

for mentioned
in GM study
at the VI
meeting

1. PUBLIC HEALTH STATEMENT

1.1 WHAT IS VINYL CHLORIDE?

Vinyl chloride is a colorless gas with a mild, sweet odor. Most of the vinyl chloride produced in the United States is used to make polyvinyl chloride (PVC), a material used to manufacture a variety of plastic and vinyl products including pipes, wire and cable coatings, packaging materials, furniture and automobile upholstery, wall coverings, housewares, and automotive parts. Much smaller amounts of vinyl chloride are used as a refrigerant gas and in the manufacture of other chlorinated compounds. The major sources of release of vinyl chloride to the environment are atmospheric emissions and wastewater discharges from the plastics industries (primarily vinyl chloride and PVC manufacturers). Most of the vinyl chloride released to the environment eventually ends up in air.

1.2 HOW MIGHT I BE EXPOSED TO VINYL CHLORIDE?

Humans are exposed to vinyl chloride from environmental and occupational sources. The low levels of vinyl chloride found in the environment (often called background levels) are usually more than a thousand times lower than levels found in occupational locations. Background levels in the environment are usually expressed in terms of parts of vinyl chloride present in a billion parts of air or water (ppb). Background levels found in the air we breathe result from the discharge of exhaust gasses from factories that manufacture or process vinyl chloride, or evaporation from areas where chemical wastes are stored. Highest background levels have been measured in air near vinyl chloride factories or over chemical waste storage areas. Air inside new cars may contain levels of vinyl chloride higher than expected background levels, because vinyl chloride may seep into the air from the new plastic parts. (also see AP 71)

Background levels in drinking water come from factories that release wastes into rivers and lakes, from seepage into water in areas where chemical wastes are stored, or from contact with polyvinyl chloride pipes. In the past, concentrations exceeding expected background levels were present in foods packaged in plastic that contained vinyl chloride.

Occupational sources, such as what might be experienced in vinyl chloride manufacturing or processing factories, may result in exposure to levels in the air much higher than those from environmental sources. Levels in the air in occupational locations are usually expressed in terms of parts of vinyl chloride per million parts of air (ppm).

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found near vinyl chloride production plants (Gordon and Meeks 1977, Pellizzari et al. 1979, IARC 1979, EPA 1985b), and levels have ranged from undetectable to $23.4 \mu\text{g}/\text{m}^3$ (0.01 ppm) over landfills (Stephens et al. 1986, Baker and Mackay 1985). It is unlikely that levels in ambient air would result in significant exposure.

Several epidemiological studies associated occupational exposure with adverse health effects, including cancer; however, these studies (see Sect. 4, Toxicological Data) did not quantify exposure. A NIOSH survey of three vinyl chloride manufacturing plants reported a time-weighted average concentration of 0.18 to $69 \text{ mg}/\text{m}^3$ (0.07 to 27 ppm) in workplace air (Fishbein 1979). Concentrations in some plants were as high as 100 to $800 \text{ mg}/\text{m}^3$ (39 to 315 ppm) (Fishbein 1979). There seems little doubt that occupational exposure remains the most important source of exposure to vinyl chloride.

Levels in drinking water as high as $10 \mu\text{g}/\text{L}$ have been detected (Dykken and Hess 1982, HSDB 1987), but most monitoring studies have reported no detectable vinyl chloride in drinking water (HSDB 1987, Coniglio et al. 1980). Data were not located regarding the monitoring of vinyl chloride in soil, but exposure from contact with contaminated soil is likely to be negligible because dermal absorption is not considered significant (Hefner et al. 1975a).

In the past, vinyl chloride had been detected in various foods, as a result of migration from polyvinyl chloride food wrappings and containers (EPA 1985b). Currently, the FDA regulates the use of vinyl-chloride-containing polymers to maintain levels of vinyl chloride in food at ≤ 5 ppb. A recent report suggests that migration of vinyl chloride into food from polymers containing very low levels would be negligible, and that intake from food is expected to be negligible (Kontominas et al. 1985).

