IV. ENVIRONMENTAL DATA AND ANALYTICAL METHODS

Environmental Concentrations

Ethylene dichloride concentrations ranging from 0.4 to 5 ppm were found in a wool-scouring plant in Massachusetts in 1937. [136]

Other information on workroom air concentrations in American industry was reported by Elkins. [137] Ethylene dichloride was collected on silica gel by sampling air at 5-10 liters/min for 10-30 minutes. The absorbed ethylene dichloride was extracted from the silica gel with isopropyl alcohol, subjected to alkaline hydrolysis, and the resulting inorganic chloride was determined by titration. The industries surveyed and the concentrations found are summarized in Table IV-1.

TABLE IV-1

CONCENTRATIONS OF ETHYLENE DICHLORIDE IN AMERICAN INDUSTRIES

	Samples	Plants	Samples > 75 ppm	Concentration, ppm	
Operation	No.	No.	No.	Max.	Avg.
Rubber cementing	24	3	8	140-200	85-110
Leather finishing	7		2	95	65
Fabric spreading	NR*	1	NR	210	125
Drum filling	NR*		0	45	35
Metal cleaning	11		4	250	180

* not reported
Adapted from Elkins [137]

Workroom air concentrations in an industry manufacturing adrenalir in Russia were reported by Loginova and Novikova. [138] Ethylene dichloride was used in an 8-sq m room equipped with general room air ventilation only. A total of 30 breathing zone samples were taken in the center of the room and at points considered to have high concentrations of vapor. Twenty-five of the 30 measurements exceeded the maximum permissible concentration of 12.4 ppm (50 mg/cu m). The highest concentration of ethylene dichloride was found during its suction transfer from a carboy into the extractor. During the 7-10 minutes required for this transfer operation, concentrations of 5.6 to 22.5 ppm (22.7-90.0 mg/cu m) were found. Ethylene dichloride vapor was also released during the discharge of brine into a sewer after it had been used for washing the ethylene dichloride extract. [138]

Cetnarowicz [9] reported ethylene dichloride concentrations in a petroleum refinery which used an extraction solvent containing 80% ethylene dichloride and 20% benzene to separate and purify mineral oils from paraffins. The concentrations determined at 4 locations within the refinery ranged from 10 to 200 ppm (0.04-0.8 mg/liter). The results of 2-3 samples collected at each site are presented in Table III-1.

The measured benzene concentrations ranged from 10-25 μg/liter. The sampling and analytical methods used in this study were not given. [9]

In another study, Brzozowski et al [104] reported environmental concentrations of ethylene dichloride measured during fumigation of potato fields. The fumigation process required work crews to transfer ethylene dichloride from barrels to buckets and then pour the contents around the nests of the larvae.

Because of the specific work regimen, the collection of one breathing zone sample required following employees to 10 application sites. The sample was analyzed by a modification of the alkaline hydrolysis method and the ethylene dichloride concentration was determined to be 4 ppm (16 μg/liter). In order to avoid this collection inconvenience, simulated conditions were set up in the laboratory and concentrations were then measured to be around 15 ppm (58-60 μg/liter). A sample obtained during the pouring of ethylene dichloride from barrels into buckets and subsequently analyzed indicated a concentration of approximately 60 ppm. [104]

An intensive study of ethylene dichloride concentrations in an aircraft factory was reported by Kozik. [105] Ethylene dichloride was the solvent for glue used to make rubber tanks. The data are presented in detail in Table XII-3 and are further summarized in Figures XII-1 and XII-2. In this plant, the ventilation system was designed to exhaust the air through the floor to keep the vapor from rising toward the glue applicators. The methods of determining ethylene dichloride and the sampling times were not given. The concentrations reported ranged from less than 5 to 52 ppm. About half of the measurements were less than 12 ppm, and about 10% were greater than 30 ppm. From the description of the process and the data presented, a TWA concentration of about 15 ppm was estimated for the majority of exposed workers.

