

5. POTENTIAL FOR HUMAN EXPOSURE

5.1 OVERVIEW

Propylene glycol is released to the environment in manufacturing and processing waste streams and as the result of disposal of industrial and consumer products containing this compound. The major sources of releases are from the use and disposal of this compound in de-icing solutions. Because of its solubility in water and lack of adsorption and partitioning to soils, propylene glycol will have high mobility in soil and potential to leach into groundwater. Upon release to the environment, the compound is expected to partition to and be transported in surface water and groundwater. Propylene glycol is rapidly degraded in all environmental media; it is not expected to persist or bioaccumulate in aquatic organisms.

Biodegradation is the most important transformation process in surface waters and soils. Assuming first order kinetics, the half-life of propylene glycol in water is estimated to be 1-4 days under aerobic and 3-5 days under anaerobic conditions. The half-life of propylene glycol in soil is expected to be equal to or slightly less than that for water. Vapors released to the atmosphere readily undergo rapid photochemical oxidation via reaction with hydroxyl radicals with an estimated half-life of 0.8 days. Little information was found on concentrations of this compound in any environmental media. Propylene glycol is a Generally Recognized as Safe (GRAS) food additive that is widely used in food and tobacco products, pharmaceuticals, and cosmetics.

The most important routes of exposure to propylene glycol for members of the general population are ingestion and dermal contact with products containing this compound. The general public also may be exposed to small amounts of propylene glycol released from newly installed carpet with polyvinyl backing. In occupational settings, workers are exposed via dermal contact and possibly inhalation in applications involving the heating or spray application of fluids containing this compound.

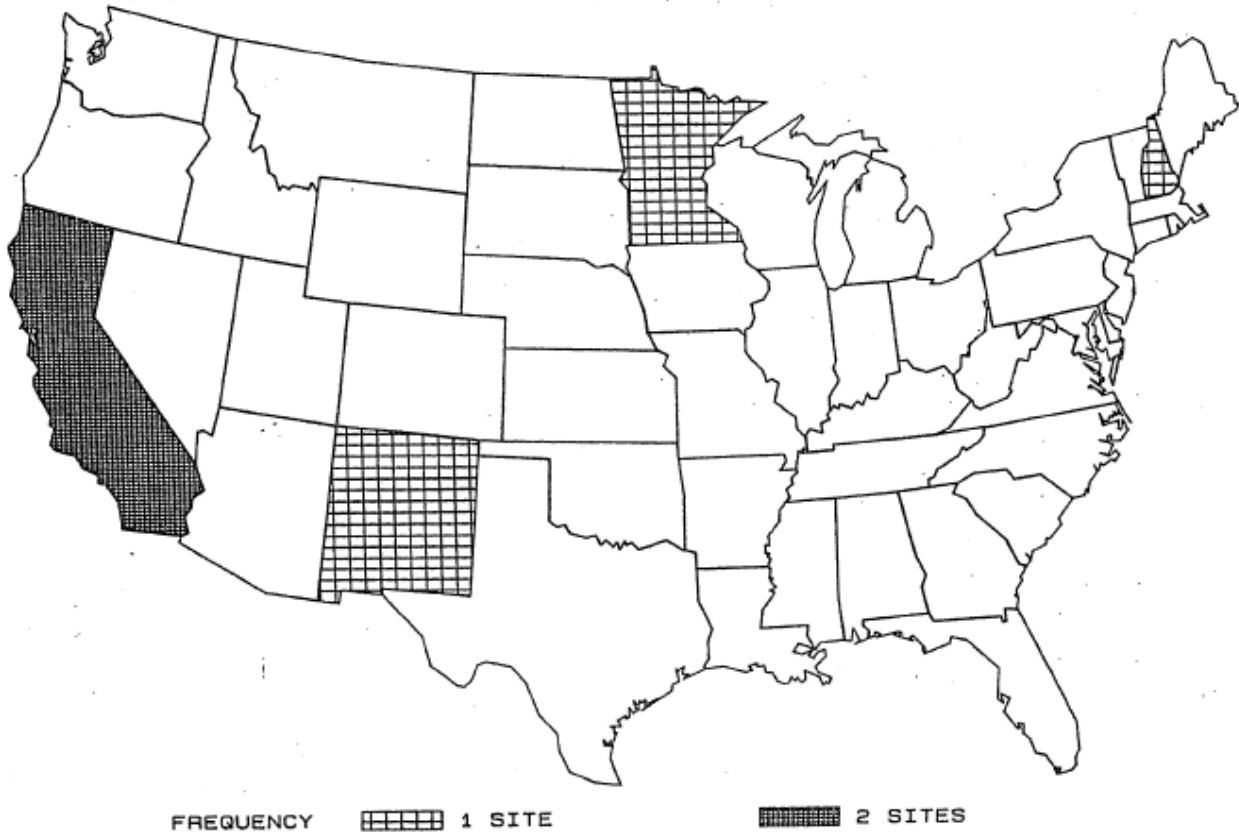
Propylene glycol has been identified in at least 5 of 1,416 hazardous waste sites that have been proposed for inclusion on the EPA NPL (HazDat 1995). However, the number of sites evaluated for propylene glycol is not known. The frequency of these sites within the United States can be seen in Figure 5-1.

