5. PRODUCTION, IMPORT/EXPORT, USE, AND DISPOSAL

5.1 PRODUCTION

Commercial production of ethylene glycol in the United States began in 1925 (McClelland and Rector 1951; Miller 1966). The reported U.S. production volume was 2.189 million pounds (993 metric tons) during that year (McClelland and Rector 1951). Large-scale commercial use of ethylene glycol as an antifreeze began in 1930; this use led to a strong demand for ethylene glycol, especially during and after World War II (Brown et al. 1980; McClelland and Rector 1951). Production volume information is not available for this period. By 1950, the U.S. production volume had risen to 510 million pounds (230,000 metric tons) (Brown et al. 1980; McClelland and Rector 1951). Production continued to rise steadily, reaching approximately 900,000 metric tons by 1968 (Brown et al. 1980). Ethylene glycol production rose more dramatically in late 1960s and early 1970s due to the additional demand for use of this substance in the manufacturing of polyester fiber and film (Brown et al. 1980; CMR 1972, 1975). Production in 1970 was approximately 1,400,000 metric tons (Brown et al. 1980). Production fluctuated between 1,500,000 and 1,800,000 metric tons over the next 18 years, reaching 1,820,000 metric tons by 1978 (Brown et al. 1980).

Production volume information is not available for years following 1978; however, production capacity data for the 1980s, 1990s, and early 2000s have been located. Total reported U.S. production capacities were 2,638,000 metric tons during 1981, 2,820,000 metric tons during 1990, 3,727,000 metric tons during 2001, and 3,242,000 metric tons during 2008 (CMR 1981, 1990, 2001; SRI 2008). The growth of ethylene glycol production capacity over these decades has been attributed to the demand for this substance in the manufacture of plastics, especially polyethylene terephthalate (PET) resin bottles (CMR 1981, 1987, 1984, 1990, 1993, 1998, 2001, 2004). The companies that produced ethylene glycol in the United States, their production sites, and their annual capacities during 2008 (the most recent year for which figures are available) are shown in Table 5-1 (SRI 2008).

Table 5-2 summarizes the number of facilities in each state that manufactured or processed ethylene glycol in 2006, the ranges of maximum amounts on site, if reported, and the activities and uses as reported in the Toxics Release Inventory (TRI) (TRI06 2008). The data listed in this table should be used with caution since only certain types of facilities are required to report. This is not an exhaustive list.

The first method used in the commercial production of ethylene glycol in the United States was the conversion of chlorohydrin to ethylene oxide and subsequent hydrolysis to ethylene glycol (Forkner et al.

Table 5-1. Companies that Produce Ethylene Glycol in the United States and Annual Capacities During 2008

Company	Location	Capacity (million pounds/year)	Capacity (metric tons)
The Dow Chemical Company	Plaquemine, Louisiana	465	211,000
	Seadrift, Texas	575	260,900
	Taft, Louisiana	1,545	701,000
Eastman Chemical Company			
Chemicals and Fibers Group	Longview, Texas	200	90,740
Equistar Chemicals, LP	Bayport, Texas	580	263,100
Formosa Plastics Corporation, USA	Point Comfort, Texas	660	299,400
Huntsman LLC			
Huntsman Performance Products	Port Neches, Texas	805[a]	365,200
Old World Industries, Inc.	Pasadena, Texas	695	315,300
PD Glycol	Beaumont, Texas	790	358,400
Shell Chemical Company	Geismar Louisiana	830	376,600
Total		7,145	3,242,000

