United States
Environmental Protection
Agency

Office of Monitoring Systems
and Quality Assurance
Washington DC 42060

Research and Development

EPA-600/S4-82-015 July 1982

EPA

Project Summary

Direct Measurement of Volatile Organic Compounds in Breathing-Zone Air, Drinking Water, Breath, Blood, and Urine

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Methods for determining individual human exposure to volatile organic compounds (VOC) encountered during normal daily activities were field-tested on university student volunteers in two geographical areas. The following equipment and analytical protocols were tested:

- **A personal air quality monitor employing the synthetic adsorbent Tenax-GC® to collect organic vapors for later analysis by gas chromatography/mass spectrometry (GC/MS).**
- **A specially-designed spirometer for collecting samples of expired human breath on duplicate Tenax-GC® cartridges for later GC/MS analysis.**
- **A purge and trap analytical protocol for determining VOC levels in blood and urine.**

Results included the following:

- **The personal monitor and spirometer proved feasible for collecting abundant quantitative data on most of the 15 target organic vapors.**
- **Air exposures to many VOC varied widely, sometimes over 3 orders of magnitude, among students on the same campus that had been monitored over the same time period and day.**
- **A log-linear relationship between breathing-zone air exposures and concentrations in exhaled breath was suggested for three chemicals: tetrachloroethylene, 1,1,1-trichloroethane, and vinylidene chloride.**
- **The analytical protocols for blood and urine gave different results in different laboratories. The cause of this problem is being investigated.**
- **Air was the main route of exposure for all target compounds except the two trihalomethanes (chloroform and bromodichloromethane), which were transmitted mainly through water.**
- **Estimated total daily intake through air and water of the target organics ranged from 0.3 to 12.6 mg, with 1,1,1-trichloroethane at the highest concentrations in both geographic areas.**

This Project Summary was developed by EPA's Office of Office of Monitoring Systems and Quality Assurance, Washington, D.C., to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Few studies have attempted to measure individual human exposure to organic substances simultaneously with measurements of body burden. Yet a knowledge of exposure and body burden is crucial in arriving at decisions of great economic consequence concerning the regulation of these substances. The present study is a pilot effort to develop the methods

required to determine individual human exposure and body burden for a number of volatile organic compounds (VOC) (Table 1).

The main objective of the study was to field-test the following methods for measuring human exposure to VOC:

- A personal air quality monitor to sample breathing-zone air;
- A specially designed spirometer to sample exhaled breath;
- Analytical protocols for measuring VOC in air, tap water, breath, blood, and urine.

A second objective was to compare levels of VOC in breathing-zone air and drinking water with levels of the same compounds in human breath.

Although the EPA report deals with all of these objectives, this Project Summary will omit discussion of the blood and urine results, which were of questionable accuracy.

Two areas were selected for study: a petrochemical manufacturing center in Texas and a nonindustrial community in North Carolina. Volunteers from local universities were sought.

Beaumont, Texas was selected to represent the petrochemical area. Lamar University is bordered on the north and south by oil storage tank farms, and on the northwest by the urban area of Beaumont. Winds from the south cross over major refineries and petrochemical plants before reaching the University.

Chapel Hill, N.C. was selected to represent the non-industrial area. Students at the University of North Carolina (UNC) formed the study population.

At both Universities, students were selected only if they were not currently enrolled in a course involving direct contact with organic chemicals, not employed in occupations involving exposure to organic chemicals, and not engaged in hobbies involving potential exposure to organic chemicals.

A questionnaire was administered to each student to determine factors possibly related to exposure, such as residence on or off campus, dietary habits, hobbies, parents' occupations, etc. The questionnaire had been approved by the human rights committee at the University of Miami Medical School.

In all, 17 students were selected: 11 at Lamar University (five sampled on March 4, 1980 and six on the following day); and six at UNC (three students sampled on June 10, 1980 and three on the following day). Each participant signed a consent form and received a small incentive when sampling was completed.

