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

## 5.1 PRODUCTION

Aluminum is the most abundant metal and the third most abundant element in the earth's crust, comprising about 8.8% by weight (88 g/kg). It is rarely found free in nature and is found in most rocks, particularly igneous rocks, which contain aluminum as aluminosilicate minerals (Staley and Haupin 1992). Bauxite is a naturally occurring, heterogeneous material consisting of primarily one or more aluminum hydroxide minerals in addition to a variety of aluminosilicates, iron oxide, silica, titania, and other impurities in trace amounts. It is the most important raw material for the production of aluminum. More than 90% of the bauxite consumed in the United States in 2005 was converted to alumina ($Al_2O_3$) for the production of aluminum (USGS 2003, 2006b). Other raw materials sometimes used in the production of aluminum include cryolite, aluminum fluoride, fluorspar, corundum, and kaolin minerals (Browning 1969; Dinman 1983; IARC 1984; Lide 2005; O'Neil et al. 2001; USGS 2003).

In 2004, primary aluminum was produced in 41 countries, with China, Russia, Canada, and the United States, in decreasing order of metal produced, accounting for 52% of the total world production of 29.8 million metric tons. In 2005, 6 U.S. companies, operating 15 primary aluminum smelters, produced an estimated 2.5 million metric tons of aluminum metal. Four smelters were temporarily idled during 2004 and 2005. In the United States, about 3 million metric tons of aluminum were recovered from purchased scrap in 2005, with 63% of this coming from new (manufacturing) scrap and 37% from old scrap (discarded aluminum products) (USGS 2004, 2006a).

In 2003, 22 countries reported bauxite mine production, with Australia, Brazil, Guinea, and Jamaica accounting for 67% of the total world bauxite product of 146 million metric tons. World production of alumina was 55.5 million metric tons in 2003. Australia, China, the United States, Brazil, and Jamaica, in descending order of alumina output, were the principal producers, accounting for 64% of the world's alumina production. U.S. production of alumina, which is nearly all derived from imported metallurgical-grade bauxite, was 4.35 million metric tons in 2003 (USGS 2003, 2006a).

The principal method used in producing aluminum metal involves three major steps: refining of bauxite by the Bayer process to produce alumina, electrolytic reduction of alumina by the Hall-Héroult process to produce aluminum, and casting of aluminum into ingots (Browning 1969; Dinman 1983; IARC 1984).

In the first step (Bayer process), bauxite ($Al_2O_3 \cdot H_2O$) is digested at high temperature and pressure in a strong solution of caustic soda. The resulting hydrate is then crystallized and calcined in a kiln to produce alumina (aluminum oxide). In the second step (Hall-Héroult process), alumina is reduced to aluminum metal by an electrolytic process involving carbon electrodes and cryolite flux ($3NaF \cdot AlF_3$). The electrolytic reduction process of transforming alumina into aluminum is carried out in electrolytic cells or pots. The areas where this occurs are called potrooms. Two types of electrolytic cells may be used, a prebake or a Söderberg cell. Their design differs, but the principle is the same. Alumina is dissolved in the cell in an electrolyte at a high temperature (950–970 °C) and a low voltage (4–6 volts). A high current is applied to the melted fraction. The alumina is reduced to aluminum at the cathode and the metal sinks to the bottom of the electrolytic cell. The aluminum is then removed by siphoning. The oxygen from the alumina migrates to the carbon anode of the cell, where it reacts to form carbon dioxide and carbon monoxide. The aluminum produced using the Hall-Héroult electrolytic reduction process may be refined to a maximum purity of 99.9%. In the third step (casting), aluminum is taken from the cell to holding furnaces from which it is poured into molds and cast into aluminum ingots (IARC 1984; Lewis 2001; Staley and Haupin 1992). Current U.S. manufacturers of aluminum are given in Table 5-1.

Aluminum is also an integral part of a variety of aluminum compounds used in industrial, domestic, consumer, and medicinal products. The methods of production for these compounds are described in the following section. Current U.S. manufacturers of selected aluminum compounds are given in Table 5-2.

Aluminum chloride can be produced by the reaction of purified gaseous chlorine with molten aluminum, as well as by the reaction of bauxite with coke and chlorine at about 875 °C (Lewis 2001).

Aluminum fluoride can be produced by heating ammonium hexafluoroaluminate to red heat in a stream of nitrogen. Other methods include the action of hydrogen fluoride gas on aluminum trihydrate; the reaction of hydrogen fluoride on a suspension of aluminum trihydrate followed by calcining the hydrate formed; fusion of cryolite or sodium fluoride with aluminum sulfate; or the reaction of fluosilicic acid on aluminum hydrate (HSDB 2006; Lewis 2001; O'Neil et al. 2001).

Aluminum hydroxide is produced from bauxite. The bauxite ore is first dissolved in a solution of sodium hydroxide, and then the aluminum hydroxide is precipitated from the sodium aluminate solution by neutralization (as with carbon dioxide) or by autoprecipitation (Bayer process) (Lewis 2001).

