IV. ENVIRONMENTAL DATA AND ENGINEERING CONTROLS

Sampling and Analysis

Airborne chloroprene concentrations can be measured directly with chemical indicator (Draeger) tubes by passing a known volume of air through the sampling tube, thus producing a stained zone on the indicator portion of the tube; the length of the stained zone is a measure of the concentration [73]. These tubes have been found to be satisfactory for concentrations in the range of 5-90 ppm, provided other organic vapors with double bonds (propene, butene, butadiene, vinyl chloride, etc) are not present [73]. The tube contains permanganate, which is reduced to manganese dioxide in the presence of a double bond, resulting in a yellow-brown stain. E. I. du Pont de Nemours & Company [11] reported that in the absence of olefinic compounds, Draeger tubes gave "very good agreement" when tested against a gas-chromatographic method (the coefficient of variation of the ratio is 10-15%) [73].

In 1954, Senderikhina [34] reported a method of microcombustion, which has since been used for analysis of airborne chloroprene samples in the USSR. The air samples were collected in ethanol and burned, liberating hydrogen chloride, which was then trapped in ammonium hydroxide and measured by turbidometric means, titrating the chloride ion. The presence of other chlorinated hydrocarbons interferes with the method, as it is nonspecific for chloroprene.

Babina [74], in 1969, described a colorimetric method using adsorption on silica gel, desorption with heat, and trapping of evolved chloroprene in acetic acid. Desorption from silica was nearly complete

within 5 minutes when 0.05-0.5 mg of chloroprene had been adsorbed. This sampling method was reported to be five times faster than collection in ethanol. The desorbed chloroprene was coupled with a paranitrophenyl diazonium salt [74]. The absorption at 380 nm was determined. The sensitivity was 0.005 mg, but ammonia interfered with the assay.

In 1971, Apoian et al [75] described an ultraviolet spectrophotometric method for chloroprene analysis. The authors described the construction of standard curves and the range (0.5-50 mg of chloroprene/10 ml of alcohol) of chloroprene sensitivity, but neither graphic presentation nor description of linearity within this range was presented. Sampling required the use of four impingers in series, each filled with 10 ml of 96% alcohol and immersed in ice. The type of alcohol was not stated. Air was drawn through the impingers at a flowrate of up to 5 liters/hour. Ultraviolet spectra were taken, and the absorption maxima at 222.6 nm were recorded. The method was described as five times more sensitive than microcombustion. The method is inconvenient because it requires keeping the impingers in ice and is impractical for personal sampling.

Hollis and Hayes [76], in 1962, described a gas-liquid chromatographic method of chloroprene analysis using 100-foot squalane capillary columns with triode argon detection. Using this system, 2-chloroprene was separated from the monochloro isomers of butene and 1-chloro-1,3-butadiene (alpha-chloroprene) at 30 C. The method was presented merely as a means of separating isomers, but the authors stated that, for precise work, exact calibration for each compound in the particular chromatograph being used would be necessary. No sampling method was

employed; known standards were injected directly into the chromatograph columns.

In 1974, NIOSH published its Manual of Analytical Methods [77]. E. I. du Pont de Nemours & Company [78] modified the general method, Organic Solvents in Air (P & CAM 127) [77], to separate and analyze 2-chloro-1,3-butadiene, 1-chloro-1,3-butadiene, 2,3-dichloro-1,3-butadiene, and toluene; 1,4-dichloro-2-butene was not tested. The method used adsorption on commercial charcoal tubes, sampling volumes as large as 10 liters, and two 12-foot x 1/8-inch stainless steel columns. The first column contained 10% silicon rubber U C W98 on Chromosorb W 80-100 mesh (Hewlett-Packard), and the second contained 20% Carbowax 20 M on Chromosorb P. Using conditions of helium carrier gas at 50 psig, 200 C injection port, 300 C detector, and 100 C oven, the following retention times were obtained: carbon disulfide, 225 seconds; 2-chloroprene, 300 seconds; 1-chloroprene, 360 seconds; 2,3-dichloro-1,3-butadiene, 660 seconds; and toluene, 790 seconds. The acceptable range of concentration for all compounds tested was 0.3-300 ppm. Recovery of chloroprene from the charcoal tubes ranged from 92% at 5 ppm to 100% at 86 ppm. Desorption efficiency ranged from 92% at 25 ppm to 98% at 390 ppm. A 10-liter air sample was used. Up to 280 ppm of chloroprene can be adsorbed onto charcoal from dry air, prior to breakthrough, using a 10-liter air sample.

A second analytical method for chloroprene alone was also described by Du Pont [78]. This procedure involved the use of the second column only, Carbowax 20 M on Chromosorb P. One-milliliter air samples were injected directly into the column. Chloroprene had a retention time of 150 seconds under the following conditions: column temperature, 100 C;

injection port, 200 C; detector, 200 C; helium flow, 25 ml/minute at 50 psig; hydrogen flow, 30 ml/minute at 10 psig; and airflow, 200 ml/minute at 30 psig. This method gave a linear response from 1 to 800 ppm.

Petrotex Chemical Corporation uses a very similar gas-chromatographic method with 6-foot columns packed with Carbowax 400 on Porasil S. The method is also satisfactory [11].