Table 1. Target Chemicals in Lamar University & University of North Carolina Study

Chemical	Air & Breath	Drinking Water
1. *Benzene*	X	X
2. *Chloroform*	X	X
3. *1,2-Dichloroethane*	X	X
4. *1,1,1-Trichloroethane*	X	X
5. *Trichloroethylene*	X	X
6. *Tetrachloroethylene*	X	X
7. *Bromodichloromethane*	X	X
8. *Chlorobenzene*	X	X
9. *Vinylidene chloride*	X	X
10. *1,1-dichloroethane*	X	
11. *1,2-dichloropropane*	X	
12. *Dibromochloromethane*	X	
13. *Ethylene dibromide*	X	
14. *Dichlorobenzene (m- or p- isomer)*	X	
15. *o-dichlorobenzene*	X	

Sampling and Analysis

Each morning air monitors and water sample vials (3 per person) were distributed to each of the 11 Lamar students. Participants carried the monitors for a 5-9 hour period while they attended classes, ate lunch, commuted, or carried out other normal daily activities. They filled a water sample vial each time they drank. At the end of the day, air monitors and tap water samples were collected.

A personal sampler employing Tenax GC® polymer to collect organic compounds was used to collect all air samples in the study. The sampler consists of an MSA Model C-200 pump and an attached Tenax cartridge.

Breath samples were collected on Tenax GC cartridges via a specially designed spirometer. The subject inhaled pure air and exhaled through a two-way Douglas valve mouthpiece into a Tedlar bag. A Nutech pump pulled the exhaled air across a Tenax cartridge. About 75 liters (10 minutes of normal breathing) was collected.

During June, 1980, tap water, breath and air samples were collected at UNC. The criteria and methods of sampling were the same as for Lamar University. Six students participated as subjects.

Analysis of the Tenax cartridges for air and breath was performed by a thermal desorption GC-MS procedure described fully in previous publications (1).

Tap water samples were analyzed by a purge and trap method based on that of Bellar and Lichtenberg (2). Both a Hall Electrolytic Conductivity Detector and a flame ionization detector were operated simultaneously to detect both the halogenated compounds and benzene.

Quality Control

Standards, blanks, and controls were interspersed throughout the analysis period. The standards were prepared fresh daily and transferred to smaller containers which were stored in the refrigerator until used.

The blanks and controls were prepared one day prior to the sampling trips. Lab blanks and controls remained refrigerated in the laboratory during the trip; field blanks and controls were transported to and from the field alongside the samples.

The air controls were spiked with the following eight compounds via a permeation system: chloroform, 1,2,-dichloroethane, 1,1,1-trichloroethane, carbon tetrachloride, tetrachloroethylene, trichloroethylene, bromodichloromethane, and benzene.

The breath blanks were run on the spirometer with the mouthpiece plugged and the intake air forced through the exhaled bag. The controls were collected in the same manner except each cartridge was spiked with about 500 ng of each of the compounds.

Tap water blanks were prepared from distilled water. Controls were spiked to give a concentration of 10 ng/mL of each of the following nine compounds: chloroform, 1,2-dichloroethane, 1,1,1-trichloroethane, carbon tetrachloride, trichloroethylene, tetrachloroethylene, chlorobenzene, *o*-dichlorobenzene, and bromodichloromethane.

Results

Percent recoveries for the air and breath analyses ranged between 85-153% at UNC.

Percent recoveries for drinking water control samples in the Lamar study varied widely, from 25% for tetrachloroethylene to >100% for chloroform. The peaks for trichloroethylene and 1,1,2-trichloroethane overlap, so it was not possible to determine whether one or both compounds were present, nor to quantitate either compound. Adjustments in the analytical protocol led to greatly improved percent recoveries at Chapel Hill three months later. Mean recoveries ranged between 92% and 118% for the seven spiked compounds. The relative standard deviation ranged between 4 and 12% for the UNC study.

In addition to the quality control samples, three blind quality assurance samples were prepared for water. These samples were encoded prior to submission to the analyst. The results indicate good recoveries for chloroform and chlorobenzene; moderate recoveries for carbon tetrachloride; but only 50% recovery of tetrachloroethylene. Recoveries of 1,1,1-trichloroethane, on the other hand, were consistently 40-50% greater than the spiked value.

Of 15 compounds sought in air, six were found in all 17 field samples, and four others in more than half of the samples (Tables 2 and 3). Six of these 10 compounds showed high variability, ranging over 2-3 orders of magnitude. Geometric means for one compound—1,1,1-trichloroethane—exceeded 50 $\mu g/m^3$ in each student group. Geometric means for seven other compounds generally fell between 1 and 10 $\mu g/m^3$ for each group. No significant difference in concentration means between the two student groups was detected for any compound.

Five compounds were found in all 17 breath samples, and two others were found in more than 50% of the samples (Tables 4 and 5). Five of these seven compounds showed high variability. Geometric means for these seven compounds ranged from about 1-15 $\mu g/m^3$.

