

IV. ENVIRONMENTAL DATA AND BIOLOGIC EVALUATION

Environmental Concentrations and Engineering Controls

There is little information available about the concentrations of 1,1,1-trichloroethane to which workers have been routinely exposed.

Concentrations of 1,1,1-trichloroethane developed in cleaning electrical equipment were reported by Burkatskaya et al [104] in 1973. The sampling and analytical method were not described. The greasy parts were sprayed with or dipped into the solvent. Parts were sprayed for 4-5 minutes and dried with a jet of air for 2-3 minutes. The room had an exhaust fan and a general two-way exhaust that provided 35-40 air changes (time interval not given).

Concentrations of 1,1,1-trichloroethane in the shop area during the spraying period were 27-70 ppm. These concentrations declined rapidly when the spraying and drying process was completed and, after 30 minutes, the room air concentration was not measureable.

Concentrations found in different parts of the room when the dipping tanks opened were 25-55 ppm. When the parts were taken from the bath, about 250 ppm of 1,1,1-trichloroethane were found in the workroom air. [104]

An average breathing zone concentration of 410 ppm 1,1,1-trichloroethane was found in a degreasing operation study reported by Hervin and Reifschneider [105] in 1973. A 3 x 3 x 3 foot metal hood vented to the outside air was provided for operations involving the use of 1,1,1-trichloroethane. The bottom of the hood was a basin which contained 5 gallons of solution. The basin was covered when not in use. The operation

involved dipping the metal parts in the solution and then standing them upright for visual inspection. The operator then shook the parts and handed them to the packer who placed them in a wooden box. This operation normally was performed intermittently for a few hours each day.

Eight breathing zone and general area samples were collected with charcoal tubes during the survey and analyzed by gas chromatography. The operations were noted for about 2 hours by the investigators. [105]

Concentrations of 1,1,1-trichloroethane in the workroom of a printing plant were studied by Tada. [60] The samples were collected from various parts of the room on the third to fifth day of the week and the 1,1,1-trichloroethane concentrations were determined by the alkali-pyridine-benzidine method. The survey showed that the workers were exposed to 1,1,1-trichloroethane at 37 ppm on the average for 7 hours/day.

Colorimetric indicator tubes (designed for methyl bromide) were used by Weitbrecht [61] to estimate air concentrations of 1,1,1-trichloroethane in a room where it was used by nine women for washing brass frames in open containers. The average concentrations found by this method were 10 ppm in the general room air and 20 ppm at the worksite. The average exposure concentrations of two of the women were estimated at 40 ppm by another non-specific colorimetric indicator method.

Kay et al [106] reported on atmospheric sampling in the vicinity of vapor degreasing operations in 21 factories. Workers wore personal samplers to measure their average exposure over most of a working day and other atmospheric samples were taken at selected points around the degreasing tanks. Some of the factories used 1,1,1-trichloroethane and others used trichloroethylene. Of 71 workers using trichloroethylene, 18

were exposed in excess of the TLV (100 ppm) throughout their working day. During the survey, concentrations of 1,1,1-trichloroethane were "well below toxic levels" (apparently meaning 350 ppm) during normal vapor degreasing.

In this same study, [106] methods of operation and ventilation were highlighted as important safeguards. The authors reported samples taken near vapor degreasing plants at 21 factories in England. They found that lip exhaust ventilation was provided at three-fourths of the open top tanks surveyed. Extraction rates varied (tank to tank) from 0 to > 100 cu ft/min. Lips slots were commonly found to be closed, by dropage of heavy objects or deposits of dirt. Conditions were found to be poorest at tanks without lip exhausts, and over half of the operators were receiving concentrations above the TLV. This was aggravated in some conditions by poor general ventilation. Also, downward drafts caused solvent vapor to be blown out of the tanks and into the workers' breathing zone. The authors suggested that this effect could be limited by the use of covers and screens at the tank. The authors [106] found that manual unloading of tanks as well as preparation of work for the tanks, caused a sharp increase of 1,1,1-trichloroethane in the workers' breathing zones.

