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Use of Breath Analysis to Monitor Trichloroethylene Exposures

Richard D. Stewart, MD, MPH; Carl L. Hake, PhD; Jack E. Peterson, PhD, Milwaukee, Wis

Trichloroethylene (TCE) postexposure breath decay curves were obtained from ten male and ten female volunteers who were exposed daily in a controlled-environment chamber to TCE vapor, 20, 100, or 200 ppm for one, three, or 7½ hours. Alveolar breath samples were collected in glass pipettes for TCE analysis by gas chromatography.

The series of TCE breath decay curves obtained was highly reproducible and the narrow range of TCE in the breath at a specific time in the early postexposure period of persons identically exposed indicated that breath analysis could be used as a rapid method with which to estimate the magnitude of recent TCE exposure.

The TCE breath concentration in the immediate postexposure period accurately reflected the vapor concentration to which the subject had been most recently exposed. Breath samples collected eight to 24 hours following exposure were accurate indicators of the time-weighted average vapor exposure experienced by the subject on the previous day.

Trichloroethylene (TCE) is one of the most widely used chlorinated aliphatic hydrocarbon solvents in industry. Its chemical stability, nonflammability, volatility, and poor solubility in water make it a very versatile solvent. It is used for metal degreasing, the manufacture of chemicals, fat and wax extraction, and as an ingredient in printing inks, paints, lacquers, varnishes, and adhesives.

To protect American workmen against excessive TCE vapor exposure an industrial Threshold Limit

Value (TLV) of 100 ppm has been established.¹ This requires that a reliable monitoring system be employed to insure that the TLV is not exceeded. The oldest surveillance system relies on the periodic analysis of air samples from the breathing zone of the workmen. This procedure is adequate in those industrial settings which are stable and unchanging. Work areas with widely fluctuating TCE concentrations require frequent, and ideally, continuous monitoring of the breathing zone for TCE, a desirable, always expensive, and not always feasible procedure.

To circumvent the disadvantages of air monitoring an alternative surveillance technique has been advocated: the Biological Threshold Limit value. This system employs the workman as his own biologic monitor of TCE exposure by measuring the body burden of the absorbed TCE as reflected in breath TCE excretion,²⁻⁵ blood TCE,^{2,5} or the urinary excretion of the major metabolites.^{3,4,6-15}

Of the methods for estimating TCE body burden, breath analysis following exposure has provided a more accurate reflection of exposure than has been gleaned from the measurement of the urinary metabolites of TCE.³ Because of the simplicity of breath sample collection and the economy of analysis this investigation was undertaken to develop the required postexposure TCE breath decay curves with which to estimate the magnitude of an industrial exposure.

Experimental Procedure

Ten male and ten female volunteers were exposed daily to TCE vapor concentrations of 20, 100, or 200 ppm for periods of one, three, or 7½ hours each day. Serial breath analyses for TCE concentration were performed after each exposure and a family of breath TCE decay or excretion

curves was obtained. This investigation was performed with strict adherence to the ethical and technical requirements for human inhalation experimentation previously detailed,¹⁶ which included the informed consent of each subject after the nature of the procedure had been fully explained.

The 20 healthy adults ranged in age from 19 to 46 years. Before exposure, each was given a comprehensive medical examination which included a complete history and physical examination with the laboratory studies listed below.

Exposure Schedule.—Table 1 in the article by Stewart et al¹⁷ (this issue), details the exposure sequences for this series of experiments. The concentration excursions occurring during the fluctuating TCE vapor experiment are presented in Table 1 of this article.

Exposure Chamber.—The experiments were conducted in a controlled-environment suite of three rooms: a 20×20×8 foot testing room, a 5×4×8 foot toilet facility, and a 4×5×6½ foot grounded audiometric booth. The airflow through the rooms to the exhaust was approximately 500 cu ft/min, which created a slight negative pressure within the suite. The ambient temperature in the testing facility was maintained at 22 to 23 C, while the relative humidity ranged between 45% to 55%.

Liquid TCE was pumped at a constant rate into a heated flask. A stream of air flowing through the flask swept the TCE vapor into the return air duct of the air conditioner. The proportion of fresh air used by the air conditioner was varied along with the TCE pumping rate to achieve vapor concentration control.

Analysis of Exposure Chamber Atmosphere.—The TCE used in these experiments was shown by infrared analysis to be authentic TCE. The concentration of TCE in the chamber atmosphere was continuously recorded by an infrared spectrometer equipped with a long path-length gas cell set at 5.25 meters. The gas cell was continuously flushed with air drawn from the test facility through one-fourth-inch diameter polyethylene tubing. The absorbance at 11.75μ was measured. A gas

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| Elapsed Time, min | TCE, ppm | Event |
|-------------------|----------|----------------------------|
| 0 | 50 | 7½ and 3 hr subjects enter |
| 80 | 100 | |
| 140 | 200 | |
| 179.8 | 200 | 3 hr subjects exit |
| 180 | 50 | |
| 247 | 100 | |
| 297 | 200 | |
| 330 | 50 | 1 hr subjects enter |
| 357 | 100 | |
| 377 | 200 | |
| 389.8 | 200 | 1 hr subjects exit |
| 390 | 100 | |
| 450 | 100 | 7½ hr subjects exit |

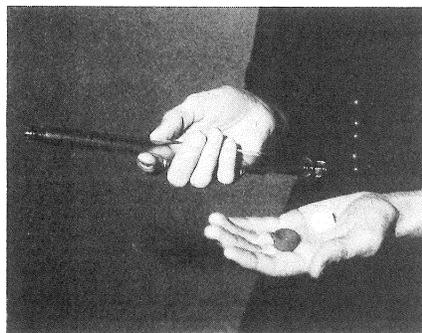


Fig 1.—Glass pipette (50 ml) used for collecting breath samples. One cap has a predrilled hole for gas sampling. Both caps have Saran liners that seal the pipette chamber, permitting storage of the breath sample for prolonged intervals.

chromatograph equipped with a hydrogen flame ionization detector and an automatic sequential sampler provided the second independent analytical method. The infrared analytical data were monitored every second by an online Digital PDP-12 computer, which displayed the mean vapor concentration for each 30-second interval of exposure. Calibration standards of TCE and pure air were prepared in Saran bags and analyzed by both monitoring methods before and hourly during each experiment.