UNC tap water showed consistently higher mean chloroform values than the Lamar University sources (220 ppb to 150 ppb) (Table 6a and b). Bromodichloromethane values were similar in the two supplies (20 ppb at Lamar; 17 ppb at UNC). Total trihalomethanes exceeded the primary drinking water standard of 100 ppb in all 38 water samples from the two areas.

All of the tap water samples contained chloroform and bromodichloromethane. Some samples contained small amounts of tetrachloroethylene and chlorobenzene. No benzene, carbon tetrachloride, 1,2-dichloroethane, vinylidene chloride, or 1,1,1-trichloroethane was detected.

Table 2. *Estimated Levels of Selected Vapor-Phase Organics in Ambient Air Associated with Human Participants—Lamar University Student Study ($\mu g/m^3$)*

	Participant No.											
Compound	30001	30002	30003	30004	30005	30011	30012	30013	30014	30015	30016	LOD[a]	QL[b]
Benzene	9.5	2.5	11	2.9	3.6	4.8	5.8	8.3	3.2	5.3	386	0.08	0.40
Chloroform	1.4	1.5	3.8	8.3	5.2	4.0	4.8	6.0	3.2	1.9	4.8	0.08	0.40
Vinylidene chloride	416	1.4	76	1.0	1.1	—	7.0	5.7	2.1	4.6	—	0.12	0.60
1,1-Dichloroethane	1.8	—	0.93	—	—	—	—	—	—	—	—	0.12	0.60
1,2-Dichloroethane	11	0.49	—	0.32	0.52	1.0	0.94	0.95	0.72	0.71	13	0.12	0.60
1,1,1-Trichloroethane	592	22	1069	8.5	8.3	31	62	72	12	67	40	0.16	0.80
Trichloroethylene	19	7.5	26	1.6	0.90	3.8	2.0	63	0.99	2.4	3.7	0.16	0.80
1,2-Dichloropropane	—	—	—	—	—	—	—	—	—	—	—	0.20	1.00
Tetrachloroethylene	174	161	7.2	5.4	5.6	5.0	30	718	4.5	172	9.3	0.24	1.20
Bromodichloromethane	1.6	1.5	—	3.2	1.0	—	1.1	3.7	0.84	—	—	0.24	1.20
Dibromochloromethane	—	—	—	—	—	—	—	—	—	—	—	0.24	1.20
Ethylene dibromide	—	—	—	—	—	—	—	—	—	—	—	0.28	1.40
Chlorobenzene	—	—	—	—	0.47	—	—	—	—	—	2.1	0.16	0.80
Dichlorobenzene isomer	8.4	73	8.0	6.9	2.5	6.4	3.0	23	1.8	4.3	33	0.20	1.00
o-Dichlorobenzene	—	—	—	2.4	0.38	—	0.20	—	—	—	—	0.20	1.00

[a]*Limit of Detection (LOD) was defined as S/N = 4 for m/z ion selected for quantification, all values in $\mu g/m^3$.*
[b]*Quantifiable Limit (QL) was defined as 5 x LOD or S/N = 20, all values in $\mu g/m^3$.*

Table 3. *Estimated Levels of Vapor-Phase Organics in Ambient Air for Several Human Subjects—University of North Carolina at Chapel Hill Study ($\mu g/m^3$)*

	Participant Number					
Compound	40001	40002	40003	40011	40012	40013
Benzene	14	7.5	3.8	3.2	4.2	3.0
Chloroform	7.8	5.1	3.7	3.2	17	2.2
Vinylidene chloride	14	27	9.8	3.5	5.7	7.0
1,1-Dichloroethane	—[a]	—	—	—	—	—
1,2-Dichloroethane	—	—	1.1	0.42	0.45	0.63
1,1,1-Trichloroethane	165	194	93	14	70	57
Trichloroethylene	9.7	2.2	10.8	4.6	2.2	183
1,2-Dichloropropane	—	—	—	—	—	—
Tetrachloroethylene	2.5	2.6	2.1	1.2	4.3	127
Bromodichloromethane	—	—	—	—	4.3	—
Dibromochloromethane	—	—	—	—	—	—
Ethylene dibromide	—	—	—	—	—	—
Chlorobenzene	—	—	—	0.17	0.18	—
Dichlorobenzene isomer	35	0.58	0.46	0.29	15	0.63
o-Dichlorobenzene	1.5	0.32	—	—	0.27	135

[a]*— = not detected.*

Discussion

The concentrations of some chemicals reached levels of 100-1000 $\mu g/m^3$ in air

and 100-200 $\mu g/m^3$ in human breath. Although the air levels are far below the workplace standards of the Occupational Safety and Health Administration, their chronic effects are unknown and could be of significant public health concern.

