

## 5. POTENTIAL FOR HUMAN EXPOSURE

### 5.1 OVERVIEW

Acrolein may be released to the environment in emissions and effluents from its manufacturing and use facilities, in emissions from combustion processes (including cigarette smoking and combustion of petrochemical fuels), from direct application to water and wastewater as a slimicide and aquatic herbicide, as a photooxidation product of various hydrocarbon pollutants found in air (including propylene and 1,3-butadiene), and from land disposal of some organic waste materials. Acrolein is a reactive compound and is unstable in the environment.

In ambient air, the primary removal mechanism for acrolein is predicted to be reaction with photochemically generated hydroxyl radicals (half-life 15-20 hours). Products of this reaction include carbon monoxide, formaldehyde, and glycolaldehyde. In the presence of nitrogen oxides, peroxyxynitrate and nitric acid are also formed. Small amounts of acrolein may also be removed from the atmosphere in precipitation. Insufficient data are available to predict the fate of acrolein in indoor air. In water, small amounts of acrolein may be removed by volatilization (half-life 23 hours from a model river 1 m deep), aerobic biodegradation, or reversible hydration to  $\beta$ -hydroxypropionaldehyde, which subsequently biodegrades. Half-lives less than 1-3 days for small amounts of acrolein in surface water have been observed. When highly concentrated amounts of acrolein are released or spilled into water, this compound may polymerize by oxidation or hydration processes. In soil, acrolein is expected to be subject to the same removal processes as in water. This compound can be highly mobile in soil; however, volatilization and degradation processes are expected to attenuate movement through soil.

Data regarding the monitoring of acrolein in the environment are limited. During the 1960s, acrolein was detected at concentrations averaging between 5 and 8 ppb in air samples collected in Los Angeles, CA. These data provide insight regarding maximum atmospheric levels of acrolein in urban areas during this period. During 1976, acrolein levels in air samples collected in Edison, NJ, were not detectable in 14 of 19 samples and averaged 0.31 ppb in the 5 positive samples. No data indicated that acrolein is a contaminant of drinking water supplies. The EPA STORET data indicate that acrolein occurs at a low frequency in wastewater streams, ambient surface water, and groundwater in the United States. In the only report of acrolein occurrence in municipal landfill leachate, 170 ppb acrolein was detected in leachate from one site in Wisconsin. The contract laboratory statistical database indicates that acrolein has been found in soil samples at 1 of 357 sites at a mean concentration of 6.5 ppb, and in water samples at 3 of 357 hazardous waste sites at concentrations ranging between 10.3 and 51,000 ppb; however, no distinction was made between groundwater and surface water samples. The National Priority List Technical Data Base indicates that acrolein has been detected at 7 of 1177 National Priority List (NPL) sites; the frequency of these sites within the United States can be seen in Figure 5-1 (View 1989). However, the level of

