	4.0	3.4
m,p-Xylene	56	49	11	12	9.0
Chloroform	10	7.8	12	1.6	3.2

Table VII. Maximum concentrations of selected organics in air and breath: TEAM Study, Elizabeth and Bayonne combined, Fall 1981

Chemical	Personal Air		Outdoor Air		Breath
	Night (N=347)	Day (N=340)	Night (N=83)	Day (N=88)	(N=295-339)
1,1,1-Trichloroethane	8,300	330,000	40	470	520
Benzene	510	270	91	44	200
Carbon tetrachloride	1,100	900	14	7	250
Trichloroethylene	350	1,400	15	11	30
Tetrachloroethylene	250	12,000	27	57	280
Styrene	76	6,500	11	5	31
m,p-Dichlorobenzene	1,500	790	13	57	160
Ethylbenzene	380	1,500	20	16	290
o-Xylene	750	830	27	19	220
m,p-Xylene	3,100	1,800	70	37	350
Chloroform	220	89	22	9	29

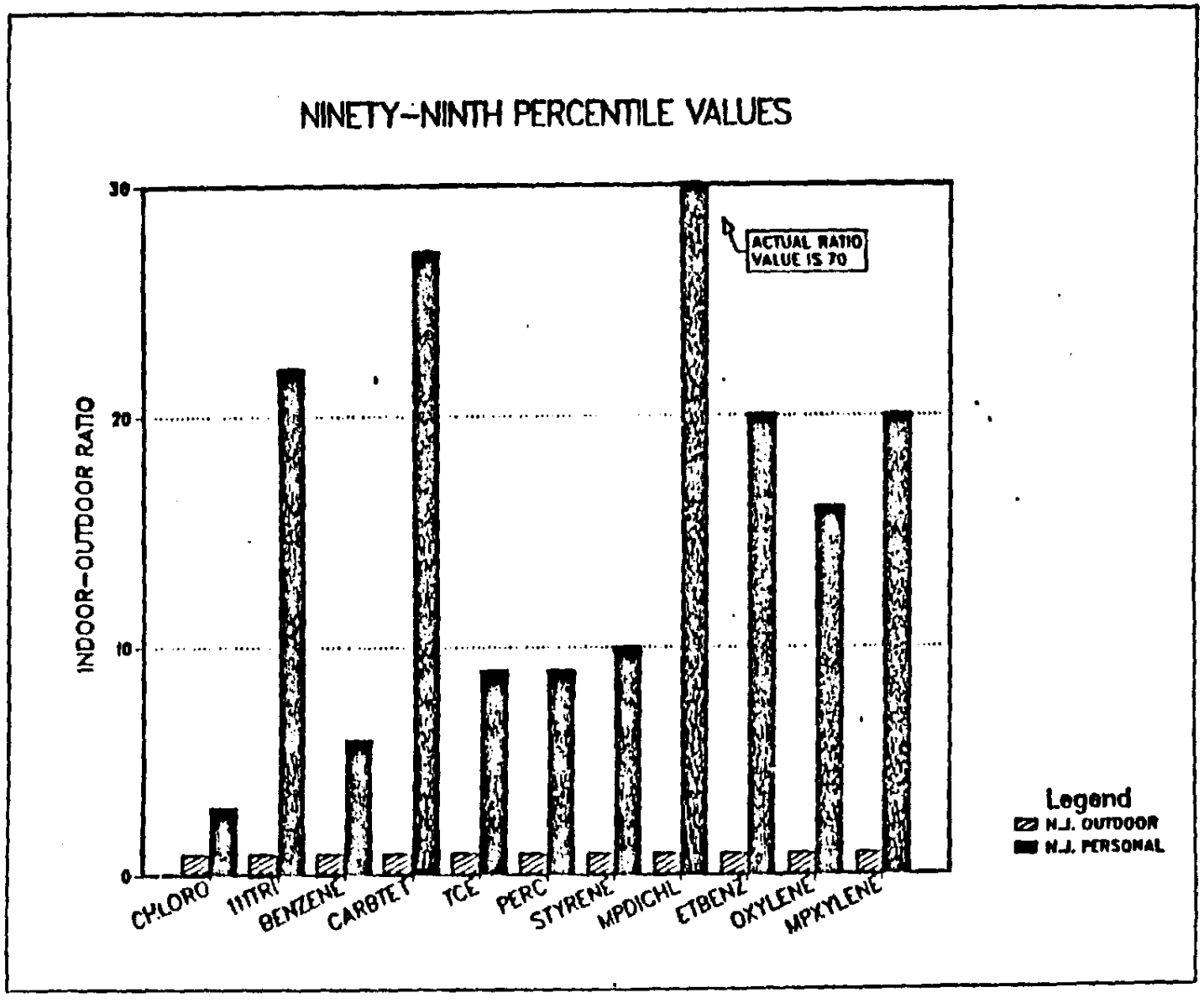

Figure 1. Overnight 12-hour average ratios of 90 matched pairs of indoor/outdoor samples in Elizabeth and Bayonne, NJ.

Table VIII. Spearman correlations between breath values and preceding personal air and outdoor air concentrations: TEAM Study, Elizabeth, New Jersey, Fall, 1981

	r_s		P	
Chemical	Personal Air (N 190)	Outdoor Air (N 55)	Personal Air	Outdoor Air
m,p-Dichlorobenzene	.56	.27	.0001	.06
Tetrachloroethylene	.46	.31	.0001	.02
Trichloroethylene	.40	.37	.0001	.009
m,p-Xylene	.39	.23	.0001	.09
Ethylbenzene	.34	.17	.0001	.21
1,1,1-Trichloroethane	.29	.17	.0001	.23
o-Xylene	.25	.24	.0005	.08
Benzene	.22	.27	.002	.05
Styrene	.22	.08	.002	.60
Chloroform	.05	.00	.51	.98

Table IX. Outdoor concentrations (ug/m^3) in Elizabeth and Bayonne compared to U.S. values

	Median			75th Percentile	
	N[a]	U.S.[a]	NJ[b]	U.S.	NJ
1,1,1-Trichloroethane	1669	2.8	4.6	5.5	9.1
Benzene	2292	8.9	7.6	15	14
m,p-Xylene	1191	12	8.9	23	17
o-Xylene	1885	5.2	3.0	10	5.4
Ethylbenzene	669	5.2	3.0	7.8	6.0
Tetrachloroethylene	1711	2.3	3.1	4.8	8.5
Trichloroethylene	1638	0.81	1.4	1.8	2.8
m,p-Dichlorobenzene	392	0.28	1.0	1.6	1.5
o-Dichlorobenzene	674	0.066	0.17	0.36	0.35
Styrene	2	-	0.64	-	1.0
Chloroform	1739	0.35	0.60	0.73	1.8
Carbon tetrachloride	1747	1.2	0.84	1.7	1.2

a N = Number of samples measured in urban and suburban areas: U.S. 1970-1980. Source: Volatile Organic Chemicals in the Atmosphere: Assessment of Available Data, Environmental Sciences Research Laboratory, U.S. EPA Research Triangle Park, NC, 1982.

b Weighted values for Elizabeth and Bayonne combined (population 122,000), N = 170-175 12-hour samples for all chemicals.

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