The great variability exhibited by seven of the 10 most prevalent compounds indicates that it would have been erroneous to characterize either student group as a geographical cohort with uniform exposures. If validated by future studies, this conclusion would have important implications for epidemiological studies, which have often traditionally assigned similar exposure histories to residents of a given region.

For both student groups studied, methyl chloroform is the main contributor, supplying over half the total intake of all target chemicals at UNC, and more than ⅓ at Lamar. The relative importance of benzene, chloroform, and vinylidene chloride was also very similar for each group, ranging between 4% and 8%. However, tetrachloroethylene was far more important for the Lamar group than the UNC group (35% to 7%), while trichloroethylene was relatively more important at UNC (13% to 3.5%).

Spearman correlation coefficients were computed between air and breath samples for each student group (Table 7). Three chemicals in breath showed significant correlations with their concentrations in air.

Table 4. *Estimated Levels of Selected Vapor Phase Organics in Breath—Lamar University Student Study ($\mu g/m^3$)*

	Participant No.												
Compound	30001	30002	30003	30004	30005	30011	30012	30013	30014	30015	30016	LOD	QL
Benzene	2.9 ± 1.1	1.4 ± 0.2	0.7 ± 0.0	1.71 ± 0.28	0.99 ± 0.33	1.8 ± 0.13	2.2 ± 0.15	1.7 ± 0.15	1.1 ± 0.20	1.9 ± 0.52	1.3 ±	0.11	0.55
Chloroform	T[a]	T	T	T	T	T	2.48	T	T	T	T	0.11	0.55
Vinylidene chloride	15 ± 2.8	0.08	26 ± 8.0	0.08	2.9	0.08	0.08	0.5 T	5.8 ± 1.6	3.8 ± 1.2	0.08	0.16	0.82
1,1-Dichloroethane	—[b]	—	—	—	—	—	—	—	—	—	—	0.16	0.82
1,2-Dichloroethane	—	—	—	—	—	—	—	T	—	T	—	0.16	0.82
1,1,1-Trichloroethane	161 ± 16	0.66 ± 0.16	93 ± 21	T	T	T	2.5	T	1.7 ± 0.46	6.5 ± 0.75	T	0.22	1.10
Trichloroethylene	—	1.11 ± 0.04	T	T	—	T	T	1.45 ± 0.10	T	1.07 ± 0.04	T	0.2	1.10
1,2-Dichloropropane	—	—	—	—	—	—	—	—	—	—	—	0.27	1.37
Tetrachloroethylene	69 ± 5.4	96 ± 0.20	98 ± 1.0	13 ± 1.5	13 ± 0.71	T	24 ±	161 ± 31	1.0 ±	176 ± 0.91	T	0.33	1.65
Bromodichloromethane	—	—	—	—	—	—	—	—	—	—	—	0.33	1.65
Dibromochloromethane	—	—	—	—	—	—	—	—	—	—	—	0.33	1.65
Ethylene dibromide	—	—	—	—	—	—	—	—	—	—	—	0.38	1.92
Chlorobenzene	—	—	—	—	—	—	—	—	—	—	—	0.22	1.10
Dichlorobenzene isomer	T	31 ± 2.5	T	T	T	T	1.3 ±	20 ± 6.2	6.1 ±	23 ± 3.0	T	0.27	1.37
o-Dichlorobenzene	—	—	—	—	—	—	—	—	—	—	—	0.27	1.37

[a] T = trace amount.
[b] — = not detected.

