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

5.1 PRODUCTION

Zinc is widely distributed in nature, constituting 20–200 ppm (by weight) of the earth's crust (Goodwin 1998), but it is not found as elemental zinc in nature (Lloyd and Showak 1984). The procedure used to mine zinc varies with the composition of the ore. The mineral sphalerite (ZnS) provides ca. 90% of the zinc produced today (Goodwin 1998). Zinc ore is mined using both underground mining and open pit mining (Stokinger 1981). The mined zinc ores are too low in zinc content for direct reduction to refined metal; thus, they are first concentrated. Production of concentrates requires crushing and grinding followed by gravity or magnetic methods of separation or flotation. These processes may be combined, depending on the complexity of the ore. A caustic-leach process is used to decrease the extent of metal loss during the concentration process. In this process, the metal is leached by caustic soda, the resulting electrolyte is purified with zinc dust and lime, and the zinc is electrodeposited. The crude zinc may be dissolved in sulfuric acid and purified by electrodeposition. Two processes are used to produce metallic zinc from the ore concentrates that are not subjected to caustic soda leaching. In one process, the ore concentrate containing zinc sulfide is roasted in the presence of air to produce zinc oxide, which is combined with coke or coal and retorted to approximately 1,100 °C to produce metallic zinc. In the other process, the roasted zinc oxide is leached with sulfuric acid, and the solution is electrolyzed to produce zinc of >99.9% purity. The electrolytic processing of zinc is replacing smelting as the most commonly used process (Lloyd and Showak 1984; Stokinger 1981).

Continued low zinc prices in 2001 have resulted in operation reductions and facility closures across the United States. By the end of 2001, 12 mines in 5 states were in operation in the United States. Alaska was the leading zinc-mining state, followed by (in descending order) Tennessee, Missouri, New York, and Montana. Alaska also had the largest production of recoverable zinc in the United States in 2001, followed by Missouri, Montana, and New York. In 2001, three companies operated three primary zinc refineries (Zinc Corporation of America, Monaco, Pennsylvania; Big River Zinc Corporation, Sauget, Illinois; and Pasminco Ltd., Clarksville, Tennessee) (USGS 2001). Tables 5-1 and 5-2 summarize the facilities that manufacture or process zinc and zinc compounds, respectively, in the United States. The information in this table was obtained from the Toxics Release Inventory (TRI), and it summarizes the reported release data for 2001 (TRI01 2003). However, this list does not include all facilities that manufacture or process zinc and zinc compounds. Tables 5-1 and 5-2 also list the maximum amounts of

Table 5-1. Facilities that Produce, Process, or Use Zinc

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
AL	10	1,000	999,999	1, 4, 5, 7, 8, 11
AR	7	1,000	999,999	1, 4, 5, 7, 8, 12, 14
AZ	2	1,000	999,999	8
CA	16	1,000	9,999,999	1, 3, 4, 5, 7, 8, 12
CO	2	10,000	999,999	2, 3, 8
CT	3	1,000	99,999	1, 5, 6
FL	3	1,000	99,999	8, 12
GA	8	1,000	99,999	1, 2, 3, 5, 7, 8
IA	7	0	999,999	1, 5, 8, 13
ID	2	10,000	49,999,999	1, 3, 5, 12
IL	19	100	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11
IN	16	100	999,999	1, 5, 6, 7, 8
KS	6	0	99,999	1, 8, 12, 13
KY	12	100	999,999	1, 2, 3, 4, 5, 7, 8, 11, 12, 13
LA	9	100	999,999	1, 5, 7, 8, 10, 11, 12
MA	5	1,000	99,999	1, 5, 7, 8, 9, 12
MD	2	100,000	999,999	7
ME	1	10,000	99,999	8
MI	14	100	999,999	1, 2, 3, 5, 7, 8, 10, 12
MN	3	10,000	99,999	8
MO	3	100	999,999	1, 5, 7, 8
MS	4	1,000	999,999	7, 8, 9
NC	10	0	9,999,999	1, 4, 8, 9, 13, 14
NE	2	10,000	99,999	1, 3, 5, 7, 9, 13
NH	1	10,000	99,999	1, 5
NJ	7	1,000	49,999,999	1, 2, 3, 5, 6, 8
NY	7	0	999,999	1, 2, 3, 5, 7, 8, 9
OH	31	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 12, 13
OK	10	0	999,999	1, 2, 3, 5, 7, 8, 9, 11, 12
OR	1	10,000	99,999	12
PA	24	0	999,999	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14
RI	2	100	99,999	1, 5, 8
SC	7	100	999,999	1, 5, 8, 9, 11, 12, 13
SD	2	10,000	99,999	1, 5, 8, 12, 14
TN	10	0	49,999,999	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
TX	17	1,000	999,999	1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 14