Hervin and Polakoff [79] used a Gastech halide meter in 1972 during a Health Hazard Evaluation of polychloroprene cement usage by a garage door manufacturer. How well such a halide meter functions in chloroprene detection and quantitation cannot be determined from this report because no chloroprene was detected in the trial.

The NIOSH method for chloroprene [80], using conditions validated for general organic solvents [77] (P & CAM 127, 10% FFAP on Chromosorb W), failed the validation test for chloroprene. The proper conditions were not used in the evaluation of desorption of chloroprene from activated charcoal tubes [80]. A second validation was carried out [81] using a 4-ft long, 1/3-in O.D. stainless steel column packed with 50/80 mesh Porapak Q. This method was validated for the range 12.3-47.5 ppm and is described in Appendix II. It has not been validated at the proposed occupational exposure limit, nor has the column been tested for identification of other compounds suspected to be present in the air of chloroprene manufacturing and polymerizing plants.

Although the method developed by Du Pont is claimed to have a greater sensitivity than the NIOSH method, NIOSH has not tested or validated the Du Pont method. NIOSH believes that its own method may be satisfactory for validation at a lower concentration than that at which its current

validation has been made.

Adsorption on charcoal tubes is a satisfactory method for chloroprene sampling, as desorption efficiencies range from 92% to more than 98% depending on the amount of chloroprene adsorbed. This is the product of the duration of sampling and the concentration in the air. Draeger tubes are acceptable for quick sampling. If olefins are present, the results obtained with these tubes will be high, and verification of the results by charcoal adsorption, carbon disulfide elution, and Carbowax gas chromatography is recommended. In this method, the sampling device is small and portable; thus it is useful for both personal and area monitoring. Chloroprene can be identified in combination with many other compounds. The sampling tubes, personal pumps, and gas-chromatographic columns required for this method are all commercially available.

Environmental Levels

Little information has been found concerning levels of atmospheric chloroprene. The first available sampling data were taken in 1948 by Nystrom [20]. Air concentrations of 56-334 ppm were measured at a Swedish chloroprene factory using an iodometric titration method. Lejhancova [23], in 1968, reported chloroprene air concentrations of 17-81 ppm (60-290 mg/cu m) in a plant manufacturing rubberized fabric in Czechoslovakia. No methods for sampling or analysis were described.

In 1954, Mnatsakanian presented data that had been included in the report by Apoian [75] on chloroprene air concentrations taken 500 and 7,000 meters from the chloroprene plant in Erevan, USSR. Mean diurnal levels were 0.5 and 0.04 ppm (1.8 and 0.14 mg/cu m), respectively. Chloroprene

air concentrations at the same distances were also determined between 1963 and 1964 to be 0.11 and 0.04 ppm, respectively. The methods of collection and analysis were not specified. Using a newly developed ultraviolet detection method, Apoian et al [75] reported in 1971 that the mean diurnal chloroprene air concentration in the Erevan plant was 7.9 ppm (28.4 mg/cu m), while the peak concentration was approximately 62 ppm (223 mg/cu m). Mean airborne chloroprene concentrations at 500 and 7,000 meters were 0.2 and 0.056 ppm, respectively. Katosova [43], in 1973, noted that the chloroprene air concentration in the Erevan plant was 5 ppm.

In 1975, Volkova et al [82] stated that chloroprene air concentrations ranged from 2.3 to 14.1 ppm in the Moscow Chemical Products Plant, where polychloroprene latex was used in the manufacture of rubber goods. At the Kazan Rubber Products Plant, the concentration of chloroprene in the air of the working zone averaged 2.2-2.8 ppm. These authors reported also, that, in the shoe industry, which used a polychloroprene latex containing about 0.1% free chloroprene, the work areas around shoe-gluing machines with local exhaust ventilation had a mean concentration of chloroprene in air of 1.7 ppm (6.1 mg/cu m). When the exhaust system was not working, the concentration of chloroprene in the air might rise to 20-30 mg/cu m. In 1976, Volkova et al [41] investigated the health of workers in a plant manufacturing gloves from polychloroprene latex. The use of latex in this operation gave rise to concentrations of chloroprene in air of 0.3 to 2.2 ppm.

At one chloroprene polymerization facility, preliminary air monitoring conducted in 1973 showed chloroprene emission sources in the workplace with levels as high as 6,760 ppm (WE Egan, written communication,

May 1975). These levels were peak levels obtained by collection in glass sampling flasks and analysis by gas chromatography. The data are shown in Table IV-1. Eight-hour time-weighted average exposure levels found at the same plant in 1975 ranged from 0.51-39.18 ppm (Table IV-1), which were considerably below those found in 1973. The 1975 survey was carried out using charcoal tube collection of the samples with subsequent gas-chromatographic analysis. No information on the individual assay methods was supplied. More recently (1976), average air concentrations of 2-9 ppm were reported in US chloroprene manufacturing plants, including the one from which the previous data were obtained [11 (pp 9,41,51)]. Investigation by Hervin and Polakoff [79] of a factory using polychloroprene rubber cement found no detectable chloroprene with the Gastech halide meter.