## Table 5-1. U.S. Manufacturers of Aluminum[a]

| Company | Location |
|---|---|
| Alcan Aluminum Corporation, Alcan Specialty Aluminas | Sebree, Kentucky |
| Alcoa, Inc., Alcoa Primary Metals | Alcoa, Tennessee |
| | Badin, North Carolina |
| | Goose Creek, South Carolina |
| | Massena, New York |
| | Wenatchee, Washington |
| Century Aluminum | Hawesville, Kentucky |
| | Ravenswood, West Virginia |
| Columbia Falls Aluminum Company | Columbia Falls, Montana |
| Eastalco Aluminum Company | Frederick, Maryland |
| Goldendale Aluminum Company | Goldendale, Washington |
| Intalco Aluminum Corporation | Ferndale, Washington |
| Noranda Aluminum Inc. | New Madrid, Missouri |
| Northwest Aluminum Company | The Dalles, Oregon |
| Ormet Primary Aluminum Corporation | Hannibal, Ohio |

[a]Derived from SRI 2006

## Table 5-2. U.S. Producers of Selected Aluminum Compounds[a]

| Company | Location | Annual capacity ($10^3$ metric tons)[b] |
|---|---|---|
| Alumina, calcined (Aluminum oxide) | | |
| Alcoa, Inc., Alcoa World Alumnia | Point Comfort, Texas | |
| Almatis, Inc. | Bauxite, Arkansas | |
| Kaiser Aluminum | Gramercy, Louisiana | |
| Ormet Primary Aluminum Corporation | Burnside, Louisiana | |
| Sherwin Alumina Company | Corpus Christi, Texas | |
| Aluminas (specialty grades) | | |
| Albemarle Corporation | Pasadena, Texas | |
| Almatis, Inc. | Bauxite, Arkansas | |
| AluChem, Inc. | Cincinnati, Ohio | |
| Axens North America | Savannah, Georgia | |
| Engelhard Corporation, Adsorbents & Catalysts | Port Allen, Louisiana | |
| | Vidalia, Louisiana | |
| Huber Engineered Materials | Fairmount, Georgia | |
| INEOS Silicas Americas, LLC | Joliet, Illinois | |
| Porocel Corporation | Little Rock, Arkansas | |
| Saint-Gobain Ceramics & Plastics, Inc., Grains & Powders Division | Worcester, Massachusettes | |
| Sasol North America Inc., Ceralox Division | Westlake, Louisiana | |
| | Tucson, Arizona | |
| SPI Pharma Group | Lewes, Delaware | |
| Treibacher Schleifmittel North America, Inc. | Niagara Falls, New York | |
| UOP, LLC | Baton Rouge, Louisiana | |
| Washington Mills Electro Minerals Company | Niagara Falls, New York | |
| Aluminum ammonium sulfate | | |
| Holland Company, Inc. | Adams, Massachusetts | |
| Aluminum chlorhydrate (aluminum chloride, basic) | | |
| GEO Specialty Chemicals, Inc. | Baltimore, Maryland | |
| | Bastrop, Louisiana | |
| | Counce, Tennessee | |
| The Gillette Company, North Chicago Manufacturing Center | North Chicago, Illinois | |
| Gulbrandsen Companies, Gulbrandsen Chemicals, Inc. | Orangeburg, South Carolina | |
| Gulbrandsen Companies, Gulbrandsen Technologies, Inc. | La Porte, Texas<br>Phillipsburg, New Jersey | |
| Puerto Rico Alum Corporation | Penuelas, Puerto Rico | |
| Reheis, Inc. | Berkeley Heights, New Jersey | |
| Summit Research Labs | Huguenot, New York | |
| | Phoenix, Arizona | |