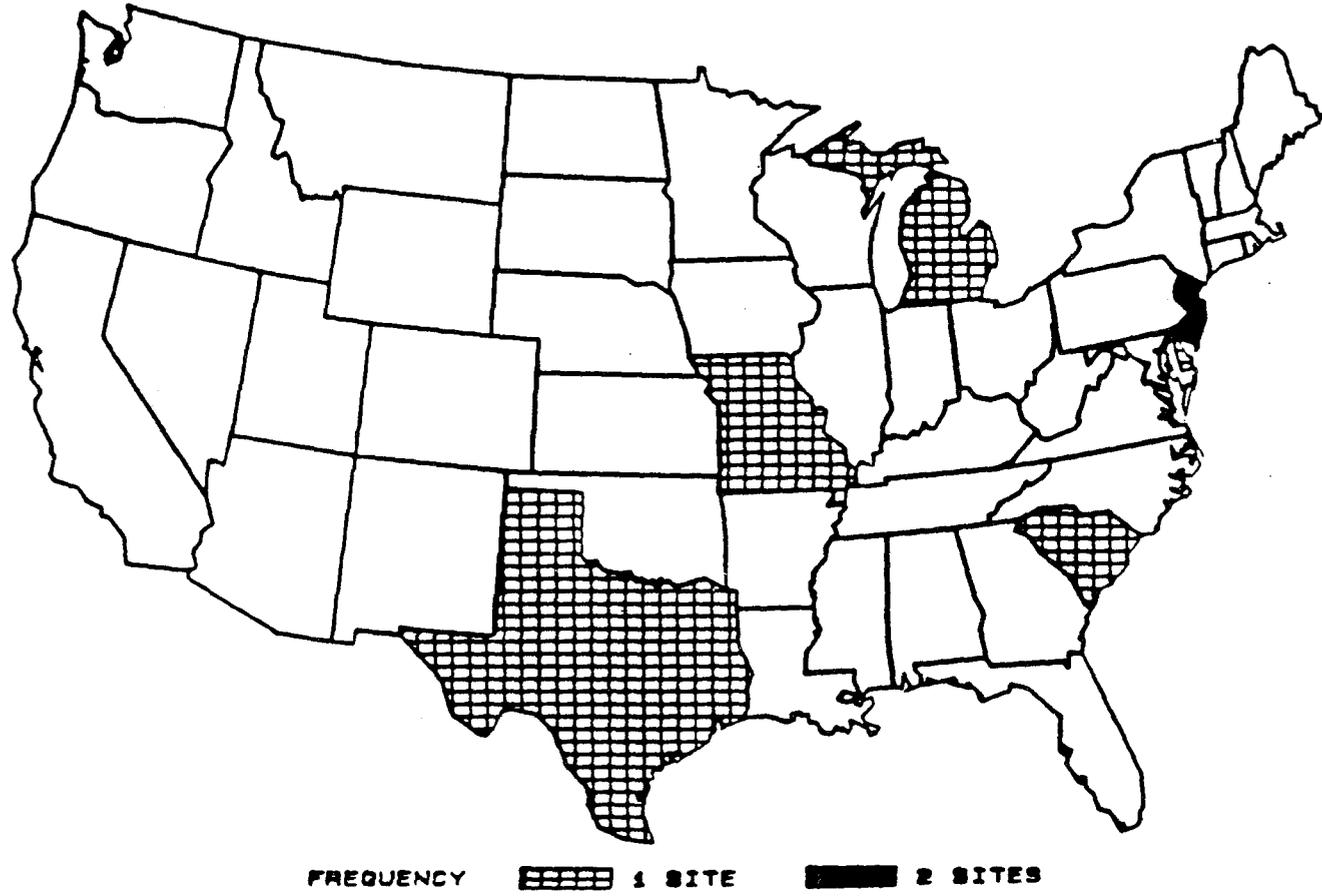


FIGURE 5-1. Frequency of Sites with Acrolein Contamination

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contamination or the media in which this compound was found was not reported. Acrolein is a gaseous constituent of cigarette smoke and has been detected at levels equivalent to 3-220  $\mu\text{g}$  per cigarette. Acrolein is formed when fats are heated. It has also been found in foods and food products such as raw cocoa beans, volatiles from cooked mackerel and white bread, and vegetable oils, wine, whiskey, and lager beer. Sufficient data are not available to establish the level of acrolein typically found in these items.

Monitoring data indicate that the general population may be exposed to acrolein through inhalation of contaminated air and through ingestion of certain foods. One of the most important sources of acrolein exposure may be via the heating of fats contained in all living matter. Because of the lack of recent, comprehensive monitoring data, the average daily intake of acrolein and the relative importance of each source of exposure cannot be determined. Estimating the typical level of exposure to acrolein is complicated because acrolein is a common contaminant of tobacco smoke, and there is wide variation among individuals regarding the frequency and level of exposure to tobacco smoke.

There is potential for exposure to acrolein in many occupational settings as the result of its varied uses and its formation during the combustion and pyrolysis of materials such as wood, petrochemical fuels, and plastics. As a result, it would be difficult to list all the occupations in which work-related exposure to acrolein occur. It appears that occupational exposure can occur via inhalation and dermal contact.