Table 5. *Estimated Levels of Vapor Phase Organics in Breath of Human Subjects—University of North Carolina at Chapel Hill Study ($\mu g/m^3$)*

	Participant Number					
Compound	40001	40002	40003	40011	40012	40013
Benzene	1.0 ± 0.05	1.4 ± 0.23	1.4 ± 0.18	1.1 ± 0	NC[a]	1.5 ± .41
Chloroform	2.8 ± 1.5	3.0 ± 0.16	5.1 ± 2.8	1.8 ± 0.28	NC	1.7 ± 0.41
Vinylidene chloride	4.5 ± 0.39	14 ± 1.3	5.5 ± 1.3	3.9 ± 0.09	7.7 ± 0.05	7.9 ± 0.65
1,1-Dichloroethane	—[b]	—	—	—	—	—
1,2-Dichloroethane	—	—	—	—	0.37	0.48
1,1,1-Trichloroethane	23 ± 3.6	48 ± 11	19 ± 5.7	6.1 ± 0.04	8.5 ± 1.8	13 ± 0.34
Trichloroethylene	1.1 ± 0.12	0.55 ± 0.19	1.2 ± 0.36	0.65 ± .05	0.49 ± 0.11	32 ± 0.70
1,2-Dichloropropane	—	—	—	—	—	—
Tetrachloroethylene	3.4 ± 0.44	3.3 ± 0.19	4.3 ± 0.76	8.8 ± 1.1	7.5 ± 0.68	48 ± 5.5
Bromodichloromethane	—	—	—	—	—	—
Dibromochloromethane	—	—	—	—	—	—
Ethylene dibromide	—	—	—	—	—	—
Chlorobenzene	—	—	0.27	—	0.11[c]	—
Dichlorobenzene isomer	0.54 ± .03	4.5 ± 0	2.2 ± 0.56	0.92 ± 0	5.3 ± 0.71	1.1 ± 0.36
o-Dichlorobenzene	—	—	—	—	—	—

[a] NC = missing values.
[b] — = not detected.
[c] Given value is below the limit of detection.

Table 6a. *Quantities of Target Compounds Found in Tap Water (ng/mL), Lamar University*

Number	Chloroform	1,2-Dichloroethane	1,1,1-Trichloroethane	Carbon Tetrachloride and/or Bromodimethane	Trichloroethylene and/or 1,1,2-Trichloromethane	Tetrachloroethylene	Chlorobenzene
1-30001	110	—[a]	—	16	NC[b]	—	—
1-30002	260	—	—	18	NC	—	—
2-30002	130	—	—	23	NC	—	—
1-30003	550	—	—	44	NC	T[c]	—
1-30004	160	—	—	25	NC	—	—
2-30004	99	—	—	18	NC	—	—
1-30005	140	—	—	25	NC	—	—
2-30005	120	—	—	22	NC	—	—
1-30011	120	—	—	20	NC	—	—
2-30011	120	—	—	18	NC	0.2	0.2[d]
3-30011	110	—	—	23	NC	—	—
1-30012	120	—	—	22	NC	—	—
2-30012	170	—	—	26	NC	—	—
3-30012	110	—	—	17	NC	—	—
1-30013	140	—	—	18	NC	—	—
2-39913	160	—	—	22	NC	0.1[d]	—
3-30013	130	—	—	18	NC	—	—
1-30014	160	—	—	20	NC	—	—
2-30014	130	—	—	18	NC	—	—
3-30014	110	—	—	13	NC	—	—
1-30015	110	—	—	7.4	NC	0.2[d]	0.2[d]
2-30015	140	—	—	18	NC	—	—
1-30016	120	—	—	13	NC	—	—
2-30016	120	—	—	13	NC	—	—
3-30016	120	—	—	14	NC	0.1[d]	—
LOD	1.0	0.6	0.2	0.4	1.3	1.1	0.6

[a] — = not detected.
[b] NC = missing data.
[c] T = trace amount.
[d] Given value is below limit of detection.

Table 6b. *Quantities of Target Compounds Found in Tap Water (Chapel Hill) (ng/mL)*

Sample	Chloroform	1,2-Dichlbroethane	1,1,1-Trichloroethane	Bromodichloromethane	Trichloroethylene	Tetrachloroethylene	Chlorobenzene
40001-1	260	ND	ND[a]	20	2.8	3.8	ND
40001-2	260	ND	ND	19	3.0	3.8	ND
40002-1	220	ND	ND	17	ND	1.8	ND
40002-3	250	ND	ND	18	ND	1.8	ND
40003-1	200	ND	ND	18	ND	1.8	1.4
40003-2	230	ND	ND	18	ND	1.8	ND
40011-1	200	ND	ND	17	ND	1.7	ND
40011-2	210	ND	ND	16	ND	1.8	ND
40011-3	220	ND	ND	17	ND	1.8	1.5
40012-1	210	ND	ND	17	ND	1.8	ND
40012-2	210	ND	ND	16	ND	1.8	ND
40013-1	180	ND	ND	15	ND	1.3	1.5
40013-2	200	ND	ND	15	1.3	1.3	ND
Mean[b]	220	—	—	17	0.6	2.0	0.4
SD	23	—	—	2	1	0.8	0.6
CV (%)	10	—	—	12	170	40	150
Median	220	—	—	17	ND	1.8	ND
LOD[c]	0.05	0.06	0.1	0.1	0.05	0.05	ND

[a] Not detected.
[b] Mean of all values (ND = ½ LOD).
[c] Limit of detection (S/N = 3).