The following recommendations were made: (1) Degreasing tanks should be sited in well ventilated areas giving particular attention to tanks in confined areas, (2) vapor degreasing tanks should be provided with efficient lip exhaust systems (35 cu ft/min was suggested as an adequate extraction rate) and covered by protective screens to prevent escape of 1,1,1-trichloroethane vapor, (3) work should be arranged so that it can be contained in the freeboard zone of the tank during the removal of excess solvent and stacked to ensure complete drainage of the degreasing solvent,

(4) operations which require high temperature, such as welding, should not be carried out in areas where 1,1,1-trichloroethane may be present, due to breakdown to toxic products. [106]

Recent sampling by Kramer et al, [64] as part of a matched pair study of two textile plants, found that workers were exposed to an average daily concentration of 115 ppm 1,1,1-trichloroethane. During cleaning operations at noon, this level rose to about 350 ppm. Air samples were analyzed by gas chromatography.

1,1,1-Trichloroethane exposures during vapor degreasing were reported by Skory et al [107] as average concentrations and average peak concentrations. Exposures found during different phases of the work were: idling degreaser, 76 ppm (average peak concentration 187 ppm); racking and loading, 73 ppm (average peak concentration 164 ppm); cleaning parts, 95 ppm (average peak concentration 182 ppm); unloading parts, 131 ppm (average peak concentration 268 ppm).

To minimize exposure to 1,1,1-trichloroethane during these operations, the authors suggested that parts should be withdrawn slowly from the degreaser so as not to pull solvent out, heating input and condensing capacity should be properly balanced, the nozzle of the sprayer should be kept below the vapor-air interface during spraying applications, air flow in the degreasing area should be controlled so drafts do not sweep across the top of the vapor degreaser or toward the operator, and lip exhausts should be properly operated. [107]

Environmental Sampling and Analytical Methods

(a) Collection Methods

Most analytical methods are dependent upon the effectiveness and reproducibility of the uptake of 1,1,1-trichloroethane by different collection media. Air samples are usually collected and transported to a laboratory, then desorbed or chemically treated, and finally analyzed quantitatively.

Silica gel, which has been used as a collection medium, [108-110] is a polar adsorbent and shows pronounced selectivity in adsorbing polar molecules, particularly water. [111] A laboratory study with 1-inch silica gel tubes indicated that the silica gel could become saturated with water and lose its collection efficiency when sampling 3 liters of air. [111]

Activated charcoal has been used as a collection medium followed by analysis by gas chromatography. [112] Charcoal is nonpolar and will generally adsorb organic vapors in preference to water vapor resulting in less interference from atmospheric moisture than with silica gel. [111]

Williams and Umstead [113] reported the use of porous polymer beads as a collection medium. With this method, the same column was used for sample collection and gas chromatographic analysis. This method consolidates collection and analysis into one operation, but only one analysis can be made on each sample. This method has not been developed for field use.

When solid collection media are used, it is necessary to desorb the collected contaminant from the medium. Desorption from charcoal was studied by Otterson and Guy [114] who recommended the use of different desorbing agents depending upon the comparative gas chromatograph retention

times for the desorber and the contaminant. Carbon disulfide was determined to be the best desorbent for 1,1,1-trichloroethane collected in charcoal tubes. [114]

Liquids have been used to collect chlorinated hydrocarbons from contaminated atmospheres. Midget impingers containing m-xylene or tetrachloroethylene have been used for collection in conjunction with gas chromatographic analysis, [114,115] and bubble bottles containing a pyridine solution have been used for collection in conjunction with colorimetric analysis. [60] The successful use of impingers for collection of breathing zone samples requires careful handling of glassware during collection and shipment of samples to the laboratory to avoid spillage.

Other investigators have collected grab samples of contaminated atmospheres directly in a variety of containers ranging from plastic bags to hypodermic syringes. [55,59,114]

(b) Analysis

Several methods have been used to quantify 1,1,1-trichloroethane in air samples. The analytical methods can be divided into two broad categories: (1) methods based on 1,1,1-trichloroethane chemical reactions, and (2) methods based on its physicochemical characteristics.

