

5. POTENTIAL FOR HUMAN EXPOSURE

5.1 OVERVIEW

Vinyl acetate is released to the environment, principally to the atmosphere, as a result of emissions from manufacturing, processing, and storage facilities. Vinyl acetate partitions to the atmosphere and to surface water and groundwater. The compound is transformed by photochemical oxidation in the atmosphere, and by hydrolysis and biodegradation in surface waters, groundwater, and soils. As a result of its high vapor pressure and water solubility/hydrolysis, vinyl acetate should not bioconcentrate in terrestrial or aquatic organisms or biomagnify in food chains.

Workplace exposure via inhalation or dermal contact appears to be the most important source of human exposure to vinyl acetate. Populations living in areas surrounding hazardous waste sites may be exposed to vinyl acetate through inhalation of contaminated air and ingestion of or dermal contact with contaminated water; the latter route may be particularly important for populations living near certain types of disposal sites (e.g., underground injection sites). The relative importance of these pathways in terms of human exposure potential is difficult to establish given the limited monitoring data available for vinyl acetate. Most people, however, are probably exposed to very small, amounts of vinyl acetate through: (1) inhalation of contaminated ambient air and cigarette smoke; (2) dermal contact with products containing the compound (e.g., glues and paints); and (3) ingestion of residual vinyl acetate monomers in food (i.e., that may have migrated from plastic food wraps) or food items containing the compound as a starch modifier.

EPA had identified 1,177 NPL sites in 1989. We do not know how many of the 1,177 NPL sites have been evaluated for vinyl acetate. Vinyl acetate has been found at 3 of the total number of sites evaluated for that compound. As more sites are evaluated by EPA, this number may change (View 1989). The frequency of these sites within the United States can be seen in Figure 5-1.