<u>Environmental Sampling and Analytical Methods</u>

(a) Collection Methods

Most analytical methods are dependent on the effectiveness and reproducibility of the uptake of ethylene dichloride 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, is a polar adsorbent and shows pronounced selectivity in adsorbing polar molecules, particularly in preference to nonpolar molecules such as ethylene dichloride. [139] A laboratory study indicated that water vapor in the workroom could displace ethylene dichloride when sampling more than 3 liters of air through 1-inch silica gel tubes. [140]

More recently, activated charcoal has been used as a collection medium in conjunction with analysis by gas chromatography. [141] 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. [140]

Williams and Umstead [142] reported the use of porous polymer beads as a collection medium. With this sampling method, the same column was used for sample collection and gas chromatographic analysis. This method consolidated collection and analysis into one operation, but only one analysis could be made on each sample. The method has not been developed for field use.

Liquids have been used to collect chlorinated hydrocarbons from contaminated atmospheres. Elkins et al [143] used amyl acetate in a sampling train to collect ethylene dichloride from sampled air. Midget impingers containing m-xylene have been used for collection in conjunction with gas chromatographic analysis. [144] Bubbler bottles containing a pyridine solution have been used for collection in conjunction with colorimetric analysis. [145] Impingers and bubblers present hazards from glassware and chemicals when used in personal sampling units for collection of breathing zone samples.

Other investigators have collected grab samples of contaminated atmospheres directly in a variety of containers ranging from plastic bags to hypodermic syringes. [146]

(b) Desorption Methods

When solid collection media are used, it is necessary to desorb the collected contaminant from the medium. Isopropyl alcohol and heat have been used to desorb chlorinated hydrocarbons from silica gel. [137] Desorption from charcoal was studied by Otterson and Guy. [146] They 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 ethylene dichloride collected in charcoal tubes.

(c) Analysis

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

(1) Chemical methods

The 3 chemical methods that have been used extensively are: (A) dechlorination of collected vapor samples with strong alkalis followed by titration of the chloride ion (alkaline hydrolysis) [137]; (B) colorimetric measurement of the reaction products of ethylene dichloride and pyridine heated in alkali solution (Fujiwara reaction) [145]; and (C) direct reading colorimetric indicators. [148]

(A) The dechlorination method (alkaline hydrolysis) requires collection of the ethylene dichloride-contaminated air by a suitable collection medium followed by alkaline hydrolysis in isopropyl alcohol, and titration of the liberated chloride with silver nitrate. [137] The percentage of chlorine hydrolyzed is determined by comparison between samples and known controls. A disadvantage is that it is not specific for ethylene dichloride.

(B) In the colorimetric analytical method based on the Fujiwara reaction, a stream of air containing ethylene dichloride is passed through a bottle containing pyridine. [145] Potassium hydroxide and methylethyl ketone are then added to an aliquot of the sample, and this mixture is heated in a boiling water bath, cooled during a fixed time period, and the color developed is determined with a spectrophotometer. This method requires less time than the dechlorination method, but the problem of nonspecificity with mixtures of chlorinated hydrocarbons remains.

(C) The third chemical method utilizes direct reading detector tubes. [147] These are glass tubes packed with solid chemicals that change color when a measured and controlled flow of air containing ethylene dichloride passes through the packed material. 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. [147] In either case, the analysis is not specific for ethylene dichloride since liberated halogen ions produce the stain and any halogen or halogenated compounds will interfere. Regulations on detector tubes (42 CFR 84.50) provide that measurements with colorimetric indicator tubes shall be correct within ±25% of the values read. There are commercially available detector tubes which fulfill this criterion.

(2) Physicochemical methods.