The three chemical methods that have been used extensively are: (1) dechlorination of collected vapor samples with strong alkalis followed by titration of the chloride ion (alkaline hydrolysis) [60,116]; (2) colorimetric measurement of the reaction products of tetrachloroethane and pyridine heated in alkali solution (Fujiwara reaction) [60,117]; and (3) direct reading colorimetric indicators. [55,61,118]

The dechlorination method (alkaline hydrolysis) requires collection of the 1,1,1-trichloroethane contaminated atmosphere by a suitable collection medium followed by alkaline hydrolysis in isopropyl alcohol, and titration of the liberated chloride with silver nitrate. [116] The percentage of chlorine hydrolyzed is determined by comparison between samples and known controls. A disadvantage of this method is that chlorine is not easily removed from 1,1,1-trichloroethane and the amount removed depends on the duration of the dechlorination process. Another disadvantage is that it is not specific for 1,1,1-trichloroethane.

In the colorimetric analytical method based on the Fujiwara reaction, a stream of air containing 1,1,1-trichloroethane is passed through a bottle containing pyridine. [60] Potassium hydroxide is then added to a portion of the sample, and this mixture is heated in a boiling water bath and cooled during a fixed time period. A portion of the potassium hydroxide solution, to serve as a blank, is similarly heated and cooled. Absorption coefficients of the pyridine layer are determined with a spectrophotometer. This method requires less time than the dechlorination method, but the problem of specificity with mixtures of chlorinated hydrocarbons remains.

The third chemical method utilizes direct reading detector tubes. [60,61,118] These are glass tubes packed with chemicals that change color when a measured and controlled flow of air containing 1,1,1-trichloroethane passes through the chemical. Depending on the type of detector tube, the air may be drawn directly through the tube and compared with a calibration chart, or the air may be drawn into a pyrolyzer accessory prior to the detection tube. [118] In either case, the analysis is not specific for 1,1,1-trichloroethane since liberated halide ions produce the stain and any

halogen or halogenated compounds will interfere. Federal regulations on detector tubes provide that measurements with colorimetric indicator tubes shall be correct +25% of the values read (42 CFR 84.50).

Photodetection (halide meters), [119] infrared spectrometry, [120] and gas chromatography [115] are among the analytical methods that are based on the physicochemical properties of 1,1,1-trichloroethane.

Halide meters are made to detect the increased brightness of an arc across metal electrodes when they are enveloped by an atmosphere contaminated with halogens and halogenated compounds. These instruments are sensitive to all halogens and halogenated compounds and consequently they are not specific for 1,1,1-trichloroethane. Halide meters are suitable for continuous monitoring if 1,1,1-trichloroethane is the only halogenated contaminant present in the sampled air. [119]

An infrared spectrophotometer in conjunction with a suitable recorder can be used to document instantaneous concentrations or to record continuously. With this method, concentrations are measured directly and it is not necessary to collect individual samples or to transport them to a laboratory for analysis. Infrared spectrophotometry has been used for continuous monitoring of industrial operations for chlorinated hydrocarbons. [120] The atmosphere of relevant working stations must be sampled and must correspond to the breathing zone of the workers at the working stations. Infrared analysis is subject to interferences from other air contaminants and these interferences are not easily detected or resolved without substantial knowledge of infrared spectrophotometry.

Gas chromatography provides a quantitative analytical method which can be specific for different chlorinated hydrocarbons. [112] Every

compound has a specific retention time in a given chromatography column, but several compounds in a mixture may have similar retention times. [121] This problem can be overcome by altering the stationary phase of the chromatography column or by changing the column temperature or other analytical parameters. Altering conditions usually will change the retention times and separate the components.

A mass spectrometer can be used subsequent to gas chromatography to identify the substance present in a gas chromatographic peak more positively. Linked gas chromatograph-mass spectrometer instruments perform this identification automatically. A charcoal capillary tube has been used to trap and transfer the material associated with a gas chromatographic peak to a mass spectrometer for qualitative identification when only unlinked units are available. [122]

A comparative study of a colorimetric method, a gas chromatographic method, and colorimetric detection tubes for analysis of 1,1,1-trichloroethane was reported in 1970 by Fukabori. [55] The data are presented in Table XII-11. They suggest that the detector tubes give higher values than the other two methods used.

(c) Conclusions and Recommendations

(1) Compliance Method

Based on this review of air sampling and analytical methods, it is recommended that 1,1,1-trichloroethane in air samples be collected with activated coconut shell charcoal, desorbed with carbon disulfide, and analyzed by gas chromatography. Although the indirect system of measurement which requires collection and desorption prior to analysis is a disadvantage, this sampling and analytic method has the following attributes:

(A) Charcoal tubes are easy to prepare, ship, and store.

