GLYCOL ETHERS

Glycol ethers are federal hazardous air pollutants and were identified as toxic air contaminants in April 1993 under AB 2728.

CAS Registry Numbers: See Table I

Molecular Formulas: See Table I

$CH_3OCH_2CH_2OCH_3$
Ethylene glycol dimethyl ether

Glycol ethers, as defined in the federal Clean Air Act Section 112(b) and listed as "Must Be Quantified for Emissions Inventory" for the Air Toxics "Hot Spots" Program (AB 2588), are diethylene glycol dimethyl ether, diethylene glycol monobutyl ether, diethylene glycol monoethyl ether, diethylene glycol monomethyl ether, ethylene glycol diethyl ether, ethylene glycol dimethyl ether, ethylene glycol monobutyl ether, ethylene glycol monoethyl ether, ethylene glycol monoethyl ether acetate, ethylene glycol monomethyl ether, ethylene glycol monomethyl ether acetate, ethylene glycol monopropyl ether, and triethylene glycol dimethyl ether (CAPCOA, 1993). Currently, the inclusion of propylene glycol ethers in the definition of glycol ethers is being debated within the United States Environmental Protection Agency (U.S. EPA), but no decisions have been made.

PHYSICAL PROPERTIES OF GLYCOL ETHERS

The physical properties and characteristics of glycol ethers are described in Tables I and II (Howard, 1990; Merck, 1989; Sax, 1989; U.S. EPA, 1994a).

SOURCES AND EMISSIONS

A. Sources

Glycol ethers are mainly used as solvents (HSDB, 1993). The primary stationary sources that have reported emissions of glycol ethers in California are described in Table III (ARB, 1997b).

Ethylene glycol monobutyl ether (2-butoxyethanol) is registered as an adjuvant for agricultural products; it is used to facilitate the application of other agricultural products. The licensing and regulation of pesticides for sale and use in California are the responsibility of the Department of Pesticide Regulation (DPR). Information presented in this fact sheet regarding the permitted pesticidal uses of ethylene glycol monobutyl ether has been collected from pesticide

labels registered for use in California and from DPR's pesticide databases. This information reflects pesticide use and permitted uses in California as of October 15, 1996.
For further information regarding the pesticidal uses of this compound, please contact the Pesticide Registration Branch of DPR (DPR, 1996).

B. Emissions

The total emissions of glycol ethers from stationary sources in California are estimated to be at least 4.2 million pounds per year, based on data reported under the Air Toxics "Hot Spots" Program (AB 2588). Emissions for some individual glycol ethers are listed in Table III. Of the 4.2 million pounds per year total emissions reported, 2.9 million pounds per year emissions were not specified individually, and were reported under the general group, glycol ethers. This was based on data reported under the Air Toxics "Hot Spots" Program (ARB, 1997b).

C. Natural Occurrence

No information about the natural occurrence of the glycol ethers was found in the readily-available literature.

AMBIENT CONCENTRATIONS

No Air Resources Board data exist for ambient measurements of glycol ethers.

INDOOR SOURCES AND CONCENTRATIONS

Potential sources of glycol ethers in indoor air include paints and other coatings, inks, adhesives, nail polishes, cosmetics, household cleaning products, and other consumer products (Hodgson and Wooley, 1991). Indoor data on glycol ethers is very limited. Sheldon et al. (1988b) measured ethyoxyethyl acetate (ethylene glycol monoethyl ether acetate) levels in six public buildings located in the eastern United States. Ethyoxyethyl acetate was present in measurable levels in four of the buildings at concentrations ranging from 1.31 to 9.58 micrograms per cubic meter. Corresponding outdoor levels were below the limits of detection.

ATMOSPHERIC PERSISTENCE

Glycol ethers exist in the atmosphere in the gas phase. The dominant atmospheric loss process for the glycol ethers is by reaction with the hydroxyl radical. Based on this reaction, the atmospheric half-life and lifetime of 2-butoxyethanol, 2-ethoxyethanol, 1-acetoxy-2-ethoxyethane, and 2-methoxyethanol are in the ranges of 0.6 to 0.9 days and 0.8 to 1.3 days, respectively (Atkinson, 1989, 1994). Its reaction products include hydroxyesters, hydroxyacids, hydroxycarbonyls, peroxyacyl nitrates, and formaldehyde (Kao, 1994).