Source: SRI 2008

5. PRODUCTION, IMPORT/EXPORT, USE, AND DISPOSAL

Table 5-2. Facilities that Produce, Process, or Use Ethylene Glycol

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
AK	8	10,000	9,999,999	2, 3, 4, 7, 9, 12
AL	69	0	99,999,999	1, 2, 3, 6, 7, 8, 9, 10, 11, 12, 13, 14
AR	43	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
AZ	33	0	999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
CA	168	0	999,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
CO	43	0	49,999,999	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12
CT	24	1,000	999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12
DE	27	0	999,999	1, 5, 6, 7, 8, 10, 11, 12, 13
FL	64	0	49,999,999	2, 3, 4, 6, 7, 8, 9, 10, 11, 12
GA	101	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
HI	2	10,000	999,999	12
IA	75	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
ID	27	0	999,999	1, 2, 3, 5, 7, 8, 10, 11, 12
IL	150	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
IN	109	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
KS	59	0	999,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
KY	83	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
LA	114	0	10,000,000,000	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
MA	64	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
MD	45	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
ME	18	1,000	999,999	1, 2, 3, 5, 6, 7, 9, 10, 11, 12, 14
MI	136	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MN	68	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MO	110	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MS	50	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
MT	20	1,000	999,999	1, 2, 3, 4, 7, 8, 9, 10, 11, 12
NC	140	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
ND	10	1,000	9,999,999	7, 8, 9, 10, 11, 12
NE	23	0	9,999,999	2, 3, 4, 7, 8, 9, 10, 11, 12
NH	22	0	99,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
NJ	153	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
NM	25	100	999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
NV	15	0	999,999	1, 2, 3, 4, 5, 6, 7, 11, 12, 13
NY	86	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
OH	138	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
OK	56	0	9,999,999	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12

Table 5-2. Facilities that Produce, Process, or Use Ethylene Glycol

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
OR	44	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
PA	121	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
PR	47	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
RI	31	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
SC	108	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
SD	5	1,000	99,999	7, 8, 11, 12
TN	108	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
TX	261	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
UT	32	100	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
VA	98	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
VT	8	0	99,999	11, 12
WA	54	0	99,999,999	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 14
WI	94	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
WV	85	0	10,000,000,000	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
WY	15	100	9,999,999	2, 3, 4, 7, 9, 10, 11, 12

[a]Post office state abbreviations used
[b]Amounts on site reported by facilities in each state
[c]Activities/Uses:

1. Produce
2. Import
3. Onsite use/processing
4. Sale/Distribution
5. Byproduct

6. Impurity
7. Reactant
8. Formulation Component
9. Article Component
10. Repackaging

11. Chemical Processing Aid
12. Manufacturing Aid
13. Ancillary/Other Uses
14. Process Impurity

Source: TRI06 2008 (Data are from 2006)

2004; Rebsdat and Mayer 2005). A second method was introduced in 1937, the direct oxidation of

ethylene to ethylene oxide followed by hydrolysis to ethylene glycol (Brown et al. 1980; CMR 2008;

Forkner et al. 2004). This soon became the primary method for the production of ethylene glycol and is

currently the only method used in the United States (Brown et al. 1980; Forkner et al. 2004; Rebsdat and

Mayer 2005).

Other methods that have been used to manufacture ethylene glycol include the direct oxidation of

ethylene and synthesis from carbon monoxide, methanol, hydrogen, and formaldehyde (Forkner et al.

2004; Rebsdat and Mayer 2005). The methanol and formaldehyde used in the latter method is obtained

from syngas, which is originally obtained from coal.

Ethylene oxide is converted to ethylene glycol through uncatalyzed neutral hydrolysis (pH 6–10) in the

presence of a large excess of water at high temperatures and pressures (Forkner et al. 2004; Rebsdat and

Mayer 2005). Selectivity of ethylene glycol is 89–91% in this process. The primary byproduct is

diethylene glycol with higher glycols such as triethylene and tetraethylene glycols formed in smaller

amounts. The product mixture is fed through a series of evaporators to remove the water and then

through vacuum distillation for separation and refinement of the individual glycols.

5.2   IMPORT/EXPORT

Both U.S. imports and exports of ethylene glycol have increased since the 1970s. Annual ethylene glycol

imports rose from 29,300 metric tons in 1977 to 289,000 metric tons in 2006, while annual exports rose

from 56,800 metric tons in 1978 to 573,000 metric tons in 2006 (HSDB 2009; ITA 2007). From 2000 to

2006, the average annual U.S. import and export quantities were 317,000 and 556,000 metric tons,

respectively (ITA 2007). Annual U.S. ethylene glycol import and export quantities reported for different

years are listed in Table 5-3. Over 70% of the ethylene glycol imported into the United States during

2006 was imported from Saudi Arabia (114,846 metric tons) and Canada (93,669 metric tons) (ITA

2007).