TABLE IV-1

ATMOSPHERIC CHLOROPRENE CONCENTRATIONS
AT A POLYMERIZATION PLANT

Area	No. of Samples	Mean Concentration* (Range)	No. of Samples	Mean 8-hour TWA Concentration** (Range)
Make-up	10	554 (14 - 1,420)	17	12.0 (1.6 - 39.2)
Reactor	21	1,015 (130 - 6,760)	-	-
Monomer Recovery	2	223 (6 - 440)	4	2.0 (0.2 - 6.8)
Latex	2	205 (113 - 252)	6	0.7 (0.5 - 1.7)

* All values in ppm, 1973 sampling
**All values in ppm, 1975 sampling

From WE Egan (written communication, May 1975)

Engineering Controls

Engineering controls must be designed and operated to reduce the inhalation of chloroprene vapors and limit skin contact with chloroprene liquid. Closed systems of production should be used wherever possible to limit possible exposure of employees to chloroprene. Closed systems are effective only when their integrity is maintained by frequent inspection for, and prompt repair of, any leaks. Where the use of closed systems is not compatible with the process, local exhaust ventilation must be provided to direct the hazardous chemical away from the employee. Guidance for designing ventilation systems can be found in Industrial Ventilation--A Manual of Recommended Practice [83] and in the American National Standards Institute's Fundamentals Governing the Design and Operation of Local Exhaust Systems (Z9.2-1971) [84].

Enclosures, ductwork, and exhaust hoods must be kept in good repair so that design velocities are maintained. Airflow measurements must be taken at each exhaust hood at least every 6 months, and preferably monthly. Continuous airflow indicators (such as simple oil or water manometers) are recommended; they should be properly mounted and marked to show design airflows.

Because any monomer in the polymerized latex will be volatilized during the drying of films, coatings, foam, and other products, it is necessary to provide ventilation for drying ovens and other process equipment [12]. Other areas where ventilation may be necessary include open latex drums, open transfer points, dipping machines, spray units, and tanks [12].

Biologic Evaluation

No literature on biologic evaluation and biologic monitoring has been found.

V. WORK PRACTICES AND SANITATION

In the manufacture and use of chloroprene, work practices and sanitation must be designed to minimize ingestion, inhalation, and contact with skin and eyes. Good work practices are a primary means of controlling certain exposures and will often supplement other control measures. Enclosure of manufacturing processes and operations is effective in controlling exposure only when the integrity of the system is maintained. Systems should be closed whenever possible. Closed systems should be inspected frequently for leaks, and any leaks found should be promptly repaired. Special attention should be given to the condition of seals and joints, access ports, pumps, and possibly hazardous locations, such as polymerization areas and the vicinity of latex-storage tanks.

Ventilation systems require annual inspection and maintenance to ensure their effective operation. The effects of any changes or additions to the ventilation systems or to the operations being ventilated should be assessed promptly, including measurements of airflow and of environmental concentrations of chloroprene. Work practices should not introduce obstructions or interferences that would reduce the effectiveness of the ventilation. Further protective measures include the use of personal protective equipment and clothing and purging of appropriate equipment prior to and during servicing and maintenance operations.

The handling of chloroprene should follow appropriate guidelines for flammable liquids as specified in 29 CFR 1910.106 (a-e). Large spills represent a fire hazard; therefore, special precautions must be taken to prevent spills. Large spills may be handled by containment, evacuation,

and disposal. Storage tanks must be diked to contain the contents of tanks. Areas where major spills are likely to occur should be constructed so that they may be closed off until properly protected personnel can ventilate, enter, and clean the area. Chloroprene spills should be cleaned up immediately. Large spills should be pumped from the diked area to another tank. Because the main danger from large spills is fire, all operations that may be a source of ignition must be stopped until the spill is cleared. Also, precautions should be taken to prevent polymerization, eg, add antioxidants and cover with foam [11 (p 18)], since uncontrolled polymerization can generate sufficient heat to initiate combustion. Firefighters should be equipped with self-contained breathing apparatus operating in the pressure-demand mode and an impervious suit. Firefighters and other personnel should be warned that chloroprene combustion products may include noxious gases such as hydrogen chloride.

Small spills should be absorbed with rags, vermiculite, sand, etc, and the area should be flushed with water. Workers should wear appropriate respirators and protective clothing during cleanup. Contaminated rags should be stored in metal containers with tight-fitting lids prior to disposal. Disposal of chloroprene and polychloroprene wastes shall be done in compliance with local, state, and federal waste disposal regulations. Liquid waste should be burned completely, with concomitant entrapment of evolved hydrogen chloride. Solid waste should be burned or disposed of in a landfill.

In areas and at operation sites where the use of respiratory protective devices is required, the employee entering and working in such areas should wear the appropriate type of respirator as specified in

Chapter I. In addition, the employee must observe and participate in the respiratory protective program. Since respirators may fail as a result of many factors, the employee should be made aware of the need for cleanliness and maintenance of respirators on a continuing basis.