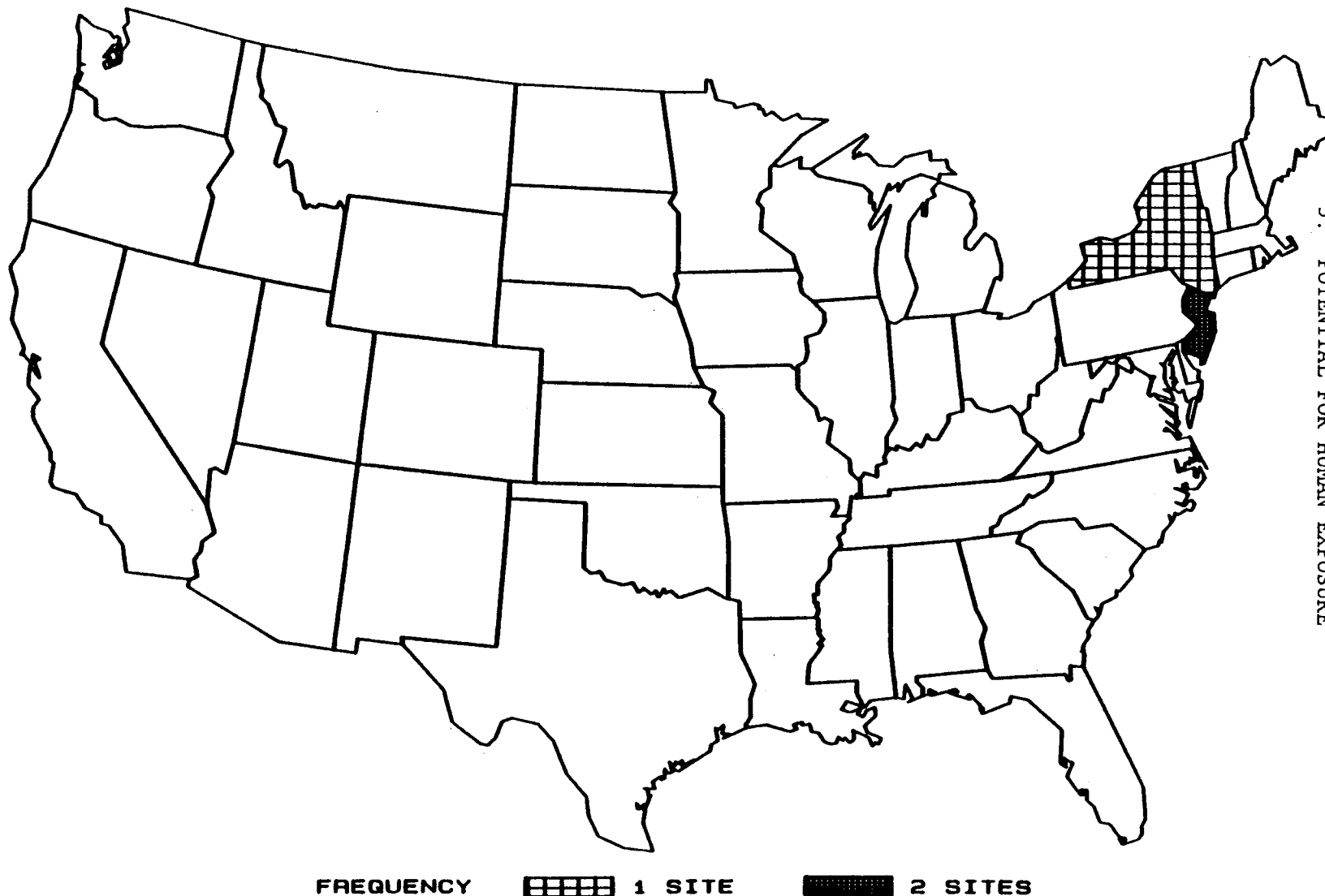
5.2 RELEASES TO THE ENVIRONMENT

Vinyl acetate is released to the environment as a result of its commercial production, use, storage, and disposal. According to the SARA Section 313 Toxics Release Inventory (TRI), an estimated total of at least 8.8 million pounds of vinyl acetate was released to the environment from manufacturing and processing facilities in the United States in 1987 (see Table 5-1) (TR187 1989). The quality of the TRI data must be viewed with caution since the 1987 data represent first-time reporting of estimated releases by these facilities. Only certain types of facilities were required to report. This is not an exhaustive list.

5.2.1 Air

Releases to the atmosphere accounted for about 75%, or 6.6 million pounds, of the estimated total environmental releases from domestic

FIGURE 5-1. FREQUENCY OF NPL SITES WITH VINYL ACETATE CONTAMINATION *



* Derived from View 1989

TABLE 5-1. Releases to the Environment from Facilities That Manufacture or Process Vinyl Acetate^a

State ^c	No. of facilities	Range of reported amounts released in thousands of pounds ^b						Off-site waste transfer
		Air	Underground injection	Water	Land	Total Environment ^d	POTW ^e transfer	
AL	4	0.1-35	0-0	0-1.7	0-0.3	0.1-37	0-0.3	0-0
CA	16	0.1-53	0-0	0-0	0-0	0.1-53	0-3.4	0-79.4
CT	1	0.5-0.5	0-0	0-0	0-0	0.5-0.5	0.8-0.8	0-0
DE	2	8.3-29	0-0	0-0.4	0-0.3	8.3-29.7	0-0.3	0-0.3
GA	8	0-5.8	0-0	0-0.3	0-30	0.1-30.3	0-5.2	0-5.8
IA	1	36-36	0-0	0-0	0-0	36-36	0-0	0-0
IL	16	0.3-96.1	0-0	0-1.3	0-1.3	0.3-96.1	0-0.3	0-19.6
IN	2	0-0.9	0-0	0-0	0-0	0-0.9	0-0	0-0
KS	2	0.1-14.4	0-0	0-0	0-0	0.1-14.4	0-0.6	0-0
KY	5	1.3-504	0-0	0-0.1	0-0.1	1.3-504	0-0.3	0-33
LA	4	0-212	0-0	0-3.5	0-0	0-215.5	0-11.1	0-0
MA	2	0.5-72.6	0-0	0-0.3	0-0	0.5-72.9	0-48	0-0.5
MD	1	14.2-14.2	No data	0-0	0-0	14.2-14.2	1.7-1.7	2-2
MI	3	0.1-40.3	0-0	0-0	0-0	0.1-40.3	0-0.3	0-10.9
MO	2	0.1-0.1	0-0	0-0	0-0	0.1-0.1	0-0	0-0.1
NC	5	0.3-20.2	0-0	0-0	0-0	0.3-20.2	0-3.9	0-0.2
NH	1	0.3-0.3	0-0	0-0	0-0	0.3-0.3	0-0	0.3-0.3
NJ	11	0.1-63.6	0-0	0-0.1	0-0.3	0.1-63.6	0-24	0-17
NY	3	0-2.5	0-0	0-0	0-0	0-2.5	0-0.5	0-0.5
OH	7	0.2-90.7	0-0	0-1.1	0-0	0.2-90.7	0-5.5	0-2
OR	2	1-1	0-0	0-0	0-0	1-1	0-0	0-0
PA	5	1-100	0-0	0-0.3	0-0.9	1-100.9	0-0.1	0-2.1
PR	2	0.7-0.7	0-0	0-0	0-0	0.7-0.7	0.1-0.1	0.1-0.1