5.2 RELEASES TO THE ENVIRONMENT

Releases of propylene glycol are not required to be reported under SARA Section 313; consequently there are no data for this compound in the 1993 Toxic Release Inventory (EPA 1995c). There are at least 5 NPL

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Figure 5-1. Frequency of NPL Sites with Propylene Glycol Comtamination*



*Derived from HazDat 1995

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hazardous waste sites where propylene glycol has been identified in some environmental media (HazDat 1995).

5.2.1 Air

Little information was found regarding the release of propylene glycol to the atmosphere. Propylene glycol used as a solvent in paints, inks, and coatings will slowly volatilize to the atmosphere (EPA 1987a). During the application of de-icing solutions to aircraft, an estimated 49-80% of de-icing solutions containing both ethylene glycol and propylene glycol are released on airport runway aprons. The remainder is retained on the aircraft or is immediately dispersed to the air (Sills and Blakeslee 1992); however, release to the atmosphere is expected to be limited by the compound's low vapor pressure.

There is no information on releases of propylene glycol to the atmosphere from domestic manufacturing and processing facilities because these releases are not required to be reported (EPA 1995c). Propylene glycol has not been detected in air samples collected at any hazardous waste sites where it was detected in some environmental media (HazDat 1995).

5.2.2 Water

Propylene glycol is released to surface waters in waste water from production and processing facilities and from spills and in runoff (e.g., through the use of the compound in de-icing fluids). Propylene glycol concentrations up to 19,000 mg/L (ppm) were detected in storm water runoff at the Salt Lake City Airport in Utah (Sills and Blakeslee 1992). Propylene glycol was detected, but the concentration was not quantified in effluents from a chemical manufacturing plant in Memphis, Tennessee (EPA 1976). Propylene glycol may also be released to surface waters as a metabolite of propylene glycol dinitrate which is a military propellant found in waste water streams from munitions facilities (EPA 1979, 1987a; Kaplan et al. 1982; Walker and Kaplan 1992).

There is no information in the Toxic Release Inventory (TRI) on releases of propylene glycol to surface or groundwater from domestic manufacturing and processing facilities because these releases are not required to be reported (EPA 1995c).

Groundwater samples collected from a perched water table at the Ottawa Airport in Canada contained 4 mg/L (ppm) of propylene glycol (Sills and Blakeslee 1992). Propylene glycol also has been detected in

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groundwater samples collected at two hazardous waste sites where it was detected in various environmental media (HazDat 1995).

5.2.3 Soil

The major sources of propylene glycol releases to soil are the disposal of used antifreeze fluids and de-icing fluids containing the compounds (EPA 1979, 1987a).

There is no information in the TRI on releases of propylene glycol to soil from domestic manufacturing and processing facilities because these releases are not required to be reported (EPA 1995c). Propylene glycol has not been detected in any soil samples collected at hazardous waste sites although it has been detected in other environmental media (HazDat 1995).