2.2.3.2 Human exposure potential

Monitoring data indicate that people living in the vicinity of vinyl chloride, PVC, or vinyl chloride copolymer manufacturers, or hazardous waste sites that contain vinyl chloride, would be exposed to this compound through inhalation of contaminated air, whereas people not living near these sources would be exposed to negligible levels. Locations of large industrial sources include, but are not limited to: Plaquemine, Louisiana; Houston, Texas; Lake Charles, Louisiana; Calvert City, Kentucky; Point Comfort, Texas; Oklahoma City, Oklahoma; Baton Rouge, Louisiana; Delaware City, Delaware; Pensacola, Florida; and Aberdeen, Massachusetts (CNR 1986a,b). The greatest likelihood for human inhalation exposure to vinyl chloride is occupational. NIOSH estimated that 27,000 workers are definitely exposed to vinyl chloride, and workers probably exposed may be as many as 2.2 million (Sittig 1985).

The level of vinyl chloride in drinking water is expected to be highest in areas where the raw water supplies are contaminated with vinyl chloride. The most probable source of surface water contamination is wastewater from vinyl chloride, PVC, and vinyl chloride copolymer manufacturers. The most probable sources of groundwater contamination are landfills. It has been shown that use of PVC pipes may result in leaching of vinyl chloride monomer into drinking water supplies;

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INSIGNIFICANT AMOUNTS OR
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animals and humans. Further understanding of the mechanism of action on other systems, such as the CNS, could be gained.

2.3.3.2 Monitoring of human biological samples

The most practical biological monitoring procedure appears to be quantification of urinary output of thiodiglycolic acid, the predominant urinary metabolite of vinyl chloride (Heger et al. 1982). Individual variation, however, renders this method unreliable at exposure concentrations <5 ppm (Tarkowski 1984).

2.3.3.3 Environmental considerations

Limited data are available regarding the vinyl chloride levels in foodstuffs. Monitoring data on levels of vinyl chloride in food contained in PVC packaging materials are needed. Intake of vinyl chloride by ingestion of contaminated food was assumed to be negligible, based on strict FDA regulations and one laboratory study (Kontominas et al. 1985) that simulated actual food packaging and food storage conditions. This assumption should be verified with monitoring data.

Data on the amount of leaching of vinyl chloride from rigid PVC water pipes into drinking water need to be obtained. Monitoring data alone cannot reveal the extent of the leaching problem, because monitoring data frequently reflect levels in drinking water supplies before transport through PVC distribution systems.

Limited data are available on the persistence of vinyl chloride in the environment, particularly in surface waters, soil, and groundwater. Although a half-life for vinyl chloride in surface water has been estimated, significant uncertainty exists. Due to lack of data, it was not possible to estimate a half-life for vinyl chloride in soil or groundwater.

we now
have
data

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5. MANUFACTURE, IMPORT, USE, AND DISPOSAL

5.1 OVERVIEW

Vinyl chloride is produced at 10 locations in the United States. During 1986, an estimated 8.5 to 8.6 billion lb of this chemical was produced in the United States. It is produced by thermal cracking of ethylene dichloride. Vinyl chloride is used almost exclusively in the United States for the production of polyvinyl chloride (PVC) and several copolymers. These compounds yield a wide range of end-use products which are used by industries and consumers.

5.2 PRODUCTION

Domestic production of vinyl chloride during 1986 was estimated to range between 8.5 and 8.6 billion lb. This was -94 to 98% of available production capacity in 1986. In 1985, 7.8 billion lb of vinyl chloride was produced in the United States (C&EN 1987).

Manufacturers and sites of production are as follows (CMR 1986a): Borden Chemical in Geismar, Louisiana; Dow Chemical in Oyster Creek, Texas, and Plaquemine, Louisiana; Formosa Plastics in Baton Rouge, Louisiana, and Point Comfort, Texas; BF Goodrich in Calvert City, Kentucky, and La Porte, Texas; PPG Industries in Lake Charles, Louisiana; Shell Oil in Deer Park, Texas; and Vista Chemical in Lake Charles, Louisiana.

Vinyl chloride is produced commercially by thermal cracking of ethylene dichloride (EDC). EDC used in this process is made by either direct chlorination of ethylene using liquid chlorine, or oxychlorination of ethylene using dry hydrochloric acid and oxygen (Cowfer and Magistro 1985). Vinyl chloride is usually supplied as a liquid under pressure (IARC 1979). The technical grade product is available in 99.9% purity (Sax and Lewis 1987).