TABLE 5-1 (Continued)

State ^c	No. of facilities	Range of reported amounts released in thousands of pounds ^b						
		Air	Underground injection	Water	Land	Total Environment ^d	POTW ^e transfer	Off-site waste transfer
SC	10	0.1-7.5	0-0	0-0.3	0-0	0.1-7.7	0-2.6	0-0.3
SD	1	0.3-0.3	0-0	0-0	0-0	0.3-0.3	0-0	0-0
TN	2	0.3-0.6	0-0	0-0	0-0	0.3-0.6	0-0.1	0-0
TX	27	0-1,873	0-1,540	0-0.3	0-0	0-1,873	0-0.3	0-128.6
VA	2	0.8-5.4	0-0	0-0	0-0	0.8-5.4	0-0.3	0-0
WI	1	0.3-0.3	No data	0-0	0-0	0.3-0.3	0-0	No Data
WV	1	64-64	No data	0-0	0-0	64-64	19-19	14-14
WY	1	0.5-0.5	No data	0-0	0-0	0.5-0.5	0-0	0-0

^aTRI87 1989

^bData in TRI are maximum amounts released by each facility. Quantities reported here have been rounded to the nearest hundred pounds, except those quantities more than 1 million pounds, which have been rounded to the nearest thousand pounds.

^cPost office state abbreviation

^dThe sum of all releases of the chemical to air, land, water, and underground injection wells by a given facility.

^ePublicly owned treatment works

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manufacturing and processing facilities in 1987, according to TRI (TR187 1989).

The industrial organic chemicals, plastic materials and resins, paints and allied products, and commercial printing industries have been identified as potential sources of atmospheric releases of vinyl acetate (EPA 1987d). Emission factors for volatile organic compounds (VOCs) and nonmethane hydrocarbons (NMHCs) have been developed for vinyl acetate production via the ethylene vapor-phase process. Emissions of VOCs from uncontrolled sources (excluding fugitive emission sources) in a typical vinyl acetate production plant have been estimated to total about 176 kg/hour; this estimate includes about 36 kg/hour from vinyl acetate storage facilities (Dylewski 1980). Fugitive emissions from valves and pump seals contribute an estimated additional 0.0021 kg NMHC/hour and 0.0020 kg NMHC/hour, respectively (Langley et al. 1981).

5.2.2 Water

Vinyl acetate has been detected in groundwater samples taken at an estimated 0.71% of the NPL hazardous waste sites that have had samples analyzed in the Contract Laboratory Program (CLP) at a geometric mean concentration of 10 ppb for the positive samples (CLPSD 1989). The compound was not detected in surface water samples at NPL sites participating in the CLP. Note that these data from the CLP Statistical Database represent frequency of occurrence and concentration information for NPL sites only.

According to TRI (TR187 1989), an estimated total of at least 10,000 pounds of vinyl acetate were released to surface waters in 1987 from domestic manufacturing and processing facilities; an additional 147,219 pounds were released in effluents to publicly owned treatment works (POTWs).