Because there is evidence that chloroprene is a mutagen in lower organisms, that it has effects on reproduction, and that it may be a carcinogen, NIOSH recommends that only self-contained or supplied-air respirators be used to prevent respiratory exposure to chloroprene during the situations in which respirators are required. Such respirators provide maximal protection against inhalation of toxic agents when properly fitted and donned, with testing for leakage after donning. Respirators provided by employers for use by employees should meet the requirements of 29 CFR 1910.134.

A major hazard of handling chloroprene that can be minimized by good work practices is skin and eye contact. Studies with animals indicate that systemic poisoning may result from skin contact with chloroprene [18,20,51]. Skin contact causes chemical burns; the severe effects are increased by the penetration of chloroprene into the clothing and shoes, which act as reservoirs and intensify the contact. Clothing contaminated with chloroprene must be removed immediately [11 (pp 18,19)] and thoroughly laundered before reuse. Care should be exercised to keep contaminated clothing away from street clothes. Shoes on which chloroprene has been spilled are to be rendered useless and discarded. Protective clothing must be made of material impermeable to chloroprene. When it is necessary to work with liquid chloroprene, the following special handling techniques should be employed routinely. All body surfaces should be protected

against contact with the liquid by the use of gloves, aprons, face shields, rubber boots, and other protective equipment or clothing. The liquid should be placed in closed containers. When exposure to liquid dichlorobutenes is possible, acid suits with supplied air should be used.

In the event of skin contact, the exposed area should be thoroughly washed with soap and water and a physician contacted. If the eyes are contaminated with chloroprene, they must be flushed with water for 15 minutes. Medical attention should be obtained as quickly as possible.

The flashpoint of chloroprene is -20 C (-4 F) [4]. It is classified as a flammable liquid of Class 1 B as defined in 29 CFR 1910.106(a)(19)(ii). The explosive limits in air at 20 C range from 4 to 20% (Table XII-1). Because chloroprene's flashpoint is -20 C, fire is a serious potential hazard, especially during spills. Work practices should be followed that ensure that no flames or other sources of ignition, such as cigars, cigarettes, pipes, lighters, and matches, are permitted in the area where chloroprene is stored, handled, or manufactured.

Safety showers, eyewash fountains, and fire extinguishers shall be located in or near areas where chloroprene exposure is likely to occur and shall be properly maintained. Handwashing facilities, soap, and water must be available to the employees. As good hygiene practices, eating in chloroprene manufacturing and polymerization work areas shall be prohibited, and hands should be washed before eating. Medical and first-aid facilities should be available as prescribed in 29 CFR 1910.151 (a-c). Selective assignment of employees may have to be practiced to protect individuals who display hypersensitivity to chloroprene.

The present method for the manufacture of chloroprene in the United States involves the chlorination of butadiene [6], so suitable controls for safe use of butadiene and chlorine should be used. Engineering controls required for the safe handling of chlorine are discussed in the NIOSH criteria document on occupational exposure to chlorine [87] and the Manufacturing Chemists' Association's (MCA) Safety Data Sheet SD-80 [88]; handling of butadiene is discussed in MCA Safety Data Sheet SD-55 [89]. The major hazards from butadiene are its flammability and explosive characteristics. Dichlorobutenes are intermediates in chloroprene manufacture, and caution must be taken to avoid exposure to these substances as well.

In summary, precautions must be exercised against overexposure to chloroprene. It is important that employees be informed of hazards associated with the use of chloroprene before job placement and when any process changes are made that may alter their exposure. Appropriate emergency procedures should be prominently displayed. The US Department of Labor "Material Safety Data Sheet" shown in Appendix III, or a similar form approved by the Occupational Safety and Health Administration, must be filled out. In addition, all employees in the chloroprene manufacturing and polymerization areas shall be instructed on the location of the safety sheet. If all of these work practices are observed and good engineering controls are installed, employees working with chloroprene should be adequately protected from associated hazards.

VI. DEVELOPMENT OF STANDARD

Basis for Previous Standards

The present federal standard (29 CFR 1910.1000) for chloroprene is an 8-hour time-weighted average (TWA) concentration of 25 ppm (90 mg/cu m). This standard was adopted from the listing published in 1968 by the American Conference of Governmental Industrial Hygienists (ACGIH) [86].

This 25-ppm value has remained unchanged since it was first recommended as a maximal allowable concentration (MAC) by Cook [90] in 1945. The MAC of 25 ppm was based on the report of Von Oettingen et al [18] in 1936. In this study, inhalation of chloroprene for up to 91 days at a mean concentration of 56 ppm, with a range from 28 to 98 ppm, produced signs of toxicity in male rats and mice. The mice were more susceptible; 9 of 20 mice versus 2 of 10 rats died during the course of the study. Some deaths may have resulted from bacterial infection. In their summary, the authors [18] stated that "with continued exposure, 0.3 mg/liter (300 mg/cu m) [of chloroprene] and less, may cause toxic effects" (0.3 mg/liter = 83 ppm). Cook [90] suggested the establishment of a "25 ppm level (for humans) until further data are available as to effects on man on prolonged exposure."