5.3 ENVIRONMENTAL FATE

5.3.1 Transport and Partitioning

Propylene glycol has a low vapor pressure (0.07 mm Hg at 20 °C) and is miscible with water (see Table 3-2). If released to the atmosphere (e.g., as vapors generated at elevated temperatures), propylene glycol should exist almost entirely in the vapor phase (Eisenreich et al. 1981). The high solubility of propylene glycol in water ensures at least partial removal of the compound will occur by wet deposition (EPA 1987a). Therefore, upon release to the environment, the compound is expected to be transported primarily in aqueous media (EPA 1979). The low Henry's law constant values for the compound (1.2×10^{-8} to 1.7×10^{-8} atm-m³/mole range; see Table 3-2) suggest that releases to surface water will not partition to the atmosphere via volatilization (Simmons et al. 1976; Thomas 1990). Adsorption to sediment or soil particulates is also not expected to be significant on the basis of the low K_{oc} value (see Table 3-2).

Based on the low K_{oc} value, propylene glycol is expected to have a very high mobility in soil and could leach into groundwater (Swarm et al. 1983). The low octanol/water partition coefficient (K_{ow}) (see Table 3-2) suggests that bioconcentration and biomagnification are also not likely to occur. No measured BCF values were located for this compound.

Propylene glycol is expected to be highly mobile in moist soils and may leach to groundwater upon release to surface soils; however, rapid biodegradation is expected to limit the extent of the leaching (see

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Section 5.3.2) (EPA 1987a). The compound may also volatilize from dry surface soils (EPA 1979, 1987a; Hine and Mookerjee 1975).

5.3.2 Transformation and Degradation

5.3.2.1 Air

Propylene glycol released to the atmosphere is expected to undergo rapid photochemical oxidation via reaction with hydroxyl radicals. The half-life for the photochemical oxidation of propylene glycol has been estimated to be 20-32 hours (EPA 1987a; Howard et al. 1990).

5.3.2.2 Water

Biodegradation by a variety of acclimated and unacclimated microorganisms, under both aerobic and anaerobic conditions, is the most important transformation process for propylene glycol in surface waters. The half-lives for the biotransformation of propylene glycol generally range from 1 to 4 days under aerobic conditions and from 3 to 5 days under anaerobic conditions (EPA 1987a).

Propylene glycol rapidly disappears from culture flasks containing activated sludge microorganisms under both aerobic and anaerobic conditions (Kaplan et al. 1982). Some propylene glycol was lost from sterile cultures after 9 days. An 8% and 16% loss of propylene glycol was observed in sterile anaerobic and aerobic cultures, respectively. In active cultures, propylene glycol was not detected after 2 days in aerobic nutrient broth. When used as a sole carbon source, propylene glycol disappeared after 4 days under aerobic and 9 days under anaerobic conditions. Raja et al. (1991) reported a novel biotreatment process using *Pseudomonas* and *Aerobacter* bacteria. The *Pseudomonas* were able to use the propylene glycol to produce volatile acids, while *Aerobacter* degraded the volatile acids quickly to carbon dioxide and water.

Propylene glycol is not expected to undergo significant abiotic transformation in surface waters via hydrolysis or oxidation (EPA 1979, 1987a). Glycols generally are resistant to hydrolysis (Harris 1990). For example, the half-life for reaction of propylene glycol with hydroxyl radicals in aqueous solution has been estimated to be 1.3-2.3 years (Harris 1990).

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5.3.2.3 Sediment and Soil

Biodegradation by a variety of microorganisms under both aerobic and anaerobic conditions is the most important transformation process for propylene glycol in soils, with half-lives similar to or less than those in surface waters (EPA 1987a). The soil microbe *C. glycolicum* degraded propylene glycol under anaerobic conditions to acid and alcohol end products (Gaston and Stadtman 1963). Ouattara et al. (1992) reported anaerobic degradation of propylene glycol by strains of the sulfate-reducing bacteria *Desulfovibrio* isolated from anoxic soil of a rice field. Propylene glycol was degraded to acetate in the presence of sulfate with the production of carbon dioxide. The rates of biodegradation of propylene glycol in soils are significantly dependent on substrate concentrations, soil types, and ambient soil temperatures, but nutritional supplements had minimal effects (Klecka et al. 1993). Generally, the rate of propylene glycol biodegradation was faster in soils with low glycol concentrations, high organic carbon content, and higher ambient soil temperatures (in the range of -2-25 °C). Propylene glycol present in soils at concentrations <6,000 mg/kg (ppm) biodegraded at an average rate of 2.3 mg/kg soil/day at -2 °C, 27.0 mg/kg (ppm) soil/day at 8 °C and at an average rate of 93.3 mg/kg (ppm) soil/day at 25 °C (Klecka et al. 1993). Based on these results, biodegradation is expected to play a major role in removing propylene glycol residues from soils adjacent to airport runways and taxiways.