(B) Estimation of exposure with personal samplers is easily achieved.

(C) Desorption with carbon disulfide is efficient and reproducible. However, unusual care is required in the handling of carbon disulfide, to prevent inhalation and skin contact, and ignition by sources such as steam pipes.

(D) 1,1,1-Trichloroethane can be identified in combination with many other compounds.

(E) At the sample volumes recommended, interference by moisture is minimal.

(F) Sampling tubes and personal pumps are commercially available.

(2) Monitoring Methods

Exposure to 1,1,1-trichloroethane associated with its continuous and constant use can be monitored by infrared spectrophotometry, portable gas chromatography or, if it is the only halogenated hydrocarbon in the workroom air, halide meters can be used. Air from representative work-sites can be drawn directly into the infrared spectrophotometer or halide meter by a multiprobe sampling apparatus. A time-location study of the workroom at the different probe locations can be used to estimate TWA exposures to 1,1,1-trichloroethane.

Direct reading colorimetric tubes (gas detection tubes) can be used as an inexpensive way to monitor 1,1,1-trichloroethane concentrations. The tubes must be used as instructed by the manufacturer. They are not

suitable for determining compliance with the standard, as variability is larger here than with chemical and GC methods.

Biologic Evaluation of Exposure

Three studies were reported of occupational exposure evaluation by analysis of breath for 1,1,1-trichloroethane or urine for trichlorinated compounds. [59-61]

Prost et al [59] collected alveolar air samples at the end of the work day from 12 workers involved in a degreasing operation. The investigators [59] considered that their study was adequate to make formal conclusions. They were able to differentiate a group of workers with higher exposure from another group with lower exposure.

Trichloroacetic acid concentrations in the urine of 15 workers were determined in a printing plant where the average daily exposure to 1,1,1-trichloroethane was 35 ppm. The average concentration of TCA found in the urine on the 3 days were 3.0-3.7 mg/liter.

Weitbrecht [61] found TCA concentrations of 20-60 mg/liter in the urine of seven women with 1,1,1-trichloroethane exposures estimated at 10-20 ppm. In this study, the atmospheric measurements were questionable and also the women were subjected to exposure through the skin.

Prost et al [59] also studied TCA excretion by workers and concluded it was not as reliable for evaluation of exposure as analysis of breath for 1,1,1-trichloroethane.

Experimental studies have shown considerable variation in results of breath analyses among investigators. [35,55,56] The concentrations in the breath depend upon past exposure history, exposure concentrations, exposure

times, time since last exposure, physical activity during and after exposure, and individual factors. [35,39,52,54-58]

Although considerable data have been collected, they have not been synthesized into useable form to be able to quantitatively evaluate exposure to 1,1,1-trichloroethane by either breath or urine analysis.

V. DEVELOPMENT OF STANDARD

Basis for Previous Standards

The first Threshold Limit Value (TLV) for 1,1,1-trichloroethane was published by the American Conference of Governmental Industrial Hygienists (ACGIH) in 1953. [123] The value set was a time-weighted average TWA of 500 ppm. The basis for this standard was not reported but most likely it was the work of Adams et al, [73] published in 1950. In 1959, Elkins [116] suggested a maximum allowable concentration (MAC) of 250 ppm, and cited the paper by Adams et al. [73]

The ACGIH published its first documentation for the TLV of 500 ppm for 1,1,1-trichloroethane in 1962. [124] This value was based on the studies of Torkelson et al [36] and Stewart et al. [35] The ACGIH report concluded that to prevent lightheadedness, the 500 ppm limit should not be exceeded for "appreciable periods."