## Table 5-2. U.S. Producers of Selected Aluminum Compounds[a]

| Company | Location | Annual capacity ($10^3$ metric tons)[b] |
|---|---|---|
| | Somerset, New Jersey | |
| Thatcher Company | Salt Lake City, Utah | |
| Westwood Chemical Corporation | Middletown, New York | |
| Aluminum chloride (anhydrous)[c] | | |
| Gulbrandsen Companies, Gulbrandsen Chemicals, Inc. | Orangeburg, South Carolina | 25 |
| Toth Aluminum Corporation | Vacherie, Louisiana | 10[d] |
| Vanchlor Catalysts, LLC | Allentown, Pennsylvania | 8[d] |
| Vanchlor Company, Inc. | Lockport, New York | 15 |
| Aluminum chloride (hydrous)[e] | | |
| Arkema, Inc., Specialty Chemicals Division | Axis, Alabama | 2 |
| Chattem, Chemicals, Inc. | Chattanooga, Tennessee | 1 |
| Delta Chemical Corporation | Ashtabula, Ohio | 10 |
| | Baltimore, Maryland | 50 |
| GEO Specialty Chemicals, Inc. | Baltimore, Maryland | 9 |
| | Bastrop, Louisiana | 6 |
| The Gillette Company, North Chicago Manufacturing Center | North Chicago, Illinois | Not applicable |
| Gulbrandsen Companies, Gulbrandsen Technologies, Inc. | Phillipsburg, New Jersey | 9 |
| Holland Company, Inc. | Adams, Massachusetts | Not applicable |
| Puerto Rico Alum Corporation | Penuelas, Puerto Rico | 1 |
| Reheis, Inc. | Berkeley Heights, New Jersey | 3 |
| Southern Ionics, Inc. | Westlake, Louisiana | 60 |
| Summit Research Labs | Huguenot, New York | Not applicable |
| | Phoenix, Arizona | Not applicable |
| | Somerset, New Jersey | Not applicable |
| Westwood Chemical Corporation | Middletown, New York | Not applicable |
| Aluminum chloride (aluminum trichloride) | | |
| Mallinckrodt, Inc., Pharmaceuticals Group | St. Louis, Missouri | |
| Aluminum chlorohydrate (polyaluminum chloride) | | |
| Delta Chemical Corporation | Ashtabula, Ohio | |
| | Baltimore, Maryland | |
| GEO Specialty Chemicals, Inc., Aluminum Products Group | Baltimore, Maryland<br>Bastrop, Louisiana | |
| Gulbrandsen Companies, Gulbrandsen Chemicals, Inc. | Orangeburg, South Carolina | |
| Gulbrandsen Companies, Gulbrandsen Technologies, Inc. | La Porte, Texas<br>Phillipsburg, New Jersey | |
| Holland Company, Inc. | Adams, Massachusetts | |

## Table 5-2. U.S. Producers of Selected Aluminum Compounds[a]

| Company | Location | Annual capacity ($10^3$ metric tons)[b] |
|---|---|---|
| Kemiron Companies, Inc. | Kalama, Washington | |
| | Savannah, Georgia | |
| | Spokane, Washington | |
| Puerto Rico Alum Corporation | Penuelas, Puerto Rico | |
| Summit Research Labs | Huguenot, New York | |
| | Phoenix, Arizona | |
| | Somerset, New Jersey | |
| Westwood Chemical Corporation | Middletown, New York | |
| Aluminum fluoride | | |
| Alcoa, Inc., Alcoa World Alumina | Point Comfort, Texas | 60 |
| CERAC, Inc. | Milwaukee, Wisconsin | Not applicable |
| ConocoPhillips | Billings, Montana | <1[f] |
| | Ponca City, Oklahoma | <1[f] |
| Ozark Fluorine Specialties, Inc. | Tulsa, Oklahoma | <2 |
| Aluminum hydroxide | | |
| Almatis, Inc. | Bauxite, Arkansas | |
| Franklin Industries, Inc., Franklin Industrial Minerals | Dalton, Georgia | |
| Huber Engineered Materials | Fairmount, Georgia | |
| | Kennesaw, Georgia | |
| | Quincy, Illinois | |
| IMERYS Pigments & Additives | Talking Rock, Georgia | |
| Kaiser Aluminum & Chemical Corporation | Gramercy, Louisiana | |
| Sherwin Alumina Company | Corpus Christi, Texas | |
| Aluminum nitrate | | |
| Blue Grass Chemical Specialties, LLC | New Albany, Indiana | |
| Mallinckrodt Baker, Inc. | Phillipsburg, New Jersey | |
| Mineral Research and Development | Harrisburg, North Carolina | |
| Thatcher Company | Salt Lake City, Utah | |
| Aluminum phosphate (aluminum orthophosphate) | | |
| Innophos, Inc. | Chicago Heights, Illinois | |
| Johnson Matthey, Inc., Alfa Aesar | Ward Hill, Massachusetts | |
| PCS Phosphate Co., Inc. | Cincinnati, Ohio | |
| United-Erie, Inc. | Erie, Pennsylvania | |
| Aluminum phosphide[g] | | |
| Bernardo Chemical, Ltd, Inc. | | |
| Degesch America, Inc. | | |
| Inventa Corporation | | |
| Midland Fumigant, Inc. | | |
| Pestcon Systems, Inc. | | |