Among the analytical methods that are based on the physicochemical properties of ethylene dichloride are: (A) photodetection (halide meters), [150] (B) infrared spectrometry, [149] and (C) gas chromatography. [146]

(A) Halide meters are made to detect the increased brightness of an a-c arc across metal electrodes when they are enveloped by an atmosphere contaminated with halogenated compounds other than fluorides. These instruments are sensitive to all halogens and halogenated compounds except fluorides and consequently they are not specific for ethylene dichloride. Halide meters are suitable for continuous monitoring if ethylene dichloride is known to be the only halogenated contaminant present in the sampled air. [147]

(B) An infrared spectrophotometer in conjunction with a suitable recorder can be used to record concentrations relatively instantaneously or 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. There is the need to assure that the atmosphere of relevant working stations is sampled, and that such samples correspond to the breathing zone of the workers at the working stations. [149] 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.

(C) Gas chromatography provides a quantitative analytical method which can be specific for different chlorinated hydrocarbons. [148] Every compound has a specific retention time in a given chromatograph column, but several compounds in a mixture may have similar retention times. This problem is easily overcome by altering the stationary phase of the chromatograph column or by changing the column temperature or other analytical parameters. Altering conditions will usually change the retention times and separate the components.

A mass spectrometer can be used subsequent to gas chromatography to more positively identify the substance present in a gas chromatographic fraction. 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 were available. [151]

(d) Conclusions and Recommendations

(1) Compliance Method

Based on review of air sampling and analytical methods, it is recommended that ethylene dichloride in air samples be collected with activated coconut shell charcoal, desorbed with carbon disulfide, and analyzed by gas chromatography. Although this system of measurement is indirect and requires collection and desorption prior to analysis, it 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.

(D) Ethylene dichloride can be identified in combination with many other compounds.

(E) At the sample volumes recommended, ie, 2-20 liters, interference by moisture is minimal.

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

(2) Monitoring Methods

Exposure to ethylene dichloride associated with its continuous and constant use can be monitored by infrared spectrophotometry 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 peak, ceilings, and TWA exposures to ethylene dichloride.

V. DEVELOPMENT OF STANDARD

Basis for Previous Standards

The Subcommittee on Threshold Limits [152] of the National Conference of Governmental Industrial Hygienists published its first Maximum Allowable Concentration (MAC) for ethylene dichloride in 1942. The value was 100 ppm and was derived from the regulations of California, Colorado, Kansas, Massachusetts, Michigan, Minnesota, Oklahoma, and Wisconsin.

In 1945, Cook [153] compiled MAC data for a list of substances of industrial importance. The MAC values for ethylene dichloride for 6 governmental agencies are presented in Table V-1.

TABLE V-1

EARLY STANDARDS FOR ETHYLENE DICHLORIDE

SOURCE	MAC, ppm
California Industrial Accident Commission	100
Massachusetts Department of Labor and Industries	75
New York State Department of Labor	100
Oregon State Board of Health	100
Utah Department of Health	100
United States Public Health Service	100

Derived from Cook [153]

Based on Cook's list [153] and the 1942 MAC values [152], the American Conference of Governmental Industrial Hygienists (ACGIH) (formerly the National Conference of Governmental Industrial Hygienists) issued MAC values for 1946 [154] including a MAC for ethylene dichloride of 100 ppm.

The following year, 1947, the Committee on Threshold Limits of the ACGIH changed the MAC value to 75 ppm, but did not give its reasons for this change. [155] In 1948, the nomenclature for allowable concentrations of toxic substances in air changed from MAC to Threshold Limit Values (TLV) in order to avoid confusion about the word "allowable" in the MAC concept. [156]

The TLV was maintained at 75 ppm until 1952. At that time, the ACGIH changed the TLV back to 100 ppm. Again, no information was given about the reasons for the change. [157] The definition of TLV as a time-weighted average (TWA) was formulated in 1953 by the ACGIH. [158]

The <u>Documentation of Threshold Limit Values</u>, [159] first published in 1962 by the ACGIH, justified the TLV of 100 ppm for ethylene dichloride by the experimental animal study of Spencer et al. [108]

At the ACGIH conference in 1962, the TLV for ethylene dichloride was lowered to 50 ppm. [160] The TLV documentation of 1966 [161] justified this value with 4 other references, [82,90,107,154] in addition to the report of Spencer et al. [108] The documentation included information (D Fassett, private communication to the TLV Committee, 1962) that repeated industrial exposures at 25-50 ppm were safe. This information, coupled with the revision of the TLV's of trichloroethylene and carbon tetrachloride, were the basis for the new ethylene dichloride TLV of 50 ppm.