AB 2588 RISK ASSESSMENT INFORMATION

The Office of Environmental Health Hazard Assessment reviews risk assessments submitted under the Air Toxics "Hot Spots" Program (AB 2588). Of the risk assessments reviewed as of December 1996, for non-cancer health effects, glycol ethers contributed to the total hazard index in 31 of the approximately 89 risk assessments reporting a total chronic hazard index greater than 1, and presented an individual hazard index greater than 1 in 4 of these risk assessments. Glycol ethers also contributed to the total hazard index in 18 of the approximately 107 risk assessments reporting a total acute hazard index greater than 1, and presented an individual hazard index greater than 1 in 9 of these risk assessments (OEHHA, 1996b).

HEALTH EFFECTS

This section discusses the glycol ethers for which there is the most toxicological information.

Possible routes of human exposure to glycol ethers are inhalation, ingestion, and dermal contact.

Non-Cancer: Acute exposure to high levels of the glycol ethers in humans results in narcosis, pulmonary edema, and severe liver and kidney damage. Acute exposure to lower levels of glycol ethers in humans causes conjunctivitis, temporary corneal clouding, and upper respiratory tract irritation. Chronic exposure to the glycol ethers in humans results in fatigue, lethargy, nausea, anorexia, tremor, and anemia (U.S. EPA, 1994a). Some studies have shown that propylene glycol ethers may be safer replacements for ethylene glycol ethers (ARCO, 1996).

Acute and chronic non-cancer Reference Exposure Levels (REL) for the following glycol ethers are listed in the California Air Pollution Control Officers Association Air Toxics "Hot Spots" Program, Revised 1992 Risk Assessment Guidelines. The toxicological endpoints considered are also indicated (CAPCOA, 1993).

ACUTE DATA

Name	REL($\mu g/m^3$)	Toxicological Endpoint	CAS #
Ethylene glycol monobutyl ether	1.5×10^3	Blood	111-76-2
Ethylene glycol monoethyl ether	3.7×10^2	Reproductive/developmental	110-80-5
Ethylene glycol monoethyl ether acetate	1.6×10^3	Reproductive/developmental	111-15-9
Ethylene glycol monomethyl ether	3.2×10^2	Reproductive/developmental	109-86-4

CHRONIC DATA

Name	REL($\mu g/m^3$)	Toxicological Endpoint	CAS #

Ethylene glycol monobutyl ether	2.0×10^1	Reproductive/Respiratory	111-76-2
Ethylene glycol monoethyl ether	2.0×10^2	Reproductive/Respiratory	110-80-5
Ethylene glycol monoethyl ether acetate	6.4×10^1	Reproductive/Respiratory	111-15-9
Ethylene glycol monomethyl ether	2.0×10^1	Reproductive/Respiratory	109-86-4
Ethylene glycol monomethyl ether acetate	5.7×10^1	Reproductive/Respiratory	110-49-6

The United States Environmental Protection Agency (U.S. EPA) has established a Reference Concentration (RfC) for ethylene glycol monomethyl ether of 0.02 milligrams per cubic meter (mg/m^3) based on testicular effects in rabbits. The U.S. EPA estimates that inhalation of this concentration or less, over a lifetime, would not likely result in the occurrence of chronic non-cancer results. The oral Reference Dose (RfD) is under review, and the provisional RfD is calculated to be 0.001 milligrams per kilogram per day (mg/kg/d). The U.S. EPA estimates that consumption of this dose or less, over a lifetime, would not likely result in the occurrence of chronic non-cancer effects. The U.S. EPA has established a RfC for ethylene glycol monoethyl ether of 0.2 mg/m^3 based on decreased testis weight, seminiferous tubule degeneration, and decreased hemoglobin in rabbits, but has not established an oral RfD. However, a provisional oral RfD has been calculated to be 0.4 mg/kg/d.

