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

5.1 PRODUCTION

The element chlorine was discovered in 1774, and the first patent for its use as a bleaching agent came as early as 1799 (Deutsch 1947). However, it wasn't until the late 1800s that adequate electrolytic equipment became available to produce chlorine on an industrial scale. Chlorine production increased steadily from 5,400 metric tons in 1900 to 63,500 metric tons in 1920 (Deutsch et al. 1963). U.S. chlorine production then underwent an extremely dramatic increase over the next 50 years. Production volumes in 1930, 1940, 1950, 1960, and 1970 were 181,000, 608,000, 1,814,000, 4,172,000, and 8,800,000 metric tons, respectively (Curlin et al. 1991; Deutsch et al. 1963; Robertson 1978). Reasons for this increase were the demand for use of chlorine as a bleaching agent, the demand for its use in the manufacture of other important industrial chemicals, and the further development of electrolytic cell technology, which improved plant production capacities by almost 200% (Bommaraju et al. 2004; Deutsch et al. 1963). Growth during this period was supported by the widespread construction of chlorine-producing plants by alkali producers who were interested in manufacturing chlorine and caustic soda (sodium hydroxide) as co-products, an effort that gave birth to the chlor-alkali industry (Bommaraju et al. 2004; Deutsch et al. 1963; Schmittinger et al. 2006). In 1915, there were only 15 chlorine-producing factories in the United States; by 1960, there were 240 (Deutsch et al. 1963).

During the 1970s and 1980s, U.S. chlorine production fluctuated between 11,200,000 metric tons in 1979 and 8,300,000 metric tons in 1982 (Curlin et al. 1991). Chlorine production rose steadily through the 1990s, reaching 12,100,000 metric tons in 1999 (The Chlorine Institute 2008). With the exception of a spike to 12,300,000 metric tons in 2004, production has steadily declined over the past decade (The Chlorine Institute 2008). The 2008 U.S. production volume for chlorine was reported to be 10,600,000 metric tons by the U.S. Census Bureau (2009). Environmental pressures have strained the chlorine market since the 1970s. Regulations have contributed to such changes as moving away from the use of mercury and asbestos in chlorine production, ending the use of chlorine in pulp and paper bleaching, and curtailing the production of certain chlorinated end products (Bommaraju et al. 2004; CMR 1977, 1980, 1989, 1992, 1995, 2000, 2003, 2006; Robertson 1978; Schmittinger et al. 2006). Negative effects on the market have been balanced by the development of alternative chlorine production methods and increases in demand for other chlorine end products, especially polyvinyl chloride. Although there are still operational facilities that use the older mercury and asbestos production methods, the newer chlorine production facilities are based on the more efficient membrane technology (Bommaraju et al. 2004; The Chlorine Institute 2008). The companies that produced chlorine in the

United States, their production sites, and their annual capacities for 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 chlorine (Cl_2) 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.

5.2 IMPORT/EXPORT

Annual U.S. chlorine import and export quantities reported for different years are listed in Table 5-3. The available data indicate that annual imports of chlorine into the United States have increased steadily over the past 20 years, rising from 251,000 metric tons in 1984 to 429,000 metric tons in 2007 (CMR 1989, 1992, 2000; HSDB 2009; ITA 2007; U.S. Census Bureau 2008). The decline in U.S. chlorine exports during the early 2000s (24,200 metric tons in 2000 to 10,400 metric tons in 2004) has been attributed to increasing energy costs, which have rendered the chlorine produced in the United States uncompetitive, especially in the Asian market (CMR 2006; ITA 2007). However, U.S. chlorine exports in 2006 were bolstered by a 9-fold increase in shipments to Mexico, accounting for approximately 82% (32,201 metric tons) of the 39,481 metric tons of chlorine exported during that year (ITA 2007). U.S. exports of chlorine fell to 25,740 in 2007 (US Census Bureau 2008).