Cook's suggestion for an MAC of 25 ppm was adopted by the ACGIH in 1946 [91]. In 1948, the nomenclature for permissible concentrations of toxic substances in the air was changed from an MAC to a threshold limit value (TLV) to avoid confusion about the word "allowable" in the MAC concept [92]. This in essence, however, changed the standard from a ceiling concentration not ever to be exceeded to an average concentration

that could be exceeded for comparatively short times. The definition of a TLV as a TWA concentration was formulated in 1953 by the ACGIH, thus changing the standard for chloroprene to a TLV of 25 ppm as an 8-hour TWA concentration. The 1966 ACGIH listing [93] included the notation "skin" along with the recommended 25-ppm TLV to indicate that liquid chloroprene could be absorbed through the skin and cause systemic effects. The 1971 ACGIH Documentation of Threshold Limit Values for Substances in Workroom Air [94] gave the basis for the 25-ppm TWA value for chloroprene. Cited in the Documentation were the studies by Von Oettingen et al [18] (see above); by Nystrom [20], who stated that a tolerated limit for humans in occupational environments should be below 300 mg/cu m (83 ppm) even though rats tolerated this concentration for 13 weeks; and by Ritter and Carter [21], who reported that occupational hair loss resulted from small intermediate chloroprene polymers and not from chloroprene itself. The list of TLV's for 1976 added a tentative short-term environmental limit (STEL) of 35 ppm (135 mg/cu m); however, no basis for it has been given [95].

The International Labour Office (ILO) published Permissible Levels of Toxic Substances in the Working Environment [96] for several countries in 1970. The standards for chloroprene in the USSR, Bulgaria, Poland, and German Democratic Republic are maximal air concentrations, ie, absolute limits never to be exceeded [96]. They are concentrations that may be expected to produce no detectable physical deviations from normal in any exposed person. In the USSR, harmful concentrations have been defined loosely as levels that cause any type of aberration [96,97]. Other Eastern European countries have tended to use the USSR's values as guidelines [96].

Some countries tend to follow the concept of maximal air concentrations in setting their standards, while others follow the guidelines and values of the ACGIH [96]. Table VI-1 shows the present international chloroprene standards.

TABLE VI-1

LISTING OF INTERNATIONAL CHLOROPRENE STANDARDS

Country	mg/cu m	ppm
Bulgaria	2	0.56
Czechoslovakia	50* 100**	14* 28**
Federal Republic of Germany	36	10
Finland	90	25
German Democratic Republic	10	2.8
Great Britain	92	25
Poland	4***	1.1
Rumania	50	14
Soviet Union	0.05	0.014
Sweden	90	25
United States	90	25
Yugoslavia	90	25

*Mean concentration
**For brief exposures (peak)
***Was 2 until 1974

Adapted from references 96,99,102

The USSR standard of 2 mg/cu m (0.56 ppm) reportedly was based on scientific papers spanning three decades. Sanotskii [22] stated that the 2-mg/cu m maximal air concentration for chloroprene was set in the USSR in the 1940's on the basis of calculations and data in the literature; no further information was given. The International Labour Office [96] reported that the 1970 Russian standard for chloroprene was 2 mg/cu m. In 1975, the standard was still reported as 2 mg/cu m by Winell [98] and Volkova et al [82]. Although the Russian standard was quoted as 2 mg/cu m as recently as March 1976 [41], Sanotskii [22] has since recommended that the maximal air concentration allowed in the Russian workplace be 0.05 mg/cu m (0.014 ppm). This change was stated to be based on the toxic effects observed in rats and on the results of some human studies carried out in the USSR by Volkova et al [41]. Increased numbers of chromosomal aberrations were observed in the lymphocytes of women employed in a plant using polychloroprene latex and in bone marrow cells from mice exposed to chloroprene vapor. Reproductive effects in male rats, which included testicular atrophy and decreases in spermatozoic motility and acid resistance, were also reported.

The Czechoslovak Committee of Maximal Air Concentration [99] addressed the lack of a published basis for the Soviet standard in 1968. The Czechoslovak standard was a mean of 100 mg/cu m (27 ppm), based on the work of Von Oettingen et al [18) and Roubal [19], but was lowered to a mean of 50 mg/cu m (13.6 ppm), with a peak of 100 mg/cu m, in 1967 after private consultation of the Committee with Roubal [99]. In 1942, Roubal [19] had reported chloroprene-induced loss of scalp hair and chest pains in humans exposed at workplace concentrations of approximately 76 ppm.

The West German standard had been 90 mg/cu m (25 ppm) until 1975, when the maximal workplace concentration (MAK) was dropped to 36 mg/cu m (10 ppm). The reason for this change, given in the 1975 MAK Documentation [2], was uneasiness over the findings of Davtian et al [55] and Khachatrian [28,29]. The Documentation [2] reiterated the view that the Khachatrian papers were ambiguous and difficult to evaluate.

Basis for the Recommended Standard

(a) Permissible Exposure Limit

From the review of the literature presented on the biologic effects of chloroprene in Chapter III, it is apparent that, excluding reproductive and questionable carcinogenic effects, little toxicologic data from human and animal exposures are available to justify altering the standard for chloroprene in the work environment. Most of the reported effects occurred above 25 ppm. Chloroprene produces a wide array of effects, so that identification of primary target organs or systems at low concentrations is difficult. No information on chloroprene pharmacokinetics in animals or humans has been found. Mnatsakanian's [100] attempts to identify a mechanism of action for chloroprene required such high exposure concentrations for rats, from 556 to above 5,560 ppm, that consideration of his results for setting human exposure limits is not possible.