A reduction of the TLV to 350 ppm was recommended by the ACGIH in 1963 on basis of odor, complaints of other forms of irritation, and concern for undue exposure to chlorinated hydrocarbons. [125,126]

The American Industrial Hygiene Association (AIHA) published Emergency Exposure Limits for 1,1,1-trichloroethane in 1964. [127] These limits were 2,500 ppm for 5 minutes, 2,000 ppm for 15 and 30 minutes, and 1,000 ppm for 60 minutes. Exposures for the stated times at these concentrations "will cause definite anesthetic effects and incoordination but no organic injury is expected and recovery should occur within minutes after a subject is withdrawn from exposure." [127] The data from which the emergency limits were derived came from studies on the anesthetic

trichloroethane [3,31-35] and the reports of Stewart et al, [35] Torkelson et al, [36] Stewart, [47] Rowe et al, [58] Plaa et al, [66] Adams et al, [73] and Rennick et al. [78]

The American National Standard Acceptable Concentrations of Methyl Chloroform (1,1,1-trichloroethane) (ANSI Z37.26-1970), [8] published in 1970, gave an acceptable TWA of 400 ppm for protection of health, assuming an 8-hour workday, an acceptable ceiling concentration of 500 ppm if the TWA was below 400 ppm, and a maximum peak above the ceiling of 800 ppm for not more than 5 minutes and not more than once in 2 hours. This standard was based on the reports of Stewart et al, [35] Torkelson et al, [36] Stewart, [47] Stewart and Dodd, [53] Adams et al, [73] Rennick et al, [78] and Prendergast et al. [85]

"Permissible Levels of Toxic Substances in the Working Environment" for many countries was published by the International Labour Office in 1970. [128] The standards for five countries are shown in Table V-1.

TABLE V-1

PERMISSIBLE LEVELS OF
1,1,1-TRICHLOROETHANE IN
THE WORKING ENVIRONMENT OF FIVE COUNTRIES

Country	Standard		Qualifications
	mg/cu m	ppm	
Finland	2,700	500	8 hours continuous exposure
Germany (Fed Rep)	1,080	200	MAC
Japan	1,900	350	None stated
Yugoslavia	1,080	200	None stated
Rumania	1,000	185	None stated

Adapted from reference 128

The documentation of the TLV of 350 ppm, originally given in 1966, [126] was updated in 1971. [129] Additional references cited in this documentation were Irish, [14] Stewart et al, [39] Stewart, [47] Hatfield and Maykowski, [50] Rowe et al, [58] and Hake et al. [91]

The German Research Society MAK Commission published the criteria for its MAC standard for 1,1,1-trichloroethane in 1972. [130] The standard was 200 ppm (1,080 mg/cu m) and it was reported to be an average, presumably a TWA for an 8-hour workday. This standard was based on experimental studies [35-37,39] of humans where subnarcotic effects were observed which could reduce a person's ability to work after repeated exposures lasting several hours. The studies cited included Stewart et al, [35,39] Torkelson et al, [36] and Salvini et al. [37]

The USSR MAC is 3.66 ppm (20.0 mg/cu m). [104]

The present US federal standard was adopted from "Threshold Limit Values of Airborne Contaminants for 1968." [131] It is an 8-hour time-weighted average of 350 ppm (1,910 mg/cu m) (29 CFR 1910.1000).

Basis for Recommended Environmental Standard

The recommended environmental action limit is based upon CNS responses to acute exposures [37, 38, 39] in man, cardiovascular and respiratory effects associated with chronic exposures [85, 88] in several species, the similarity of pathologic changes in man and several animal species, and the absence of reported effects in man at concentrations below the proposed limit. [65, 64]

Impairment of the CNS, to the extent that escape would be impossible, has occurred experimentally in human subjects when the exposure

concentration of 1,1,1-trichloroethane was increased from 0-2,650 ppm during 15 minutes. [35] Impaired coordination and balance have also been demonstrated in experimental exposures of human subjects to 1,1,1-trichloroethane at 900-1,000 ppm for 20 minutes or more. [35, 36]

Exposure at 250 ppm for 30 minutes followed immediately by exposure at 350 ppm for another 30 minutes resulted in impaired perceptual speed, reaction times, and manual dexterity. [38] These later findings [38] did not develop during the first 30 minutes of exposure at 250 ppm but exposure at this concentration for a longer period of time was not made. The study was also not conducted with repetitive exposures, and the effects of breathing the vapor through a mouthpiece and the use of menthol to disguise the odor of 1,1,1-trichloroethane were not assessed. The experiment with mice [74] indicated accumulative effects on the CNS of 1,1,1-trichloroethane exposure.