5.3   USE

Ethylene glycol has been used in a wide variety of industrial applications because of its unique chemical

and physical properties. Ethylene glycol dissolves in water and is miscible in alcohol and acetone, has the

capacity to hold large amounts of heat before boiling, and lowers the freezing point of water (Lewis 2001;

O'Neil et al. 2001; Rebsdat and Mayer 2005). In addition, ethylene glycol is hygroscopic (has the ability

Table 5-3. U.S. Ethylene Glycol Imports and Exports by Year in Metric Tons

Year	Imports	Exports	Reference
1977	29,300	NA	HSDB 2007
1978	NA	56,800	HSDB 2007
1982	17,000	NA	HSDB 2007
1983	NA	31,600	HSDB 2007
1985	130,000	270,000	HSDB 2007
1986	156,980	NA	CMR 1987
1989	167,869	NA	CMR 1990
1994	239,000	423,000	CMR 1996
1997	172,000	898,000	CMR 1998
2000	287,000	534,000	ITA 2007
2001	332,000	334,000	ITA 2007
2002	363,000	527,000	ITA 2007
2003	316,000	660,000	ITA 2007
2004	277,000	724,000	ITA 2007
2005	351,000	540,000	ITA 2007
2006	289,000	573,000	ITA 2007

NA = not available

to absorb twice its weight in water), is suitable for use as an industrial humectant (drying agent), and possesses excellent solvent properties (Forkner et al. 2004; Lewis 2001; O'Neil et al. 2001). Approximately 35% of all ethylene glycol produced is used to make PET solid-state resins, 26% is used in antifreeze, 24% is used to make polyester fibers, 4% is used to make polyester film, 3% is used in PET chip resin exports, and 8% is used in surface coatings, polyester and alkyd resins, chemical intermediates, and other miscellaneous industrial applications (CMR 2004).

Ethylene glycol plays an essential role in the transportation industry, where it is used as an ingredient in hydraulic brake fluids, as the major component in automotive antifreeze/coolant, and as a component of de-icing fluids for aircraft, runways, and taxiways (Forkner et al. 2004; Lewis 2001; O'Neil et al. 2001; Rebsdat and Mayer 2005). Another important industrial use for ethylene glycol is as an intermediate in the synthesis of esters, ethers, and resinous products, particularly polyester fibers and resins (O'Neil et al. 2001; Rowe and Wolf 1982). As a solvent, ethylene glycol is used in the paint and plastic industries in the formulation of printers' inks, stamp pad inks, and inks for ball point pens, and as a softening agent in cellophane (O'Neil et al. 2001). Ethylene glycol has also been used as a stabilizer for soy bean foam used in fire extinguishers and in the manufacture of explosives, plasticizers, elastomers, and synthetic waxes (Lewis 2001; O'Neil et al. 2001). According to Browning (1965), small amounts of ethylene glycol have been used in pharmaceutical preparations (components of skin lotions and powders, and as a substitute for glycerin); more recent information describing this use has not been located.

5.4   DISPOSAL

Two promising methods for the complete (>99%) destruction of ethylene glycol in waste water are ultraviolet (UV) light-catalyzed oxidation and supercritical oxidation. In the UV light-catalyzed oxidation method, ethylene glycol-containing waste water in the presence of 10% hydrogen peroxide is oxidized by UV irradiation (200–250 nm) with light from a mercury lamp (DOE 1993b). The UV/hydrogen peroxide undergoes photochemical decomposition to produce OH radicals that are strong oxidants capable of oxidizing most organic compounds stepwise to complete mineralization (e.g., carbon dioxide and water). In the supercritical water oxidation method, the waste water is subjected to oxidation at >550 °C and 4,000 psi pressure with a residence time of <30 seconds (DOE 1993a).

A new technology, *in situ* vitrification (a thermal treatment technology) (Drajun 1991), has shown potential for the remediation of soil contaminated with ethylene glycol. During the *in situ* vitrification process, contaminated soil is transformed into silicate glass using large amounts of electrical energy and a

crystalline product similar to obsidian is formed. Another novel approach involving an encapsulated biooxidation method proposes that sodium percarbonate encapsulated in polyvinylidene chloride be inserted in subsurface soil by a method called hydraulic fracturing. Oxygen slowly released from the encapsulated sodium percarbonate increases the number of glycol-degrading organisms. This method is expected to remediate soils contaminated with glycols via enhanced aerobic biodegradation in subsurface soils (Vesper et al. 1994).

Distillation of used automobile and heavy duty engine coolant under reduced pressure has been assessed to be an acceptable technology for recycling ethylene glycol in terms of economic potential, waste reduction potential, and product quality that meets both American Society for Testing and Materials (ASTM) and SAE standards (EPA 1993d).