## Table 5-2. U.S. Producers of Selected Aluminum Compounds[a]

| Company | Location | Annual capacity ($10^3$ metric tons)[b] |
|---|---|---|
| Aluminum potassium sulfate (Potash alum) | | |
| Holland Company, Inc. | Adams, Massachusetts | |
| Aluminum sodium sulfate (Soda alum) | | |
| General Chemical Corporation | East St. Louis, Illinois | |
| Aluminum sulfate (Alum, commercial) | | |
| Alchem, Inc. | Rockwell, North Carolina | |
| Bay Chemical and Supply Company | Odem, Texas | |
| C & S Chemicals, Inc. | Austell, Georgia | |
| | Bartow, Florida | |
| | Joliet, Illinois | |
| | Randolph, Minnesota | |
| | Waycross, Georiga | |
| Delta Chemical Corporation | Ashtabula, Ohio | |
| | Baltimore, Maryland | |
| GAC Chemical Corporation | Searsport, Maine | |
| GAC MidAmerica, Inc. | Indianapolis, Indiana | |
| | Saukville, Wisconson | |
| | Toledo, Ohio | |
| Gemini Industries, Inc. | Santa Ana, California | |
| General Chemical Corporation | Ashdown, Arkansas | |
| | Augusta, Georgia | |
| | Catawba, South Carolina | |
| | Cedar Springs, Georgia | |
| | Cleveland, Ohio | |
| | Covington, Virginia | |
| | Denver, Colorado | |
| | Detroit, Michigan | |
| | East Point, Georgia | |
| | East St. Louis, Illinois | |
| | Hopewell, Virginia | |
| | Jacksonville, Florida | |
| | Johnsonburg, Pennsylvania | |
| | Kalamazoo, Michigan | |
| | Macon, Georgia | |
| | Marrero, Louisiana | |
| | Menasha, Wisconsin | |
| | Middletown, Ohio | |
| | Newark, New Jersey | |
| | Pine Bluff, Arkansas | |
| | Pittsburg, California | |

## Table 5-2. U.S. Producers of Selected Aluminum Compounds[a]

| Company | Location | Annual capacity ($10^3$ metric tons)[b] |
|---|---|---|
| | Port St. Joe, Florida | |
| | Savannah, Georgia | |
| | Springfield, Tennessee | |
| | Tacoma, Washington | |
| | Tampa, Florida | |
| | Vancouver, Washington | |
| | Wisconsin Rapids, Wisconsin | |
| GEO Specialty Chemicals, Inc., Aluminum Products Group | Bastrop, Louisiana | |
| | Chattanooga, Tennessee | |
| | Childersburg, Alabama | |
| | Counce, Tennessee | |
| | Demopolis, Alabama | |
| | De Ridder, Louisiana | |
| | Georgetown, South Carolina | |
| | Monticello, Mississippi | |
| | Pennington, Alabama | |
| | Plymouth, North Carolina | |
| | Savannah, Georgia | |
| W. R. Grace & Co., Grace Davison | Curtis Bay, Maryland | |
| | Lake Charles, Louisiana | |
| Holland Company, Inc. | Adams, Massachusetts | |
| Kemiron Companies, Inc. | Antioch, California | |
| | Savannah, Georgia | |
| | Spokane, Washington | |
| Mallinckrodt Baker, Inc. | Paris, Kentucky | |
| Mallinckrodt, Inc., Pharmaceuticals Group | St. Louis, Missouri | |
| National Alum Corporation | Woodbine, Georgia | |
| Puerto Rico Alum Corporation | Penuelas, Puerto Rico | |
| Rhodia, Inc., Services & Specialties Division | Dominguez, California | |
| | Portland, Oregon | |
| Russ Chemical Company, Inc. | Odessa, Texas | |
| Southern Ionics, Inc. | Baton Rouge, Louisiana | |
| | Calhoun, Tennessee | |
| | Chickasaw, Alabama | |
| | Pasadena, Texas | |
| | Westlake, Louisiana | |
| | West Point, Mississippi | |
| Thatcher Company | Henderson, Nevada | |
| | Missoula, Montana | |

## Table 5-2. U.S. Producers of Selected Aluminum Compounds[a]

| Company | Location | Annual capacity ($10^3$ metric tons)[b] |
|---|---|---|
| | Salt Lake City, Utah | |
| U.S. Aluminate Company, Inc. | Fairfield, Ohio | |
| | Michigan City, Indiana | |
| Sodium aluminosilicate | | |
| Albemarle Corporation | Pasadena, Texas | |
| W.R. Grace & Co., Grace Division | Curtis Bay, Maryland | |
| | Lake Charles, Louisiana | |
| Huber Engineered Materials | Etowah, Tennessee | |
| | Havre de Grace, Maryland | |
| | Longview, Washington | |
| INEOS Silicas Americas, LLC | Joliet, Illinois | |
| The PQ Corporation, Zeolyst and Catalyst Division | Kansas City, Kansas | |
| UOP, LLC | Chickasaw, Alabama | |
| Zeolyst International | Kansas City, Kansas | |
| Sodium aluminum phosphate | | |
| Astaris, LLC | Carondelet, Missouri | |
| Innophos, Inc. | Chicago Heights, Illinois | |
| | Nashville, Tennessee | |

[a]Derived from SRI 2006
[b]SRI Consulting estimates as of February 1, 2006; annual capacities were only reported for aluminum chloride (anhydrous), aluminum chloride (hydrous), and aluminum fluoride.
[d]Plant is on standby
[c]Capacities are on 100% $AlCl_3$ basis.
[e]Capacities, which are expressed as 100% $AlCl_3$, are nominal and easily expandable.
[f]Aluminum fluoride is reclaimed from refinery operations in small quantities.
[g]Manufacturers for aluminum phosphide were obtained from EPA 1998.