The major toxic effects on workers from chloroprene worker exposure are abnormalities in CNS function [1,20,46] and skin and eye irritation [19,24]. With respect to effects on CNS function, chloroprene is similar to other chlorinated hydrocarbons. Further, it produces changes regarded as typical of chlorinated hydrocarbon toxicosis, including degenerative

changes in the liver, resembling those produced by methylene chloride, dichloroethane, and chloroform. Complaints commonly reported in the past by workers using chloroprene include headache [41], impairment of memory [46], irritability [20], decreased pulse rate [25,41], increased pulse rate [25], chest pains [19,20,25,41], sleepiness [46], extreme fatigue [19,20,41], loss of scalp hair [21,23,68,69], and irritation of the conjunctiva [19,24]. Symptoms of severe fatigue and chest pains disappeared and scalp hair returned when workers were removed from exposure to chloroprene; however, chest pains recurred on intensified activity [20]. In most instances, the air concentrations at which these effects occurred are unknown.

Nystrom [20] reported that exposure to chloroprene at air concentrations of 3,500 mg/cu m (about 972 ppm) led to nausea and giddiness after 15 minutes; exposures from 56 ppm to more than 334 ppm led to narcosis and, at what was judged to be a very high concentration, death in a worker. Hair loss in women, after exposure to concentrations of 17-81 ppm, was described by Lejhancova [23]. Exposure at lower concentrations has given rise to toxic signs, the significance of which is difficult to judge. For example, chloroprene at air concentrations of 0.08-0.14 ppm has been reported to cause parallel increases in urinary excretion of 17-ketosteroids and coproporphyrin and increased micturition [33,100]. Excretion was observed to increase with increased exposure, but all quantities were within the normal ranges. Other symptoms and signs of exposure to chloroprene in humans have not been linked to specific air concentrations and are therefore unsuitable for development of an environmental limit.

There is no question that chloroprene is toxic at high concentrations. Von Oettingen et al [18] reported that exposure of rats to chloroprene at air concentrations of 6,227 ppm killed all animals within 1 hour. Exposure at air concentrations of 1,751 or 612 ppm for 8 hours killed all animals within 3-5 days; exposure at 278 ppm killed 25% of the exposed rats. Nystrom [20] reported that exposure of rats to chloroprene at air concentrations of 334 ppm for 8 hours/day resulted in the death of 50% of the rats by the 13th week. This exposure led to significant decreases in body weight, red blood cell count, and blood hemoglobin concentration, but increased the leukocyte count. Exposure at 56 ppm for 8 hours/day for 5 months caused no deaths. None of the changes seen at 334 ppm were observed at 56 ppm, and changes found in post-mortem examinations were described by the author as "inconsiderable." Von Oettingen et al [18] found enlarged spleens and edema of the lungs, brain, and liver when rats were exposed to chloroprene at air concentrations ranging from 27 to 97 ppm (the average was 56 ppm), but no deaths resulted. However, the chloroprene used in the study by Von Oettingen et al [18] was not stated to have been protected from air oxidation. Nystrom [20] has shown that the oxidized form of chloroprene was about four times as toxic to rats as pure chloroprene; LD50's for subcutaneous injection were 2 μl/g versus 0.5 μl/g of body weight for pure and oxidized chloroprene, respectively. Mnatsakanian [101] has stated that peroxides of chloroprene play a key role in chloroprene's toxic effects.

The study by Culik et al [66] demonstrated the lack of embryotoxicity to rats at chloroprene concentrations of 25 ppm and below. Deleterious effects on male fertility were not reported to have been observed in this

study. Questionable evidence of teratology (skeletal abnormalities) were found with the highest exposure of the dams. Investigations have reported the results of studies on embryotoxicity after exposure to chloroprene vapor concentrations of less than 1 to 4 ppm [59-61,62]. It is not possible to evaluate these studies adequately for several reasons. Proper controls were not always included. Animal exposure was sometimes carried out in the chloroprene manufacturing plant where many other compounds in addition to chloroprene were found in the air. Total embryonic mortality was neither defined nor broken down into preimplantation and postimplantation deaths; mortality only was given as a percentage. As no litter size or number of affected litters was indicated in many instances, the significance of a percentage of total embryonic mortality is difficult to interpret.

Salnikova and Fomenko [64] reported the appearance of hydrocephalus and cerebral herniation in all fetuses from rat dams given chloroprene in oral doses of 0.5 mg/kg during 14 days of pregnancy. Inhalation of 1.11 ppm chloroprene vapor between the 5th and 14th days of pregnancy also resulted in percentages of hydrocephalus ranging from 6 to 34 in several series of experiments, while no cases of hydrocephalus were observed in controls. These data suggest that chloroprene may be teratogenic in animals.