With exposures at 500 ppm, 7 hours/day for 5 days, CNS effects such as sleeplessness, lightheadedness, headache and an abnormal Romberg test were reported. [39]

Based on a case report of a fall resulting in injury associated with 1,1,1-trichloroethane exposure [51] and the experimental evidence that nervous system responses that might be manifested as accident proneness can occur with exposures at 450 ppm, [37] it is recommended that a ceiling exposure be established below this concentration.

1,1,1-Trichloroethane has been shown to have a direct effect on the cardiovascular system. [32, 46, 75, 76, 79, 80] The first response that has been detected upon administration of 1,1,1-trichloroethane was decreased peripheral resistance to blood flow. [80] The blood pressure

fell within seconds and continued to fall as the heart lost its contractile strength. [79, 80] These effects have been found experimentally with concentrations of 8,000 ppm or more during exposures of no more than 5 minutes.

Heart muscle from rats which had been anesthetized for 1 hour with 1,1,1-trichloroethane had impaired oxygen consumption, [32] and heart muscle from unexposed rats developed impaired contractility when exposed to 1,1,1-trichloroethane in the aeration mixture. [80] Fractional analysis of LDH from a patient poisoned with 1,1,1-trichloroethane showed that the heart was the major source of the increased amounts of this enzyme in the patient's blood. [46]

Autopsy findings of gross congestion and pulmonary edema in workers overcome by 1,1,1-trichloroethane exposures [49, 50] are evidence of cardiovascular effects of the type observed experimentally, [79, 80] or clinically. [46] Neither blood pressure changes nor ECG changes were found in humans experimentally exposed to 1,1,1-trichloroethane at concentrations of 2,650 ppm or less. [35, 36] In other experimental human exposures, blood pressure and ECG changes were not reported. [37, 38, 39] There were no significant ECG findings in the four reported cases of acute occupational exposures [51] or the one reported case of 1,1,1-trichloroethane ingestion. [42]

Changes that may be attributable to cardiovascular insufficiency have been reported in chronic animal experiments. [74, 77] Congestion of the liver and lungs was found in mice after nine 2-hour/day exposures on alternate days to 1,1,1-trichloroethane at 1,000 ppm, [74] but these authors did not adequately describe their control techniques. A more

recent study, repeating this work, has found neither congestion of the lungs nor liver, nor traces of inflammation around the biliary duct area. [132] Nonspecific inflammatory changes have been reported in several species exposed at 370 ppm continuously for 90 days. [85]

Human exposures at an average TWA concentration of 115 ppm 1,1,1-trichloroethane have been reported by Kramer et al [64] in workers exposed for 8 hours/day, 5 days/week for up to 5 years. Upon laboratory testing (hematology, blood chemistry, urinalysis and ECG) as well as medical interviews, no adverse effects were reported.

Exposures of humans at 4 to 53 ppm in four Japanese printing plants have been reported by Seki et al. [65] The investigators reported tests of vibrational sense, routine laboratory examinations in hematology and urinalysis, and medical interviews. No adverse effects were reported at these concentrations.

No adverse health effects were reported in the study by Kramer et al [64] when workers were exposed at 1-175 ppm 1,1,1-trichloroethane. Some of these workers had, for 1-2 years, previously been exposed at concentrations as high as 838 ppm, and if there had been any effects at the time, recovery had occurred because the subjects were reported to be healthy when the study began. To some extent, animal studies support these observations in exposed workers. Significant findings were not demonstrated in rats, mice, dogs and monkeys exposed at 250 ppm continuously for 90 days [84] and only minimal findings at 370 ppm continuously for 90 days. [85] In another study, minimal effects were reported in hepatic function of mice exposed continuously for 14 weeks at 250 ppm. [41] Other investigators have not reported any significant effects at similar levels in man and animals. [35,36,38,132]

Respiratory irritation has been reported in man and several other species. At 400 ppm eye, nose and throat irritation have been experienced by subjects during exposure to 1,1,1-trichloroethane. [35,37] Varying degrees of lung congestion were found in all species exposed continuously for 90 days to 1,1,1-trichloroethane at 135 ppm. [85] The authors stated, however, in view of pneumonitis in the surviving animals and in the control group, that no positive conclusions could be drawn connecting the 1,1,1-trichloroethane exposure to the effects. Irritation of the upper respiratory tract was reported among women during occupational exposure to 1,1,1-trichloroethane. [61] No other studies of respiratory disease associated with chronic occupational exposure to 1,1,1-trichloroethane have been reported. The recommended ceiling limit should protect workers from acute irritation effects, but it is not known if it will protect them from chronic respiratory effects.