Breath Sample Collection and TCE Analysis.—Alveolar breath samples were obtained from each subject before exposure, five minutes prior to termination of exposure, and at the following postexposure times: one and 30 minutes, one, two, four hours, and at 9 AM the morning after exposure. The samples were collected in 50-ml glass pipettes fitted with screw caps containing Saran liners (Fig 1 to 5). One of the caps had a predrilled hole through which a

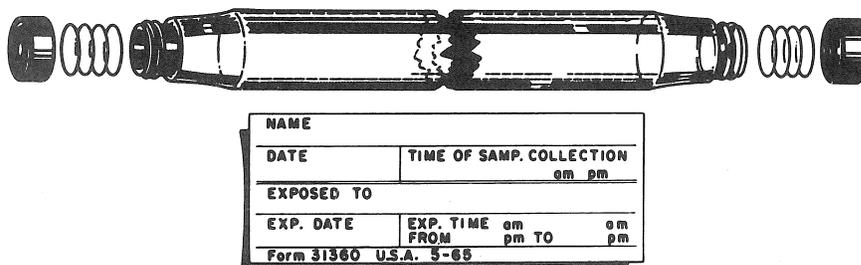


Fig 2.—Schematic drawing of breath pipette.

gas sampling syringe could be introduced to pierce the Saran liner and the main pipette chamber. The subject flushed the pipette three times with his exhaled breath and after holding the fourth breath for 30 seconds, exhaled and collected the end-tidal portion of his expired breath.

In the breath sample TCE was analyzed with a Varian Aerograph Series 2700 gas chromatograph equipped with a hydrogen flame ionization detector. Breath aliquots were injected directly into a 1-foot×one-eighth-inch stainless steel chromatographic column that contained Poropak Q and operated at 140 C.

Clinical Testing.—The subjects underwent a training program in the controlled-environment chamber for one week prior to the inhalation experiments. During this period they became proficient in testing procedures (R. D. Stewart et al, unpublished data).

Before each exposure a physical examination was performed on each subject. At this time a battery of clinical laboratory studies was performed (R. D. Stewart et al, unpublished data). This battery was repeated at appropriate intervals in the post-exposure period.

After entering the controlled-environment suite, the subjects were under continual surveillance by medical personnel and all important chamber activities were video taped by closed-circuit TV. During the experiments, electrocardiogram (EKG) lead II was continuously monitored by telemetry.

During the five-day period that the male subjects were exposed to TCE 200 ppm, low doses of alcohol were administered to several of the subjects. The dosage schedule and the resultant blood alcohol concentrations are discussed in detail in the companion communication (see Table 2 of Stewart et al¹⁷).

Twenty-four hour urine samples were collected from the subjects following each exposure and analyzed for trichloroacetic acid, trichloroethanol, and creatinine. The correlation of the excretion of the urinary metabolites of TCE with the various vapor exposures is the subject of another report (C. L. Hake et al, unpublished data).

Results

Trichloroethylene was readily detected in the expired breath of each of the subjects following exposures to the three vapor concentrations. These postexposure TCE breath data for male and female subjects are summarized in Table 2. Examination of these breath data reveals that a predictable excretion pattern for TCE exists for each of the three vapor concentrations studied. Furthermore, the rate of excretion of TCE in the breath is seen to be a function of the duration of the exposure.

The breath decay curves obtained are presented in Fig 6. It is apparent that the concentration of TCE in the immediate postexposure period was highest following the 200 ppm vapor exposure. The decay of TCE in the breath was exponential with the rate of excretion being influenced by the duration of exposure. With the exception of the one- and three-hour exposure to TCE 20 ppm experiments, TCE was detected in the breath of all subjects the day following the exposure. This figure also shows the influence of ethyl alcohol ingestion on the breath decay of TCE in subjects exposed to 200 ppm for 7½ hours.

The variation in the TCE breath concentrations in the postexposure period between individuals identically exposed is presented in Table 2 and Fig 7. This individual variation was remarkably small when contrasted to the wide differences noted in the concentration of the urinary metabolites of the same subjects (C. L. Hake et al, unpublished data). The range of TCE breath concentration of subjects exposed to 200 ppm did overlap in part the TCE breath range of persons exposed for a similar length of time to 100 ppm. This overlap was less marked in the later postexposure pe-



Fig 3.—Breath sample is "collected" by sealing one end of the pipette with the lips, flushing the chamber with three exhaled breaths, and then, after holding a fourth breath for 30 seconds, exhaling through the pipette chamber so that the end-tidal portion can be collected.



Fig 4.—Distal cap is secured while the subject is still expiring through the pipette chamber. After the distal cap is secure, the proximal end of the pipette is removed from the mouth and quickly sealed with a finger tip.