Table 7. *Spearman Correlation Coefficients Between Air and Breath for Estimated Levels of Selected Vapor Phase Organics—Both Groups*

	n		$r_{Air\text{-}Breath}$	
	UNC	Lamar	UNC	Lamar
Benzene	5	11	.70	.04
Chloroform	5	11	.60	.20
Vinylidene chloride	6	11	.48	.67*
1,1-Dichloroethane	6	11	.00	.00
1,2-Dichloroethane	6	11	.44	.07
1,1,1-Trichloroethane	6	11	.94**	.63*
Trichloroethylene	6	11	.94**	.41
1,2-Dichloropropane	6	11	.00	.00
Tetrachloroethylene	6	11	.20	.80**
Bromodichloromethane	6	11	.20	.00
Dibromochloromethane	6	11	.00	.00
Ethylene dibromide	6	11	.00	.00
Chlorobenzene	6	11	.31	.00
Dichlorobenzene isomer	6	11	.03	.08
o-Dichlorobenzene	6	11	.00	.00

* $p < .01$
** $p < .05$

1,1,1-Trichloroethane in Exhaled Breath Compared to Mean Breathing-Level Concentrations Averaged Over the Preceding 6-9 Hours for Two Student Groups

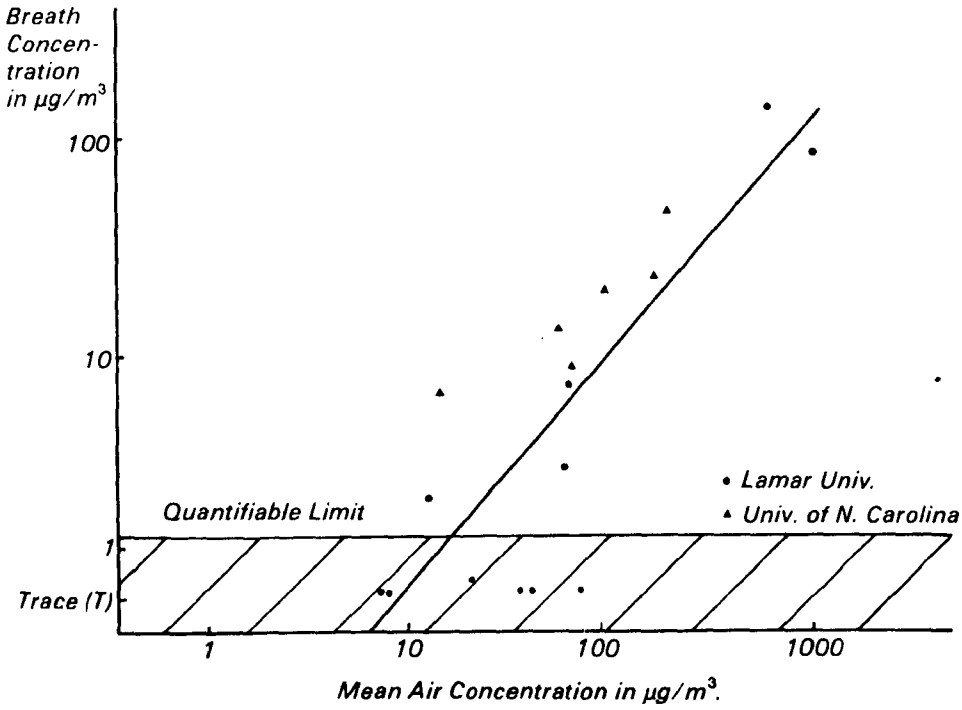

Figure 1. *Correlation between air exposures and breath concentrations for 1,1,1-trichloroethane. $R^2 = .68$.*

For all three chemicals 50% or more of the variance in breath levels was explained by the preceding air exposures. A simple log-linear model appears capable of predicting breath levels to within a factor of 3 or 4, given the air exposures for the preceding eight hours. This approach yields the following regression parameters:

Tetrachloroethylene:
$C_B = 10^{.23} C_A^{.72 \pm .13}$

1,1,1-Trichloromethane:
$C_B = 10^{-.98} C_A^{.91 \pm .23}$

Vinylidene chloride:
$C_B = 10^{-.24} C_A^{.71 \pm .17}$

where C_B = Concentration in breath, C_A = Concentration in air.