Vinyl acetate has been detected in waste water from a polyvinyl acetate production facility at a concentration of 50 mg/L (Stepanyan et al. 1970)

5.2.3 Soil

Vinyl acetate has been detected in soil samples taken at an estimated 2.13% of the NPL hazardous waste sites included in the CLP at a geometric mean concentration of 19.5 ppb for the positive samples (CLPSD 1989). Note that these data from the CLP Statistical Database represent frequency of occurrence and concentration information for NPL sites only.

According to the TRI, an estimated total of at least 33 thousand pounds of vinyl acetate were released to soils in 1987 from domestic manufacturing and processing facilities; an additional 2.1 million pounds were released by underground injection (TR187 1989).

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5.3 ENVIRONMENTAL FATE

5.3.1 Transport and Partitioning

No information was found in the available literature regarding the transport and partitioning of vinyl acetate in environmental media. However, estimates of the movement of the compound between the air, water, and soil compartments following release to the environment can be made on the basis of available physical and chemical property data.

Vinyl acetate is a volatile compound that is released mainly to the atmosphere. Vinyl acetate is also highly soluble in water. Therefore, dissolution of vinyl acetate released to the atmosphere in rainwater and transport of the compound back to surface waters and soils in wet deposition can be expected.

Using the vapor pressure and water solubility data presented in Table 3-2, a Henry's law constant value of 4.8×10^{-4} atm-m³ mol⁻¹ can be calculated. The magnitude of this value indicates that volatilization to the atmosphere will be an important transport process for vinyl acetate released to surface waters. Using this value and the methods reviewed by Thomas (1982), a volatilization half-life of about 4 hours at 20°C can be estimated for a river 1 meter deep flowing at a current of 1 m/second, with a wind velocity of 3 m/second.

Vinyl acetate released to surface soils is also expected to volatilize to the atmosphere. Releases of vinyl acetate to subsurface soils may leach to and be transported in groundwater, depending upon site-specific hydrogeological conditions, if the compound is not transformed or degraded (Section 5.3.2.2). Sorption of the compound to soils and sediments is not expected, given its high water solubility and low K_{oc} value.

The log octanol/water partition coefficient for vinyl acetate has been reported to be 0.21 (Fujisawa and Masuhara 1981) and 0.73 (Howard 1989). The magnitude of these values indicates that bioconcentration and food chain biomagnification will not be important processes for vinyl acetate.

5.3.2 Transformation and Degradation

5.3.2.1 Air

Vinyl acetate does not absorb ultraviolet light at wavelengths longer than 250 nm (Daniels 1983), therefore, direct photolytic degradation of the compound in the troposphere is not expected to occur. However, vinyl acetate has been found to undergo rapid photochemical oxidation and polymerization in laboratory studies in the absence of inhibitor (HSDB 1989). The average second order rate constant for reaction with singlet molecular oxygen has been reported to be $0.82 \text{ L mole}^{-1} \text{ sec}^{-1}$ (Datta and Rao 1979). In smog chamber

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studies with NO_x concentrations representative of rural and urban atmospheres, the photooxidation half-life of vinyl acetate was determined to be 4.1-6.5 hours (Joshi et al. 1982).

5.3.2.2 Water

Vinyl acetate undergoes hydrolysis in surface water and groundwater. The hydrolytic half-life of the compound at 25°C and pH 7.0 has been estimated to be 7.3 days (Mabey and Mill 1978). Decreasing pH decreases the hydrolysis rate; for example, the rate is minimal at pH 4.4 (Daniels 1983). Acetic acid and acetaldehyde are the main products of vinyl acetate hydrolysis (Daniels 1983; Stuckey et al. 1980).