Aluminum nitrate as the nonahydrate is formed by dissolving aluminum or aluminum hydroxide in dilute nitric acid and allowing the resulting solution to crystallize (Grams 1992; Lewis 2001).

Aluminum oxide is produced during the recovery of bauxite, which is crushed, ground, and kiln dried, followed by leaching with sodium hydroxide, forming sodium aluminate, from which alumina trihydrate is precipitated and calcined (Bayer process). Aluminum sulfate obtained from coal mine waste waters can be reduced to aluminum oxide (HSDB 2006; Lewis 2001).

Aluminum phosphide can be manufactured in a high degree of purity, by heating aluminum and phosphorus. It can also be prepared from red phosphorus and aluminum powder, or from aluminum and zinc phosphide (HSDB 2006; O'Neil et al. 2001).

Aluminum sulfate is manufactured by reacting freshly precipitated pure aluminum hydroxide, bauxite, or kaolin, with an appropriate quantity of sulfuric acid. The resulting solution is evaporated and allowed to crystallize. Aluminum sulfate can also be produced by the treatment of pure kaolin or aluminum hydroxide or bauxite with sulfuric acid. The insoluble silic acid is removed by filtration and the sulfate is obtained by crystallization. It can be prepared similarly from waste coal mining shale and sulfuric acid (HSDB 2006; Lewis 2001).

Table 5-3 lists the facilities in each state that manufacture or process aluminum (fume or dust), the intended use, and the range of maximum amounts of aluminum that are stored on site. Table 5-4 lists the facilities in each state that manufacture or process aluminum oxide (fibrous form), the intended use, and the range of maximum amounts of aluminum oxide that are stored on site. The data listed in Tables 5-3 and 5-4 are derived from the Toxics Release Inventory (TRI04 2006). Only certain types of facilities were required to report (EPA 1995). Therefore, this is not an exhaustive list.

## 5.2 IMPORT/EXPORT

Nearly all of the bauxite consumed in the United States is imported; domestic mines have supplied <1% of the U.S. requirements for bauxite for many years. Import sources for bauxite (2001–2004) are Jamaica (37%), Guinea (32%), Brazil (12%), Guyana (11%), and other (8%). Import sources for alumina (2001–2004) are Australia (53%), Suriname (26%), Jamaica (10%), and other (11%). More than 90% of the bauxite consumed in the United States in 2005 was converted to alumina (USGS 2003, 2006a).

## Table 5-3. Facilities that Produce, Process, or Use Aluminum (Fume or Dust)

| State[a] | Number of facilities | Minimum amount on site in pounds[b] | Maximum amount on site in pounds[b] | Activities and uses[c] |
|---|---|---|---|---|
| AK | 1 | 10,000 | 99,999 | 12 |
| AL | 37 | 0 | 9,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 |
| AR | 38 | 0 | 499,999,999 | 1, 3, 4, 5, 6, 7, 8, 11, 12, 13 |
| AZ | 17 | 0 | 9,999,999 | 1, 3, 4, 5, 6, 7, 8, 11, 12, 13 |
| CA | 70 | 0 | 999,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 |
| CO | 11 | 1,000 | 999,999 | 1, 2, 4, 5, 8, 11, 12 |
| CT | 19 | 0 | 9,999,999 | 1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 |
| DE | 4 | 1,000 | 9,999 | 2, 3, 4, 6, 7, 8, 11 |
| FL | 14 | 0 | 999,999 | 1, 5, 7, 8, 9, 11, 12 |
| GA | 20 | 0 | 9,999,999 | 1, 2, 3, 4, 5, 7, 8, 9, 11, 12, 13, 14 |
| IA | 39 | 0 | 499,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14 |
| ID | 7 | 10,000 | 999,999 | 1, 3, 4, 5, 7, 12, 13 |
| IL | 93 | 0 | 49,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 |
| IN | 107 | 0 | 99,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 |
| KS | 25 | 0 | 9,999,999 | 1, 2, 3, 5, 7, 8, 9, 10, 11, 12 |
| KY | 60 | 0 | 49,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 |
| LA | 16 | 0 | 9,999,999 | 1, 5, 6, 7, 8, 10, 11, 12, 13 |
| MA | 10 | 0 | 999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 |
| MD | 13 | 1,000 | 999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9 |
| ME | 5 | 100 | 99,999 | 1, 3, 4, 5, 8, 9, 12 |
| MI | 76 | 0 | 99,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 |
| MN | 27 | 100 | 9,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 |
| MO | 49 | 0 | 99,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 |
| MS | 16 | 0 | 9,999,999 | 1, 3, 5, 7, 8, 10, 11, 12 |
| NC | 37 | 0 | 49,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 |
| ND | 2 | 1,000 | 9,999 | 1, 5, 8 |
| NE | 4 | 1,000 | 99,999 | 1, 5, 6, 7, 8, 11 |
| NH | 3 | 100 | 499,999,999 | 8 |
| NJ | 51 | 0 | 49,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13 |
| NV | 11 | 100 | 499,999,999 | 1, 2, 3, 5, 7, 8, 9, 10, 12, 13 |
| NY | 35 | 0 | 999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 12 |
| OH | 116 | 0 | 49,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 |
| OK | 26 | 0 | 49,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13 |
| OR | 29 | 0 | 49,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 |
| PA | 104 | 0 | 499,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 |
| PR | 6 | 100 | 99,999 | 4, 8, 12 |
| RI | 3 | 1,000 | 999,999 | 7, 8, 9 |
| SC | 28 | 0 | 9,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12 |