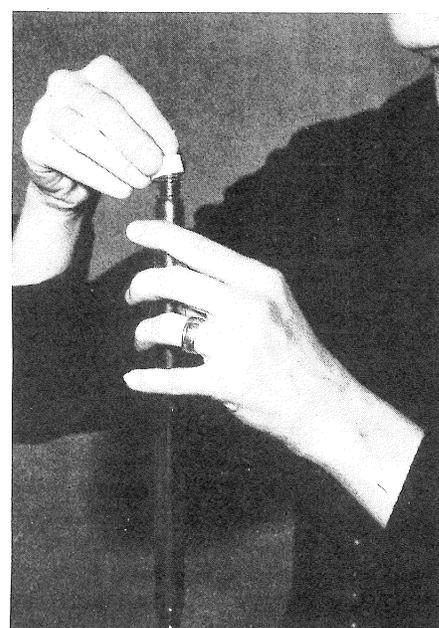


Fig 5.—Breath sampling is completed by securing the proximal cap.

riod. Part of the variation was attributed to the technique of breath sample collection and to genuine, reproducible differences between persons.

Table 3 presents the daily variation observed in the individual subjects exposed to TCE, 100 ppm. In most instances these individual variations were small enough to permit the differences between subjects to become apparent. Note that male subject 1 consistently had a higher post-exposure breath TCE concentration than did the other three male subjects.

Figure 7 shows that female subjects had lower TCE breath concentrations 16 hours following exposure to 100 ppm for 7½ hours than did their similarly exposed male counterparts. This "sex" difference was the major factor in the wide range of TCE breath concentrations observed 16 hours postexposure.

Fluctuating TCE vapor exposures altered the slope of the breath decay curves. This influence was most evident in the early postexposure period of the male subjects who had been ex-

posed to 200 ppm immediately before concluding their time-weighted average exposure of 100 ppm. Note in Table 1 that the immediate post-exposure breath concentrations of the one- and three-hour subjects were comparable to those following exposure to a nonfluctuating 200 ppm exposure, and that their breath TCE concentrations remained higher in the first four postexposure hours than had been the case when they were exposed to the same time-weighted average, but nonfluctuating concentration of TCE vapor. The 7½-hour subjects who were also exposed to the fluctuating TCE exposure, but who concluded their exposure at 100 ppm, had breath decay curves similar to the breath decay curves obtained following exposure to a nonfluctuating TCE vapor concentration of 100 ppm.

The influence of the fluctuating TCE vapor exposure which terminated at a vapor concentration twice that of the time-weighted average was no longer discernible the day following exposure, at which time the concentration of TCE in the breath was a reliable reflection of the time-

weighted average exposure. Therefore, it appears that a breath sample obtained in the immediate post-exposure period reflects the most recent solvent concentration to which the subject has been exposed, while a breath sample obtained the following day is indicative of the time-weighted average exposure and is not influenced by the fluctuation of the vapor concentration during exposure.

The ingestion of very modest amounts of ethyl alcohol during the latter stages of the TCE vapor exposure produced a dramatic effect on the TCE concentration in the expired breath in the early postexposure period. Table 3 in the article by Stewart et al¹⁷ (this issue) shows that TCE breath concentrations were twice normal in the early postexposure period and that the TCE breath concentrations remained elevated for at least two hours into the postexposure period, a time at which the blood alcohol concentrations would have been exceedingly low. The mechanism for this elevation was not readily apparent, but it was believed not to be due to the increased solubility of TCE in