As in surface waters, abiotic transformation of propylene glycol in soil is not expected to be a significant process (EPA 1987a).

5.4 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT**5.4.1 Air**

No information was located on the concentration of propylene glycol in the ambient atmosphere. Propylene glycol was detected in air samples collected in a large scale environmental chamber analyzing volatile organic emissions. Quasi-steady-state emission rates of the propylene glycol at 24 hours and 168 hours after the start of the experiment were 690 $\mu\text{g}/\text{m}^2/\text{hour}$ and 193 $\mu\text{g}/\text{m}^2/\text{hour}$, respectively from newly installed carpet with polyvinylchloride backing (Hodgson et al. 1993).

5.4.2 Water

Available information on the environmental impact of de-icing solutions on airport storm water runoff has been summarized in a recent review article by Sills and Blakeslee (1992). Monitoring data from several

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contractor and airport authority reports reveal that storm water runoff from airports may contain several hundred to several thousand mg/L (ppm) glycols. Propylene glycol levels up to 19,000 mg/L (ppm) were detected in storm water from the Salt Lake City International airport. Although the potential for groundwater contamination is quite low for many airports with predominantly heavy soil, the movement of glycols through unsaturated silty sand can be potentially high (Sills and Blakeslee 1992). At the Ottawa International Airport in Canada, groundwater in the perched water table, which contained sandy soil, was found to contain propylene glycol at levels up to 4 mg/L (ppm). Peak concentrations occurred in June and declined to nondetectable levels by the fall.

5.4.3 Sediment and Soil

No information was found on soil concentrations of propylene glycol.

5.4.4 Other Environmental Media

Propylene glycol has been identified in negligible amounts in the water-soluble component of cigarette smoke (Schumacher et al. 1977).

Propylene glycol has also been found to migrate into a number of foods from regenerated cellulose films containing the compound as a softening agent. The compound was detected in chocolates at 20-1,460 mg/kg (ppm) after 5.5 months of storage and at 25-1,890 mg/kg (ppm) after 15 months, in fruit cakes at 10-154 mg/kg (ppm) after 84-336 days of storage, in meat pies at <10-118 mg/kg (ppm) after 3-7 days of storage, in toffee at <10-1,530 mg/kg (ppm) after 168-450 days of storage, in madeira cake at <10-365 mg/kg (ppm) after 2 1-28 days storage, and in boiled sweets at <10-272 mg/kg (ppm) after 168-450 days storage (Castle et al. 1988a).

Propylene glycol is also used in some cosmetic and oral drug formulations and is a GRAS additive in foods (FDA 1982), where it is used as an emulsifying and plasticizing agent, humectant, surfactant, and solvent. Propylene glycol is added to foods at concentrations ranging from <0.001% in eggs and soups to up to 97% in seasonings and flavors (EPA 1979). Propylene glycol is a naturally occurring by-product in the fermentation of some beers and has been detected in the concentration range of 1.0-51.0 mg/L (ppm) in several commercially packaged beers (Williamson and Iverson 1993).