No adequate data on which to base a firm judgment on the carcinogenicity of chloroprene are available at this time. A number of studies (listed in Chapter III) have been initiated after a great deal of publicity about two papers published by Khachatrian [28,29]. These papers suggested that working in plants manufacturing polychloroprene synthetic

rubber from acetylene or in shoe factories in which concomitant exposure to chloroprene and many organic solvents occurs may increase the risk of skin and lung cancer. Surveys in the same manufacturing plant in 1968 had found air concentrations of chloroprene ranging from 0.04 to 61 ppm [75]. The mean daily concentrations were as high as 15 ppm (average 7.7 ppm). There are many shortcomings and inconsistencies in these papers that preclude a firm judgment that occupational exposure to chloroprene may cause cancer.

Pell [30] has suggested that a 25-ppm workplace environmental limit for chloroprene is safe despite the fact that he noted a disproportionately high incidence of lung cancer in maintenance workers, a group expected to have relatively high exposure to chloroprene. The frequency of occurrence of lung cancer in chloroprene workers was the same as expected when compared with the US male population.

The presently available data appear to be insufficient to formulate firm conclusions on the carcinogenicity of chloroprene. However, chloroprene is mutagenic in Salmonella [15,52]. Likewise, sex-linked recessive lethal mutations have been induced in Drosophila (E Vogel, written communcation, July 1976). Infertility has been reported after chloroprene exposure of male mice and rats [18]. Administration of chloroprene to male rats has also been associated with embryonic mortality [18,41], testicular atrophy [41], and reduced numbers and motility of live spermatozoa in animals with nonatrophied testicles [41,56]. Although exposure of humans to chloroprene has not produced all the effects summarized above, male workers have had decreased numbers and motility of viable spermatozoa after occupational exposure to chloroprene [22]. A threefold excess of miscarriages by wives of chloroprene workers has been

reported [22]. There seems to be no great risk of teratogenicity from inhalation of chloroprene by rats and mice, although one study [64] reported hydrocephalus and cerebral herniation, and another [66] found some skeletal abnormalities. The lethal effects of chloroprene on embryos are somewhat less clear cut. There have been several studies on this subject that may indicate increased preimplantation death in rats [55,56,61,62]. Chloroprene has also been associated with increased chromosomal aberrations in blood cells of chloroprene-exposed workers as compared with those of controls [41,43].

Several investigators have reported adverse effects on reproduction or reproductive function following exposure of males to chloroprene. Von Oettingen et al [18] reported interference with reproduction in male rats from skin applications of 0.5-1.5 ml of chloroprene (20 applications during 34 days). Exposure of male rats at concentrations of 120-6,227 ppm (434-22,419 mg/cu m) and of male mice at concentrations of 12-152 ppm (42-548 mg/cu m) for 8 hours resulted in sterility or impotence in 13/19 rats and in 8/14 mice. Unexposed male rats (five) and mice (five) were both potent and fertile. Five female mice exposed to chloropene at a concentration of 151 ppm (594 mg/cu m) for 8 hours all became pregnant on mating with unexposed males. Degenerative changes in the testes were observed in some of the animals exposed by inhalation. Davtian et al [55] observed that chloroprene inhalation at 1 ppm to male rats did not affect fertilization capacity; however, mating of these animals resulted in a significant excess of embryonic mortality. The investigators reported that this same low concentration of chloroprene induced chromosomal aberrations in bone marrow cells in these animals. The study suggests that germinal and somatic cells

are identically sensitive to low-level (1 ppm) exposure to chloroprene. Davtian [56] reported a significant excess of embryonic mortality following exposure of male rats to chloroprene at a concentration of 0.04 ppm (0.15 mg/cu m). At the same exposure level, testicular atrophy and a reduction in the numbers and motility of sperm in animals with nonatrophied testes also were reported. Consistent with the above-mentioned mutagenic and adverse reproductive effects in animals is the report by E Vogel (written communication, July 1976) demonstrating chloroprene-induced, recessive lethal mutations in Drosophila. In this assay system, genetic damage is observed two generations subsequent to exposure of the male fruit fly. Further evidence for the mutagenicity of chloroprene has been demonstrated in Salmonella typhimurium strains by Bartsch et al [15,52] and by the report from Litton Bionetics (RS Barrows, written communication, August 1976).

Observations in humans are consistent with findings in animal experimental systems. Three studies have indicated a significant excess of chromosomal aberrations in blood cells of workers exposed to chloroprene as compared with those in controls [41,43, and NP Bochkov, written communication, March 1976]. In one study [43], the chloroprene concentration was reported to be 5 ppm. In a second study [41], the concentration in air ranged between 0.8 and 1.95 ppm. No environmental data were reported in the third study. In addition, morphologic disturbances in the sperm of workers exposed to chloroprene levels ranging from 0.28 to 1.94 ppm have been reported [22]; a threefold increase of spontaneous abortion in the wives of chloroprene-exposed workers also was reported.

Because there are indications that occupational exposure to chloroprene may increase the incidence of cancer of the lungs, may exert embryotoxic and fetotoxic effects, and may interfere with reproductive processes, particularly in the male, as well as produce chromosomal aberrations in peripheral lymphocytes [41-43], NIOSH believes that it is prudent to limit occupational exposure to chloroprene to concentrations in the air of the workplace no greater than 1 ppm, determined in samples collected from the worker's breathing zone during 15-minute periods. Scheduling of sampling should be performed by a qualified industrial hygienist to conform with good industrial hygiene practice.