5.3 IMPORT

Imports of vinyl chloride were -200 million lb in 1987 (C&EN 1987).

5.4 USES

The use pattern for vinyl chloride is as follows (CMR 1986a): polyvinyl chloride (PVC), 85%; exports, 13%; and other, mostly copolymer use, 2%. This use pattern indicates that vinyl chloride monomer is used almost exclusively in the United States by the plastics industry. Very small amounts are used as a refrigerant gas and as an intermediate in the production of chlorinated compounds (Curry and Rich 1980, Gosselin et al. 1984, IARC 1979). Limited quantities of vinyl chloride were used in the United States as an aerosol propellant, and as an ingredient of

drug and cosmetic products; however, these practices have been discontinued (EPA 1985b).

Vinyl chloride is industrially important because of its inherent flame retardant properties, its wide variety of end-use products, and the low cost of producing polymers from vinyl chloride (Cowfer and Magistro 1985). Principal end-use products include: PVC pipes, wire and cable coatings, packaging materials, furniture and automobile upholstery, wall coverings, housewares, and automotive parts and accessories; vinyl chloride-vinyl acetate copolymer floor coverings, phonographic records, and flexible film; vinyl chloride-acrylonitrile battery cell separators; and vinyl chloride-vinylidene chloride copolymer food packaging film (Curry and Rich 1980, Salkind and Pearlman 1978, Farkas 1980).

5.5 DISPOSAL

EPA requires that persons who generate, transport, treat, store, or dispose of this compound comply with regulations of the Federal Resource Conservation and Recovery Act (RCRA). The recommended method of disposal, reported by Sittig (1985), involves the incineration of this chemical after mixing it with another combustible fuel. ~~Gas should be taken to ensure that complete combustion has taken place, in order to avoid formation of phosgene. An acid scrubber is recommended to remove HCl.~~ at 1800 °F and
In addition to this method, other disposal techniques have been developed for the recovery of vinyl chloride from PVC latexes (Sittig 1985).

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6. ENVIRONMENTAL FATE

6.1 OVERVIEW

Effluents and emissions from vinyl chloride and PVC manufacturers are responsible for the majority of vinyl chloride released to the environment. When released to the atmosphere, vinyl chloride is expected to be removed by reaction with photochemically generated hydroxyl radicals (half-life = 1.2 to 1.8 days). Reaction products include HCl, formaldehyde, formyl chloride, acetylene, chloroacetaldehyde, chloroacetylchloranil, and chloroethylene. In photochemical smog situations, vinyl chloride has a half-life of 3 to 7 h. When released to water, volatilization is expected to be the primary fate process (half-life = 8.7 to 43.3 h). In waters containing photosensitizers, such as humic materials, sensitized photodegradation may also be important. When released to soil, vinyl chloride will either volatilize rapidly from soil surfaces, or leach readily through soil, ultimately entering groundwater.

6.2 RELEASES TO THE ENVIRONMENT

The major source of release of vinyl chloride to the environment is believed to be emissions and effluents from plastic industries (primarily vinyl chloride and PVC manufacturers). Vinyl chloride released in wastewater is expected to volatilize fairly rapidly (on the order of hours to days) into the atmosphere. Other sources of release include disposal of vinyl chloride wastes in landfills, incomplete combustion of PVC, tobacco smoke, spills, and biodegradation of trichloroethylene, tetrachloroethylene, and 1,1,1-trichloroethane in groundwater (IARC 1979, HSDB 1987, Wakeman and Johnson 1978, Wilson and Wilson 1985, Smith and Dragun 1984). EPA estimated that prior to 1975, 110 million kg/year of vinyl chloride escaped into the atmosphere from PVC production facilities in the United States (IARC 1979). Worldwide emissions of vinyl chloride into the atmosphere during 1982 was ~400 million lb (Hartmans et al. 1985).