No information is available on the reproductive or developmental effects of the glycol ethers in humans. Inhalation and oral exposure to several specific glycol ethers has been reported to result in testicular damage, reduced fertility, maternal toxicity, early embryonic death, birth defects, and delayed development in animal studies (U.S. EPA, 1994a). The State of California has determined under Proposition 65 that ethylene glycol monoethyl ether, ethylene glycol monoethyl ether acetate, ethylene glycol monomethyl ether, and ethylene glycol monomethyl ether acetate are male reproductive and developmental toxicants (CCR, 1996).

Cancer: No information is available on the carcinogenic effects of the glycol ethers in humans. No increase in tumors was reported in rats and mice exposed to ethylene glycol monoethyl ether by gavage. The U.S. EPA has not classified the glycol ethers for carcinogenicity (U.S. EPA, 1994a). The International Agency for Research on Cancer has not classified the glycol ethers as to human carcinogenicity (IARC, 1987a).

TABLE I - PHYSICAL PROPERTIES OF GLYCOL ETHERS

Molecular Formula, Substance Name, & CAS Registry No.	Synonyms	Molecular Weight	Boiling Point	Melting Point	Flash Point	Vapor Density	Vapor Pressure	Density/ Specific Gravity	Log Octanol/Water Partition Coefficient
$C_6H_{14}O_3$ Diethylene glycol dimethyl ether CAS No: 111-96-6	bis(2-methoxyethyl) ether; diglyme; diglycol methyl ether; 1,1'-oxybis(2-methyoxyethane)	134.18	162 °C	-68 °C	158 °C	---	2.96 mm Hg at 25 °C	0.9451 at 20/20 °C	-0.06 (est.)
$C_8H_{18}O_3$ Diethylene glycol monobutyl ether CAS No: 112-34-5	2-(2-butoxyethoxy)-ethanol; butyl digol	162.23	230.6 °C	-68.1 °C	172 °F	5.58	0.02 mm Hg at 25 °C	0.9536 at 20/20 °C	0.91 (est.)
$C_6H_{14}O_3$ Diethylene glycol monoethyl ether CAS No: 111-90-0	2-(2-ethoxyethoxy)-ethanol; diethylene glycol ethyl ether; diglycol monoethyl ether	134.18	195 - 202 °C	---	201 °F	4.62 (air = 1)	0.13 mm Hg at 25 °C	0.9855 at 20/4 °C	-0.15 (est.)
$C_5H_{12}O_3$ Diethylene glycol monomethyl ether CAS No: 111-77-3	2-(2-methoxyethoxy)-ethanol; methyl digol; methoxyethoxy ethanol; diethylene glycol methyl ether; diglycol monomethyl ether	120.15	193 °C	<-84 °C	200 °F	4.14 (air = 1)	0.20 mm Hg at 25 °C	1.035 at 20/4 °C	-0.68 (est.)
$C_6H_{14}O_2$ Ethylene glycol diethyl ether CAS No: 629-14-1	1,2-diethoxyethane; ethyl glyme	118.18	121.4 °C	-74 °C	95 °C (open cup)	4.07 (air = 1)	9.4 mm Hg at 20 °C	0.8417 at 20/20 °C	---
$C_4H_{10}O_2$ Ethylene glycol dimethyl ether CAS No: 110-71-4	1,2-dimethoxyethane; glycol dimethyl ether; glyme; monogiyme; dimethaxyethane; 2.5-dioxahexane; ethylene dimethyl ether; monoethylene glycol dimethyl ether	90.12	82 - 83 °C	-58 °C (also reported at -71 °C)	4.5 °C	3.1 (air = 1)	48 mm Hg at 20 °C	0.86285 at 20/4 °C	---

(Howard, 1990; Merck, 1989; Sax, 1989; U.S. EPA 1994)

TABLE I - PHYSICAL PROPERTIES OF GLYCOL ETHERS (CONTINUED)