## Table 5-3. Facilities that Produce, Process, or Use Aluminum (Fume or Dust)

| State[a] | Number of facilities | Minimum amount on site in pounds[b] | Maximum amount on site in pounds[b] | Activities and uses[c] |
|---|---|---|---|---|
| TN | 57 | 0 | 99,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 |
| TX | 62 | 0 | 499,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 |
| UT | 18 | 0 | 9,999,999 | 1, 4, 5, 7, 8, 11, 12, 13 |
| VA | 27 | 0 | 999,999 | 1, 2, 3, 5, 7, 8, 11, 12 |
| VT | 3 | 0 | 999,999 | 8, 11, 12 |
| WA | 19 | 0 | 999,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 12, 13 |
| WI | 48 | 0 | 499,999,999 | 1, 2, 3, 5, 6, 7, 8, 9, 11, 12, 13, 14 |
| WV | 15 | 0 | 9,999,999 | 2, 3, 6, 7, 8, 9, 10, 11, 12 |
| WY | 1 | 1,000 | 9,999 | 7 |

[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: TRI04 2006 (Data are from 2004)

## Table 5-4. Facilities that Produce, Process, or Use Aluminum Oxide (Fibrous Forms)

| State[a] | Number of facilities | Minimum amount on site in pounds[b] | Maximum amount on site in pounds[b] | Activities and uses[c] |
|---|---|---|---|---|
| AK | 2 | 10,000 | 999,999 | 10 |
| AL | 56 | 1,000 | 99,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13 |
| AR | 41 | 0 | 499,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 |
| AZ | 16 | 1,000 | 499,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13 |
| CA | 96 | 0 | 49,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 |
| CO | 13 | 100 | 9,999,999 | 2, 5, 7, 8, 10, 11, 12, 13 |
| CT | 34 | 0 | 99,999,999 | 2, 3, 4, 7, 8, 10, 11, 12 |
| DE | 5 | 10,000 | 9,999,999 | 6, 7, 8, 10 |
| FL | 24 | 1,000 | 9,999,999 | 1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 |
| GA | 59 | 0 | 49,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 |
| HI | 3 | 10,000 | 999,999 | 10, 12 |
| IA | 21 | 100 | 49,999,999 | 1, 2, 3, 4, 5, 7, 8, 11, 12 |
| IL | 88 | 0 | 49,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 |
| IN | 88 | 0 | 499,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 |
| KS | 25 | 100 | 9,999,999 | 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12 |
| KY | 55 | 100 | 499,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 |
| LA | 47 | 0 | 499,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 |
| MA | 38 | 0 | 49,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 |
| MD | 22 | 1,000 | 499,999,999 | 1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 13 |
| ME | 7 | 1,000 | 999,999 | 6, 7, 8, 11, 12 |
| MI | 67 | 0 | 999,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 |
| MN | 27 | 100 | 99,999,999 | 1, 2, 3, 5, 6, 7, 8, 10, 11, 12 |
| MO | 55 | 100 | 499,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 |
| MS | 22 | 1,000 | 499,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 |
| MT | 11 | 0 | 499,999,999 | 2, 3, 6, 10, 11, 12 |
| NC | 50 | 0 | 499,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 |
| ND | 4 | 1,000 | 9,999,999 | 7, 10 |
| NE | 10 | 1,000 | 999,999 | 2, 4, 8, 10, 11, 12, 13 |
| NH | 12 | 1,000 | 499,999,999 | 1, 2, 3, 4, 7, 8, 9, 11, 12 |
| NJ | 45 | 0 | 999,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 |
| NM | 6 | 1,000 | 999,999 | 7, 8, 10, 11, 12 |
| NV | 3 | 100 | 999,999 | 1, 5, 6, 8, 9, 10 |
| NY | 78 | 0 | 999,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 |
| OH | 145 | 0 | 499,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 |
| OK | 41 | 1,000 | 49,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13 |
| OR | 14 | 100 | 99,999,999 | 2, 3, 4, 6, 8, 10, 11, 12 |
| PA | 114 | 0 | 499,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 |