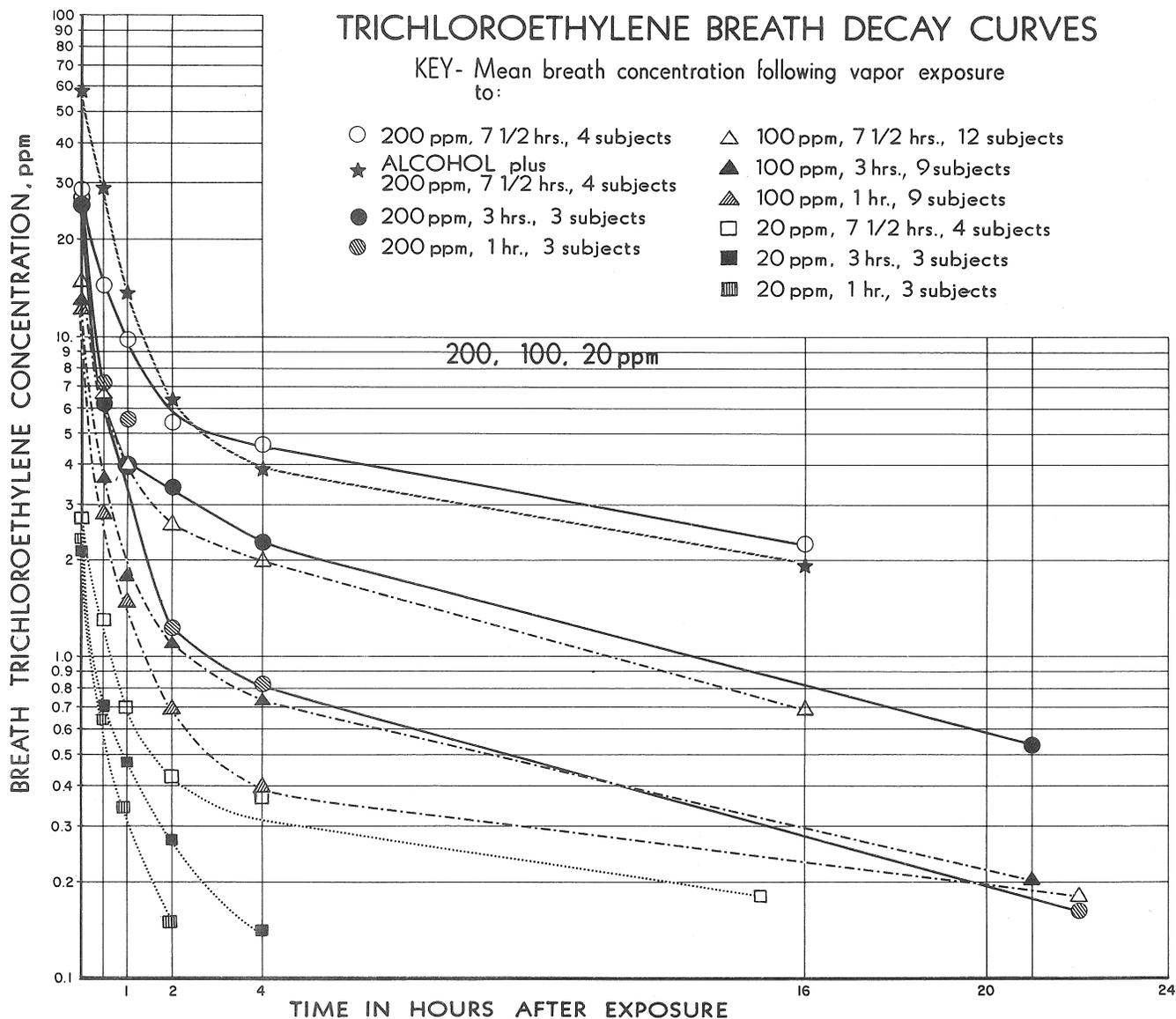


Fig 6.—The TCE postexposure breath decay curves obtained from adults who were exposed for periods of one, three, and 7½ hours to trichloroethylene vapor, 20, 100, and 200 ppm.

blood that contained ethyl alcohol.

Ingestion of small amounts of alcohol produced a dramatically evident vasodilatation of the skin capillaries on the face and trunk of the subjects. This phenomenon, the "degreasers' flush," is the subject of a companion paper¹⁷ (page 1).

The breath pipettes used in this investigation were satisfactory provided that the breath samples were properly collected and promptly analyzed. In this series of experimental human exposures 15% of all breath samples collected yielded unsatisfactory analytical results. In 8% it was immediately apparent that the sub-

ject had failed to tighten securely one of the plastic screw caps. In the remainder of the unsatisfactory breath samples, the pipette caps had been adequately tightened, but the low TCE concentrations indicated that most probably the sample had been improperly collected.

Comments

The analysis of expired breath for TCE in the postexposure period is a good diagnostic test of exposure. The detection of TCE in the breath by infrared spectroscopy constitutes an unequivocal diagnosis of exposure. When it is known that exposure to

TCE has occurred, gas chromatography can be used to measure the concentration of the solvent in the breath. This method is rapid, simple, and less costly than the infrared method. The diagnosis of exposure to a clinically significant vapor concentration of this solvent can be made for periods up to 100 hours post-exposure.³

The data reported in this paper indicate that the use of breath analysis provides an excellent screening test useful in estimating the time-weighted average TCE exposure. Subjects identically exposed for five consecutive days had very similar