### 5.2 RELEASES TO THE ENVIRONMENT

#### 5.2.1 Air

Potential sources of atmospheric release of acrolein include: emissions from facilities involved in the manufacture or use of products containing acrolein; volatilization from treated waters and contaminated waste streams; formation as a photooxidation product of various hydrocarbon pollutants such as propylene, 1,3-butadiene, and other diolefins (Graedel et al. 1978; Maldotti et al. 1980); and emissions from combustion processes. Specific combustion sources include exhaust gas from engines powered by gasoline, diesel or other petrochemical fuels, power plants, burning vegetation (i.e., forest fires), combustion of cellulose materials such as wood, cotton, tobacco, and marijuana, and combustion of polyethylene plastics (Hodgkin et al. 1982; Jonsson et al. 1985; Lipari et al. 1984). Acrolein is also a pyrolysis product of polyethylene, animal fats and vegetable oils, cellophane, plastics, and paraffin wax (Boettner and Ball 1980; EPA 1980; Potts et al. 1978; Tanne 1983; Wharton 1978). The concentrations of acrolein in emissions from various combustion and pyrolysis processes are listed in Table 5-1.

Recent estimates of the atmospheric loading rate of acrolein from sources in the United States were not located. Anderson (1983) estimated

TABLE 5-1. Acrolein in Emissions from Combustion

Source	Concentration	References
Auto exhaust gas:		
Gasoline engine	Not detected to 12.1 ppm (detection limit 0.01 ppm) 0-7.79% of total aldehydes, excluding acetone	Lipari and Swarin 1982; Nishikawa et al. 1987a; Seizinger and Dimitriades 1972; Sigsby et al. 1987; Zweidinger et al. 1988
Diesel engine	0.05-0.3 ppm	IARC 1985; Seizinger and Dimitriades 1972
Ethanol engine	Not detected (detection limit 0.01 ppm)	Lipari and Swarin 1982
Cigarette smoke	3-220 µg/cigarette	Hoffman et al. 1975; Horton and Guerin 1974; Magin 1980; Manning et al. 1983
Marijuana smoke	92-145 µg/cigarette	Hoffman et al. 1975; Horton and Guerin 1974
Smoke from burning:		
Wood	50 ppm	Einhorn 1975
Cotton	60 ppm	
Kerosene	<1 ppm	
Emissions from woodburning fireplaces	21-132 mg/kg wood	Lipari et al. 1984
Emissions from power plants:		
Coal-fueled	0.002 lb aldehydes/1000 lbs fuel	Natusch 1978
Gas-fueled	0.2 lb aldehydes/1000 lbs fuel	
Oil-fueled	0.1 lb aldehydes/1000 lbs fuel	
Pyrolysis of polyvinyl chloride food-wrap film during hot wire cutting	27-151 ng/cut	Boettner and Ball 1980
Emissions from the combustion of polyethylene foam	2-23 ppm	Potts et al. 1978
Pyrolysis of polyethylene foam	76-180 ppm	Potts et al. 1978
15 cm above heated cooking oil	2.5-30 mg/m <sup>3</sup>	EPA 1980b

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the total loading rate of acrolein in 1978 to be 91,450 pounds from facilities involved in its production and use as a chemical intermediate. Loading rates from various industrial sources were as follows: acrylic acid manufacturers, 15,175 pounds; refined acrolein and glycerin manufacturers, 55,660 pounds; methionine manufacturers, 18,150 pounds; and miscellaneous intermediate uses, 2420 pounds. These loading rates were based on a total production volume of 350 million pounds for acrolein in 1978, with 87% of this volume consumed in the production of acrylic acid and its derivatives.

### 5.2.2 Water

Acrolein may be released to water in effluents from its manufacturing plants and use facilities (see Section 4.3 for specific information regarding uses) and from its direct application to water as an aquatic herbicide (IARC 1985; Lue-Hing et al. 1981; WSSA 1983). Data regarding the amount of acrolein released to United States waters were not located.

### 5.2.3 Soil

The occurrence of acrolein in soil at one hazardous waste site in the United States and leachate from one municipal landfill in Wisconsin provides evidence that this compound has been released to soil as the result of land disposal of some organic wastes. No data were located regarding the amount of acrolein released to soil.

## 5.3 ENVIRONMENTAL FATE

### 5.3.1 Transport and Partitioning

Acrolein is relatively unstable in the atmosphere; therefore, transport within the atmosphere is expected to be limited. The relatively high vapor pressure of acrolein [220 mm Hg at 20°C (Eisenreich et al. 1981; Hess et al. 1978)] suggests that this compound will not partition from the vapor phase to particulates in the atmosphere. Occurrence of acrolein in rainwater (Grosjean and Wright 1983; Nishikawa et al. 1987b) indicates that this compound may be removed from the atmosphere by washout.