Vinyl acetate also undergoes biologically-mediated transformation. The results of several older laboratory studies with aqueous solutions of the compound suggest the occurrence of biodegradation by domestic sewage effluent microorganisms both under aerobic (Pahren and Bloodgood 1961; Price et al. 1974) and anaerobic (Chou et al. 1979; Stuckey et al. 1980) conditions. In a more recent laboratory study, 17 isolates of bacteria and yeasts, capable of utilizing vinyl acetate as a sole carbon source under aerobic conditions, were obtained from samples of domestic sewage and loamy soil. Microorganisms contained in a sludge inoculum were also found to be capable of biotransforming vinyl acetate under anaerobic conditions. Under both aerobic and anaerobic conditions, enzymatic hydrolysis of vinyl acetate yielded acetaldehyde as a metabolic intermediate and acetate as an end product, although the reaction was more rapid under aerobic conditions. A half-life of 12 hours was obtained for the enzymatic hydrolysis utilizing one of the bacterial isolates under aerobic conditions, whereas, the half-life for the nonenzymatic hydrolysis of the compound in a sterile medium was found to be 60 hours (Nieder et al. 1990).

5.3.2.3 Soil

In soils, vinyl acetate is also expected to be transformed by hydrolysis and biotransformation. The rate of hydrolysis should increase as soil moisture content and pH increase. As described in Section 5.3.2.2, microbial isolates obtained from a loamy soil were found to be capable of utilizing vinyl acetate as a sole carbon source under aerobic conditions (Nieder et al. 1990). Metabolism studies utilizing one of the bacterial isolates indicated that vinyl acetate was transformed via enzymatic hydrolysis to acetaldehyde and acetate. The half-life for this biologically-mediated hydrolysis was found to be about one-fifth that of the nonenzymatic hydrolysis of the compound (12 versus 60 hours).

Aqueous solutions containing 4.5 g/L of polyvinyl acetate have been reported to undergo biotransformation by the soil fungi Aspergillus niger and Penicillium following incubation for 15 days at 22°-25° C (Garcia 1988). Polyvinyl acetate was the sole carbon source in the test media. Evidence of

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biotransformation included increased biomass of the fungi and increased esterase levels in the media.

5.4 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

5.4.1 Air

Despite large releases of vinyl acetate to the atmosphere, data on ambient air levels are limited to a single report from Texas City, Texas (Houston/Gulf Coast area), of concentrations of 0.07-0.57 ppm (Gordon and Meeks 1975). Note that these values should not be considered to represent typical ambient air concentrations, since a number of the manufacturers of vinyl acetate are located in Texas City (see Section 4.1). The compound has also been detected in air samples taken at the Kin-Buc waste disposal site located near Edison, New Jersey at a concentration of 0.5 $\mu\text{g}/\text{m}^3$ (0.00014 ppm) (Pellizzari 1982).

5.4.2 Water

No information was found in the available literature regarding concentrations of vinyl acetate in domestic surface waters or groundwaters. Available groundwater monitoring data for NPL sites are reported in Section 5.2.2.

5.4.3 Soil

No information was found in the available literature regarding concentrations of vinyl acetate in domestic soils. Available soil monitoring data for NPL sites are reported in Section 5.2.3.

5.4.4 Other Environmental Media

Available monitoring data for other environmental media are limited to reports of vinyl acetate as a constituent of the vapor phase of cigarette smoke at concentrations of 400 ng/cigarette (Guerin 1980) and 0.5 $\mu\text{g}/\text{puff}$ (Battista 1976).

5.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

Human exposure to vinyl acetate is most well defined for workplace populations. The National Occupational Exposure Survey (NOES), conducted by NIOSH from 1980-1983, estimated that 50,282 workers employed at 5,046 plant sites were potentially exposed to vinyl acetate in the United States in 1980 (NIOSH 1990b). The NOES database does not contain information on the frequency, concentration, or duration of exposure; the survey provides only estimates of workers potentially exposed to chemicals in the workplace.

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Workers involved in the production, storage, processing, and transport of vinyl acetate are exposed primarily via inhalation-of vapors and skin and eye contact with the liquid or vapor forms of the compound (NIOSH 1978). Workplace air concentration levels reviewed by NIOSH (1978) were generally within the recommended 15-minute ceiling limit of 4 ppm. In another survey of vinyl acetate production facilities in Texas, the following workplace airborne concentrations were reported: average TWA concentrations--5.2-8.2 ppm; average breathing zone concentrations--8.6 ppm; intermittent exposure concentrations --about 50 ppm; and potential short-term exposures--up to 300 ppm (Deese and Joyner 1969).