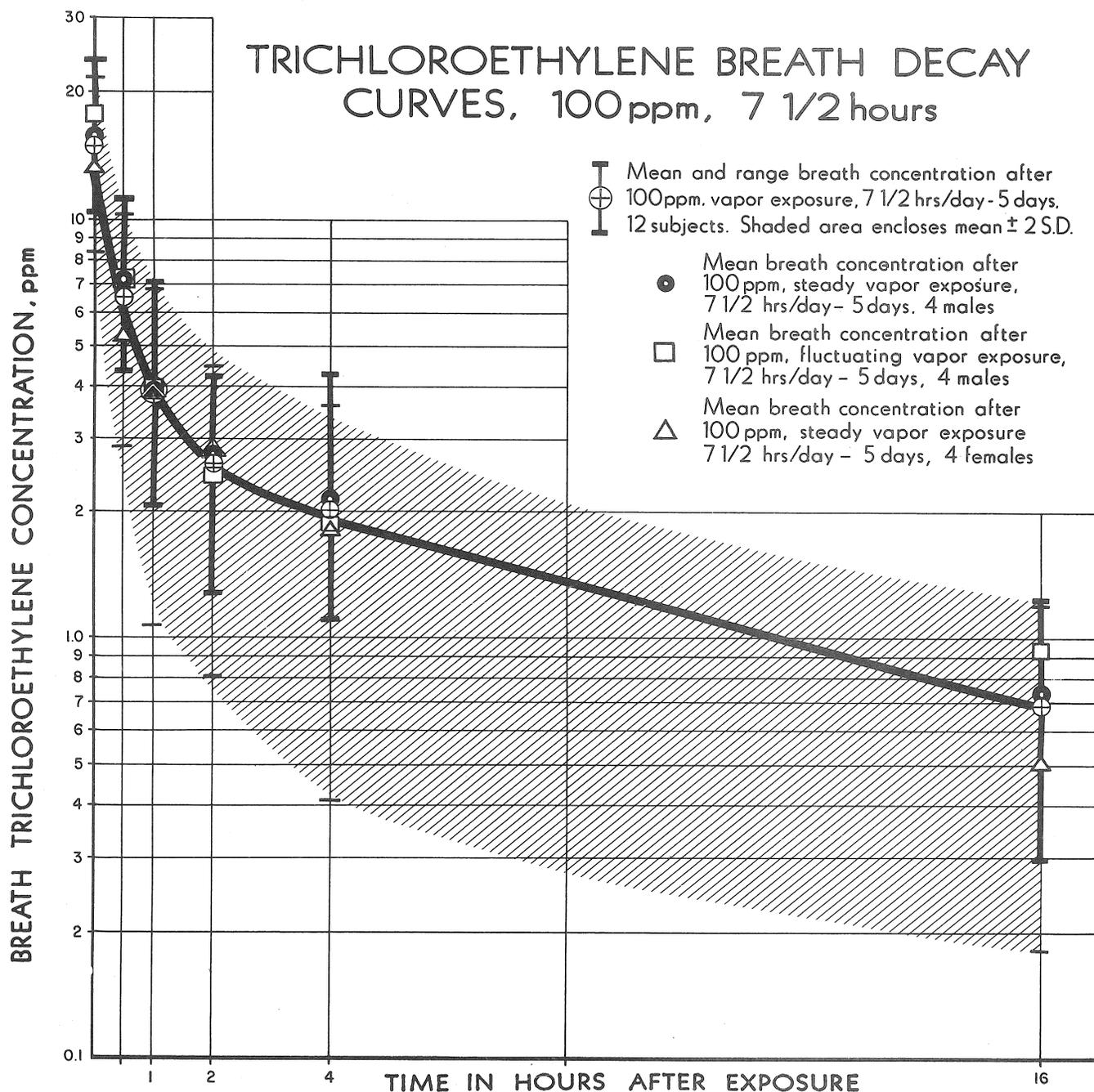


Fig 7.—The TCE postexposure breath decay curves. Male and female subjects had been exposed to 100 ppm for 7½ hours. Group means, ranges, and 2 SD from the mean are plotted.

breath decay curves, quite adequate for screening purposes.

The TCE breath decay data obtained during this series of experiments is in agreement with the TCE breath decay data obtained in 1968 at a different location.³ Data from the 1968 experiments are presented in Fig 8. So excellent is the agreement that the current 200 ppm post-exposure breath decay curves can be

superimposed upon those reported previously. The only data point which is not in good agreement is the previously reported four-hour post-exposure TCE breath concentration following a 100 ppm vapor exposure. Only two subjects were used in the previous study to define this point, so the importance of this minor discrepancy between decay curves is not thought to be particularly worri-

some.

In the present series of experiments, subjects exposed to time-weighted vapor concentrations of 100 ppm, but whose terminal exposure was to 200 ppm, had decay curves which were substantially different in the early postexposure period from decay curves from the same persons obtained after exposure to nonfluctuating concentrations of 100 ppm. In the

Table 2.—Postexposure TCE Breath Concentration: After Exposure to TCE, 20 ppm, Minimal Fluctuation, Five Consecutive Days