From the data presented above, it is evident that a ceiling should be placed on occupational exposure to 1,1,1-trichloroethane. Evidence of CNS response at 450 ppm [37] and minimal to no response at 250 to 350 ppm [38] leads to the conclusion that 350 ppm is a reasonable ceiling concentration. This ceiling will assure a safe TWA as excursions above the action level will not lead to the chronic effects described in humans and animals. Although information on workers exposed to 1,1,1-trichloroethane for over 6 years is scarce, workers who had experienced TWA's of 217 ppm for up to 6 years showed no adverse effects, and thus it is unnecessary to recommend a TWA limit below 350 ppm to prevent chronic effects. To provide some assurance that the environmental limit is not exceeded, an action level of 200 ppm is recommended.

It is recognized that many workers handle small amounts of 1,1,1-trichloroethane or work in situations where, regardless of the amounts used, there is only negligible contact with the substance. Under these conditions, it should not be necessary to comply with all the provisions of this recommended standard. However, concern for worker health requires that protective measures be instituted below the enforceable limit to ensure that exposures stay below that limit. Therefore, environmental monitoring and recordkeeping is recommended for those work situations which involve exposure above the recommended action level of 200 ppm determined as a TWA for a 10 hour-day, 40 hour-week, to delineate work areas that do not require control of inhalation hazards. The environmental action level has been chosen on the basis of professional judgment rather than on quantitative data that delineate nonhazardous areas from areas in which a hazard definitely exists.

In view of individual variation in human response to noxious substances, as well as the variation in worker exposure to 1,1,1-trichloroethane, NIOSH recommends comprehensive preplacement and annual examinations be made available to all workers exposed to 1,1,1-trichloroethane. In certain cases, a given individual may exhibit symptoms warranting a more frequent examination schedule. Recognition of the selective hazard to the nervous, hepatic and cardiovascular systems leads to emphasis of these factors for any physical examination.

For the medical program to be effective, it is important that the worker recognize the signs and symptoms as well as hazards of working with 1,1,1-trichloroethane. At the onset of specific symptoms attributable to exposure, the physician should be consulted. Thus, NIOSH recommends that

employees be informed of health hazards and that warning signs be posted in appropriate locations in plants where 1,1,1-trichloroethane is manufactured, used or stored. Further information should be transmitted through a continuing educational program instituted by the employer.

During day-to-day work, where the occurrence of spills, sprays and splashes, as well as the generation of high concentrations of 1,1,1-trichloroethane in accidental and emergency situations, is likely to occur, appropriate control measures need to be taken. To prevent the escape of hazardous quantities of 1,1,1-trichloroethane, various engineering control procedures are recommended to contain the chemical and ensure safe working habits in the vicinity of its use, manufacture and storage. These work practices include handling, storage, ventilation, maintenance of equipment, personal hygiene and emergency procedures. Due to the hazard of a buildup of 1,1,1-trichloroethane concentration above the environmental ceiling in small work areas, special instructions are given for working in confined spaces.

To monitor the concentration of 1,1,1-trichloroethane, it is necessary to periodically sample the employees' breathing zone air. NIOSH has reviewed the literature on sampling and analytical methods in chapter IV and has recommended the sampling and analytical method presented in Appendices I and II.

Although it is known that many potentially harmful substances used in industry enter the maternal bloodstream and are capable of crossing the placenta, there is insufficient evidence at this time to exclude women of childbearing age from working in areas where 1,1,1-trichloroethane is manufactured, stored, or used. Data are available from only one study in

rats and mice, and although cleft palate, supernumerary vertebra, and split sternbra occurred, the lack of new data, ie number of animals per litter, and confirmation from other studies, precludes a firm statement of teratogenicity. The incidence of these abnormalities in large samples of these strains of rats and mice is not known. The observation of these abnormalities in this small sample experiment is not sufficient to warrant special restriction of women of child bearing age. Based on the insufficiency of the experiment, it is not recommended that pregnant females be advised of any potential hazard unless a repetition of the experiment provides confirmation of the results.