## Table 5-4. Facilities that Produce, Process, or Use Aluminum Oxide (Fibrous Forms)

| State[a] | Number of facilities | Minimum amount on site in pounds[b] | Maximum amount on site in pounds[b] | Activities and uses[c] |
|---|---|---|---|---|
| PR | 9 | 100 | 9,999,999 | 2, 3, 7, 8, 10, 11, 12 |
| RI | 2 | 10,000 | 99,999 | 2, 3, 7 |
| SC | 41 | 0 | 999,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12 |
| SD | 4 | 1,000 | 99,999 | 5, 8, 11 |
| TN | 70 | 100 | 49,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 |
| TX | 103 | 0 | 999,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 |
| UT | 19 | 0 | 999,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13 |
| VA | 29 | 0 | 9,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 |
| VI | 1 | 1,000,000 | 9,999,999 | 10 |
| VT | 6 | 1,000 | 99,999 | 8, 11, 12 |
| WA | 38 | 0 | 999,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 |
| WI | 43 | 100 | 499,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 |
| WV | 33 | 0 | 49,999,999 | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 |
| WY | 5 | 10,000 | 999,999 | 6, 10, 11 |

[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: TRI04 2006 (Data are from 2004)

## 5.3 USE

In 2005, transportation accounted for an estimated 39% of domestic consumption of aluminum, predominantly as automotive applications, with the remainder used in packaging, 28%; building, 14%; consumer durables, 6%; electrical, 6%; and other, 7% (USGS 2004, 2006a).

Aluminum chloride, anhydrous form, is used as an acid catalyst (especially in Friedel-Crafts-type reactions), as a chemical intermediate for other aluminum compounds, in the cracking of petroleum, in the manufacture of rubbers and lubricants, and as an antiperspirant. The hexahydrate form is used in preserving wood, disinfecting stables and slaughterhouses, in deodorants and antiperspirants, in cosmetics as a topical astringent, in refining crude oil, dyeing fabrics, and manufacturing parchment paper (O'Neil et al. 2001).

Aluminum chlorohydrate is an ingredient in commercial antiperspirant and deodorant preparations and is also used for water purification and treatment of sewage and plant effluent (Lewis 2001)

Aluminum hydroxide (alumina trihydrate) is used as an adsorbent, emulsifier, ion-exchanger, mordant in dyeing, and filtering medium. It is also used in the manufacturing of glass, paper, ceramics and pottery, printing inks, lubricating compositions, detergents, in the waterproofing of fabrics, in antiperspirants, dentifrices, and as a vaccine adjuvant (Baylor et al. 2002; Lewis 2001; O'Neil et al. 2001). Aluminum hydroxide is used as a flame retardant in the interiors of automobiles, commercial upholstered furniture, draperies, wall coverings, and carpets (Subcommittee on Flame-Retardant Chemicals 2000). Aluminum hydroxide is used as an antacid (O'Neil et al. 2001). Finely divided (0.1–0.6 microns) aluminum hydroxide is used for rubber reinforcing agent, paper coating, filler, and cosmetics (Lewis 2001). Aluminum hydroxide is also used pharmaceutically, as an antihyperphosphatemic, to lower the plasma phosphorus levels of patients with renal failure (O'Neil et al. 2001).

Aluminum nitrate is used in textiles (mordant), leather tanning, the manufacturing of incandescent filaments, catalysts in petroleum refining, nucleonics, anticorrosion agent, nitrating agent, and antiperspirants (Lewis 2001; O'Neil et al. 2001).

More than 90% of the bauxite consumed in the United States in 2005 was converted to alumina (aluminum oxide). Nonmetallurgical uses of bauxite include abrasives, chemicals, and refactories. Of the total alumina used in the United States in 2005, approximately 90% was used for primary aluminum

smelters and the remainder was used for nonmetallurgical uses, including abrasives, chemicals, refactories, and in specialty industries (USGS 2003, 2006b). Other uses of aluminum oxide are in the manufacture of ceramics, electrical insulators, catalyst and catalyst supports, paper, spark plugs, crucibles and laboratory works, adsorbent for gases and water vapors, chromatographic analysis, fluxes, light bulbs, artificial gems, heat resistant fibers, food additive (dispersing agent), and in hollow-fiber membrane units used in water desalination, industrial ultrafiltration, and hemodialysis (HSDB 2006; Lewis 2001). Another application of aluminum oxide, which may have wide occupational use in the future, is as a dosimeter for measuring personnel radiation exposure (McKeever et al. 1995; Radiation Safety Guide 1999; Radiation Safety Newsletter 1998).