Monitoring data are insufficient to establish ambient levels of vinyl acetate in environmental media. However, the compound has fairly limited residence times in environmental media as a result of its reactivity (see Section 5.3.2). Contaminated environmental media may be important sources for populations living in the vicinity of continuous emission point sources, such as industrial manufacturing, processing, storage, or disposal sites (e.g., underground injection sites), or hazardous waste sites.

Although few monitoring data exist, given the high production volume and extensive use of vinyl acetate, most people are probably exposed to very small amounts of vinyl acetate through: (1) inhalation of contaminated ambient air and cigarette smoke; (2) inhalation, dermal contact, or ingestion of residual monomers in consumer products containing polyvinyl acetate (e.g., paints, adhesives, chewing gum); and (3) ingestion of food items packaged in plastic films containing vinyl acetate.

Inhalation is expected to be the main route of human exposure to the hydrolysis product of vinyl acetate, acetaldehyde. Acetaldehyde has a high vapor pressure and is miscible with water. It rapidly volatilizes (e.g., half-life in river water = 1.9 hours) from surface waters or soils to the atmosphere, where it is transformed via photolysis and reaction with hydroxyl radicals, with a half-life on the order of hours. The high water solubility of the compound suggests that releases to subsurface soil, or to surface soil that do not volatilize, will partition to soil water and possibly groundwater unless degraded by aerobic and anaerobic microorganisms. Acetaldehyde does not sorb to soils or sediments, or bioconcentrate/biomagnify in terrestrial or aquatic organisms/food chains. Acetaldehyde is a natural constituent of foods (HSDB 1991).

5.6 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

Workers involved in the production, processing, storage, and transport of vinyl acetate are potentially exposed to high concentrations of the compound. Members of the general population living in the vicinity of industrial point emission sources, and individuals living near waste sites that are contaminated with vinyl acetate may also be exposed to potentially high concentrations of the compound. The sizes of these populations and the

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concentrations of vinyl acetate in the contaminated media to which these people may be exposed have not been adequately characterized.

5.7 ADEQUACY OF THE DATABASE

Section 104(i)(5) of CERCLA, as amended, 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 vinyl acetate 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 vinyl acetate.

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 Data Needs

Physical and Chemical Properties. The physical/chemical properties of vinyl acetate are sufficiently well defined to enable assessment of the environmental fate of this compound (Tables 3-1 and 3-2).

Production, Import/Export, Use, and Disposal. Vinyl acetate is released to the environment as a result of its commercial production, use, storage, transport, and disposal. Human exposure occurs mainly in the workplace through inhalation of vinyl acetate vapors.

Domestic production of vinyl acetate in 1986 and 1987 totaled 1.7 billion pounds and 1.8 billion pounds, respectively (Daniels 1983; USITC 1986, 1987). These levels are slightly lower than the recent high of 2.1 billion pounds reported in 1985 (Daniels 1983; USITC 1985). In 1987, imports and exports of the compound totaled 1 million and 736 million pounds, respectively (Mannsville 1988). Vinyl acetate is used primarily as a chemical intermediate in the production of polymeric materials (Daniels 1983; IARC 1986; Mannsville 1982, 1988). Vinyl acetate is contained in polymeric consumer products only as residual monomer (Cincera 1983; IARC 1986; Mannsville 1988). Releases of the compound from industrial processes are mainly to the atmosphere. Underground injection is also an important source of release for certain facilities. No information was found on current disposal methods or the regulations governing disposal of vinyl acetate.

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Additional information on disposal methods and pertinent regulations would be useful in evaluating the potential for release of and exposure to vinyl acetate.

According to the Emergency Planning and Community Right-to-Know Act of 1986, 42 U.S.C. Section 11023, industries are required to submit chemical release and off-site transfer information to the EPA (EPA 1987c). The Toxics Release Inventory (TRI), which contains this information for 1987, became available in May of 1989 (TR187 1989). This database will be updated yearly and should provide a list of industrial production facilities and emissions.