The American Industrial Hygiene Association's <u>Hygienic Guide Series</u> recommended an 8-hour TWA of 50 ppm for ethylene dichloride in 1965 and alluded to the acceptability of exposure at 3,000 ppm for 12-20 minutes. [162] These recommendations were based in part on the 1964 TLV's from the ACGIH, [163] and reports of Spencer et al, [108] Heppel et al, [106] and Menschick. [86]

Subcommittee Z-37 of the American National Standards Institute (ANSI) recommended an 8-hour day TWA of 50 ppm for ethylene dichloride in 1969. [6] It also recommended an acceptable ceiling concentration for an 8-hour workday of 100 ppm if the TWA was below 50 ppm, and a maximum peak above the ceiling concentration of 200 ppm for no more than 5 minutes in any 3 hours. The recommendations were based in part on the animal experiments of Heppel et al [107] and Spencer et al. [108]

The 1971 Documentation of Threshold Limit Values for Substances in Workroom Air [164] confirmed the TWA of 50 ppm adopted by ACGIH in 1966. Bardodej [165] was among the references added to those that had been cited in the 1964 Documentation. The justification for a TLV of 50 ppm was the belief that at this concentration no hepatic injury would occur and the symptoms of intoxication would be minimal. [164]

Documentation of MAC in Czechoslovakia, [165] published in 1969, suggested a mean MAC of 12.5 ppm (50 mg/cu m) and a peak MAC of 62.5 ppm (250 mg/cu m) based in part on the industrial observations of Elkins [137] and the animal experiments of Heppel et al [107] and Spencer et al. [108] MAC values cited for some other countries are presented in Table V-2.

TABLE V-2

ETHYLENE DICHLORIDE STANDARDS OF EIGHT COUNTRIES

Country	Standard, ppm
Federal Republic of Germany	100
German Democratic Republic	12.5
Great Britain	50
Hungary	5
Poland	12.5
USA	50
USSR	12.5
Yugoslavia	100

Derived from reference 165

Additional information on ethylene dichloride standards, published by the International Labour Office (ILO) are presented in Table V-3. [166]

TABLE V-3

SOME ETHYLENE DICHLORIDE STANDARDS SUMMARIZED BY THE ILO

Country	Standard, ppm	Type
Bulgaria	2.5	MAC
Finland	100	MAC 8-hour continuous
Massachusetts, USA	25	8-hour TWA
Pennsylvania, USA	50	8-hour TWA
Rumania	12.5	MAC
Yugoslavia	50	MAC

Derived from reference 167

The 1969 ANSI Z-37 standard, adopted as the federal standard, 29 CFR 1910.1000, Table G2, is a TWA of 50 ppm for an 8-hour day, a ceiling concentration of 100 ppm, and a maximum peak above the ceiling of 200 ppm for no more than 5 minutes in any 3 hours.

Basis for Recommended Environmental Standard

The recommended standard is based on occupational exposure experiences, mostly from Europe where ethylene dichloride has been used extensively, and is intended to protect workers from the adverse health effects that have been reported.

Ethylene dichloride has a wide array of effects and it is difficult to identify primary target organs or systems. The information on the metabolism or mechanism of action of ethylene dichloride suggests that it is metabolized to more toxic substances such as chloroacetaldehyde, 2-chloroethanol and chloroacetic acid which inhibit glucose metabolism.