Table 5-1. Facilities that Produce, Process, or Use Zinc

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
UT	3	10,000	99,999	2, 5, 7, 10, 12
VA	5	1,000	99,999	2, 3, 7, 8, 11
WA	1	10,000	99,999	7
WI	14	0	999,999	1, 2, 3, 4, 5, 7, 8, 9, 11
WV	8	100	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 12
WY	2	1,000	99,999	1, 4, 9, 12

Source: TRI01 2003

[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

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

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
AK	4	1,000	10,000,000,000	1, 3, 5, 7, 9, 10, 12, 13
AL	68	100	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
AR	59	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
AZ	17	1,000	10,000,000,000	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14
CA	90	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
CO	14	100	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14
CT	33	100	999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
DE	11	1,000	999,999	1, 2, 4, 5, 7, 8, 10, 12, 13, 14
FL	44	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
GA	75	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
HI	2	1,000	99,999	1, 5, 7, 9
IA	58	100	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
ID	8	10,000	9,999,999	1, 2, 3, 5, 7, 8, 10
IL	193	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
IN	134	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
KS	28	0	999,999	1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13
KY	75	0	999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
LA	60	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MA	41	100	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 12, 14
MD	23	1,000	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
ME	7	100	999,999	1, 3, 5, 6, 8, 11, 12, 13
MI	142	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MN	36	100	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MO	72	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
MS	39	100	999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
MT	5	100	10,000,000,000	1, 2, 3, 4, 5, 6, 9, 12, 13, 14
NC	66	100	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14
ND	4	1,000	99,999	1, 5, 9, 12, 13
NE	27	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
NH	9	1,000	999,999	1, 5, 7, 8, 9, 10
NJ	61	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
NM	9	1,000	9,999,999	1, 3, 4, 5, 8, 9, 10, 12, 13
NV	20	0	999,999,999	1, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
NY	62	100	10,000,000,000	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
OH	261	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
OK	37	1,000	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
OR	21	0	9,999,999	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14
PA	152	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
RI	8	1,000	999,999	1, 3, 5, 6, 7, 8, 12
SC	65	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14

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

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
SD	3	1,000	9,999,999	1, 5, 7, 9, 10, 13
TN	99	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12
TX	170	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
UT	18	100	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
VA	56	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
VT	2	1,000	99,999	6, 7
WA	20	0	9,999,999	1, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13
WI	87	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
WV	25	0	9,999,999	1, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14
WY	6	0	9,999,999	1, 4, 5, 6, 9, 12, 13

Source: TRI01 2003

[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

zinc and zinc compounds, respectively, that are present at these sites and the end uses of zinc. In 2001, approximately 799,000 metric tons of zinc was produced in the United States from domestic ores. The estimated world production from mines in 2001 was 8,850,000 metric tons. The world production of zinc has increased from 1997 to 2001 (USGS 2001).

Zinc is available in many commercial forms, including ingots, lumps, sheets, wire, shot, strips, sticks, granules, granulated zinc (obtained when molten metal is poured into cold water), and powder (O'Neil et al. 2001).

5.2 IMPORT/EXPORT

In 2001, approximately 813,000 metric tons of zinc were imported to the United States as refined slab zinc, 84,000 metric tons were imported as ores and concentrates, and 7,240 metric tons were imported as rolled zinc. In 2001, the United States imported less refined slab and rolled zinc than in the previous 4 years, and more ores and concentrate than in the previous 4 years (USGS 2001).

In 2001, an estimated 696,000 metric tons of ores and concentrates, 1,180 metric tons of slab zinc, and 5,700 metric tons of rolled zinc were exported from the United States. In contrast, exports of ores and concentrates reached approximately 23,000 metric tons in 1985 and 461,000 in 1997 (DOI 1988, 1991; USGS 2001). In 2001, the United States exported the largest amounts of zinc ores and concentrates to Belgium (151,000 metric tons), Japan (141,000 metric tons), and South Korea (141,000 metric tons) (USGS 2001).

5.3 USE

Zinc metal is used most commonly as a protective coating of other metals, such as iron and steel. Methods, in general, include hot-dip galvanizing, continuous-line galvanizing, electro-galvanizing, zinc plating, zinc spraying, and painting with zinc-bearing paints. Some examples of galvanized materials include nails, water towers, and electrical transmission towers. Because zinc metal lacks strength, it is frequently alloyed with other metals (e.g., aluminum, copper, titanium, and magnesium) to impart a range of properties. When zinc metal is the primary component of the alloy, it is called a 'zinc-base' alloy, which is primarily used for casting and wrought applications. Other important applications of zinc alloys are in dye-casting, construction, and in other alloys (e.g., brass and bronze) which may be found in electrical components of many household goods. Also, alloys containing zinc and copper are used to

make U.S. one-cent coins. Zinc metal dust is widely used in paint coatings, as a catalyst, and as a reducing and precipitating agent in organic and analytical chemistry (Goodwin 1998). As shown in Table 5-3, in 2001, the reported consumption of zinc by industry was 281,000 metric tons (51.4% of total consumption) for galvanizing; 91,200 metric tons (16.8% of total consumption) for zinc-based alloys; and 74,400 metric tons (13.7% of total consumption) for bass and bronze (USGS 2001).