Molecular Formula, Substance Name, & CAS Registry No.	Synonyms	Molecular Weight	Boiling Point	Melting Point	Flash Point	Vapor Density	Vapor Pressure	Density/ Specific Gravity	Log Octanol/Water Partition Coefficient
$C_6H_{14}O_2$ Ethylene glycol monobutyl ether CAS No.: 111-76-2	2-butoxyethanol; ethylene glycol-n-butyl ether; butyl glycol; glycol butyl ether; glycol monobutyl ether; monobutyl glycol ether	118.18	171-172 °C	-70 °C	141°F (closed cup)	4.1	0.76 mm Hg at 20 °C	0.912 at 20/4 °C	0.83
$C_4H_{10}O_2$ Ethylene glycol monoethyl ether CAS No.: 110-80-5	2-ethoxyethanol; ethylene glycol ethyl ether; glycol ethyl ether; glycol monoethyl ether; hydroxy ether	90.12	135 °C	-70 °C	120 °F (open cup)	3.1	5.5 mm Hg at 25 °C	0.931 at 20/20 °C	-0.1
$C_6H_{12}O_3$ Ethylene glycol monoethyl ether acetate CAS No.: 111-15-9	1-acetoxy-2-ethoxyethane; 2-ethoxyethyl acetate; 2-ethyoxethanol acetate	132.16	156 °C	-61.7 °C	134 °F (open cup)	4.72	1.6 mm Hg at 20 °C	0.975 at 20/20 °C	0.65 (est.)
$C_3H_8O_2$ Ethylene glycol monomethyl ether CAS No.: 109-86-4	2-methoxyethanol	76.09	124.5 °C	-85.1 °C	115 °F	2.62 (air = 1)	9.5 mm Hg at 25 °C	0.9663 at 20/4 °C	-0.77
$C_5H_{10}O_3$ Ethylene glycol monomethyl ether acetate CAS No.: 110-49-6	ethylene glycol methyl ether accetae; glycol monomethyl ether acetate; 2-methoxyethanol acetate	118.13	145 °C	-65.1 °C	55.6 °C (open cup)	4.1 (air = 1)	2.0 mm Hg at 20 °C	1.0067 at 20/20 °C	---
$C_5H_{12}O_2$ Ethylene glycol monopropyl ether CAS No.: 2807-30-9	monopropyl ether of ethylene glycol; 2-propoxyethanol	104.15	150-152 °C	---	---	---	2.9 mm Hg at 25 °C	0.9112 at 20/4 °C	---
CHO Triethylene glycol dimethyl ether CAS No.: 112-49-2	triglyme; 2,5,8,11-tetraoxadodecane	178.22	216. °C	-45 °C	111 °C	---	---	0.990 at 20/4 °C	---

(Howard, 1990; Merck, 1989; Sax, 1989; U.S. EPA 1994)