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5.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

The general population is exposed to propylene glycol primarily through ingestion of food and pharmaceutical products and through dermal contact with cosmetic products containing the compound (EPA 1979, 1987a). The average daily dietary intake of propylene glycol in Japan, where the compound is used as a food additive stabilizer, was estimated to be 43 mg per person in 1982 (Louekari et al. 1990). Public school children and the general public who participate in fire fighting exercises/demonstrations where propylene glycol is used to simulate fire conditions are exposed to small amounts of propylene glycol (Rossol 1993). The general public is exposed to low concentrations of propylene glycol mist from propylene glycol-containing theatrical fog/smoke used in producing special effects during theatrical performances, rock concerts, and private parties (Rossol 1993). The general public is also exposed to small concentrations of propylene glycol from carpets with polyvinyl chloride backing. The quasi-steady-state specific emission rate of propylene glycol from these carpets was calculated to be 690 $\mu\text{g}/\text{m}^2/\text{hour}$ at 24 hours and 193 $\mu\text{g}/\text{m}^2/\text{hour}$ at 168 hours after carpet installation (Hodgson et al. 1993). NOSH estimated that about 2.5 million individuals were potentially exposed to propylene glycol in the workplace in 1970; the estimate for 1980 was 80,200 workers (HSDB 1995b). Dermal contact is expected to be the main route of worker exposure; however, inhalation of vapors or mists may also occur when the compound is heated, agitated, or sprayed (e.g., in de-icing formulations) (Rowe and Wolf 1982).

5.6 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

Workers in industries involved in the manufacture or use of products containing high concentrations of propylene glycol (e.g., antifreeze, coolants, de-icing fluids, brakes fluids, solvents) may be exposed to concentrations of the compounds at levels higher than the general population, particularly in operations involving heating or spraying of these materials. Performers and workers in theatrical productions that use propylene glycol-containing fog/smoke for special effects are likely to be exposed to higher concentrations of propylene glycol than the general population (Rossol 1993). Fire fighters who participate in frequent fire-fighting exercises involving propylene glycol fog/smoke may also belong to the high exposure group (Rossol 1993).

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 propylene glycol is available. Where adequate information

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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 propylene glycol.

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 the uncertainties of human health assessment. This definition should not be interpreted to mean that all data needs discussed in this section must be filled. 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. As seen in Table 3-2, the relevant physical and chemical properties of propylene glycol are known (ASTER 1995b; Daubert and Danner 1989; EPA 1987a; HSDB 1995b; Merck 1989). No further information is required.

Production, Import/Export, Use, Release, and Disposal. Production data are available for propylene glycol (SRI 1989, 1991, 1993, 1995). Similarly, data on the import/export volumes for propylene glycol for the last several years are available (NTDB 1995). Information on the various uses of this compound are also available (EPA 1987a; HSDB 1995b; Lewis 1993; Merck 1989; Rowe and Wolf 1982). Propylene glycol enters the environment primarily during its use as an intermediate in the synthesis of polyester fibers and resins, as a component of automotive antifreeze/coolants, and as a de-icing fluid for aircraft (Kirk-Othmer Encyclopedia of Chemical Technology 1978; Klecka et al. 1993; Lewis 1993; Merck 1989; Rowe and Wolf 1982). Propylene glycol is also used in pharmaceutical products, hair colorant formulations, food and tobacco products, as a non-toxic antifreeze in the food industry, as an air sterilant in hospitals or animal facilities, and as a special effects fog/smoke in theatrical performances or in fire training programs (Kirk-Othmer Encyclopedia of Chemical Technology 1978; Klecka et al. 1993; Merck 1989; Rossol 1993; Rowe and Wolf 1982). Information regarding the disposal of propylene glycol containing waste waters (Chou et al. 1979; Raja et al. 1991) and for remediation of propylene glycol contaminated soils (Drajun 1991; Vesper et al. 1994) is available.

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. The Toxics Release Inventory (TRI), which contains this information for 1988-1993, became available in

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May of 1995. This database will be updated yearly and should provide a list of industrial facilities and emissions. No TRI data are available for propylene glycol because this chemical is not required to be reported by chemical producers (EPA 1995c).