6.3 ENVIRONMENTAL FATE

6.3.1 Air

Based on a vapor pressure of 2660 mm Hg at 25°C, essentially all vinyl chloride in the atmosphere is expected to exist in vapor form (Verschuuren 1983, Eisenreich et al. 1981). Consequently, removal from the atmosphere by dry deposition is not expected to be an important fate process. Vinyl chloride has a relatively high partition coefficient between air and water ($H = 50$), which suggests that significant amounts of vinyl chloride would not be removed from the atmosphere by wet deposition (EPA 1985b).

Reaction of vinyl chloride vapor with photochemically generated hydroxyl radicals is predicted to be the primary degradation mechanism for this compound in the atmosphere. The half-life for this reaction in the typical atmosphere has been -1.5 to 1.8 days (EPA 1985b). Products of this reaction are HCl, formaldehyde, formyl chloride, carbon monoxide, carbon dioxide, chloroacetaldehyde, acetylene, chloroethylene, chloroacetylchloranil, and H₂O (EPA 1985b). In photochemical smog situations, the reaction half-life of vinyl chloride is predicted to range between 3 and 7 h (HSDB 1987). Reaction with ozone (half-life - 4.2 to 33 days), reaction with oxygen atoms [O(³P)] (half-life - 373 to 532 days), and direct photolysis are relatively insignificant degradation mechanisms in the atmosphere (EPA 1985b).

6.3.2 Water

The primary loss process for vinyl chloride in natural water systems is volatilization into the atmosphere. The half-life for vinyl chloride volatilization from a typical pond, river, and lake has been estimated to be 43.3, 8.7, and 34.7 h, respectively. These values are based on an experimentally determined reaeration rate ratio of -2 and assumed oxygen reaeration rates of 0.008, 0.04, and 0.01 hour⁻¹ for a typical pond, river, and lake, respectively (EPA 1985b). Predicted half-lives should be considered rough estimates since the presence of various salts in natural water systems may affect the volatility of vinyl chloride significantly (EPA 1985b). In waters containing photosensitizers, such as humic materials, photodegradation may be fairly rapid. This suggests that in some waters sensitized photodegradation would also be a significant removal mechanism (HSDB 1987, EPA 1985b).

Chemical hydrolysis of vinyl chloride does not appear to be environmentally important. The hydrolytic half-life for vinyl chloride has been estimated to be <10 years (EPA 1985b). Vinyl chloride is not expected to oxidize chemically by reaction with photochemically generated hydroxyl radicals, molecular oxygen, or alkyl peroxy radicals in natural water systems. Limited available data on the biodegradation of vinyl chloride indicate that this compound is resistant to microbial degradation under aerobic conditions (EPA 1985b). Vinyl chloride is not expected to adsorb significantly to suspended solids and sediments in water or bioaccumulate significantly in aquatic organisms (HSDB 1987).

6.3.3 Soil

The relatively high vapor pressure of vinyl chloride (2660 mm Hg at 25°C) indicates that this compound should volatilize quite rapidly from dry soil surface. The effective half-life (due to volatilization) of vinyl chloride placed 10 cm deep in dry soil is predicted to be 12 h (EPA 1985b). Evaporation from moist soil surfaces is also expected to be significant since this compound does not adsorb strongly to soil and appears to volatilize fairly rapidly from water.

Experimental data regarding adsorption of vinyl chloride to soil were not located. Based on the regression equations given by Lyman et al. (1982) and Sabljic (1984), the soil adsorption coefficient (K_{oc}) for vinyl chloride has been estimated to range between 17 and 131. These K_{oc}

values suggest that this compound would be highly mobile in soil. Thus, vinyl chloride has the potential to leach into groundwater.

Based on data in aquatic media, chemical reaction of vinyl chloride in soil does not appear to be a significant fate process, and it appears that vinyl chloride would be resistant to biodegradation under aerobic conditions.

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7. POTENTIAL FOR HUMAN EXPOSURE

7.1 OVERVIEW

Antropogenic sources!

Anthropogenic sources are responsible for all of the vinyl chloride found in the environment. Most of the vinyl chloride released to the environment will eventually locate in the atmosphere while much smaller amounts will eventually locate in groundwater. Vinyl chloride has been detected in the ambient air in the vicinity of vinyl chloride and PVC manufacturing plants and hazardous waste sites. Vinyl chloride is expected to leach into groundwater from spills, landfills, and industrial sources.