Exposure to ethylene dichloride has adversely affected the circulatory, respiratory and nervous systems, and the liver, kidneys, skin, and mucous membranes. [4,64,74-77,80,88,97,98,100] Acute exposure has often been fatal. The progression of signs and symptoms prior to death usually included headache, dizziness, nausea, vomiting, anorexia, tenderness or pain in the epigastrium, rapid and weak pulse, cyanosis, unconsciousness, then respiratory, circulatory, or kidney failure. Death was usually ascribed to circulatory failure and the most outstanding autopsy observations were pulmonary edema, hyperemia, congestion of the visceral organs, and hemorrhaging into most of the organs. [46,47,49,50,54,56,64,75,76,81] Fatalities from occupational exposure have resulted from acute exposures in which narcosis or anesthesia did not occur from inhalation of ethylene dichloride vapor. [77,80,81,86]

Many of the signs and symptoms associated with fatalities followed exposure even when death was not the final outcome. However, Rosenbaum [88] reported that when some workers experienced these symptoms 2 or more times in 2 or 3 weeks, fatalities resulted.

Rosenbaum was reporting on 10 years experience with ethylene dichloride in Russian industries where the atmospheric concentrations causing the symptomatic responses were reported to be between 75 and 125 ppm. Although this report lacked detail, it is consistent with other literature.

Byers [93] reported that many persons exposed to ethylene dichloride experienced the worst symptoms in the evening after the conclusion of a day's work. The symptoms varied from lassitude and malaise, to nausea, vomiting, and abdominal pain. The workers were exposed at daily concentrations of approximately 100 ppm, and even when the addition of ventilation reduced the atmospheric concentration to 70 ppm, not all of the symptoms were alleviated.

Environmental concentrations ranging from 10 to 200 ppm were found in an oil refinery in Poland. [9,104] Of 42 exposed workers, 6 complained of a sweetish aftertaste, dizziness, nausea, vomiting, and lack of appetite. Two of them had pain in the epigastrium and 3 had enlarged livers which were tender to pressure.

Further examination of a limited number of persons revealed that 6 of 10 workers exposed at 62-200 ppm had dryness of the mouth, an unpleasant sweetish aftertaste, dizziness (as from being drunk), lassitude, sleepiness, nausea, vomiting, constipation, and poor appetite leading to weight loss. All 10 of these workers complained of a burning sensation of the eyes and lacrimation, and 3 workers complained of pain in the epigastrium.

One of 6 workers exposed at 10-37 ppm complained of the previously mentioned symptoms. Physical examinations further showed emaciation in all workers, and augmented reflexes and autonomic neurosis in 3 of 16 workers. Eight of 16 workers had an abnormal percentile distribution of white blood cells. All signs and symptoms of disease disappeared when the workers were removed from the workplace but returned when the workers were again exposed to the ethylene dichloride-containing atmosphere.

Intermittent exposure to ethylene dichloride for a total of about 1.5 hours/day resulted in sensory and neurological problems after 6-9 months of exposure. [97] The exposure conditions were well described in this report by Guerdjikoff, [97] but the information on exposure concentrations was not complete. During one of the operations which was repeated several times daily, the workers wore an air-supplied gas mask and were only exposed to ethylene dichloride occasionally due to improper fit. These operations accounted for about 30 minutes of the total time. During another operation which required 10 minutes and was repeated 3-4 times/day, the workers were exposed at about 120 ppm of ethylene dichloride. During a final operation which occurred once daily, the workers were exposed for about 15 minutes at a higher, but unknown, concentration. [97]

The 2 workers studied by Guerdjikoff [97] experienced anorexia, epigastric pains, fatigue, irritability and nervousness after about 3 weeks of exposure and eventually experienced tremors in hands, hyperhidrosis, and difficulty in walking.

