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, chlorine production fluctuated between 11,200,000 metric tons in 1979 and 8,300,000 metric tons in 1982 (Curlin et al. 1991). The production volume in 1990 was 10,700,000 metric tons. Production volume information is not available for the years following 1990; however, production capacity data for the 1990s and early 2000s have been located. Total reported U.S. production capacities were 11,100,000 metric tons during 1992, 14,000,000 metric tons during 2000, and 13,100,000 metric tons during 2006 (CMR 1992, 2000, 2006). Environmental pressures have strained the chlorine market since the 1970s. Regulations eventually led 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). 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. The companies that produced chlorine in the United States, their production sites, and their annual capacities for 2006 (the most recent year for which figures are available) are shown in Table 5-1 (SRI 2006).

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
ATI Wah Chang	Albany, Oregon	2	2,000
Basic Chemicals Company, LLC	Geismar, Louisiana	483	438,000
	Wichita, Kansas	263	239,000
Bayer MaterialScience	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
ERCO Worldwide, Inc.	Port Edwards, Wisconsin	106	96,000
Formosa Plastics Corporation	Point Comfort, Texas	811	736,000
GE Advanced Materials; Plastics Division	Burkville, Alabama	90	82,000
	Mount Vernon, Indiana	96	87,000
Georgia Gulf Corporation	Plaquemine, Louisiana	450	408,000
Georgia-Pacific Resins, Inc.	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[b]	353,000[b]
	Corpus Christi, Texas	604	548,000
	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
Olin Corporation; Olin Chlor Alkali Products Division	Augusta, Georgia	112	102,000
	Charleston, Tennessee	285	259,000
	McIntosh, Alabama	692	628,000
	Niagara Falls, New York	250	227,000
OxyVinyls, L.P.	La Porte, Texas	580	526,000
Pioneer Americas, LLC	Henderson, Nevada	152	138,000
	St. Gabriel, Louisiana	180	163,000
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]
Titanium Metals Corporation	Henderson, Nevada	5	5,000
U.S. Magnesium, LLC	Rowley, Utah	47	43,000
Westlake Vinyls, Inc.	Calvert City, Kentucky	205	186,000
Total		13,939	12,645,000

[a]Much of the capacity is consumed captively.
[b]Unit is currently idle.

Source: SRI 2006

Table 5-2 summarizes the number of facilities in each state that manufactured or processed chlorine (Cl_2) in 2005, the ranges of maximum amounts on site, if reported, and the activities and uses as reported in the Toxics Release Inventory (TRI) (TRI05 2007). 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 454,000 metric tons in 2006 (CMR 1989, 1992, 2000; HSDB 2007; ITA 2007). 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).

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).

5.4 DISPOSAL

Chlorine is disposed of via a salt-forming reaction followed by neutralization (HSDB 2007). Chlorine gas is first introduced into a large volume solution of a reducing agent such as sodium thiosulfate,

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	65	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	43	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	29	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	104	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	17	0	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	71	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	36	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12
KY	79	0	999,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
LA	177	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	62	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 13
MI	102	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	73	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	17	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	65	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
NM	18	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
NY	105	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

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]
OK	47	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	100	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
PR	26	0	49,999,999	2, 3, 4, 6, 7, 10, 11, 12
RI	14	100	9,999,999	2, 3, 4, 6, 9, 10, 11, 12
SC	91	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	97	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
TX	191	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	65	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	98	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	50	0	499,999,999	1, 2, 3, 4, 5, 6, 9, 10, 11, 12, 13
WY	13	1,000	99,999	1, 2, 3, 5, 6, 7, 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: TRI05 2007 (Data are from 2005)

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

bisulfite, or ferrous salts or aqueous sodium hydroxide (HSDB 2007). The resulting salt solution is then neutralized and routed to a sewage treatment plant (HSDB 2007).