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Segments of the general population living in the vicinity of emission sources are exposed to vinyl chloride by inhalation of contaminated air. Average daily intake of vinyl chloride by inhalation for these people ranges from trace amounts to 2100 $\mu\text{g}/\text{day}$. The average daily intake of vinyl chloride by inhalation is expected to be essentially zero for the remainder of the population. However, short-term inhalation exposure to relatively high levels may occur during use of new cars. This is due to volatilization of vinyl chloride from vinyl polymers within the car interior.

The majority of the general population is not expected to be exposed to vinyl chloride through ingestion of drinking water. However, people who have PVC water pipes that have not been treated adequately to remove vinyl chloride monomer may ingest ~ 0.06 to $2.8 \mu\text{g}/\text{day}$ of vinyl chloride from drinking water. The average daily intake of vinyl chloride through diet is predicted to be essentially zero.

NIOSH estimated that 27,000 workers are definitely exposed to vinyl chloride and that workers probably exposed may be as many as 2.2 million. Intake is expected to occur primarily through inhalation and less importantly by absorption through skin. Workplace air in some PVC manufacturing plants was found to contain 100 to $800 \text{ mg}/\text{m}^3$ (39 to 312 ppm) vinyl chloride with peak concentrations of up to $87,300 \text{ mg}/\text{m}^3$ (34,000 ppm). A NIOSH survey of three vinyl chloride manufacturers reported a time-weighted-average exposure of 0.18 to $69 \text{ mg}/\text{m}^3$ (0.07 to 27 ppm) vinyl chloride in workplace air.

7.2 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

7.2.1 Air

Air in rural/remote and urban/suburban areas of the United States typically contain no detectable amount of vinyl chloride (Stephens et al. 1986; Grimsrud and Rasmussen 1975a,b; Harkov et al. 1984; Wallace et al. 1984; EPA 1985b). Limited monitoring data indicate that in areas near vinyl chloride and polyvinyl chloride manufacturers, the

concentration of vinyl chloride in air typically ranges from trace levels to $105 \mu\text{g}/\text{m}^3$ (Gordon and Meeks 1977, Pellizzari et al. 1979, IARC 1979, EPA 1985b), but may exceed $2600 \mu\text{g}/\text{m}^3$ (1 ppm) (Fishbein 1979). Elevated levels of vinyl chloride may also be found in the vicinity of hazardous waste landfills. Concentrations ranging from below detection limits to 5 to $8 \mu\text{g}/\text{m}^3$ (0.002 to 0.003 ppm) have been monitored in the air above some landfills (Stephens et al. 1986, Baker and Mackay 1985). Homes near a hazardous waste site in Southern California were found to contain levels as high as $1040 \mu\text{g}/\text{m}^3$ (0.4 ppm) (Stephens et al. 1986).

Typical values for the average daily intake of vinyl chloride by inhalation in urban/suburban and rural/remote areas have been estimated to be essentially zero. Assuming that the average intake of air is $20 \text{ m}^3/\text{day}$, the average daily intake of vinyl chloride by people living in source-dominated areas has been estimated to range from trace amounts to $2100 \mu\text{g}/\text{day}$.

7.2.2 Water

Vinyl chloride has been detected at varying concentrations in surface, ground, and drinking waters throughout the United States (EPA 1985b). Concentrations as high as $9.8 \mu\text{g}/\text{L}$ in surface water, $380 \mu\text{g}/\text{L}$ in groundwater, and $10 \mu\text{g}/\text{L}$ in drinking water have been reported (Dykse and Hess 1982, HSDB 1987). There was no report in the literature of vinyl chloride being detected in sediment.

The level of vinyl chloride in groundwater in the United States was determined during the 1982 EPA Groundwater Supply Survey. Water supplies from 945 sites geographically located throughout the United States were studied. Results indicate that vinyl chloride was positively identified in only 0.74% of groundwater supplies (detection limit $1 \mu\text{g}/\text{L}$). The maximum concentration detected was $8.4 \mu\text{g}/\text{L}$ (Westrick et al. 1984). Other studies have also reported the occurrence of vinyl chloride in groundwater throughout the United States at levels at or below $380 \mu\text{g}/\text{L}$ (Cotruvo 1985, Goodenkauf and Atkinson 1986, Page 1981, Coniglio et al. 1980, Stuart 1983).