5.3 USE

The major uses of chlorine during 2006 were the manufacturing of vinyl chloride to make polyvinyl chloride (PVC) plastics (36%), the manufacturing of other organic compounds (41%), the manufacturing of inorganic chemicals (15%), water treatment (4%), and pulp and paper bleaching (1%) (CMR 2006). Other miscellaneous uses accounted for 3% of total chlorine use during 2006. Chlorine is used in the production of a large number of commercial products (Bommaraju et al. 2004; Schmittinger et al. 2006). Some of the important end products for which chlorine plays a role in the production stream include refrigerants, aerosols, silicones, silicone rubber, plastics, solvents, polyethers, varnishes, foams, chlorinated rubber, polyurethane, detergents, dyes, insecticides, pesticides, disinfectants, bleaches, and white pigment enamel (Schmittinger et al. 2006). Chlorine has been used in the food industry as a bleaching agent for flour (Fukayama et al. 1986). Chlorine was used as a war gas during World War I (Compton 1987). Chlorine is also used to manufacture phosgene (O'Neil et al. 2001).

Table 5-1. Companies that Produce Chlorine in the United States and Annual Capacities for 2006

Company	Location	Capacity (thousands of short tons)[a]	Capacity (metric tons)[a]
ASHTA Chemicals, Inc.	Ashtabula, Ohio	44	40,000
Bayer MaterialScience LLC	Baytown, Texas	400	363,000
The Dow Chemical Company	Freeport, Texas	3,240	2,939,000
	Plaquemine, Louisiana	1,070	971,000
E.I. du Pont de Nemours and Company; DuPont Coatings and Color Technologies; DuPont Performance Coatings	Niagara Falls, New York	85	77,000
Equa-chlor LLC	Longview, Washington	87	79,000
ERCO Worldwide, Inc.	Port Edwards, Wisconsin	106	96,000
Formosa Plastics Corporation	Point Comfort, Texas	811	736,000
Georgia Gulf Corporation	Plaquemine, Louisiana	450	408,000
Georgia-Pacific Chemicals LLC	Green Bay, Wisconsin	9	8,000
	Muskogee, Oklahoma	6	5,000
	Rincon, Georgia	7	6,000
Kuehne Chemical Corporation	Delaware City, Delaware	16	15,000
Occidental Chemical Corporation; Chloro-Vinyls Group	Convent, Louisiana	389	353,000
	Corpus Christi, Texas	604	548,000
	Geismar, Louisiana	268	243,000
	Hahnville, Louisiana	750	680,000
	Mobile, Alabama	50	45,000
	Muscle Shoals, Alabama	150	136,000
	New Castle, Delaware	90	82,000
	Niagara Falls, New York	335	304,000
	Wichita, Kansas	263	239,000
Olin Corporation; Olin Chlor Alkali Products Division	Augusta, Georgia	120	109,000
	Charleston, Tennessee	245	222,000
	Henderson, Nevada	152	138,000
	McIntosh, Alabama	735	667,000
	Niagara Falls, New York	286	259,000
	St. Gabriel, Louisiana	180	163,000
OxyVinyls, L.P.	La Porte, Texas	580	526,000
PPG Industries, Inc.; Chemical Group	Lake Charles, Louisiana	1,375	1,247,000
	Natrium, West Virginia	510	463,000

Table 5-1. Companies that Produce Chlorine in the United States and Annual Capacities for 2006

Company	Location	Capacity (thousands of short tons)[a]	Capacity (metric tons)[a]
SABIC Innovative Plastics	Burkville, Alabama	90	82,000
	Mount Vernon, Indiana	96	87,000
Titanium Metals Corporation	Henderson, Nevada	5	5,000
Trans Carolina Products LLC	Hamlet, North Carolina	Not available	Not available
U.S. Magnesium, LLC	Rowley, Utah	47	43,000
Westlake Vinyls, Inc.	Calvert City, Kentucky	205	186,000
Total		13,856	12,570,000

[a]Much of the capacity is consumed captively.