Volatilization is expected to be a significant removal process for any acrolein released to surface waters. Based on a measured Henry's Law constant of  $3.06 \times 10^{-5}$  atm-m<sup>3</sup>/mol at 20°C, the volatilization half-life from a model river 1 m deep, flowing 1 m/sec with a wind speed of 3 m/sec was estimated to be 23 hours using the method of Thomas (1982). Veith et al. (1980) measured a bioconcentration factor (BCF) of 344 for acrolein in bluegill sunfish; however, this may be an overestimate, since total 14C was measured in the fish, which may have resulted in the measurement of acrolein metabolites. A BCF of 0.6 was estimated for acrolein using a linear regression equation based on a log octanol/water partition coefficient ( $K_{ow}$ ) of -0.01 (Bysshe 1982; Hansch and Leo 1985). These BCFs, as well as the relatively high water solubility of this compound, suggest

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that acrolein does not bioconcentrate significantly in aquatic organisms. Using a linear regression equation based on  $\log K_{ow}$  data (Lyman 1982), an adsorption coefficient ( $K_{oc}$ ) of 24 was estimated, which suggests that adsorption of acrolein to suspended solids and sediments in water would not be significant. Irwin (1988) reports a range of experimental  $K_{oc}$ , of 51-270 for adsorption of acrolein to two soils. The relatively low experimental and estimated  $K_{oc}$  values suggest that acrolein will be highly to moderately mobile in soil and that this compound has the potential to leach significantly (Swann et al. 1983). However, the adsorption of acrolein to soil has been shown to be irreversible (Irwin 1988). Irreversible sorption, biodegradation, hydration, and volatilization of acrolein in soil can be expected to significantly retard the leaching of acrolein through soil.

The relatively high vapor pressure of acrolein and its volatility from water suggest that this compound will evaporate rapidly from soil surfaces and that volatilization is probably a major removal process from soil. The relatively low  $K_{oc}$  value for acrolein indicates high mobility in soil and suggests that this compound has the potential to leach significantly (Swann et al. 1983). Degradation processes and volatilization, however, are expected to significantly retard movement of acrolein through soil.

### 5.3.2 Transformation and Degradation

#### 5.3.2.1 Air

The dominant removal process for acrolein in ambient air is predicted to be reaction with photochemically generated hydroxyl radicals in the troposphere. The atmospheric half-life for acrolein is estimated to be 15-20 hours, based on experimentally determined hydroxyl reaction rate constants ranging between  $1.90 \times 10^{-11}$  and  $2.53 \times 10^{-11}$   $\text{cm}^3/\text{molecules}\cdot\text{sec}$  at 25-26°C and an average ambient hydroxyl radical concentration of  $5.0 \times 10^5$   $\text{molecules}/\text{cm}^3$  (Atkinson 1985). Products of this reaction include carbon monoxide, formaldehyde, and glycolaldehyde. In the presence of nitrogen oxides, products include peroxyxynitrate and nitric acid (Edney et al. 1986). Direct photolysis in the ambient atmosphere occurs but is expected to be of minor importance. Gardner et al. (1987) reported that the quantum yields for irradiation of acrolein at low air pressures were 0.0066 at 313 nm and 0.0044 at 334 nm. The authors used a computer analysis of their photodissociation data to estimate the half-life of acrolein to be 10 days in the lower troposphere and less than 5 days in the upper troposphere. Experimental data indicate that reaction of acrolein with ozone ( $k = 2.8 \times 10^{-19}$   $\text{cm}^3/\text{molecules}\cdot\text{sec}$  at 25°C; half-life = 59 days) or nitrate radicals ( $k = 5.9 \pm 2.8 \times 10^{-16}$   $\text{cm}^3/\text{molecules}\cdot\text{sec}$  at 25°C; half-life - 16 days) in the troposphere would be too slow to be environmentally significant (Atkinson 1985; Atkinson et al. 1987). The fate of acrolein in indoor air is expected to be different from its fate in outdoor air because of differences in the concentrations of oxidants in indoor air compared to outdoor air and the possibility of other mechanisms of removal.