The concentration of vinyl chloride in finished drinking waters in the United States was studied during the 1976-1977 EPA National Organics Monitoring Survey (NOMS). Only 2 samples out of 113 contained detectable levels ($>0.1 \mu\text{g}/\text{L}$), and these averaged $0.14 \mu\text{g}/\text{L}$ (HSDB 1987). Results of other studies also indicate that the majority of drinking water supplies in the United States contain no detectable levels of vinyl chloride (HSDB 1987, Coniglio et al. 1980). Based on these studies, it is assumed that the average daily intake of vinyl chloride by ingestion of drinking water for most persons in the United States would be essentially zero. Estimates provided in EPA (1985a) indicate that 0.9% of the United States population is exposed to levels of vinyl chloride in drinking water $\geq 1.0 \mu\text{g}/\text{L}$, and 0.3% of the population is exposed to levels $>5 \mu\text{g}/\text{L}$.

7.2.3 Soil

Monitoring data for vinyl chloride in soil were not located in the available literature.

7.2.4 Other

In the past, vinyl chloride had been detected in various foods as a result of migration from polyvinyl chloride food wrappings and containers (EPA 1985b). Vinyl chloride has been found in vinegar at levels up to 9.4 ppm, in edible oils at 0.15 to 14.8 ppm, and in butter at 0.05 ppm when these foods were packaged and stored in PVC containers (IARC 1979). At present, the Food and Drug Administration (FDA) regulates use of vinyl chloride polymers available for use in production of articles intended to contact food. These articles include food-packaging materials, coatings, plastisols, gaskets, and parts for food-processing (see Sect 9, Regulatory and Advisory Status). A recent study on the migration of vinyl chloride from PVC under conditions closely simulating actual food packaging and storage revealed that at very low concentrations of vinyl chloride in PVC packaging material, there was essentially zero migration of vinyl chloride (Kontominas et al. 1985).

It is reported that migration of vinyl chloride from rigid PVC water pipes into drinking water occurs, and that it is directly proportional to the residual level of vinyl chloride in the pipe itself. Under certain conditions, reaction with chlorine in the water may result in the complete removal of vinyl chloride from drinking water (Fishbein 1979, Ando and Sayato 1984). During one study, it was found that drinking water which ran through recently installed PVC pipes contained vinyl chloride at 1.4 $\mu\text{g/L}$, while water which ran through a 9-year-old system contained 0.03 to 0.06 $\mu\text{g/L}$ (HSDB 1987). This suggests that use of PVC pipe in water distribution systems contributes to intake of vinyl chloride through ingestion of contaminated drinking water. Assuming that the average daily intake of water is 2 L, the average intake of vinyl chloride from water contaminated with vinyl chloride from PVC pipes is expected to range from 0.06 to 2.8 $\mu\text{g/day}$.

The interior air of two new cars was analyzed and the level of vinyl chloride was found to range from 824 to 3120 $\mu\text{g/m}^3$ (0.3 to 1.2 ppm) (EPA 1985b). The source of vinyl chloride was believed to be volatilization from vinyl plastics found in the car interiors. Levels of vinyl chloride in the air in new cars may exceed estimates of minimal risk levels for acute and intermediate exposure.

Vinyl chloride has been detected in tobacco smoke (EPA 1985b). Cigarettes and little cigars have been found to contain 5.6 to 28 ng vinyl chloride per cigarette (IARC 1979).

7.3 OCCUPATIONAL EXPOSURES

NIOSH estimates definite worker exposure to vinyl chloride to be 27,000 persons and probable worker exposure to be 2.2 million (Sittig 1985). This includes ~5000 workers employed in vinyl chloride synthesis, 5000 workers involved with polymerization processes, and as many as 350,000 workers associated with fabrication plants. Exposure is believed to occur primarily through inhalation and less frequently by absorption

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through skin (Sittig 1985). In the past, concentrations of vinyl chloride in workplace air in some plants producing PVC have been reported to range from 100 to 800 mg/m³ (39 to 315 ppm) with peak concentrations up to 87,300 mg/m³ (34,000 ppm) (IARC 1979). Currently, the Occupational Safety and Health Administration (OSHA) sets standards for occupational exposure to vinyl chloride (see Sect. 9, Regulatory and Advisory Status). A recent NIOSH survey of three vinyl chloride plants indicated that the time-weighted-average exposure to vinyl chloride varied between 0.2 to 70 mg/m³ (0.08 to 27 ppm) (IARC 1979).