Aluminum phosphate is used in ceramics, dental cements, cosmetics, paints and varnishes, pharmaceuticals (antacid), and in paper and pulp industries (Lewis 2001; O'Neil et al. 2001). It is also used as a vaccine adjuvant (Baylor et al. 2002; Malakoff 2000). Aluminum phosphate, as basic sodium aluminum phosphate (SALP), is used as an emulsifying agent in pasteurized processed cheese, cheese food, and cheese spread. Acidic SALP is used as a leavening agent in cereal foods and related products, such as self-rising flour, prepared cake mixes, pancakes, waffles, and refrigerated or frozen dough or batter products (Chung 1992; Saiyed and Yokel 2005).

Aluminum phosphide is a fumigant used primarily for indoor fumigation of raw agricultural commodities, animal feeds, processed food commodities, and non-food commodities in sealed containers or structures to control insects, and for outdoor fumigation of burrows to control rodents and moles in nondomestic areas, noncropland, and agricultural areas. Aluminum phosphide reacts with the moisture in the atmosphere to produce phosphine gas, which is the substance that is active as a pesticide. Based on available pesticide survey usage information for 1987–1996, the estimated annual usage of aluminum phosphide is about 1.6 million pounds active ingredient. Major uses of aluminum phosphide include fumigation of wheat, peanuts, and stored corn. It was noted that usage estimates for aluminum phosphide are not precise due to scarcity of usage data sources for postharvest agriculture and non-agriculture uses/sites. All aluminum phosphide containing products have been classified as restricted use (EPA 1998). According to the National Pesticide Information Retrieval System, there are five active registrants for aluminum phosphide (NPIRS 2006).

Aluminum sulfate (alum) is used in leather tanning, sizing paper, as a mordent in dyeing, water purification, fireproofing and waterproofing of cloth, clarifying oils and fats, treating sewage, waterproofing concrete, deodorizing and decolorizing of petroleum, antiperspirants, and agricultural

pesticide. It is also used as a food additive, a foaming agent in fire foams, and in the manufacturing of aluminum salts (Lewis 2001; O'Neil et al. 2001). Aluminum sulfate, as sodium aluminum sulfate, is a component of household baking powder (Chung 1992). Alum is also used as a vaccine adjuvant (Baylor et al. 2002; Malakoff 2000). Aluminum potassium sulfate (potash alum) is used in dyeing (mordant), paper, matches, paints, tanning agents, waterproofing agents, aluminum salts, food additives, baking powder, water purification, astringent, and cement hardener (Lewis 2001). Aluminum ammonium sulfate (ammonium alum) is used in dyeing (mordant), water and sewage purification, sizing paper, retanning leather, clarifying agent, food additive, the manufacture of lakes and pigments, and fur treatment (Lewis 2001).

Other aluminum compounds that are used as food additives include aluminum silicates (anticaking agents) and aluminum color additives (lakes) (Saiyed and Yokel 2005; Soni et al. 2001).

## 5.4 DISPOSAL

Production of finished aluminum products by industrial facilities typically results in the generation of very large amounts of solid aluminum hydroxide anodizing residues (Saunders 1988). These aluminum-anodizing residues are currently classified as nonhazardous under the Federal Resource Conservation and Recovery Act (RCRA) regulations. These residues are typically dewatered to reduce the volume of waste prior to being landfilled. However, the heavy metal content of these solid waste residues can be of concern, especially in production processes using two-step anodizing systems that employ solutions containing elevated heavy metal concentrations. For these types of plants, Saunders (1988) has proposed implementation of a caustic-etch recovery system that will limit both the volume of aluminum-anodizing residue and the heavy metal content of the residue. Additional information on regulations and standards for aluminum and aluminum compounds is summarized in Chapter 8.

Approximately $24.7 \times 10^6$ and $1.15 \times 10^5$ pounds of aluminum (fume or dust) and aluminum oxide (fibrous forms) were reported for on-site disposal and other releases in 2004. On-site disposal or other releases include emissions to the air, discharges to bodies of water, disposal at the facility to land, and disposal in underground injection wells. Approximately $23.7 \times 10^6$ and $1.20 \times 10^6$ pounds of aluminum (fume or dust) and aluminum oxide (fibrous forms), respectively, were reported for off-site disposal and other releases in 2004. An off-site disposal or other release is a discharge of a toxic chemical to the environment that occurs as a result of a facility's transferring a waste containing a TRI chemical off-site for disposal or

other release (TRI04 2006). The TRI data should be used with caution because only certain types of facilities are required to report (EPA 2005). This is not an exhaustive list.

In the United States, about 3 million metric tons of aluminum was recovered from purchased scrap in 2005, with 63% of this coming from new (manufacturing) scrap and 37% from old scrap (discarded aluminum products). Aluminum used beverage cans accounted for about 58% of the reported old scrap consumption in 2004. According to the Aluminum Association, Inc., the recycling rate for used aluminum beverage cans in 2004 was 51.2% (USGS 2004, 2006a).