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## 5.3.2.2 Water

Low concentrations of acrolein may degrade in natural water by either aerobic biodegradation or reversible hydration to  $\beta$ -hydroxypropionaldehyde, which subsequently undergoes aerobic biodegradation (Bowmer and Higgins 1976; Callahan et al. 1979; Tabak et al. 1981). Acrolein applied to surface waters at application rates suggested for herbicidal use can persist up to 6 days (WSSA 1983). Bowmer and Higgins (1976) measured acrolein removal in both laboratory water and in field experiments using irrigation channels. In buffered laboratory water, acrolein reached its equilibrium apparently with  $\beta$ -hydroxypropionaldehyde in approximately 300 hours (92%  $\beta$ -hydroxypropionaldehyde, 8% acrolein); in irrigation channels, acrolein removal was complete. Half-lives were reportedly less than 1 to 3 days in surface water, but values were for the combined effect of degradation and volatilization (Bowmer and Higgins 1976; Bowmer et al. 1974). Kissel et al. (1978) measured acrolein removal in buffered laboratory water and natural river water using both chemical analysis methods and bioassays. Complete hydrolysis (which according to the authors includes hydration to 3-hydroxypropanol) occurred within 150 hours, 120-180 hours, and 5-40 hours in buffered solutions at 22°C and pH 5, 7, and 9, respectively. Based on fish kill bioassays in natural river water at pH 8.1, greater than 93% degradation of acrolein occurred within 6 days.

Jacobson and Smith (1990) studied the dissipation of acrolein, applied at the highest recommended rate according to the label, to achieve a 15 ppm concentration for a 2-hour duration in an irrigation canal and a lateral of the canal which was infested with aquatic plants. The dissipation half-lives for acrolein in the irrigation and lateral canals were 275 and 64 minutes, respectively. No acrolein residues were detected (detection limit, 0.01 ppm). No residues of 3-hydroxypropanol were detected (detection limit, 2.0 ppm) in any of the water samples from either canal. These data suggest that acrolein will not persist for moderate or long periods of time in aerobic aquatic environments and that hydration of acrolein may not be an important degradation pathway for acrolein (Jacobson and Smith, 1990).

The ultraviolet (UV) spectrum of acrolein in hexane shows moderate absorption of UV light in the environmentally significant range (wavelengths greater than 290), suggesting that acrolein might undergo photolysis in natural waters; however, hydration of acrolein destroys the chromophores that absorb W light (Callahan et al. 1979), and the equilibrium appears to be far on the side of the hydration product. Thus, the potential for direct photolysis of acrolein in natural waters is probably slight. Oxidation of small amounts of acrolein in natural waters would not be environmentally significant; however, highly concentrated acrolein solutions (i.e., spills) may be polymerized by oxidation or hydration processes (Callahan et al. 1979). Insufficient data are available regarding anaerobic biodegradation to establish the significance of this process as a removal mechanism or to determine the rate at which such a process would proceed. This information

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would be particularly useful in determining the fate of acrolein under conditions frequently encountered in groundwater and in landfills,

### 5.3.2.3 Soil

Experimental data specifically pertaining to the degradation or transformation of acrolein in soil were not located. Results of studies in aquatic systems suggest that acrolein, at low concentrations, may be subject to aerobic biodegradation in soil or transformation via hydration followed by aerobic biodegradation of the hydrated product (see Section 5.3.2.2). Since acrolein is a very reactive compound, abiotic processes, such as oxidation, may be the most important degradation processes.

## 5.4 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

### 5.4.1 Air

The atmospheric concentrations of acrolein have been measured in several locations, and the most comprehensive monitoring studies are discussed below. Altshuller and McPherson (1963) and Renzetti and Bryan (1961) determined that acrolein levels in air samples collected in Los Angeles, CA, during 1960-61 averaged between 5 and 8 ppb. Air samples collected in the Los Angeles Basin over a 12-week period during 1968 contained levels ranging between none detected to 18 ppb, although most values ranged between 0.9 and 9 ppb (IARC 1985). Since Los Angeles is a high-density population center with a variety of emission sources and a smog problem related to high traffic density, air monitoring data from this area may provide insight regarding the maximum atmospheric levels of acrolein in urban areas. However, these data are considered too old to provide useful information on current ambient levels of acrolein. In a somewhat more recent survey (although still very outdated), acrolein was detected in 5 of 19 air samples collected in Edison, NJ, during 1976. Positive samples contained acrolein at levels between 0.19 and 0.44 ppb, with a mean concentration of 0.31 ppb (Brodzinsky and Singh 1982). These data are insufficient for determining the level at which acrolein typically occurs in ambient air.