7.4 POPULATIONS AT HIGH RISK

Data were not located specifically regarding subpopulations unusually sensitive to the effects of vinyl chloride. Individuals located near or downwind of production facilities, hazardous waste disposal sites, and landfills may potentially be exposed to higher ambient atmospheric levels.

Workers involved in the production or polymerization of vinyl chloride may constitute a group at risk because of the potential for occupational exposure. Since the mid 1970s, however, atmospheric levels in the workplace have often been reduced to ≤ 1 ppm (Fishbein 1979, Kilian et al. 1975, Hansteen et al. 1978). Occupationally exposed men may represent a sensitive subgroup because occupational exposure in men has been associated with an increased incidence of fetal loss in their wives (Infante et al. 1976, Waxweiler et al. 1977). No threshold concentration has been determined for this effect. Women (or couples) of child-bearing age may constitute a group at risk, because data suggest that ambient exposure to low (but not quantified) environmental levels is associated with an increase in the incidence of malformations at birth (Infante 1976; Edmonds et al. 1975, 1978; Theriault et al. 1983). No threshold has been determined for this effect.

Inhalation studies in animals demonstrated that exposure early in life resulted in greater risk of developing cancer than did exposure later in life (Drew et al. 1983). Although human studies that address the effect of age on cancer risk were not located, the animal data suggest that exposure during the younger years may result in increased cancer risk. Other animal studies suggest that prenatal exposure may increase cancer risk (Maltoni et al. 1980, 1981). Although human data were not located, the animal data may suggest that the prenatal exposure of humans to vinyl chloride may increase risk of cancer.

Animal studies have demonstrated that pretreatment with xenobiotics or drugs that induce mixed-function oxidase (MFO) potentiates the hepatotoxicity of vinyl chloride (Jaeger et al. 1974, Reynolds et al. 1975, Conolly et al. 1978). Although human data were not located, the animal data suggest that human exposure to environmental pollutants or drugs that induce MFO may result in increased sensitivity to vinyl chloride.

9. REGULATORY AND ADVISORY STATUS

9.1 INTERNATIONAL

Advisory guidance issued by the World Health Organization (WHO) for vinyl chloride was not located in the available literature.

9.2 NATIONAL

9.2.1 Regulations

9.2.1.1 Air

The Occupational Safety and Health Administration (OSHA 1983) regulations for vinyl chloride state that a worker must not be exposed to a concentration of >1 ppm over any 8-h period and that a worker must not be exposed to >5 ppm for any period of time exceeding 15 minutes. Direct contact with liquid vinyl chloride is prohibited.

EPA (1982c) has established emission standards for vinyl chloride released to the atmosphere by vinyl chloride and polyvinyl chloride plants. Emissions are not to exceed 10 ppm.

9.2.1.2 Water

Pursuant to the Safe Drinking Water Act, EPA (1987c) promulgated a maximum contaminant level (MCL) for vinyl chloride of 0.002 mg/L, equivalent to an estimated cancer risk of 10^{-5} . This regulation is to become effective January 9, 1989 and is to apply to all community drinking water systems that regularly serve the same 25 persons for at least 8 months/year.

9.2.1.3 Food

The Food and Drug Administration (FDA 1986) recently proposed to amend its regulations regarding the vinyl chloride content of polymers used in packaging materials or processing equipment for foods. Depending on the nature of the polymer and its use, proposed vinyl chloride content may range from 5 to 50 ppm.

9.2.1.4 Other

EPA (1982d) has designated vinyl chloride as a hazardous constituent of solid waste and requires that it be handled in accordance with the regulations governing the same. EPA (1987d) lists a reportable quantity (RQ) for vinyl chloride of 1 lb, but proposes that the RQ be changed to 10 lb. The RQ is the quantity that, if released to the environment, must be reported immediately to the National Response Center.