TABLE II - PHYSICAL CHARACTERISTICS OF GLYCOL ETHERS

Glycol Ether	Physical Characteristics	Solubility	Other Characteristics	Glycol Ether	Physical Characteristics	Solubility	Other Characteristics
Diethylene glycol dimethyl ether	Colorless liquid; Mild odor	Miscible with water hydrocarbon solvents, alcohol, and ether	Readily forms explosive peroxides upon exposure to air, light, or heat	Ethylene glycol monoethyl ether	Colorless liquid; Practically odorless; Slightly bitter taste	Miscible with water, hydrocarbons, ether, acetone, alcohol, and liquid esters	Solidifies at -70 ºC; Dissolves many oils, resins, and waxes
Diethylene glycol monobutyl ether	Colorless liquid; Faint butyl odor	Soluble in alcohol, ether, acetone, oils, benzene, water, and organic solvents	Can react with oxidizing materials	Ethylene glycol monoethyl ether acetate	Colorless liquid; Mild ester-like odor	Miscible with aromatic hydrocarbons; Slightly miscible with ether	---
Diethylene glycol monoethyl ether	Colorless liquid; Pleasant odor; Bitter taste	Miscible with water, acetone, chloroform, benzene, ethanol, ether, and pyridine	Hygroscopic; Slightly viscous; Stable	Ethylene glycol monomethyl ether	Colorless liquid; Mild agreeable odor	Miscible with water, benzene, alcohols, ketones, glycols, hydrocarbons, and dimethylformamide	Derived from ethylene oxide; Lowest boiling point and greatest rate of evaporation of all available glycol ethers
Diethylene glycol monomethyl ether	Colorless liquid; Pleasant odor; Bitter taste	Miscible with water, alcohol, glycerol, ether, acetone, dimethylformamide	Hygroscopic; Can react with oxidizing materials	Ethylene glycol monomethyl ether acetate	Colorless liquid; Pleasant odor	Miscible with water, oils, and most organic solvents	Stable; Solidifies at -70 ºC
Ethylene glycol diethyl ether	Colorless liquid; Sweetish odor; Bitter taste	Immiscible with water; Soluble in oils, alcohol, ether, acetone, benzene, and organic solvents	Aprotic solvents (a type of solvent which neither donates or accepts protons)	Ethylene glycol monopropyl ether	Volatile liquid; Mild ethereal odor; Bitter taste	Soluble in water, alcohol, and ether	---
Ethylene glycol dimethyl ether	Colorless liquid; Sharp ethereal odor	Miscible with water, alcohol; Soluble in hydrocarbon solvents, chloroform, ether	---	Triethylene glycol dimethyl ether	Water-white liquid; Mild ether odor	Miscible with water and hydrocarbon solvents; Completely soluble in water and hydrocarbons at 20ºC	May contain peroxides
Ethylene glycol monobutyl ether	Colorless liquid; Pleasant odor; Mobile liquid	Soluble in water, organic solvents, and mineral oils; Mixes with acetone, benzene, carbon tetrachloride, ethyl ether, n-heptane, ketones, ethers, alcohols, aromatic paraffin, and halogenated hydrocarbons	High dilution ratio with petroleum hydrocarbons	---	---	---	---

(Howard, 1990; Merck, 1989; Sax, 1989; U.S. EPA 1994)

TABLE III - SOURCES, USES, AND EMISSIONS OF GLYCOL ETHERS

Glycol Ether	California Emission Estimates (Lbs/Yr)	Major Uses
Diethylene glycol dimethyl ether	260	Solvent: Anhydrous reaction medium for organo-metallic synthesis
Diethylene glycol monoethyl ether	5,500	Solvent: Plasticizer intermediate; Brake fluid diluent
Diethylene glycol monobutyl ether	26,000	Solvent: In textile printing; Brake fluid diluent; Chemical intermediate
Diethylene glycol monomethyl ether	6,500	Solvent: Chemical intermediate; Brake fluid diluent; Coupling agent
Ethylene glycol diethyl ether	No emissions reported	Inert reaction medium; Solvent: Organic synthesis; Apriotic solvent; Detergent diluent
Ethylene glycol monobutyl ether	430,000	In hydraulic fluids; Solvent; Household cleaners; Chemical intermediate; Coupling agent
Ethylene glycol monoethyl ether acetate	150,000	Solvent; Automobile lacquers
Ethylene glycol monomethyl ether	30,000	Solvent: Jet fuel anti-icing additive; Chemical intermediate; Plasticizer; In liquid soaps, cosmetics, painting plasters, hydraulic fluids, and cleaning compounds
Ethylene glycol monomethyl ether acetate	3,100	Solvent: In textile printing, photographic film, and silk-screening inks
Ethylene glycol monopropyl ether	12,000	---
Triethylene glycol dimethyl ether	2,800	Solvent: Coupling agent
Ethylene glycol dimethyl ether	9,700	Solvent: Extractant; Additive in diesel fuel, lubricants, and pesticides
Ethylene glycol monoethyl ether	320,000	Solvent; Anti-icing agent; Chemical intermediate

(Howard, 1990; Merck, 1989; Sax, 1989; U.S. EPA 1994)