### 5.4.2 Water

Data from the EPA STORET Data Base indicate that acrolein has a low frequency of occurrence in wastewater streams, ambient surface water, and groundwater in the United States (EPA 1988b; Staples et al. 1985). Acrolein has not been found as a contaminant of drinking water (EPA 1980; Krill and Sonzogni 1986; Otson 1987). Grosjean and Wright (1983) detected acrolein, in combination with acetone, at a concentration of 0.05 ppt in rainwater collected in Los Angeles, CA; however, these compounds were not detected in rainwater samples collected in four less densely populated sites in California. The Contract Laboratory Statistical Database reports that acrolein has been detected in water at 3 of 357 hazardous waste sites in

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the United States at mean concentrations ranging from 10.3-51,000 ppb (VIAR 1987). However, this database made no distinction between groundwater and surface water monitoring data. In the only report of acrolein occurrence in municipal landfill leachate, acrolein was detected at a concentration of 170 ppb in 1 of 5 leachate samples collected from sites in Wisconsin (Sabel and Clark 1984).

### 5.4.3 Soil

The Contract Laboratory Statistical Database reports that acrolein was detected in soil at 1 of 357 hazardous waste sites in the United States, at a mean concentration of 6.5 ppb (VIAR 1987). The National Priority List Technical Data Base (View 1989) indicates that acrolein was detected at 5 of 1177 National Priority List (NPL) sites; however, the database does not contain media concentration data. Acrolein was identified in sediment/soil/water samples collected from Love Canal in Niagara Falls, NY (Hauser and Bromberg 1982); however, no quantitative data were available.

### 5.4.4 Other Media

Acrolein has been identified in foods and food components such as raw cocoa beans, chocolate liquor, souring salted pork, fried potatoes and onions, raw and cooked turkey, and volatiles from cooked mackerel, white bread, raw chicken breast, ripe arctic bramble berries, heated animal fats and vegetable oils, and roasted coffee (Cantoni et al. 1969; EPA 1980, 1985; IARC 1985; Umano and Shibamoto 1987). Sufficient data are not available to establish the level of acrolein typically encountered in these foods. Trace levels of acrolein have been found in wine, whiskey, and lager beer (IARC 1985). Further information regarding the occurrence of acrolein in food and related products is provided by EPA (1980).

Acrolein is a gaseous constituent of tobacco and marijuana smoke, occurring in both mainstream and sidestream smoke (Ayer and Yeager 1982; Hoffmann et al. 1975; Holzer et al. 1976; Rylander 1974; Weber-Tschopp et al. 1976). The level of acrolein in sidestream smoke has been found to be notably higher (12 times higher) than in mainstream smoke (Triebig and Zober 1984). The amount of acrolein emitted in tobacco smoke varies depending upon the kind of cigarette, smoking conditions, puff volume, puff rate, nature, and type of tobacco, as well as a number of other extraneous factors (Holzer et al. 1976). Smoke from various cigarettes have been found to contain 3-220 pg acrolein per cigarette (Hoffmann et al. 1975; Horton and Guerin 1974; Magin 1980; Manning et al. 1983). Smoke from a marijuana cigarette was also found to contain 92-145  $\mu\text{g}$ /cigarette (HofEmann et al. 1975; Horton and Guerin 1974). Studies performed to determine the concentration of acrolein in smoke-filled rooms (Rylander 1974; Triebig and Zober 1984; Weber-Tschopp et al. 1976) indicate that the concentration of acrolein in indoor air is highly dependent upon such factors as the number of cigarettes smoked, rate at which the cigarettes are smoked, size of the room, number of people in the room, and type of ventilation. Acrolein

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levels measured in various settings where people were smoking are: cafe, 30-100 ppb; train, 10-120 ppb; car with three smokers (windows open), 30 ppb (avg.); car with three smokers (windows closed), 300 ppb (avg.); restaurant, 3-13 ppb; tavern, 5-18 ppb; and cafeteria, 1-10 ppb (Triebig and Zober 1984).