9.2.2 Advisory Guidance

9.2.2.1 Air

The American Conference of Governmental Industrial Hygienists (ACGIH 1986b) recommends a Threshold Limit Value (TLV)-TWA for vinyl chloride of 5 ppm and a Short-Term Exposure Limit (STEL) of 10 ppm with the notation that the compound is a recognized human carcinogen. The National Institute of Occupational Safety and Health (NIOSH 1975) concluded that a TLV for vinyl chloride was inappropriate because of its carcinogenicity. NIOSH (1975) recommended that any workers exposed to vinyl chloride should wear an air-supplied respirator.

9.2.2.2 Water

EPA (1980), based on a human q_1^* of 1.74×10^{-2} (mg/kg/day)⁻¹ calculated from the incidence of tumors in a preliminary report of an inhalation study in rats (Maltoni and Lafemine 1975), estimated levels in ambient water of 20, 2, and 0.2 µg/L associated with cancer risks of 10^{-5} , 10^{-6} , and 10^{-7} , respectively, assuming daily consumption of 2 L water and 6.5 g fish and shellfish. For consumption of fish and shellfish alone, water concentrations of 5246, 525, and 52.5 µg/L correspond to cancer risk estimates of 10^{-5} , 10^{-6} and 10^{-7} , respectively. More recently, EPA (1985a, 1987b) estimated that cancer risk levels of 10^{-4} , 10^{-5} , and 10^{-6} would result from daily consumption of drinking water containing vinyl chloride at 1.5, 0.15, and 0.015 µg/L, respectively.

EPA (1985a, 1987a) promulgated health advisories for vinyl chloride in drinking water. A 10-day health advisory of 2.6 mg/L was based on a NOAEL of 30 mg/kg/day in a 13-week gavage study by Feron et al. (1975). Because data were not sufficient for derivation of a 1-day health advisory, the 10-day health advisory was adopted as a conservative 1-day health advisory. Longer-term health advisories of 0.013 mg/L for a 10 kg child and 0.046 mg/L for an adult were estimated from the NOAEL of 0.13 mg/kg/day in a lifetime dietary study in rats (Dow Chemical Company 1984, Till et al. 1983).

9.2.3 Data analysis

9.2.3.1 Reference doses (RfDs)

Reference doses for vinyl chloride have not been estimated by EPA.

9.2.3.2 Carcinogenic potency

EPA (1985a) classified vinyl chloride in IARC Group 1, and more recently, EPA (1987a) assigned the compound to Carcinogen Assessment Group (CAG) Class A. By either classification scheme, the designations have the same meaning, that evidence for carcinogenicity to humans is so convincing as to be considered "sufficient." EPA has derived several estimates of carcinogenic potency for vinyl chloride for both oral and inhalation exposure. In an early estimate, EPA (1980) derived a q_1^* for human oral exposure of 1.74×10^{-2} (mg/kg/day)⁻¹ based on preliminary reports of the incidence of total tumors in rats of both sexes exposed to vinyl chloride by inhalation at concentrations up to 10,000 ppm

(Maltoni and Lafemine 1975). A subsequent estimate of potency for oral exposure is $2.3 \text{ (mg/kg/day)}^{-1}$, which appears in EPA (1985a, 1987a) and represents the most recent analysis by CAG (EPA 1987a). This estimate was based on the incidence of lung and liver tumors in both sexes of rats exposed for lifetime to diets that contained vinyl chloride (Feron et al. 1981).

The first estimate for carcinogenic potency by inhalation exposure, $2.5 \times 10^{-2} \text{ (mg/kg/day)}^{-1}$ derived in EPA (1984), was based on the same preliminary inhalation data (Maltoni and Lafemine 1975) that was used as the basis of the EPA (1980) oral estimate. A more recent estimate of $2.95 \times 10^{-1} \text{ (mg/kg/day)}^{-1}$ (EPA 1985b) was based on the final report of the incidence of liver angiosarcomas in male and female rats exposed for up to 1 year to concentrations up to 30,000 ppm (Maltoni et al. 1980, 1981).

9.3 STATE

(Regulations and advisory guidance from the states were still being compiled at the time of printing.)

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10. REFERENCES

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CTL017573