Because no threshold is known to exist for mutagens and the epidemiologic method for detecting inherited mutations in humans is at best limited and insensitive, the standard must necessarily be based on testing in animals species. The adverse risk of genetic abnormalities being transmitted to subsequent generations by an agent with the mutagenic properties of chloroprene is the main reason for NIOSH's recommendation that the occupational exposure limit for chloroprene be lowered from its current value. The change in the standard is not necessarily based on the position that, from presently available information, the 1-ppm level is absolutely safe for protection against genetic damage. Rather, the 1-ppm standard is based upon a lower concentration that can be measured readily under field conditions by the analytic methods currently available.

Studies should be undertaken to elucidate the metabolic fate of chloroprene. Additional studies of chloroprene's toxic effects, including carcinogenesis, in various species are needed. Some of the work presently

underway may provide some of this information, but more effort in these directions is needed.

It is recognized that many workers handle neoprene latex in work situations where there is, at present, relatively low-level exposure to chloroprene monomer. These concentrations could be reduced to well within the proposed standard through process change directed toward increased recovery of unreacted monomer from the polymer. Under these conditions, it should not be necessary to comply with some of the provisions of this recommended standard. The standard has been prepared primarily to protect worker health from genetic damage during chloroprene manufacture, polymerization, and use. Concern for genetic damage requires that protective measures be instituted below the enforceable limit to ensure that exposure of workers to chloroprene stays below 1 ppm.

(b) Sampling and Analysis

Charcoal tube sampling is recommended for collection of airborne chloroprene vapors because it is an efficient, inexpensive method and is widely used for other chlorinated and nonchlorinated organic vapors. Gas chromatography is recommended for the analysis of chloroprene samples because it has been shown to be accurate and precise, and variations of the method are used for organic compounds in many industries both for sampling and for quality control. The recommended methods are presented in Appendices I and II, although other methods of comparable reliability and accuracy are acceptable. The relative merits of other sampling and analytical methods are discussed in Chapter IV.

(c) Medical Surveillance and Recordkeeping

In view of the documented effects of human exposure to acetylene-derived chloroprene and other compounds produced concomitantly with chloroprene manufacture and use, NIOSH recommends comprehensive preplacement and periodic medical examinations. Detection of respiratory and hepatic abnormalities and of cutaneous conditions that might be aggravated by exposure to an irritant chemical is especially important. Medical records, with supporting documentation, must be retained for the duration of employment plus 30 years.

(d) Personal Protective Equipment and Clothing

Impervious protective equipment, used in accordance with 29 CFR 1910, Subpart I, is recommended to minimize the risk of chemical burns and of eye and throat irritation. This equipment should include face shields, boots, aprons, gloves, and protective clothing. Clothing that has been contaminated with chloroprene must be immediately replaced to prevent burns. Respiratory protection, in accordance with Table I-1, should be used by employees who must work in concentrations of chloroprene vapor that exceed the recommended environmental limit.

(e) Informing Employees of Hazards

Continuing education is an important part of a preventive hygiene program for employees. Workers should be periodically instructed by properly trained persons about the possible sources of exposure, the adverse health effects associated with exposure to chloroprene, the engineering and work practice controls in use or being planned to limit exposure, the danger of fire or explosion from chloroprene, and environmental and medical monitoring procedures used to check on control

procedures. The functioning of monitoring equipment, such as personal samplers, should be explained so that employees understand their part in environmental monitoring. Medical monitoring procedures, especially the use of chest X-ray films and pulmonary function tests, and their importance in detecting possible adverse health effects should be explained.

(f) Work Practices

The flammability and toxicity of chloroprene necessitate conformance to proper work practices. Work practices that diminish contact with or inhalation of chloroprene, such as those discussed in Chapter V, should be followed. Procedures for emergency situations, control of airborne chloroprene, sanitation, and maintenance must be understood and followed by employees occupationally exposed to chloroprene. Employee entry into confined spaces must be controlled by a permit system or equivalent, and these areas should not be entered until the atmosphere has been tested for oxygen deficiency and chloroprene contamination. When necessary, however, proper respiratory protection should be used in entering these areas.

Engineering controls must be used when needed to keep concentrations of airborne chloroprene within the recommended concentration limit. These controls are discussed in Chapter V. During the time required to install adequate controls and equipment, make process changes, perform routine maintenance operations, or make repairs, exposure to airborne chloroprene at concentrations above the recommended environmental limit must be prevented by the use of respirators and protective clothing or, in some cases, by administrative controls.

(g) Monitoring and Recordkeeping Requirements

Industrial hygiene surveys as soon as possible after the promulgation of the recommended standard and within 30 days of any process change are necessary to determine whether exposure to chloroprene at concentrations above the recommended environmental limit may occur.

Records of environmental and industrial hygiene surveys must be kept for the duration of employment and for 30 years afterward to enable the estimation of exposures during the employee's working lifetime.