Environmental Fate. Little information is available regarding the transport and partitioning or transformation and degradation of vinyl acetate. Based on its physical/chemical properties, vinyl acetate is expected to partition to the atmosphere and surface water and groundwater (Fujisawa and Masuhara 1981; Hansch and Leo 1979). Vinyl acetate is not expected to persist, bioconcentrate, or biomagnify (Fujisawa and Masuhara 1981; Hansch and Leo 1979). The most important transformation processes for vinyl acetate are photooxidation and hydrolysis (Joshi et al. 1982; Mabey and Mill 1978); the relative importance of biodegradation is unknown (Chou et al. 1979; Pahren and Bloodgood 1961; Price et al. 1974; Stuckey et al. 1980). Additional information is needed on the transport/partitioning and transformation/degradation of vinyl acetate in all media in order to confirm the predicted behavior described above and establish the relative importance of the various transformation processes. This information will be helpful in defining the relative importance of various routes of exposure to the compound in environmental media.

Bioavailability from Environmental Media. No information was found regarding human absorption of vinyl acetate following inhalation, oral, or dermal exposures from environmental media. Limited data available for laboratory animals suggest that absorption may occur following exposure by all of these routes (Hazleton 1979a, 1980a; Smyth and Carpenter 1948; Weil and Carpenter 1969). Additional information is needed on the uptake of vinyl acetate following inhalation of workplace and ambient air, dermal contact with or ingestion of contaminated soils, and ingestion of contaminated drinking water. This information would be useful in determining the bioavailability of the compound from environmental media.

Food Chain Bioaccumulation. No information was found regarding the bioconcentration of vinyl acetate by plants, aquatic organisms, or animals, or the biomagnification of the compound in terrestrial or aquatic food chains. On the basis of the reactivity, volatility, and water solubility of the compound, bioconcentration and biomagnification are not expected to be important environmental fate processes (Fujisawa and Masuhara 1981; Hansch and Leo 1979). Additional information is needed to confirm this predicted

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behavior. This information will be useful in establishing the importance of food chain bioaccumulation as a source of human exposure to vinyl acetate.

Exposure Levels in Environmental Media. Very limited data are available concerning ambient concentrations of vinyl acetate in the atmosphere (Gordon and Meeks 1975). No data are available for surface waters, groundwater, or soils. Additional information is needed on ambient levels in these media, including media concentration levels at hazardous waste sites, and on human intake through contact with these media and ingestion of contaminated foods. This information would be useful in estimating human exposure to vinyl acetate.

Exposure Levels in Humans. Vinyl acetate is rapidly hydrolyzed by esterases in the blood to acetate and vinyl alcohol. Vinyl alcohol is rapidly converted to acetaldehyde, which in turn is metabolized to acetate (Hazleton 1979a, 1980a; Simon et al. 1985). Vinyl acetate metabolism is rapid; in vivo tests with laboratory animals indicate that most of the compound is eliminated within 24 hours after exposure (Hazleton 1979a, 1980a). Therefore, it would be difficult to measure the presence of vinyl acetate or acetaldehyde after reasonable periods following exposure to vinyl acetate. Acetaldehyde and acetate may also not be useful as indicators of vinyl acetate exposure. Because these compounds are incorporated into normal metabolic pathways, it would be difficult to determine which metabolites were due to vinyl acetate exposure and which were endogenous in biological tissues and fluids. Additional investigation of the utility of biomarkers of exposure in characterizing human exposure to vinyl acetate would be useful.

Exposure Registries. No exposure registries for vinyl acetate were located. This compound is currently not one of the compounds for which a subregistry has been established in the National Exposure Registry. The compound will be considered in the future when chemical selection is made for subregistries to be established. The information that is amassed in the National Exposure Registry facilitates the epidemiological research needed to assess adverse health outcomes that may be related to the exposure to this compound.

5.7.2 On-going Studies

On-going remedial investigations and feasibility studies conducted at NPL sites will add to the available database on exposure levels in environmental media and exposure registries.

No other long-term on-going research pertaining to environmental fate or human exposure potential of vinyl acetate was identified or located.