### 5.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

The general population may be exposed to acrolein through inhalation of contaminated air, inhalation of cigarette smoke, and through ingestion of certain foods. Widespread exposure occurs due to the formation of acrolein during the heating of fats. Because of the lack of recent comprehensive monitoring data, the average daily intake of acrolein and the relative importance of each source of exposure cannot be determined. Primary factors influencing the level of exposure to acrolein via inhalation are: location (urban versus rural), duration and frequency of exposure to tobacco smoke, concentration of tobacco smoke, duration and frequency of exposure to high concentrations of vehicle exhaust (e.g., in parking garages, in heavy traffic), occupational exposure, and downwind distance of residence or work site relative to stationary point sources. Primary factors influencing the level of exposure to acrolein via ingestion are diet and volume of intake, which is typically related to age and sex.

According to a National Occupational Exposure Survey (NOES) by NIOSH between 1981 and 1983, an estimated 1300 workers in the United States are occupationally exposed to acrolein (NIOSH 1988). This is a tentative estimate and is subject to change as further information regarding trade name compounds becomes available. There is potential for exposure to acrolein in many occupational settings as the result of its varied uses and its formation during the combustion and pyrolysis of materials such as wood, petrochemical fuels, and plastics. As a result, it would be difficult to list all the occupations in which work-related exposure to acrolein occurs. Acrolein has been detected in workplace air at a number of locations (Ahrenholz and Egilman 1983; Apol 1982; IARC 1985; Tharr and Singal 1986; Trietman et al. 1980; Woskie et al. 1988). Acrolein concentrations of 0.057-0.085 ppm were detected during system testing conducted as part of a submarine overhaul in Portsmouth Naval Shipyard in Portsmouth, NH (Tharr and Singal). Ahrenholz and Egilman (1983) reported less than 0.0044-0.18 ppm acrolein in the wire line department of Rubbermaid Inc. in Wooster, OH, and Apol (1982) reported less than 0.06 ppm in molding areas of Gerlinger Casting Corp in Salem, OR.

### 5.6 POPULATIONS WITH POTENTIALLY HIGH EXPOSURE

Those segments of the general population with potentially high exposure to acrolein from exogenic sources include people who come in frequent or prolonged contact with tobacco or marijuana smoke, people who are occupationally exposed, and people who live or work near dense traffic areas, in smoggy areas (e.g., Los Angeles), or downwind from stationary

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point sources. Patients ingesting the drug cyclophosphamide are at risk for exposure to acrolein, a metabolite of the drug. It is not known, however, if such patients would be at risk for potentially high exposure to acrolein as a result of taking the drug.

### 5.7 ADEQUACY OF THE DATABASE

Section 104(i)(5) of CERCLA, directs the Administrator of ATSDR (in consultation with the Administrator of EPA and agencies and programs of the Public Health Service) to assess whether adequate information on the health effects of acrolein is available. Where adequate information is not available, ATSDR, in conjunction with the NTP, is required to assure the initiation of a program of research designed to determine the health effects (and techniques for developing methods to determine such health effects) of acrolein.

The following categories of possible data needs have been identified by a joint team of scientists from ATSDR, NTP, and EPA. They are defined as substance-specific informational needs that, if met would reduce or eliminate the uncertainties of human health assessment. In the future, the identified data needs will be evaluated and prioritized, and a substance-specific research agenda will be proposed.

#### 5.7.1 Identification of Data Needs

**Physical and Chemical Properties.** Physical and chemical property data are essential for estimating the partitioning of a chemical in the environment. Physical and chemical property data are available for acrolein, but extensive experimental descriptions necessary for evaluating the accuracy of the data are lacking.

**Production, Use, Release, and Disposal.** Data regarding the production methods for acrolein are adequate; however, data regarding current production volumes and use patterns are lacking. Production data may be difficult to obtain, since many companies desire to maintain their confidentiality. Use, release, and disposal information is useful for determining where environmental exposure to acrolein may be high. Determining the percentage of acrolein used as a captive intermediate (i.e., consumed in closed processes in which the compound is not isolated) rather than as an isolated, refined product is important in estimating the amount of release to the environment from stationary, noncombustion-related sources. An estimate of the amount of acrolein released from stationary sources would be useful in establishing the relative importance of each source of acrolein. Even if information on the production, use, and disposal of acrolein were available, the amounts released would be difficult to estimate, since major factors contributing to its occurrence in the environment are its formation as a product of the photochemical degradation of other atmospheric pollutants and its release in emissions from a wide variety of combustion processes.