Environmental Fate. Information regarding the fate of propylene glycol in the air is available that suggests the compound would be primarily found in the vapor phase and would likely be removed from the atmosphere via wet deposition (Eisenreich et al. 1981; EPA 1979, 1987a). Propylene glycol undergoes rapid photochemical oxidation via reaction with hydroxyl radicals with an estimated half-life of 20 hours in the atmosphere (EPA 1987a). Because of its high solubility in water, the compound is expected to be transported primarily in aqueous media and will not partition to the atmosphere via volatilization from water (EPA 1979, 1987a; Thomas 1990). Adsorption to sediment or soil particles is not expected to be significant based on the low K_{oc} value and therefore propylene glycol is expected to have a high mobility in soil and potential to leach into groundwater (Swarm et al. 1983). Propylene glycol is transformed in both water and soil by microorganisms (EPA 1987a; Gaston and Stadtman 1963; Klecka et al. 1993). The half-lives for the biotransformation of propylene glycol in surface waters generally range from 1 to 4 days under aerobic conditions and from 3 to 5 days under anaerobic conditions, with half-lives in soil similar to or less than those in surface waters (EPA 1987a). No additional information on degradation of propylene glycol in air or water are required; however, additional quantitative information on the degradation of propylene glycol in soil would be useful.

Bioavailability from Environmental Media. Available information regarding the rate of propylene glycol absorption following inhalation, oral, or dermal contact has been discussed in the Toxicokinetics section (see Section 2.3). Although no data on propylene glycol's bioavailability from contaminated air are available, the bioavailability from inhalation exposure is expected to be high because propylene glycol is likely to be present in the vapor phase (Eisenreich et al. 1981) and not in the particulate phase in the adsorbed state. Similarly, no data on the bioavailability of propylene glycol from water, soil or plant material are available; however, propylene glycol is readily miscible in water and does not adsorb readily to soil. Propylene glycol, therefore, is expected to be readily bioavailable from soil and water. Information on the bioavailability of propylene glycol from actual environmental media is not required as propylene glycol is a GRAS chemical (FDA 1982).

Because the FDA (1982) has classified propylene glycol as a GRAS chemical, no monitoring data for concentrations of propylene glycol in contaminated media at hazardous waste sites are needed to assess the potential risk of adverse health effects in populations living in the vicinity of hazardous waste sites.

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Food Chain Bioaccumulation. Based on its low K_{oc} value, propylene glycol is not expected to bioconcentrate in aquatic food chains; however, no measured BCF values were located for any invertebrate or fish species. Information is also lacking regarding the biomagnification potential of propylene through aquatic food chains although it is unlikely because of the rapid degradation rate for the chemical in aquatic systems. No further information on the bioconcentration or biomagnification potential of propylene glycol is required as it is a GRAS chemical (FDA 1982).

Exposure Levels in Environmental Media. No information was located on the concentration of propylene glycol in ambient air. Propylene glycol was detected in air samples collected in a large scale environmental chamber analyzing volatile organic emissions from newly installed carpet with polyvinylchloride backing (Hodgson et al. 1993). No data on the level of propylene glycol in drinking water were located, although propylene glycol has been detected at up to 4 mg/L (ppm) in groundwater in the vicinity of an airport (Sills and Blakeslee 1992) and at unspecified concentrations in groundwater samples collected at two hazardous waste sites (HazDat 1995). Little information on the levels of propylene glycol in soils was located. Data on propylene glycol levels in foods, particularly those stored in cellulose films or in PET bottles, are available (Castle et al. 1988a; EPA 1979; Kashtock and Breder 1980; Williamson and Iverson 1993) and a recent estimate of human dietary intake of propylene glycol in Japan is available (Louekari et al. 1990). Reliable monitoring data for the levels of propylene glycol in various environmental media are not needed as this compound is a GRAS additive in foods (FDA 1982).

Exposure Levels in Humans. Little quantitative information on propylene glycol levels in various human tissues and body fluids of a control population, populations near hazardous waste sites, or occupationally exposed groups in the United States is available. Most information is available for oral exposures (Yu et al. 1985). Data on the levels of propylene glycol and its metabolites in body tissues and fluids are not needed because this chemical is a GRAS food additive (FDA 1982).

Exposure Registries. No exposure registries for propylene glycol were located. This substance is not currently one of the compounds for which a subregistry has been established in the National Exposure Registry. The substance 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 exposure to this substance.

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5.7.2 Ongoing Studies

No additional information was located on ongoing studies that would fill existing data needs for propylene glycol (FEDRIP 1995).