| 1-hr Exposure, 3 Men | | | | 3-hr Exposure, 3 Men | | | | 7½-hr Exposure, 4 Men | | | |
|----------------------|-------------------------|--------------|--------------|----------------------|-------------------------|------|-----------|-----------------------|-------------------------|------|-----------|
| Post-Exposure Time | Mean Concentration, ppm | SD | Range | Post-Exposure Time | Mean Concentration, ppm | SD | Range | Post-Exposure Time | Mean Concentration, ppm | SD | Range |
| 1 min | 2.25 | 0.61 | 3.4-1.5 | 1 min | 2.10 | 0.67 | 3.2-1.1 | 1 min | 2.74 | 0.55 | 4.1-2.0 |
| 30 min | 0.63 | 0.15 | 0.8-0.3 | 30 min | 0.69 | 0.22 | 1.0-0.2 | 30 min | 1.31 | 0.68 | 3.6-0.7 |
| 1 hr | 0.34 | 0.09 | 0.5-0.2 | 1 hr | 0.47 | 0.14 | 0.7-0.3 | 1 hr | 0.69 | 0.26 | 1.3-0.3 |
| 2 hr | 0.15 | 0.04 | 0.2-0.1 | 2 hr | 0.27 | 0.09 | 0.5-0.1 | 2 hr | 0.43 | 0.14 | 0.8-0.2 |
| 4 hr | 0.14 | 0.04 | 0.2-0.1 | 4 hr | 0.14 | 0.05 | 0.2-0.1 | 4 hr | 0.36 | 0.14 | 0.6-0.2 |
| 22 hr | Not detected | Not detected | Not detected | 19 hr | 0.06 | 0.02 | 0.1-0.05 | 15 hr | 0.18 | 0.03 | 0.2-0.1 |
| 1 min | 12.88 | 2.09 | 14.6-9.7 | 1 min | 10.4 | 0.93 | 12.1-9.5 | 1 min | 15.22 | 2.81 | 23.7-11.2 |
| 30 min | 2.78 | 0.62 | 3.7-1.8 | 30 min | 3.45 | 0.77 | 4.3-1.3 | 30 min | 7.14 | 1.83 | 11.0-4.7 |
| 1 hr | 1.53 | 0.29 | 1.9-1.1 | 1 hr | 1.96 | 0.56 | 3.1-1.3 | 1 hr | 3.90 | 1.07 | 6.5-2.7 |
| 2 hr | 0.68 | 0.23 | 1.0-0.4 | 2 hr | 0.87 | 0.18 | 1.0-0.6 | 2 hr | 2.68 | 0.55 | 4.1-2.1 |
| 4 hr | 0.38 | 0.14 | 0.6-0.2 | 4 hr | 0.64 | 0.15 | 0.9-0.4 | 4 hr | 2.12 | 0.72 | 3.4-1.3 |
| 22 hr | 0.18 | 0.08 | 0.3-0.1 | 21 hr | 0.21 | 0.07 | 0.3-0.2 | 16 hr | 0.71 | 0.10 | 0.9-0.6 |
| 1 min | 13.91 | 3.60 | 25.0-10.8 | 1 min | 20.07 | 5.69 | 32.3-12.1 | 1 min | 17.48 | 3.78 | 23.2-12.4 |
| 30 min | 3.11 | 0.84 | 5.0-1.8 | 30 min | 4.81 | 0.91 | 6.0-3.5 | 30 min | 7.20 | 1.28 | 10.5-5.9 |
| 1 hr | 1.91 | 0.73 | 3.8-0.9 | 1 hr | 2.21 | 0.78 | 4.2-1.4 | 1 hr | 3.96 | 1.79 | 7.0-0.9 |
| 2 hr | 0.65 | 0.29 | 1.1-0.1 | 2 hr | 1.20 | 0.51 | 2.1-0.6 | 2 hr | 2.50 | 0.62 | 3.5-1.3 |
| 4 hr | 0.42 | 0.13 | 0.6-0.4 | 4 hr | 0.77 | 0.39 | 1.4-0.4 | 4 hr | 1.91 | 0.55 | 2.7-1.1 |
| 22 hr | 0.17 | 0.06 | 0.2-0.1 | 21 hr | 0.25 | 0.08 | 0.3-0.2 | 16 hr | 0.92 | 0.22 | 1.3-0.6 |
| 1 min | 10.78 | 1.60 | 12.7-9.0 | 1 min | 9.64 | 1.74 | 12.9-7.1 | 1 min | 13.22 | 2.76 | 18.8-10.2 |
| 30 min | 2.41 | 0.84 | 3.9-1.3 | 30 min | 3.03 | 0.61 | 4.3-2.1 | 30 min | 5.27 | 1.65 | 9.4-2.9 |
| 1 hr | 0.78 | 0.31 | 1.2-0.4 | 1 hr | 1.22 | 0.40 | 1.8-0.5 | 1 hr | 3.97 | 1.51 | 8.4-2.5 |
| 2 hr | 0.44 | 0.14 | 0.7-0.4 | 2 hr | 1.11 | 0.42 | 1.5-0.3 | 2 hr | 2.69 | 1.34 | 6.5-1.4 |
| 4 hr | 0.49 | 0.12 | 0.6-0.4 | 4 hr | 0.81 | 0.23 | 1.1-0.4 | 4 hr | 1.91 | 0.98 | 4.8-1.1 |
| | | | | 21 hr | 0.18 | 0.05 | 0.2-0.1 | 16 hr | 0.38 | 0.12 | 0.6-0.2 |
| 1 min | 26.75 | 6.44 | 40.4-20.5 | 1 min | 25.51 | 8.19 | 40.8-16.7 | 1 min | 28.70 | 4.14 | 33.1-23.2 |
| 30 min | 6.95 | 1.60 | 8.9-5.0 | 30 min | 6.27 | 1.39 | 8.5-5.0 | 30 min | 14.19 | 3.72 | 20.0-8.9 |
| 1 hr | 5.50 | 3.18 | 8.9-2.6 | 1 hr | 4.03 | 0.58 | 4.9-3.3 | 1 hr | 9.88 | 1.98 | 12.2-7.2 |
| 2 hr | 1.20 | 0.10 | 1.3-1.1 | 2 hr | 3.35 | 0.95 | 4.8-2.6 | 2 hr | 5.53 | 1.40 | 7.8-3.9 |
| 4 hr | 0.79 | 0.27 | 1.1-0.4 | 4 hr | 2.14 | 0.84 | 3.5-1.3 | 4 hr | 4.63 | 1.21 | 7.1-4.0 |
| 22 hr | 0.16 | 0.06 | 0.2-0.1 | 21 hr | 0.53 | 0.16 | 0.9-0.3 | 16 hr | 1.79 | 0.43 | 3.0-1.2 |
| | | | | | | | | 65 hr | 0.38 | 0.05 | 0.4-0.3 |
| | | | | | | | | 72 hr | 0.55 | 0.05 | 0.6-0.5 |

Table 3.—Breath TCE Concentration (Mean & Range) After Exposure to 100 ppm, 7½ hr

| Subjects | Time Postexposure | | | | |
|--------------|---------------------|-------------------|------------------|------------------|-------------------|
| | 1 min | 30 min | 1 hr | 2 hr | 16 hr |
| Men | | | | | |
| 1 | 17.1 (23.7-12.7) | 8.2 (11.0-7.1) | 5.1 (6.5-3.6) | 2.3 (2.4-2.3) | 0.7 (.88-.60) |
| 2 | 13.2 (15.3-11.2) | 5.9 (7.2-4.7) | 3.6 (4.2-2.9) | 2.0 (2.4-1.6) | 0.63 (.68-.55) |
| 3 | 14.4 (16.7-13.5) | 7.7 (10.4-5.6) | 5.0 | 2.7 (2.9-2.6) | 0.73 (1.0-.62) |
| 4 | 16.3 (17.0-15.3) | 6.5 (8.9-4.7) | 3.5 (4.6-2.7) | 3.0 (3.4-2.4) | 0.82 (.85-.78) |
| Women | | | | | |
| 1 | 13.7 (18.1-11.8) | 6.5 (9.4-2.9) | 6.3 (8.4-4.7) | 3.7 (6.5-1.6) | 0.35 (.42-.27) |
| 2 | 14.3 (18.8-10.7) | 5.0 (5.9-3.9) | 3.7 (4.7-3.0) | 2.2 (3.0-2.1) | 0.48 (.64-.21) |
| 3 | 13.5 (15.5-10.6) | 5.6 (6.4-4.9) | 3.5 (4.3-2.7) | 2.2 (2.5-2.1) | 0.45 (.58-.34) |
| 4 | 11.0 (11.9-10.2) | 4.4 (4.9-3.5) | 3.1 (3.7-2.5) | 2.3 (2.5-2.0) | 0.38 (.45-.31) |

1968 series of experiments, the influence of fluctuating vapor exposures was also investigated but not reported. These data are now presented in Fig 9. The observation was confirmed that the early postexposure breath samples are greatly influenced by the vapor concentration to which the subject most recently has been exposed until eight hours into the postexposure period. Furthermore, exposure to a low vapor concentration at the end of a work period results in a proportionally lower TCE breath concentration in the early post-exposure period.