Source: SRI 2008; The Chlorine Institute 2008

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

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
AK	13	0	9,999,999	1, 2, 3, 5, 6, 7, 10, 11, 12, 13, 14
AL	134	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
AR	67	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
AS	2	1,000	9,999	11, 12
AZ	44	100	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
CA	143	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
CO	19	0	49,999,999	1, 2, 3, 4, 5, 6, 9, 10, 11, 12
CT	28	0	999,999	1, 2, 3, 4, 5, 6, 7, 10, 11, 12
DC	1	100,000	999,999	12
DE	31	100	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
FL	109	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
GA	105	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13
GU	2	10,000	999,999	9, 12
HI	18	0	9,999,999	1, 2, 3, 4, 6, 8, 10, 11, 12
IA	46	0	9,999,999	1, 2, 3, 5, 6, 7, 8, 10, 11, 12
ID	36	0	9,999,999	1, 2, 3, 5, 6, 7, 10, 11, 12, 13, 14
IL	72	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
IN	67	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
KS	37	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12
KY	81	0	999,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
LA	180	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MA	25	0	999,999	1, 2, 3, 5, 6, 7, 9, 10, 11, 12
MD	41	100	49,999,999	1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13
ME	63	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 13
MI	104	0	499,999,999	1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13
MN	67	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
MO	55	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MS	76	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MT	11	1,000	9,999,999	1, 4, 5, 7, 10, 11, 12, 13
NC	118	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
ND	9	100	999,999	1, 2, 3, 5, 6, 10, 11, 12
NE	18	100	49,999,999	1, 2, 3, 4, 6, 9, 10, 11, 12
NH	12	0	9,999,999	1, 2, 3, 5, 6, 9, 12, 13
NJ	66	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
NM	19	0	9,999,999	1, 2, 3, 4, 5, 6, 9, 11, 12
NV	31	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

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

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
NY	106	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
OH	120	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
OK	48	0	49,999,999	1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13
OR	55	0	9,999,999	1, 2, 3, 4, 5, 6, 8, 10, 11, 12, 13
PA	102	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
PR	27	0	49,999,999	2, 3, 4, 6, 7, 10, 11, 12
RI	15	100	9,999,999	1, 2, 3, 4, 6, 9, 10, 11, 12
SC	94	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
SD	9	100	999,999	7, 10, 11, 12
TN	99	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
TX	197	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
UT	40	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
VA	66	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
VT	2	1,000	9,999	11, 12
WA	102	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
WI	107	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
WV	52	0	499,999,999	1, 2, 3, 4, 5, 6, 9, 10, 11, 12, 13
WY	13	1,000	999,999	1, 2, 3, 5, 10, 11, 12, 13

[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)

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

Year	Imports	Exports	Reference
1975	67,000	15,000	Robertson 1978
1984	251,000	39,500	HSDB 2007
1986	298,739	Not available	HSDB 2007
1987	Not available	3,787	HSDB 2007
1988	280,840	58,073	CMR 1989
1991	272,160	Not available	CMR 1992
1998	373,766	22,680	CMR 2000
1999	325,685	21,773	CMR 2000
2000	358,015	24,231	ITA 2007
2001	358,060	20,964	ITA 2007
2002	409,695	18,566	ITA 2007
2003	412,117	15,361	ITA 2007
2004	470,884	10,448	ITA 2007
2005	476,103	12,306	ITA 2007
2006	454,414	39,481	ITA 2007
2007	429,440	25,740	U.S. Census Bureau 2008

5.4 DISPOSAL

Chlorine is disposed of via a salt-forming reaction followed by neutralization (HSDB 2009). Chlorine gas is first introduced into a large volume solution of a reducing agent such as sodium thiosulfate, bisulfite, or ferrous salts or aqueous sodium hydroxide (HSDB 2009). The resulting salt solution is then neutralized and routed to a sewage treatment plant (HSDB 2009).