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According to the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRTKA), (§313), (Pub. L. 99-499, Title III, §313), industries are required to submit release information to the EPA. The Toxics Release Inventory (TRI), which contains release information for 1987, became available in May of 1989. This database will be updated yearly and should provide a more reliable estimate of industrial production and emission.

**Environmental Fate.** Experimental data pertaining to the persistence of acrolein in soil and groundwater are lacking. Studies on volatilization from soil surfaces, anaerobic biodegradation in soil and simulated groundwater, and aerobic biodegradation in simulated groundwater would be useful in establishing the likelihood of exposure near hazardous waste disposal sites resulting from volatilization from soil surfaces or from groundwater contamination.

**Bioavailability from Environmental Media.** No studies were located regarding the bioavailability of acrolein from environmental media. Since acrolein has been detected in ambient air and in food and beverages (ppb levels), it is important to determine if acrolein can be absorbed by humans from environmental samples. However, the chemical structure of acrolein makes it a highly reactive molecule, which presumably is why its effects are, for the most part, restricted to the area of exposure (i.e., respiratory system for inhalation exposure or localized skin damage for dermal exposure). The limited information available regarding absorption parameters of acrolein in experimental animals indicates that acrolein is easily retained in the respiratory airways; however, virtually no information is available regarding absorption by the gastrointestinal tract or skin. Therefore, based on the data available, it is likely that inhalation of contaminated air will result in irritation of the eyes and respiratory tract.

**Food Chain Bioaccumulation.** A bioconcentration factor (BCF) was measured for acrolein that indicates that this compound would not bioaccumulate significantly in fish. This conclusion is supported by monitoring data that indicate that acrolein is not a common contaminant of biota in United States waters. No information was available on the bioaccumulation of acrolein in organisms at other trophic levels. Monitoring for the accumulation of acrolein in organisms from several trophic levels would be useful in estimating the levels of acrolein to which humans are exposed through dietary intake.

**Exposure Levels in Environmental Media.** Limited, mostly outdated, data were available regarding the detection of acrolein in the environment. Information on exposure to acrolein in air in urban areas, rural areas, near hazardous waste disposal sites, as well as in water (specifically, drinking water supplied from groundwater downgradient from hazardous waste disposal sites and contaminated surface waters) and soil at waste disposal sites

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would be useful. Monitoring air and water over a 1-year period would provide some indication of seasonal variations.

**Exposure Levels in Humans.** The database for both workplace exposure and ambient exposure is neither comprehensive nor current. Therefore, it is not possible to calculate a reliable estimate of average daily intake or intake resulting from occupational exposure. Even if this information was available, determination of the average daily intake of acrolein would be complicated by the variability in the frequency and amount of exposure to cigarette smoke and other acrolein sources. The development of a program for monitoring environmental media would provide information for estimating exposure levels in humans. Market basket surveys or total diet studies similar to those conducted by the United States Food and Drug Administration would provide data on typical levels of exposure via dietary intake. These kinds of studies are designed to determine the dietary intake of 16- to 19-year-old males, toddlers (2-year-old), and infants. In addition to workplace monitoring data, occupational exposure may be estimated from detailed examination of the uses of acrolein and the various processes in which acrolein is formed. For instance, since acrolein is a product of the combustion of wood, polyethylene, and petrochemical fuels, fire fighters could be exposed to elevated levels of acrolein. However, determining typical levels of exposure in this occupation would be difficult because of the variability in the kinds of materials consumed in fires.

**Exposure Registries.** An exposure registry is not available for acrolein. The development of an exposure registry would provide a useful reference tool in assessing exposure levels and frequency of exposure. In addition, a registry would allow an assessment of the variations in exposure concentrations due to such variable factors as geography, season, regulatory actions, presence of hazardous waste landfills, or manufacture and use facilities. These assessments, in turn, would provide a better understanding of the needs for research or data acquisition related to current exposure levels.

### 5.7.2 On-going Studies

The U.S. Department of Energy is sponsoring a study which is being performed by R. Zinskind and J. Stoheley at Science Applications, Inc. in La Jolla, CA, to determine the concentration of acrolein in exhaust gas from diesel tractors and other vehicles (NTIS 1988). NIOSH is updating its estimates of occupational exposure in the National Occupational Exposure Survey (NOES) by taking into account additional information concerning exposure to trade name compounds. No other pertinent on-going studies were identified.