Therefore, the concentration of TCE in the breath in the early post-exposure period is a reflection of the TCE vapor concentration to which the

subject has been exposed most recently. If the vapor concentration has been steady and nonfluctuating, this sample will accurately reflect the time-weighted vapor concentration. If, however, the TCE vapor concentration has been fluctuating during exposure, a breath sample obtained in the first four hours following exposure will not accurately reflect the time-weighted vapor exposure.

The ideal time for the collection of a TCE breath sample which will most accurately reflect the time-weighted vapor exposure is in the 12- to 16-hour period following exposure, at which time the solvent has reached a state of equilibrium within the body compartments. Thus, for the majority of industrial operations, a breath sample obtained the morning following exposure would be the best for screening purposes.

Experience in this laboratory indicates that, should it be desirable to allow the subject to collect breath samples in pipettes in the postexposure period while at home, the breath samples should be collected in duplicate pipettes to reduce the troublesome problem of pipette leakage. In addition, it is imperative that duplicate background pipette samples be collected to eliminate the possibility of background contamination yielding a false analytical result.

Ideally, it would be desirable to construct an individualized breath decay curve for each workman following exposure to a known concentration of TCE. This would provide superior breath curve, further reducing the variation due to biological differences, sampling techniques, sex, and body mass.

The influence of alcohol on the TCE breath concentration in the immediate postexposure period is dramatic. It is imperative that the laboratory performing the breath analyses be capable of analyzing breath for ethyl alcohol. Until the mechanism for this important elevation is known, other industrial compounds as well as pharmaceutical agents which have the potential for interfering with TCE metabolism should be kept in mind when TCE breath concentrations are elevated above anticipated

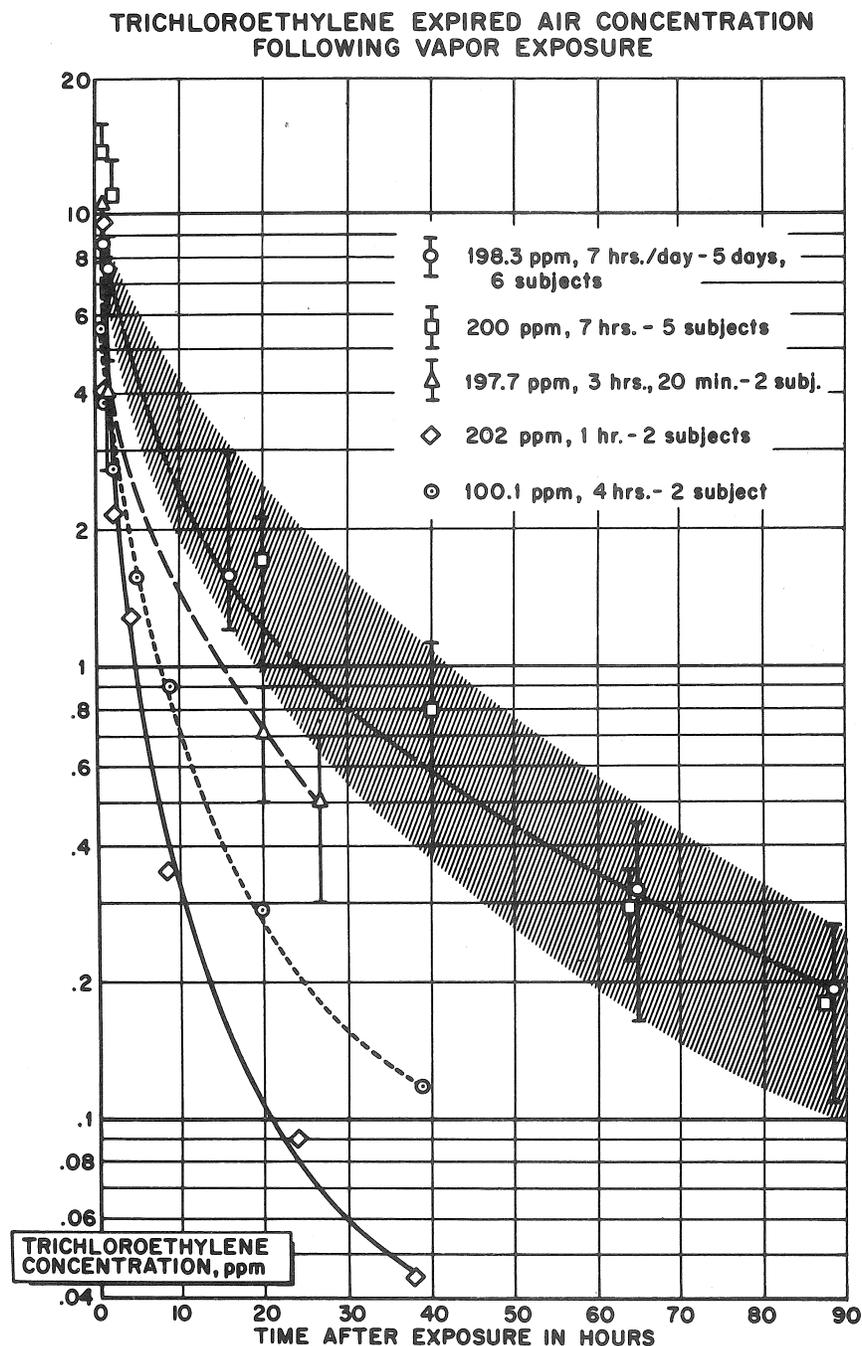


Fig 8.—Previously published trichloroethylene breath decay curves³ (redrawn from *Arch Environ Health* 20:64-71, 1970, with permission of the publishers).

levels.