Agricultural workers in Poland were exposed to ethylene dichloride by skin absorption and by inhalation when applying it in the field as an insecticide. [104] An environmental field sample showed 4 ppm ethylene dichloride but because of practical difficulties of collecting the sample, field conditions were simulated in the laboratory to better estimate the concentrations to which workers could have been exposed. This determination found about 15 ppm of ethylene dichloride. During the pouring operation, which was considered to produce the highest concentrations at which a worker would be exposed, the environmental concentration was found to be 60 ppm. Among 118 of these agricultural workers, 90 had clinical findings including conjunctival congestion in 72%, weakness in 45%, reddening of the pharynx in 42%, bronchial symptoms in 36%, metallic taste in the mouth in 34%, dermatographism in 31%, nausea in 26%, cough in 26%, liver pain in 25%, irritation of the conjnuctiva in 20%, rapid pulse in 18%, and dyspnea after effort in 18%. [104] This report justifies the recommended use of protective clothing.

In 100 factory workers exposed from 6 months to 5 years at not more than 25 ppm ethylene dichloride, no changes were found in the blood or internal organs, but heightened lability of the autonomic nervous system, diffuse red dermographism, muscular torus, bradycardia, increased hidrosis, and frequent complaints of fatigability, irritability, and sleepiness were found. [88] The TWA concentrations at which these workers were exposed were not reported.

A study where data were presented in sufficient detail to estimate a TWA exposure of 10-15 ppm for 5 years was reported by Kozik. [105] The maximum concentration reported was about 50 ppm and concentrations in excess of 20 ppm occurred about 15% of the time. The concentrations above 20 ppm were reported to have occurred when an ethylene dichloride-based glue was applied to large rubber sheets and to have been maintained for 5-6 minutes at a time several times a day. The exposed workers experienced increased morbidity, particularly from gastrointestinal, liver and bile-duct diseases, that Kozik [105] concluded were due to ethylene dichloride exposure. In addition, neurotic and asthenic conditions, autonomic distonia, and struma and hyperthyreosis were found in a group of 83 workers studied. A study of nervous system function at the beginning and the end of 14 workdays in 17 of the workers indicated impairment at the beginning of the workdays as well as at the end, compared to 10 control workers who showed no impairment at the beginning of the workday.

Reports of occupational exposures that were without effect have not been found in the literature. The report of adverse cardiac and nervous system effects in 100 factory workers exposed at not more than 25 ppm of ethylene dichloride suggests that peak exposures need to be kept below this level. This is strongly supported by the additional effects on the liver and bile ducts reported by Kozik [105] in workers when peak exposures exceeded 20 ppm about 15% of the time. Definitive studies that delineate safe peak exposures do not exist but evaluation of available data and professional judgment suggest that ethylene dichloride exposures should not exceed a ceiling of 15 ppm.

The report by Kozik [105] of adverse nervous system and liver effects in workers exposed at TWA concentrations of 10-15 ppm also suggests a much lower TWA exposure. Considering the magnitude of the effects reported and the systems involved (nervous, respiratory, cardiac, and hepatic), NIOSH recommends a time-weighted average exposure concentration of 5 ppm.

Adherence to this limit, with prevention of other sources of absorption by appropriate work practices, should prevent effects of ethylene dichloride on the respiratory tract, nervous system, liver and kidneys, and on the blood and blood clotting. However, in the complete absence of information on the susceptibility of babies to ethylene dichloride, and information [99,118] that the compound appeared in the milk of nursing mothers, it is recommended that nursing mothers not work with ethylene dichloride.

There has been a wide range of susceptibility to ethylene dichloride exposure. [76,82,88] Where groups of workers have been exposed, some have escaped serious injury, while others have died. The nature of the susceptibility was not obvious from the reports. Ethylene dichloride has been shown to be metabolized to more toxic compounds. [126,128-132] The variations in susceptibility could be due to individual variations in rate of metabolism of ethylene dichloride or to diet, previous exposure, or many other uncontrolled factors. [106,88] The recommended environmental standard should protect the more sensitive workers.

It is recognized that many workers handle small amounts of ethylene dichloride 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 of 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 one-half the recommended limit, to delineate work areas that do not require the expenditure of health resources for control of inhalation hazards. One-half the environmental limit 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.