Figures 1-3 illustrate the possible log-linear relationship between air exposures and breath concentrations of these compounds. If this preliminary observation is confirmed by future studies, an exposure-dose relationship could be established for some compounds. This would allow recent exposures to be estimated from a single non-invasive breath sampling test lasting just 5 minutes; conversely, dose could be estimated from a single personal monitoring sample.

Estimated Total Daily Intake

Only two of the seven compounds measured in tap water samples contributed significantly to the total daily intake from air and drinking water of the volunteers. Assuming daily intakes of 10 cubic meters of air and one liter of drinking water, respectively, the water accounted for 79 percent of the chloroform intake and 76% of the bromodichloromethane intake. By contrast, drinking water contributed only 7 percent of the daily air/water intake of tetrachloroethylene for the UNC students, and even less for the Lamar students.

Each student's estimated daily intake of all the target compounds from air and drinking water is listed in Table 8. The air values range from 0.3-12.4 mg/day, with a geometric mean of 1.6 mg/day and a geometric standard deviation of 3.5. The corresponding geometric mean for the water intake was 0.2 mg/day.

References

1. Pellizzari, E.D. *et al, Preliminary Study on Toxic Chemicals in Environmental and Human Samples, Parts I and II* (USEPA, Wash. D.C. 1980).
2. Bellar T.A. and J. Lichtenberg, *Journal American Water Works Association, Vol. 66, No. 12, Dec. 1974, pp. 739-744.*

Conclusions

This report documents the first field effort of a continuing exposure monitoring program at the United States Environmental Protection Agency. Sampling equipment and analytical protocols were tested on 17 subjects at two universities. The sampling equipment (personal monitors and a specially designed spirometer)

and the analytical protocols worked well for the air, breath, and tap water samples.

These results indicate that the concept of making direct measurements of individual human exposure to a significant number of volatile organic compounds is feasible. This first effort has resulted in several interesting findings, including particularly the wide variability of exposures among a homogenous group of subjects, and the apparent relationship between inhaled and exhaled concentrations of several compounds. These findings could not have been made using standard approaches of ambient monitoring.

This study was designed to test methods of measuring individual exposure; it was not designed and cannot be used to characterize geographical areas or populations beyond the actual study groups themselves. No epidemiological conclusions regarding health effects of measured exposure levels can be drawn from this study.

Tetrachloroethylene in Exhaled Breath Compared to Mean Breathing-Level Concentrations Averaged Over the Preceding 6-9 Hours for Two Student Groups