Zinc compounds have dental, medical, and household applications. In pharmaceuticals, zinc salts are used as solubilizing agents in many drugs, including insulin (Lloyd 1984; Lloyd and Showak 1984; Windholz 1983). Zinc compounds are utilized therapeutically in human medicine in the treatment of zinc deficiency (Keen and Hurley 1977). Zinc oxide accounts for the largest use of zinc compounds, and is used primarily by the rubber industry as a vulcanization activator and accelerator and to slow rubber aging by neutralizing sulfur and organic acids formed by oxidation. It also acts in rubber as a reinforcing agent, a heat conductor, a white pigment, and an absorber of UV light. In paints, zinc oxide serves as a mildewstat, acid buffer, and a pigment. It is used in animal feed as a zinc supplement and as a fertilizer-additive for zinc-deficient soils. Zinc oxide is used in cosmetics and drugs primarily for its fungicide properties, and in dentistry in dental cements. It is also used in ceramics, in glass manufacture, as a catalyst in organic synthesis, and in coated photocopy paper (Goodwin 1998). The largest uses of zinc chloride in the United States are in wood preservation, solder fluxes, and batteries. Solutions of zinc chloride are widely used in mercerizing cotton and as a mordant in dying. In medicine, zinc chloride is used as an antiseptic, disinfectant, deodorant, and in dental cements. Other uses are in organic synthesis, as a dehydrant, in rubber vulcanization, and in oil refining (Goodwin 1998). Zinc chloride is a primary ingredient in smoke bombs used for crowd dispersal, in fire-fighting exercises (by both military and civilian communities), and by the military for screening purposes (WHO 2001). Zinc sulfate is used in fertilizers, sprays, and animal feed as a trace element and disease-control agent. It is used in the manufacture of rayon (as crenulating agent), as a starting material for many zinc chemicals, in textile dying and printing, in flotation reagents, for electrogalvanizing, in paper bleaching, and in glue (Goodwin 1998). Zinc sulfide is used as a phosphor (watches, TV screens), a white pigment, and in dental materials (especially in form of lithopone) (O'Neil et al. 2001). Uses for zinc acetate are as a wood preservative, a mordant for antiseptics, a catalyst, and a waterproofing agent. Zinc cyanide has two uses: electroplating and gold extraction. The primary uses of zinc phosphate are in preparation of metal coatings and as a dental cement (Goodwin 1998). Zinc chromate is used in pigments. Zinc hydroxide uses are as an intermediate, as an absorbent in surgical dressings, and in rubber compounding (Lewis 1997).

Table 5-3. Distribution of U.S. Zinc Consumption in 2001

Use	Total (metric tons)	Percent of total
Galvanizing	281,000	51.7
Zinc-based alloys	91,200	16.8
Brass and bronze	74,400	13.7
Total[a]	543,000	100.0

Source: USGS 2001

[a]Data are rounded to more than three significant figures; may not add totals shown.

5.4 DISPOSAL

Zinc processing plants have attempted to limit releases to the environment by using techniques such as water reuse, control of particulate emissions, and filtration thickener overflow. In addition, liquid effluents are limed and allowed to settle so that zinc can precipitate out as the hydroxide (Lloyd and Showak 1984). Waste products containing zinc are also being used as a source of zinc for electrogalvanizing (Jolly 1988). Disposal procedures for spills include ferric hydroxide precipitation and cement-based fixation processes; the latter method is very effective in rendering zinc contaminants insoluble (Dawson and Mercer 1986). Unsalvageable zinc waste may be buried in an approved landfill while salvageable zinc is typically recycled. In 2002, an estimated 370,000 tons of zinc were recovered from waste and scrap in the United States; about 30% was recovered in the form of slab zinc and the remainder was recovered in alloys, oxide, and chemicals. Of the total amount of scrap recycled, 300,000 tons was derived from new scrap and 70,000 tons were derived from old scrap. About 25,000 tons of scrap in the United States were exported mainly to China, Canada, and Taiwan (USGS 2003).

In 1989, EPA applied its revised interpretation of the Bevill Amendment (exclusion) to solid waste from the extraction, beneficiation, and processing of ores and minerals. The slag from the primary zinc processing is the only zinc-related waste remaining in the Bevill exclusion (DOI 1991).