We are cognizant of some of the weaknesses inherent in the breath decay curves presented here. The number of subjects from whom TCE breath data were obtained in each of the exposure settings is small, and if these breath decay data did not corroborate those reported previously,³ one would hesitate to suggest that

they could be immediately useful in industry for screening purposes. The usefulness of this method of exposure evaluation needs to be scrutinized in the industrial setting where the effect of other factors such as physical exertion with its influence on tidal volume, temperature, and the presence of other chemical compounds, can be evaluated.

TRICHLOROETHYLENE EXPIRED AIR CONCENTRATION FOLLOWING VAPOR EXPOSURES

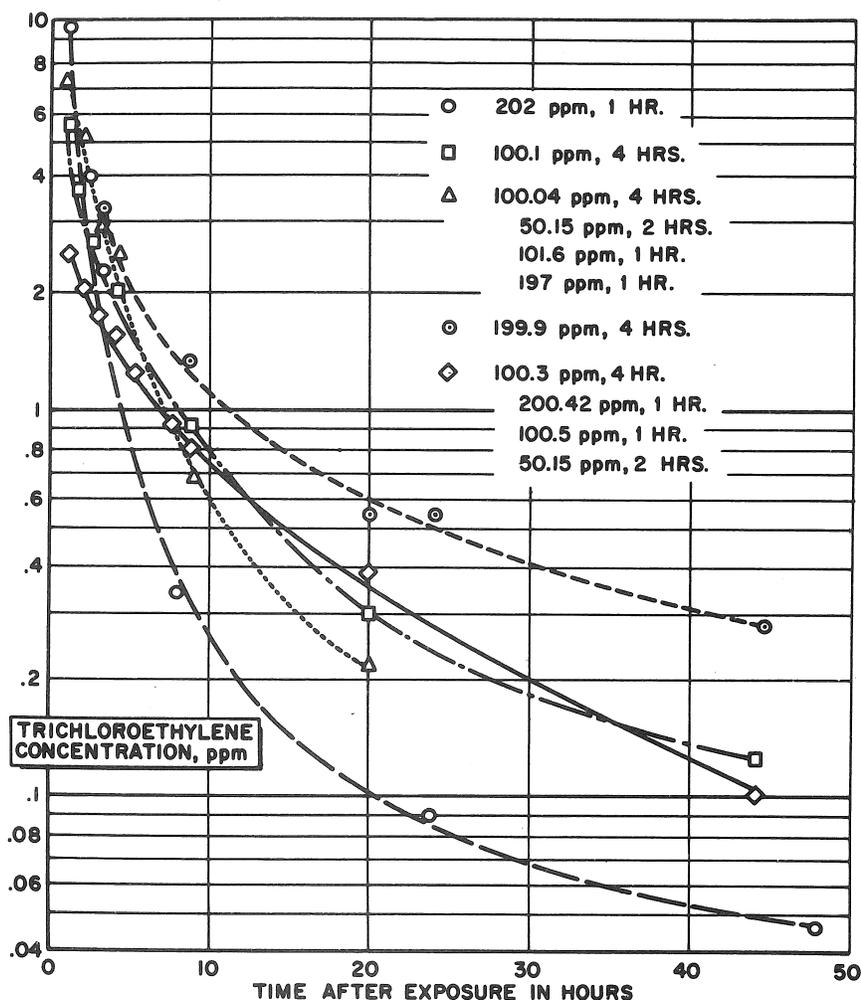


Fig 9.—The TCE breath decay curves that demonstrate the influence of fluctuating vapor exposures. Breath samples obtained in the first several hours following vapor exposure reflect the most recent vapor concentration and may not accurately reflect the time-weighted average vapor exposure. Eight hours following exposure, TCE in the breath is an accurate reflection of time-weighted average vapor exposure and is not influenced by the fluctuation in vapor concentration that may have occurred during vapor exposure.

The use of breath analysis for the purpose of estimating recent and time-weighted average exposure to TCE is attractive because of the simplicity, ease of collection, accuracy, and the low cost of the procedure. The TCE breath analysis in the post-exposure period for the purpose of estimating the magnitude of exposure appears to be superior to the measurement of the urinary metabolites. (1) One is measuring TCE directly, not a metabolite which can be found in the urine of persons exposed to other compounds. Thus, breath analysis is a specific test. (2) In contrast to the urinary metabolites which ac-

cumulate in the body with repetitive TCE exposure, breath TCE in the 24-hour period following exposure is not greatly influenced by repetitive exposures. (3) The normal biological variation between persons is low in the case of the TCE in breath as contrasted to the marked and often confusing variation noted with the two urinary metabolites of TCE³ (C. L. Hake et al, unpublished data). Finally, since the urinary metabolites are cumulative in the body as a result of repetitive exposure, while TCE in the breath is not cumulative, analysis of both has the potential for more accurately defining the magnitude of

long-term TCE vapor exposure than the use of either alone.

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