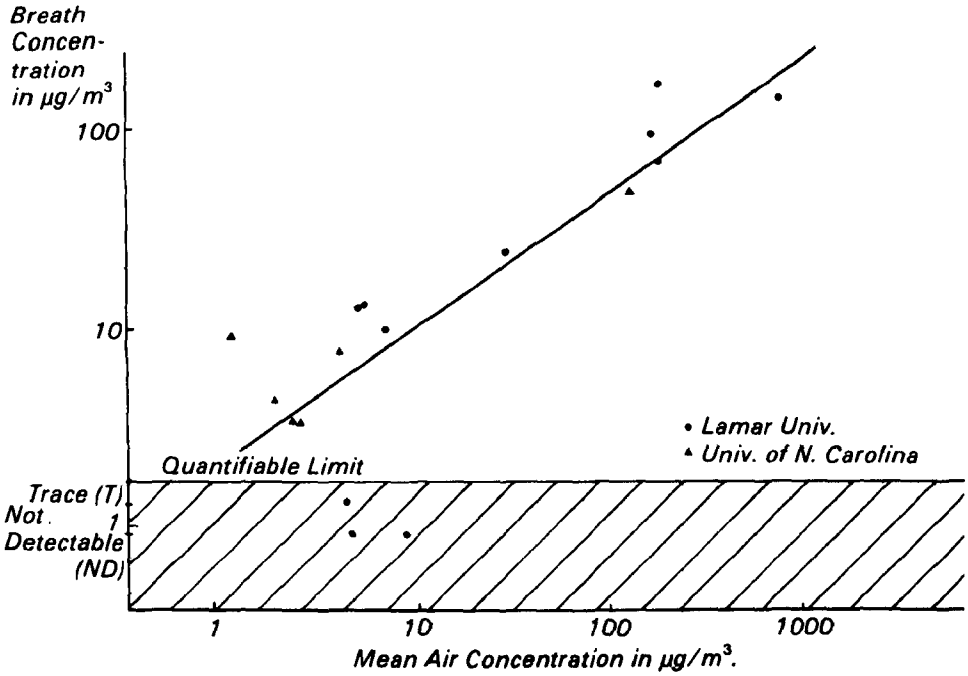

Figure 2. *Correlation between air exposures and breath concentrations for tetrachloroethylene. $R^2 = .68$.*

Vinylidene Chloride in Exhaled Breath Compared to Mean Breathing—Level Concentrations Averaged Over the Preceding 6-9 Hours for Two Student Groups

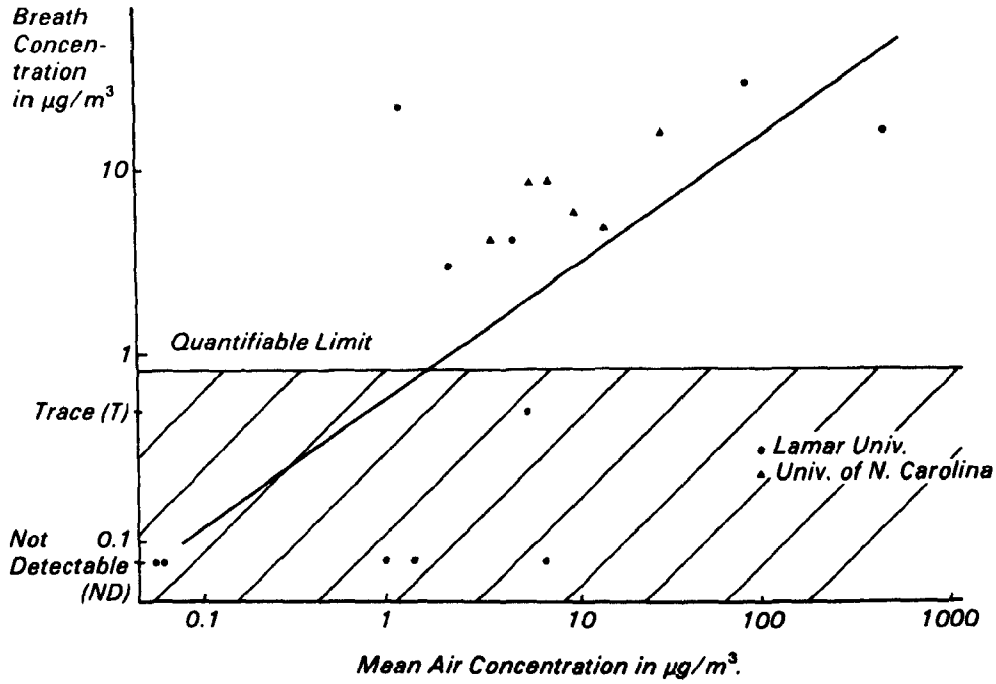

Figure 3. *Correlation between air exposures and breath concentrations for vinylidene chloride. $R^2 = .53$.*

Table 8. *Estimated Daily Intake* of 10 Volatile Organic Compounds Through Air and Water for 17 Subjects*

Subject	Air µg/day	Water	Total	Percent from Air
30001	12,400	200	12,600	98
30002	2,700	150	2,850	95
30003	12,000	600	12,600	95
30004	400	150	550	73
30005	300	150	450	67
30011	550	140	690	80
30012	1,250	160	1,410	89
30013	9,000	160	9,160	98
30014	300	150	450	67
30015	2,600	140	2,740	95
30016	1,140*	130	1,270	90
40001	2,470	280	2,750	90
40002	2,390	260	2,650	90
40003	1,250	240	1,490	84
40011	300	240	540	56
40012	1,240	230	1,470	84
40013	3,800	210	4,010	95

**Assuming 10 m^3/day and 1 liter/day intake rates for air and water.*

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The complete report, entitled "Direct Measurement of Volatile Organic Compounds in Breathing-Zone Air, Drinking Water, Breath, Blood, and Urine," (Order No. PB 82-186 545; Cost: $12.00, subject to change) will be available only from:

National Technical Information Service
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Springfield, VA 22161
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